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Synthetic light curves and orbital solutions of two eclipsing binary systems, V675 Lac and USNO-A2.0 1425-02035807

M.S. Alenazi[1] **and M.M. Elkhateeb**[2]

[1] *Physics Dept., Faculty of Science, Northern Border University, Arar, 91431-1321, Saudi Arabia*

[2] *Astronomy Dept., National Research Institute of Astronomy and Geophysics (NRIAG), 11421, Helwan, Cairo, Egypt*

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Abstract. We carried out light curve modeling for all-light curves of the variable W UMa systems V675 Lac and USNO-2035807 using ground-based observations, the Gaia 3rd data release, and ZTF databases by means of the W-D code. The accepted models revealed absolute and physical parameters, which showed that the primary components in both systems are massive and hotter than the secondary ones, and both systems were classified as overcontact. A period study of the system V675 Lac of 19 year duration shows a smooth period increase with the rate $dP/dE = 1.8936 \times 10^{-10}$ day/cycle. Investigation of the systems evolutionary status showed that the primary components for both systems are situated on the ZAMS track, while their secondary components are situated above the TAMS track.

Key words: detached, binaries: contact – stars: modelling – stars: evolutionary

1. Introduction

Eclipsing binaries are always considered as a crucial astrophysical tool for researching star formation and stellar structure, testing evolutionary hypotheses, and figuring out and determining the physical characteristics of stars. They have served as benchmark candles for measuring the galaxy's size and structure as well as for setting limits on the cosmological distance scale (Bonanos et al., 2006). Calculations of absolute parameters of eclipsing binary components (radii, temperatures, mass, luminosity, etc.) from combined photometry and spectroscopy are useful for distance determination (Vilardell et al., 2010). Studies of eclipsing binaries frequently combine data from photometric sources (light curves) and spectroscopic ones (radial velocity curves). The orbital solution and light curve modeling reveal some stellar parameters, in principle, the mean surface effective temperatures of the system components, relative stellar sizes and shapes, orbital inclinations, mass ratios, and the ratios of surface brightness. These estimated parameters can be used in studying the stellar evolution of the systems. Contact binaries, also known as the W UMa stars, are low-mass eclipsing binary systems with ellipsoidal components of orbital periods less than 1 d and continuously changing brightness (Kang et al., 2002; Percy, 2007). Most components of the W UMa type binaries share a common envelope with the same entropy, thereby making their effective temperatures almost equal over the surfaces (Paczyński et al., 2006). The structure of this paper is as follows: Section 2 deals with the basic information of the studied systems and the derivation of their times of minima. Section 3 is devoted to the light curve modeling. Section 4 presents the evolutionary status of the studied systems. Finally, Section 5 outlines our discussion and conclusions.

2. Observations and times of minima

The system USNO-A2.0 1425-02035807 (P = $0.^{d}31618$) (hereafter refer as to as USNO-2035807) was announced as a new discovered variable of W UMa type eclipsing binaries by Liakos (2019). It was detected in the field of view of the planetary nebula Sh2-188 and classified as a W UMa system in the GCVS and AAVSO databases. First observations of the system in the red (Bessell) photometric filter were carried out by Liakos (2019) at the Kryoneri Observatory of the National Observatory of Athens, Corinthia, Greece, between November 2017 and September 2019 using a 1.2-m prime focus telescope (f/3) equipped with the APOGEE ASPEN CG47 CCD camera. The stars USNO-A2.01425-02037041 and USNO-A2.01425-02034268 were used as comparison and check stars, respectively. The system GSC 03208-01986 (hereafter referred to as V675 Lac) was initially included in the Tycho catalog (TYC 3208-1986-1) with V = 11.20 and (B-V) = 0.48 (Hog et al., 1998). It was observed (unfiltered) as an NSVS variable from May 1, 1999, to February 1, 2000. The observed light curve was phased with a period of 0.404567 days and demonstrated that the system V675 Lac belongs to the W UMa binary. The system was included in the bright contact binary stars cataloged by Gettel et al. (2006) from ROTSE observations. Liakos & Niarchos (2011) observed the system on July 21–24 and August 1–3, 2010, using a 0.2 m reflector f/5 telescope at the University of Athens Observatory, Greece, in BI filters. Samec et al. (2015) (hereafter 2015-Samec) observed the system V675 Lac during four nights from 24 to 29 September, 2012, which revealed complete UBVRcIc light curves. The extensive observations from SWASP give us the opportunity to solve well-defined light curves for the years 2004, 2006, and 2007. The data for 2007 is the best and most numerous. A new BVRcIc light curve was observed by Polakis in 2017 and 2018 (hereafter 2017-Polakis and 2018-Polakis) (Eaton et al., 2019). In addition to ground-based observations, we tried to collect all available photometric observations for the studied systems from miscellaneous astronomical databases to increase the accuracy of the adopted models. A set of photometric observations were obtained

Table 1. Basic information on the variable, comparison, and check stars.

Star Name	R.A. (2000)	Dec. (2000)	B	V	B-V
V675 Lac	$22^h\ 25'16.03''$	$+41°27'52.00''$	12.01	11.52	0.49
GSC 03208-02737 (comparison)	$22^h\ 24'26.84''$	$+41°23'42.86''$	11.63	11.27	0.36
GSC 03208-02740 (check)	$22^h\ 14'10.32''$	$+41°23'36.64''$	11.21	10.22	0.99
USNO-2035807	$01^h\ 30'15.40''$	$+58°27'32.20''$	–	16.99	–
USNO-A2.0 1425-02037041 (comparison)	$01^h\ 30'18.81''$	$+58°23'10.96''$	–	18.10	–
USNO-A2.0 1425-02034268 (check)	$01^h\ 30'10.95''$	$+58°27'33.16''$	19.20	–	–

from the Gaia 3rd data release (Gaia Collaboration et al., 2016, 2023) for the systems V675 Lac and USNO-2035807 in BVR and VR passbands, respectively. Complete light curves for the system USNO-2035807 in VRI passbands were obtained from the ZTF database. Ephemeris formulas in Equation (1) adopted by Odell (Eaton et al., 2019) (derived from the NSVS plus 2017-Polakis data) and Equation (2) by Liakos (2019), are used to estimate the relevant phases of each observation for the system V675 Lac and USNO-2035807, respectively. Figure 1(a),(b) displays the observed light curves for the system V675 Lac by Liakos & Niarchos (2011) data and by the Gaia 3rd data release respectively. Figure 2 (a)–(d) displays the observed light curves by SWASP 2007, Samec et al. (2015), 2017-Polakis, and 2018-Polakis, respectively . The observed light curves of the system USNO-2035807 are displayed in Figure 3(a)-(c) for ground-based observations by Liakos (2019), Gaia 3rd data release, and ZTF data, respectively.

$$MinI = HJD2456194.7011 + 0.4045663 \times E. \quad (1)$$

$$MinI = HJD2458081.4380 + 0.3161800 \times E. \quad (2)$$

The orbital period of the system V675 Lac was studied by 2015-Samec using times of minima revealed from their observations together with estimated minima from the NSVS and Liakos & Niarchos (2011) light curves. A smooth period decrease was derived, corresponding to a timescale of 13 years (12000 orbits). Eaton et al. (2019) point out that period decrease results from 2015-Samec are not acceptable for what they claim is an "ancient" contact system, especially

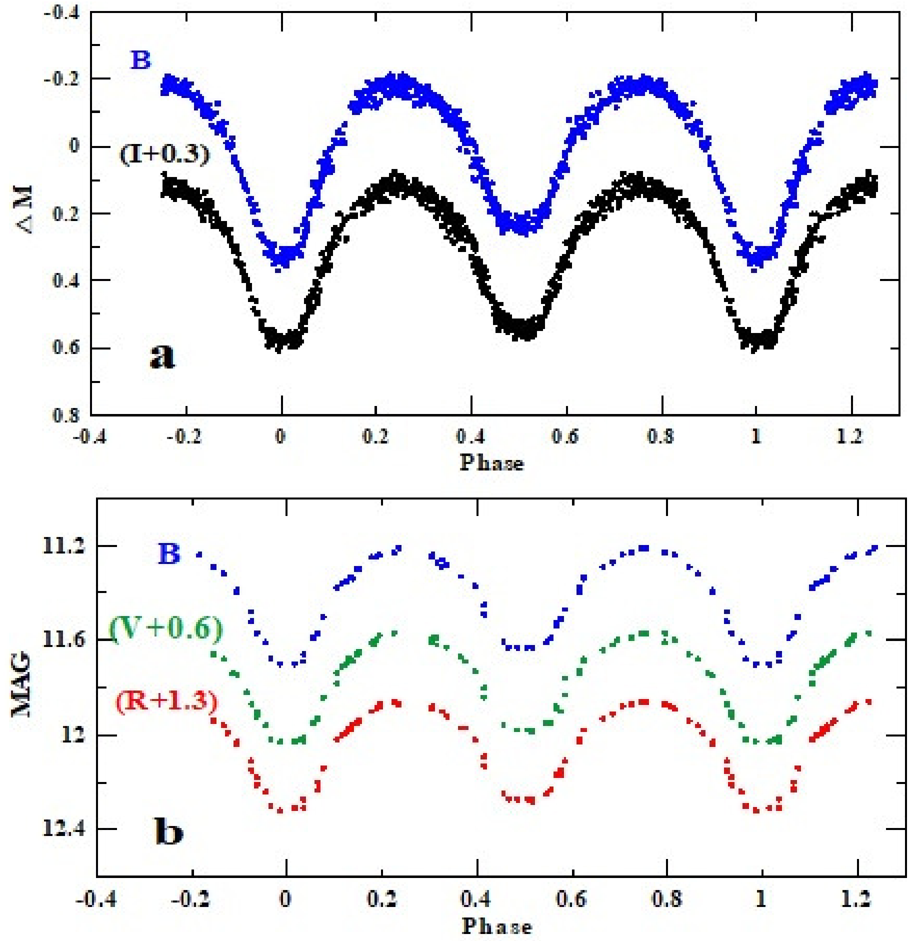

Figure 1. Observed light curves for the system V675 Lac: (a) Liakos & Niarchos (2011) data and (b) the Gaia 3rd data release.

if caused by magnetic braking, their forward period-change mechanism. They refer to the radical period decrease as resulting from the Samec's previously documented error of confusing the Modified Jullian Date (Heliocentric Jullian Date HJD - 2400000.5) with the Reduced Jullian Date (HJD - 2400000.0) in data from the Northern Sky Variability Survey (Woźniak et al., 2004). Eaton et al. (2019) downloaded archival data from NSVS and SuperWasp (SWASP) websites, also obtained new light curves by Polakis for 2017 and 2018 (BVRcIc on the UBV/Cousins system) and added the published photometry of Liakos & Niarchos (2011). They collected all light curves and derived nine epochs of min-

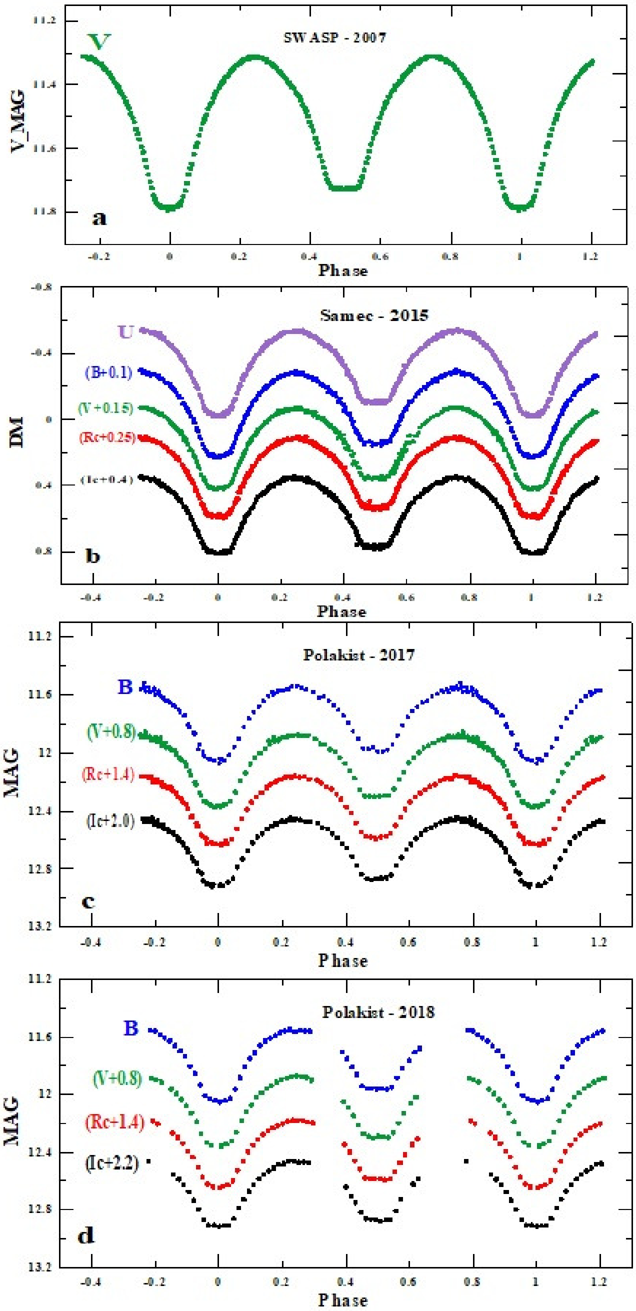

Figure 2. Observed light curves for the system V675 Lac: (a) SWASP 2007, (b) Samec et al. (2015), (c) 2017-Polakis, (d) 2018-Polakis.

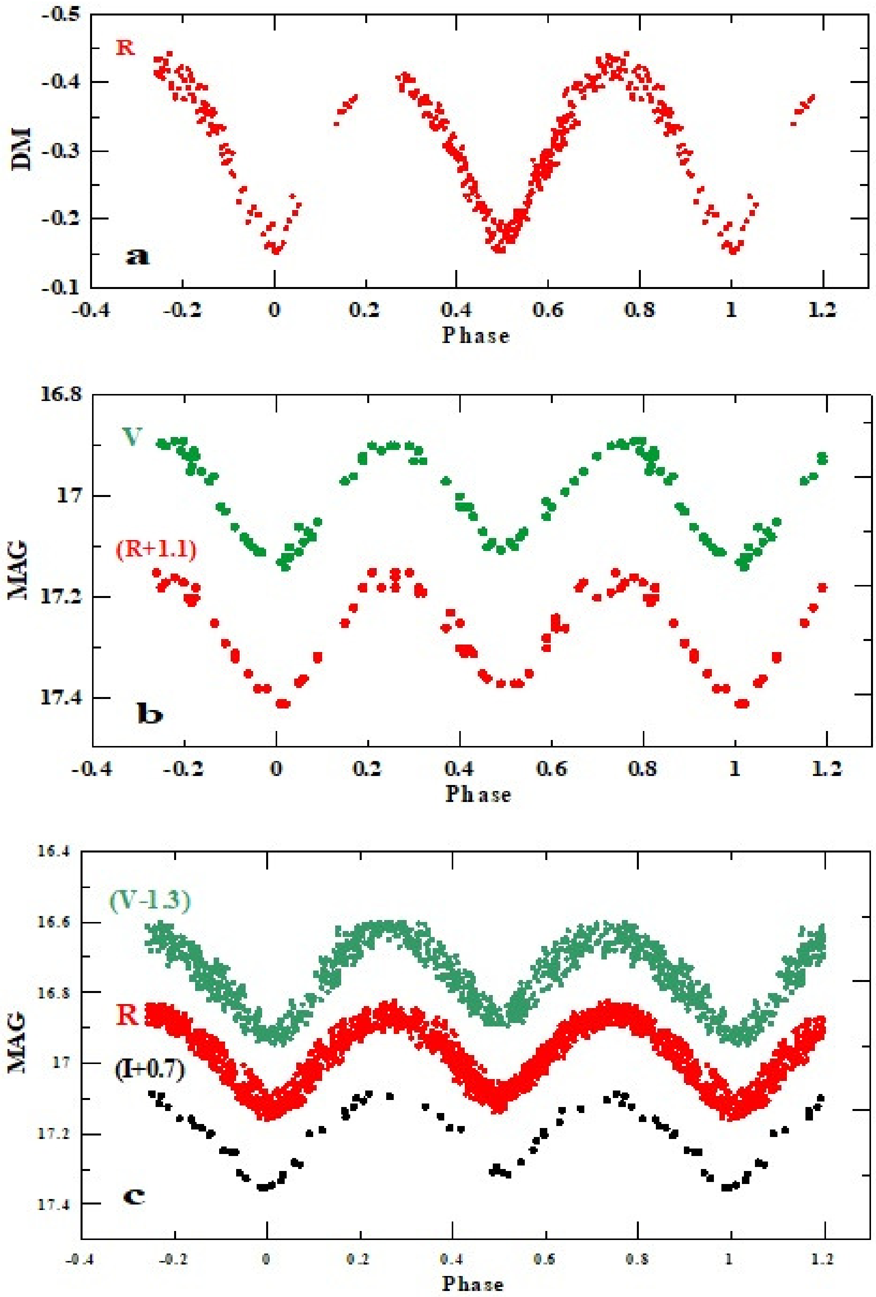

Figure 3. Observed light curves for the system USNO-2035807: (a) Liakos (2019), (b) The Gaia 3rd data release and (c) The ZTF data.

Table 2. Light minima for the systems V675 Lac and USNO-2035807.

HJD	Error	Min	Epochs (E)	(O-C)	(O-C)q	Ref.
			V675 Lac			
2451464.1096	0.0010	I	-11693	0.0022	-0.0005	1
2453247.4351	0.0003	I	-7285	-0.0005	0.0007	2
2453989.8134	0.0006	I	-5450	-0.0014	0.0005	3
2454324.7939	0.0001	I	-4622	-0.0018	0.0001	4
2454374.1509	0.0001	I	-4500	-0.0019	0.0000	5
2455400.5369	0.0006	I	-1963	-0.0006	0.0006	6
2455402.5593	0.0003	I	-1958	-0.0010	0.0002	6
2455410.4491	0.0003	II	-1938.5	-0.0012	0.0009	6
2455411.4591	0.0003	I	-1936	-0.0017	-0.0005	6
2456194.7010	0.0001	I	0	-0.0001	-0.0003	7
2456196.7237	0.0002	I	5	-0.0002	-0.0004	7
2456196.9266	0.0011	II	5.5	0.0004	0.0002	7
2456197.7353	0.0002	II	7.5	-0.0001	-0.0003	7
2456197.7356	0.0002	II	7.5	0.0003	0.0001	7
2456197.9368	0.0002	I	8	-0.0008	-0.0010	7
2456199.7584	0.0004	II	12.5	0.0002	0.0000	7
2456199.7586	0.0005	II	12.5	0.0004	0.0002	7
2457924.8343	0.0003	II	4276.5	0.0054	-0.0003	8
2457924.8346	0.0006	II	4276.5	0.0057	0.0000	8
2457924.8349	0.0002	II	4276.5	0.0060	0.0003	8
2457927.8684	0.0002	I	4284	0.0053	-0.0005	8
2458415.7778	0.0002	I	5490	0.0077	-0.0002	9
2458415.7779	0.0004	I	5490	0.0078	-0.0001	9
2458416.7898	0.0002	II	5492.5	0.0083	0.0004	9
2458416.7902	0.0001	II	5492.5	0.0087	-0.0005	9
			USNO-2035807			
2458368.5300	0.0004	I	908	0.0006	—	10
2458340.5482	0.0005	II	819.5	0.0007	—	10
2458346.5559	0.0004	II	838.5	0.0010	—	10
2458364.5761	0.0004	II	895.5	-0.0011	—	10

References: 1-NSVS, 2-SWASP (2004) , 3-SWASP (2006), 4-SWASP (2007), 5-SWASP (2007) Epoch2, 6-Liakos & Niarchos (2011), 7-Samec et al. (2015), 8-2017-Polakis, 9-2018-Polakis, 10-Liakos (2019).

ima, which fitted and showed that the system's period is increasing moderately on a timescale of $2{\times}10^6$years, which is a very different result than 2015-Samec.

In the present paper, we used the package Minima V2.3 (http://members.shaw.ca/bob.nelson/software1.html) to estimate times of minima from the seven observed light curves displayed in Figure 1(a), (b) for data from Liakos & Niarchos (2011) and the Gaia 3rd data release, and in Figure 2(a)-(d) for the data from SWASP 2007, 2015-Samec, 2017-Polakis and (2018) together with

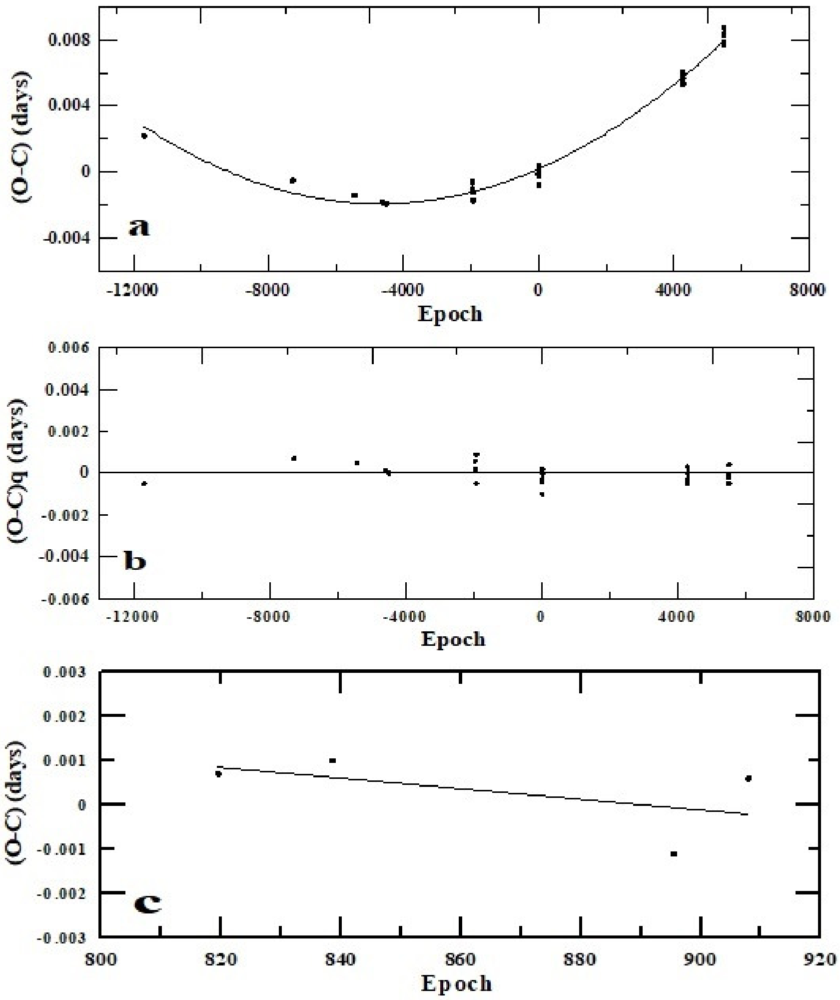

Figure 4. Period behavior of the systems: (a,b) V675 Lac, and (c) USNO-2035807.

light curves downloaded from NSVS. A total of 25 minima were estimated from the observed light curves. The orbital period of the system V675 Lac was studied by means of an O-C diagram using 25 epochs of minima derived from all available light curves spanning the time interval from 1999 to 2018, covering about 19 years (17142 revolutions). In the residuals (O-C), the C's were calculated using the linear elements in Eq. (1) and are listed in Table 2. Figure 4a represents the O-C values versus the Epoch (E) for the system V675 Lac; no distinctions have been made between primary and secondary minima. The general trend of the O-C diagram can be represented by a quadratic fit with a residual sum of squares of 4.318×10^{-6} and an R-squared of 0.987, yielding the following:

$$MinI = 2456194.7013 + 0.^{\rm d}404567188 \times E + 0.9468 \times 10^{-10} \times E^2. \quad (3)$$

Light elements of Eq. (3) give a new period (P = $0.^{d}404567188$); the period shows an increase with the rate $dP/dE = 1.8936 \times 10^{-10} day/cycle$ or $1.7084 \times 10^{-7} day/year$ or 2 second/century. The O-C residuals calculated using the quadratic ephemeris of Eq. (3) are listed in Table 2 and displayed in Figure 4b. A total of four minima were estimated for the system USNO-2035807 from the observed light curves and listed in Table 2. The residuals (O-C) and C's, were calculated using the linear elements in Eq. (2) and are listed in Table 2. As the system USNO-2035807 was discovered a few years ago and has no data base of observations (times of minima), we used the available times of minima listed in Table 2 to construct a preliminary view of the period behavior of the system using the estimated O-C values represented by a linear fit, as illustrated in Figure 4c.

3. Light curve modeling

The observed light curves of the systems V675 Lac and USNO-2035807 indicate typical short-period W UMa eclipsing binaries with continuous changes in brightness with nearly equal depth minima and maxima. Photometric analyses of the systems were carried out using the synthetic light curve and differential corrections program of the Wilson and Devinney code (W-D) (Wilson et al., 2020), which was based on the Milone (1993) model atmosphere. Mode 3 of the code was applied to the observed light curves during the calculations for both systems. We used the B-V values published for the systems at SIMBAD (http://simbad.u-strasbg.fr/simbad/) to calculate the corresponding initial temperature for the primary components T_1 using the Cox (2000) relation. The observed light curves were analyzed using all individual observations in each band. Gravity darkening (A_1, A_2) and bolometric albedo (g_1, g_2) exponents were assumed for the convective envelopes (Teff<7500 K) of the late spectral type, and we adopted $A_1 = A_2 = 0.5$ (Ruciński, 1969) and $g_1 = g_2 = 0.32$ (Lucy, 1967).

The bolometric limb darkening coefficients were adopted and interpolated using the logarithmic law for the extinction coefficients from van Hamme (1993). To establish the initial mass ratio (q), a q-search method was used because spectroscopic measurements (radial velocity) for the systems under study are not available. Therefore, some test solutions for a range of assumed mass ratios (q) with values spanning from 0.10 to 0.90 were performed. Figure 5(a),(b) shows the plotting of the sum of the squared deviations $\sum(O-C)^2$ for every q value for all studied systems. The starting points for modeling are the values of q, which correspond to the minima of $\sum(O-C)^2$ found for each system.

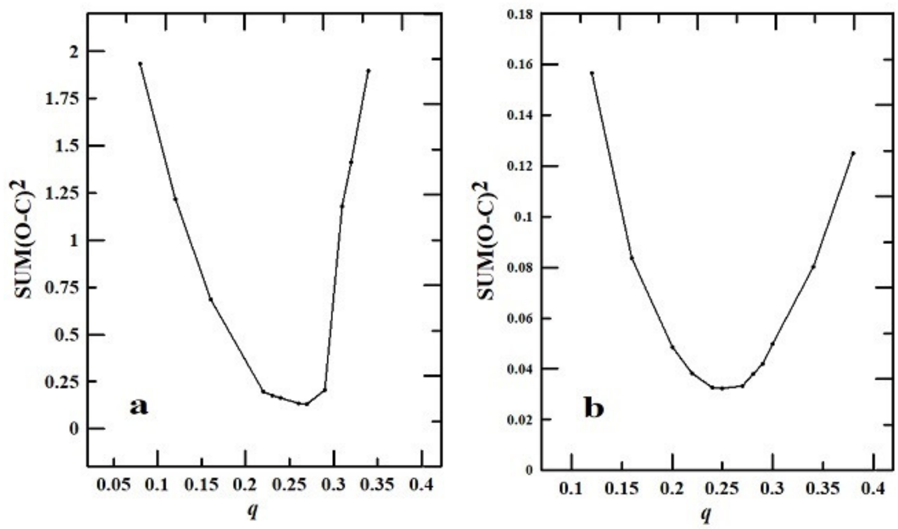

Figure 5. q-search of the binary systems: a) V675 Lac, b) USNO-2035807.

Table 3. Orbital solution parameters for the system USNO-2035807.

Parameter	(Liakos data)	ZTF data	(Gaia data)
$i[°]$	57.81±0.16	58.31±0.25	57.00±0.20
$g_1 = g_2$	0.32	0.32	0.32
$A_1 = A_2$	0.5	0.5	0.5
$q(M_2/M_1)$	0.2590±0.0012	0.2486±0.0021	0.2605±0.0023
Ω_1=Ω_2	2.2677±0.0026	2.2640±0.0045	2.3119±0.0056
T_1 [°K]	4489±5	4355±11	4496±43
T_2 [°K]	4207±4	4240±6	4196±8
Ω_{in}	2.3736	2.3496	2.3772
Ω_{out}	2.2107	2.1928	2.2134
r_1 pole	0.4914±0.0030	0.4900±0.0050	0.4814±0.0044
r_1 side	0.5385±0.0046	0.5361±0.0075	0.5241±0.0065
r_1 back	0.5718±0.0064	0.5670±0.0103	0.5534±0.0089
r_2 pole	0.2774±0.0062	0.2694±0.0108	0.2669±0.0099
r_2 side	0.2931±0.0080	0.2838±0.0137	0.2802±0.0124
r_2 back	0.3592±0.0237	0.3410±0.0358	0.3286±0.0282
$\sum$ (O-C)^2	0.44563	0.02230	0.00714

Table 4. Orbital solution parameters for the system V675 Lac.

Parameter	Liakos& Niarchos 2011	Gaia data	Samec et al. (2015)	SWASP 2007	2017-Polakis	2018-Polakis
$i[°]$	85.79±0.51	86.31±2.14	85.09 (fixed)	85.09 (fixed)	85.09 (fixed)	85.09 (fixed)
$g_1 = g_2$	0.32	0.32	0.32	0.32	0.32)	0.32)
$A_1 = A_2$	0.5	0.5	0.5	0.5	0.5	0.5
$q(M_2/M_1)$	0.2791±0.0009	0.2713±0.0017	0.2636±0.0005	0.2657±0.0011	0.2675±0.0010	0.2664±0.0009
Ω_1=Ω_2	2.3855±0.0028	2.3685±0.0039	2.3518±0.0012	2.3485±0.0032	2.3499±0.0032	2.3585±0.0028
T_1 [°K]	6675±15	6718±13	6736±3	6579±22	6639±26	6663±6
T_2 [°K]	6449±7	6471±9	6455±3	6406±9	6453±8	6468±14
$\Omega_{\rm in}$	2.4195	2.4019	2.3843	2.3891	2.3931	2.3906
$\Omega_{\rm out}$	2.2447	2.2317	2.2187	2.2222	2.2252	2.2233
r_1 pole	0.4689±0.0013	0.4710±0.0021	0.4732±0.0005	0.4743±0.0014	0.4743±0.0007	0.4723±0.0013
r_1 side	0.5071±0.0019	0.5098±0.0029	0.5125±0.0007	0.5142±0.0020	0.5143±0.0010	0.5113±0.0019
r_1 back	0.5342±0.0024	0.5367±0.0038	0.5392±0.0009	0.5416±.0025	0.5419±0.0012	0.5381±0.0024
r_2 pole	0.2638±0.0022	0.2617±0.0037	0.2596±0.0008	0.2621±0.0022	0.2631±0.0008	0.2602±0.0021
r_2 side	0.2757±0.0027	0.2735±0.0046	0.2713±0.0010	0.2742±0.0027	0.2753±0.0009	0.2719±0.0025
r_2 back	0.3149±0.0053	0.3128±0.0089	0.3105±0.0019	0.3153±0.0053	0.3170±0.0017	0.3110±0.0049
$\sum$ (O-C)^2	0.1344	0.0103	0.0646	0.0057	0.0217	0.0036

The adjustable parameters were: the mass ratio (q), the inclination (i), the temperature of the primary star (T_1) and the secondary one (T_2), the surface potential ($\Omega_1 = \Omega_2$, for over-contact systems), and the monochromatic luminosity of the primary star (L_1). The relative brightness of the secondary star (L_2) was calculated by the stellar atmosphere model. The photometric analysis was performed on all the observed light curves of the studied systems, and some trials were conducted to find a set of parameters that roughly correspond to the observed light curves. After applying the WD code (Wilson et al., 2020) condition of Mode 3 (over-contact), the best photometric fitting was obtained, and synthetic light curves were estimated for each system. The first light curve modeling for the system V675 Lac was carried out by 2015-Samec using his UBVRcIc light curves. Mode 3 (over contact) of the W-D code was applied with the starting values of the parameters estimated from BM3 (Bradstreet & Steelman, 2002). No third body was included in their constructed model, and a set of parameters were estimated that classified the system as totally eclipsing classic A-Type W UMa binary. Eaton et al. (2019) present a light curve analysis for the system V675 Lac using SWASP observed light curves in the years 2004 and 2007 (the quality of 2007 data are the better than that of 2004 (Eaton et al., 2019)) together with observed light curves by Polakis in 2017 and 2018. The W-D code was used to solve the collected light curves, and a set of absolute parameters was estimated according to the constructed model. Their accepted model for SWASP 2004 and SWASP 2007 light curves reveals a small dark spot on the leading hemisphere of the primary component, which does not appear in the model of Pokalis (2017) and (2018) light curves.

Table 5. Physical parameters for the system USNO-2035807.

Parameter	(Liakos data)	ZTF data	(Gaia data)
$M_1(M_\odot)$	0.6627±0.0271	0.6153±0.0251	0.6651±0.0272
$M_2(M_\odot)$	0.1716±0.0070	0.1530±0.0063	0.1733±0.0071
$R_1(R_\odot)$	0.7493±0.0306	0.6985±0.0285	0.7519±0.0307
$R_2(R_\odot)$	0.6423±0.0262	0.6549±0.0267	0.6382±0.0261
$L_1(L_\odot)$	0.2043±0.0083	0.1572±0.0064	0.2070±0.0085
$L_2(L_\odot)$	0.1158±0.0047	0.1242±0.0051	0.1131±0.0046
$T_1(T_\odot)$	0.7769±0.0317	0.7537±0.0308	0.7781±0.0318
$T_2(T_\odot)$	0.7281±0.0297	0.7338±0.0300	0.7262±0.0298
$M_{\rm bol1}$	6.4745±0.2643	6.7586±0.2759	6.4602±0.2637
$M_{\rm bol2}$	7.0909±0.2895	7.0148±0.2864	7.1161±0.2905
$M_{\rm v1}$	7.2287±0.2951	7.6238±0.3112	7.2090±0.2943
$M_{\rm v2}$	8.0952±0.3305	7.9865±0.3261	8.1315±0.3320
Sp. Type	$(K4)^1, (K7)^2$	$(K5)^1, (K6)^2$	$(K4)^1, (K7)^2$

Note: 1 and 2 refer to the primary and secondary components, respectively.

Table 6. Physical parameters for the system V675 Lac.

Parameter	Liakos& Niarchos (2011)	Gaia data	Samec et al. (2015)	SWASP 2007	2017-Polakis	2018-Polakis
$M_1(M_\odot)$	1.4034±0.0573	1.4170±0.0579	1.4227±0.0581	1.3728±0.0560	1.3919±0.0568	1.3995±0.0571
$M_2(M_\odot)$	0.3917±0.0160	0.3844±0.0157	0.3750±0.0153	0.3648±0.0149	0.3723±0.0152	0.3728±0.0152
$R_1(R_\odot)$	1.4779±0.0603	1.4898±0.0608	1.4948±0.0610	1.4509±0.0592	1.4678±0.0599	1.4746±0.0602
$R_2(R_\odot)$	1.4137±0.0577	1.4201±0.0580	1.4154±0.0578	1.4012±0.0592	1.4149±0.0578	1.4192±0.0579
$L_1(L_\odot)$	3.8849±0.1586	4.0505±0.1654	4.1216±0.1683	3.5335±0.1443	3.7500±0.1531	3.8399±0.1568
$L_2(L_\odot)$	3.0972±0.1264	3.1682±0.1293	3.1163±0.1272	2.9624±0.1209	3.1102±0.1270	3.1583±0.1289
$T_1(T_\odot)$	1.1552±0.0472	1.1627±0.0475	1.1658±0.0476	1.1386±0.0465	1.1386±0.0465	1.1532±0.0471
$T_2(T_\odot)$	1.1161±0.0456	1.1199±0.0457	1.1172±0.0456	1.1087±0.0453	1.1168±0.0456	1.1194±0.0457
M_{bol1}	3.2765±0.1338	3.2312±0.1319	3.2123±0.1311	3.3795±0.1380	3.3149±0.1353	3.2892±0.1343
M_{bol2}	3.5226±0.1438	3.4980±0.1428	3.5159±0.1435	3.5709±0.1458	3.5180±0.1436	3.3740±0.1377
M_{v1}	3.3610±0.1372	3.3148±0.1353	3.2956±0.1345	3.4670±0.1415	3.4003±0.1388	3.5014±0.1429
M_{v2}	3.6165±0.14	3.5906±0.1466	3.6095±0.1474	3.6676±0.1497	3.6117±0.1475	3.5942±0.1467
Sp. Type	$(F5)^1, (F6)^2$	$(F4)^1, (F6)^2$	$(F4)^1, (F6)^2$	$(F6)^1, (F7)^2$	$(F5)^1, (F6)^2$	$(F5)^1, (F6)^2$

Note: 1 and 2 refer to the primary and secondary components, respectively.

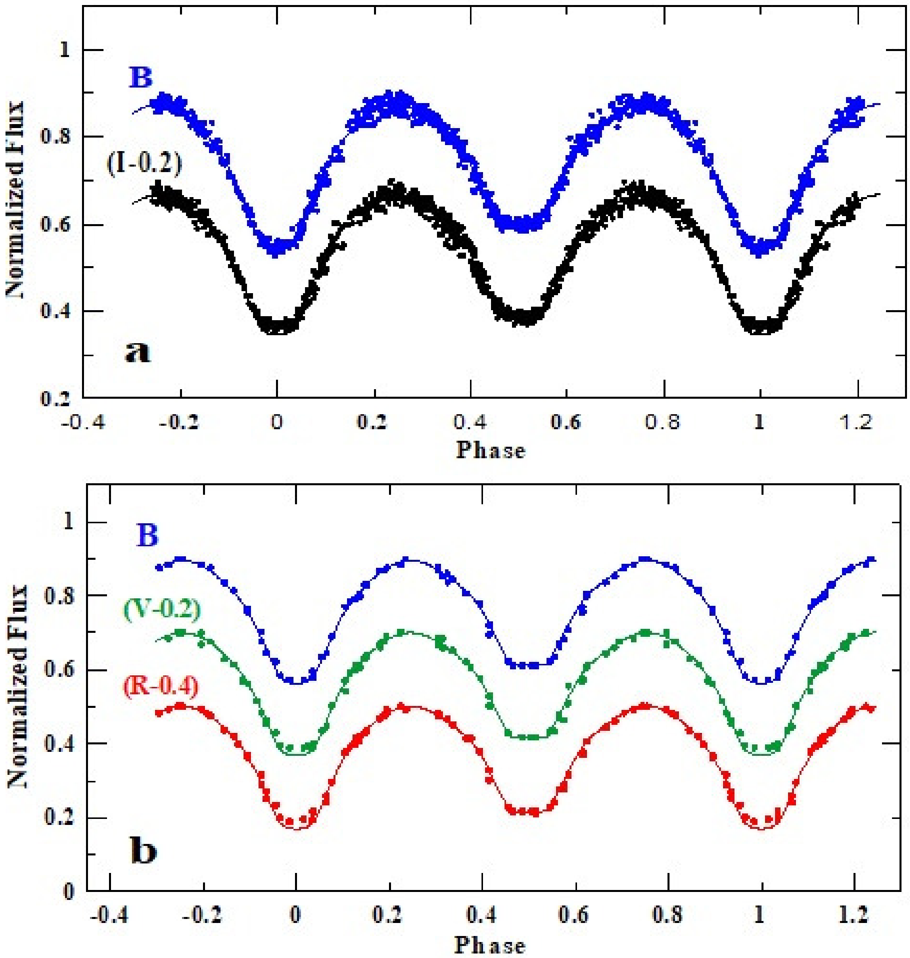

Figure 6. The light curve solutions for the systems V675 Lac: (a) Liakos & Niarchos (2011) data and (b) The Gaia 3rd data release; synthetic (lines) and observed (dots).

As Samec et al. (2015) used only his own light curves, Eaton et al. (2019) used just three observed light curves to construct their orbital solution, in the present paper we collected all ground-based observations: SWASP 2007, Liakos & Niarchos (2011), Samec et al. (2015), 2017-Polakis and (2018), together with observations downloaded from the Gaia3rd data release (Gaia Collaboration et al., 2016, 2023). A total of six complete sets of light curves were used through Mode 3 of the W-D code to construct a model-represented orbital solution for all available light curves of the system V675 Lac. The adopted model shows

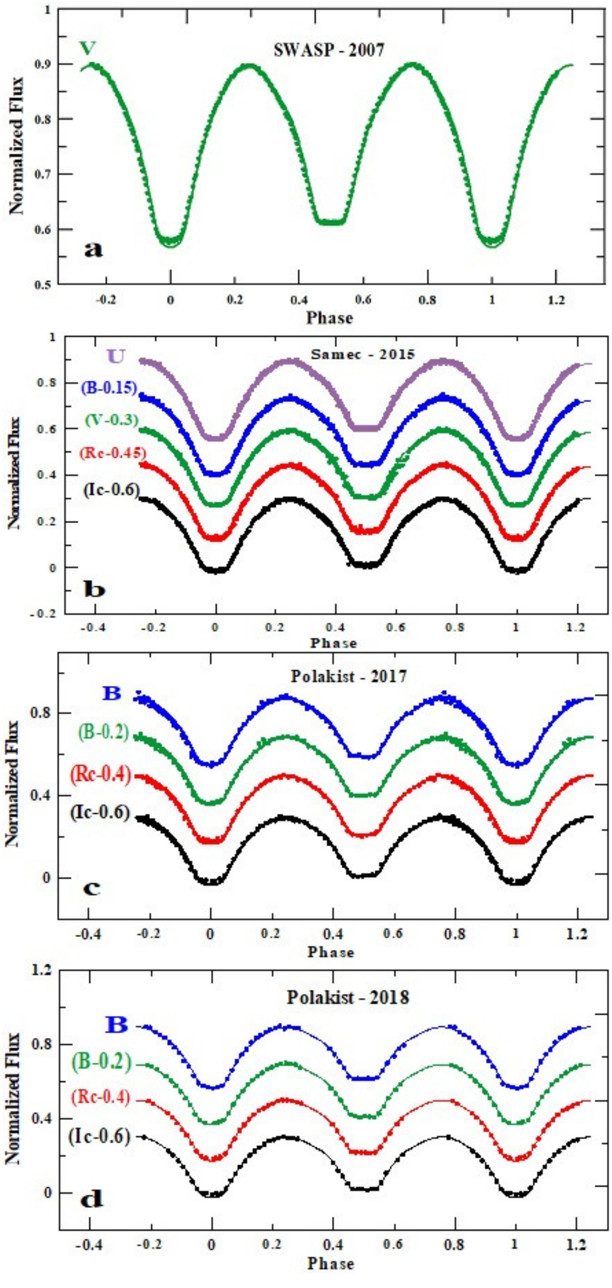

Figure 7. The light curve solutions for the systems V675 Lac: (a) SWASP 2007, (b) Samec et al. (2015), (c) 2017-Polakis, and (d) 2018-Polakis.; synthetic (lines) and observed (dots).

no spots on the primary component, as Eaton et al. (2019) suggest for SWASP 2007 observations, and demonstrates that the primary component is hotter than the secondary one. The high inclination of 85 degrees results in a long-duration secondary total eclipse. The synthetic light curve solution is given in Table 4, while the normalized curves overlain by the light curve solutions are shown in Figures 6(a), (b), and 7(a)-(d).

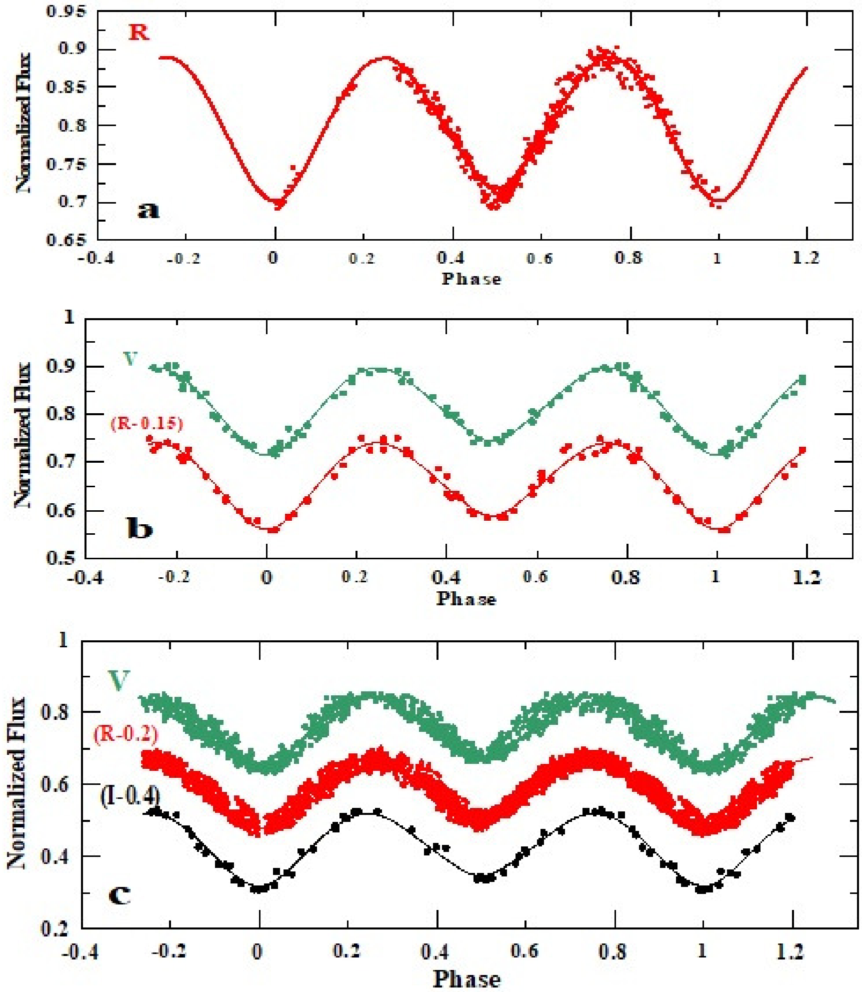

Figure 8. The light curve solutions for the system USNO-2035807: (a) Liakos (2019), (b) The Gaia 3rd data release and (c) The ZTF data; synthetic (lines) and observed (dots).

For the system USNO-2035807, we carried out the first light curve modeling using the available ground-base light curve by Liakos (2019) together with light curves downloaded from the Gaia 3rd data release and ZTF in different pass bands. The accepted solution demonstrates that the primary components are hotter than the secondary ones. Table 3 lists the estimated absolute parameters of the accepted models for each light curve, while Figures 8(a)–(c) display the synthetic and the observed light curves for the system USNO-2035807.

The calculation of the physical parameters of the eclipsing binary components is mostly estimated using spectroscopic observations of their radial velocity. Since the studied systems had no prior spectroscopic observations, the empirical Teff-mass relation provided by Harmanec (1988) was used to approximate their absolute physical parameters. Tables 5 and 6 present the absolute physical parameters that were determined for each component of the system, USNO-2035807 and V675 Lac, respectively. According to these parameters, the primary components of both systems are more massive than the secondary components. The spectral types of system components were adopted based on the parameters of the accepted orbital solutions (Popper, 1980).

The W UMa systems are subcategorized into the A-type and the W-type by Binnendijk (1970). These groups can be further divided into the A9-F8 group (A-type) and the F7-M5 group (W-type) based on their spectral types. Eaton (1983) proposed that the two types of W UMa systems can be distinguished by the presence (W-type) or absence (A-type) of magnetic spots. According to the adopted spectral types, the systems V675 Lac and USNO-2035807 can be classified as W UMa systems of the A-type and the W-type, respectively. In verifying the validity of the relation $r_1 + r_2 = 0.75$ for contact systems, according to Kopal (1959), it is found that $r_1 + r_2 = 0.8438$ for the system V675 Lac and $r_1 + r_2 = 0.7882$ for the system USNO-2035807, when using the mean values of r_1 and r_1 given in Table 3 and 4 for the studied systems. Hence, according to the calculated values, the systems V675 Lac and USNO-2035807 are overcontact eclipsing binaries with components overfilling their respective Roche lobes, as shown in Figures 9(a) and (b), which depict the three-dimensional view of the studied systems based on the calculated parameters from the adopted models using the software Package Binary Maker 3.03 of Bradstreet & Steelman (2002).

4. Evolutionary state

The mass-luminosity (M-L) and mass-radius (M-R) relations, as well as the evolutionary tracks calculated by Girardi et al. (2000) for both zero-age main sequence stars (ZAMS) and thermal-age main sequence stars (TAMS) with metallicity z = 0.019, were used to investigate the evolutionary state of the studied systems using their estimated physical parameters, which are listed in Table, 5 and 6. The primary components (S_1) for both systems are situated on the ZAMS, whilst their secondary components (S_2) are situated above the

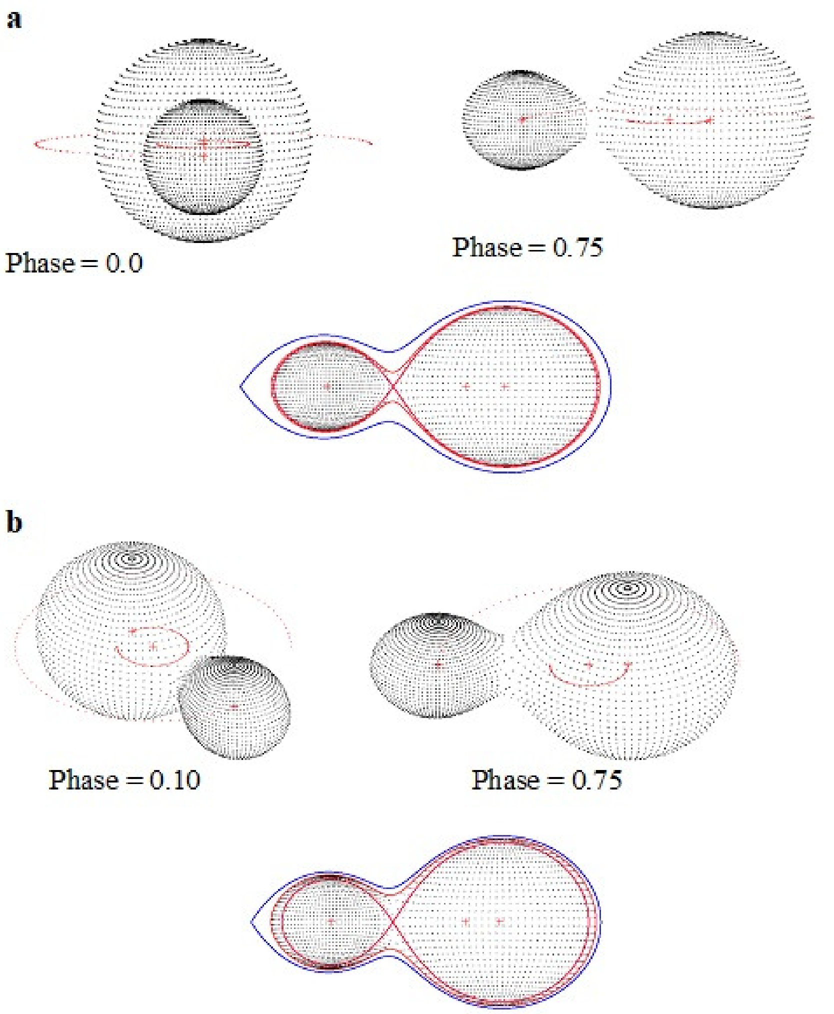

Figure 9. A three-dimensional view of the binary systems: a) V675 Lac, b) USNO-2035807.

TAMS track as shown in Figure 10(a) and (b) which displays the locations of the studied systems components S_1 and S_2 on the M-L and M-R relations. The evolutionary states of the systems were also examined using the luminosity-effective temperature (L-Teff) relation of non-rotated models and the empirical mass-effective temperature (M-Teff) relation of the intermediate and low-mass eclipsing binaries.

All the components of the systems are located on the Teff-L, therefore, an

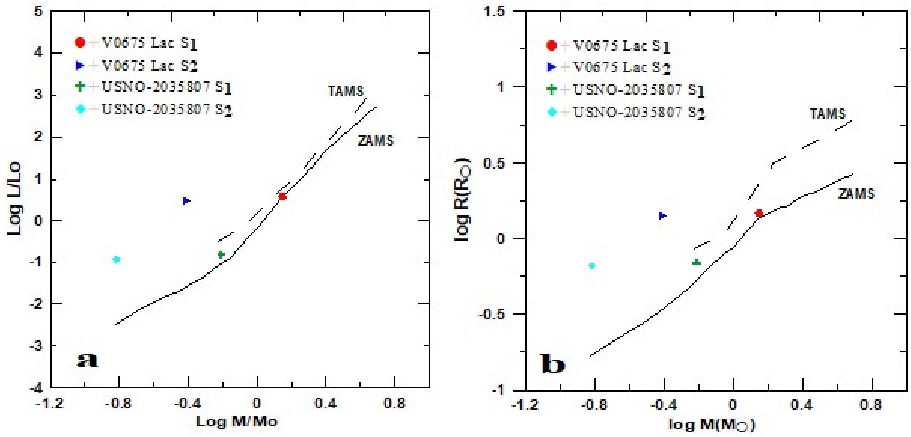

Figure 10. Positions of the components S_1, S_2 of the systems V675 Lac and USNO-2035807 on the theoretical diagram (a) mass- luminosity, and (b) mass-radius of Girardi et al. (2000).

agreement has been achieved between the masses derived from the orbital solutions and those for the stellar models, using the non-rotated evolutionary models of Ekström et al. (2012) in the range of $0.6 - 2.0\ M_{\odot}$ at solar metallicity $z = 0.014$, as illustrated in Figure 11 where each component shows a fair fit.

Figure 12 shows the M-Teff relation for low-mass and intermediate-mass stars (Malkov, 2007), and also shows that the locations of the primary components of both systems are in good agreement while the secondary components show some deviations. Such deviations are similar to that in Figure 10(a) and (b) in the M-L and M-R diagrams; we attribute this to an energy transfer via the common convective envelope from the primary to the secondary components of both systems (Lucy (1973)).

5. Discussion and conclusions

Using all available CCD ground-based observations in various pass bands together with the Gaia 3rd data release, SWASP and the ZTF database, orbital solutions for the eclipsing binary systems V675 Lac and USNO-2035807 were carried out. The adopted models reveal a set of absolute parameters that demonstrate that all the primary components of both systems are hotter and more massive than the secondary components. A total of 29 new times of minima from the observed light curves of the studied systems were calculated, and the O-C curves were constructed. The period study of the system V675 Lac of 19-year duration shows a smooth period increase with the rate $dP/dE = 1.8936 \times 10^{-10} day/cycle$. The behavior of the studied systems in M-R and M-L relations using their evolu-

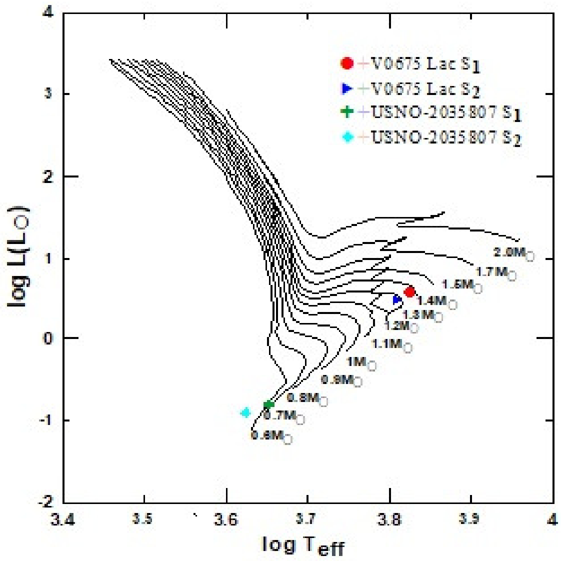

Figure 11. Positions of the components S_1, S_2 of the systems V675 Lac and USNO-2035807 on the Teff–L diagram of Ekström et al. (2012).

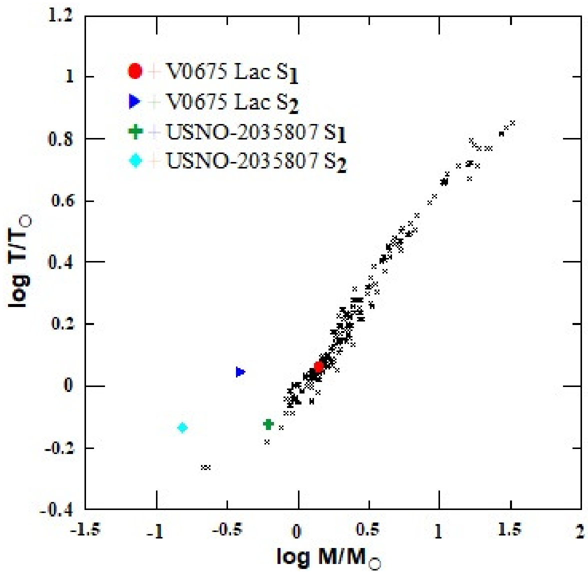

Figure 12. Positions of the components S_1, S_2 of the systems V675 Lac and USNO-2035807 on the M-Teff diagram by Malkov (2007).

tionary states was examined. The primary components S1 for both systems are situated on the ZAMS, while their secondary components S2 are situated above the TAMS track. Such deviations are also noticed when examining the M-Teff relation for low-mass and intermediate-mass stars and can be attributed to an energy transfer from the primary to the secondary components via the shared convective envelope, which accounts for the general deviation of the secondary's in W UMa systems.

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