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# Investigation of the shortest period Am type eclipsing binary TYC 6408–989–1

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**Abstract** The first $BV$ bands photometric observations and the low-resolution spectrum of the shortest period Am type eclipsing binary TYC 6408–989–1 have been obtained. The stellar atmospheric parameters of the primary star were obtained through the spectral fitting as follows: $T_{\rm eff} = 6990 \pm 117$ K, $\log g = 4.25 \pm 0.26$ cm s$^{-2}$, $[{\rm Fe/H}] = -0.45 \pm 0.03$ dex. The original spectra obtained by European Southern Observatory (ESO) were processed with an IRAF package by us. Based on the ESO blue-violet spectra, TYC 6408–989–1 was concluded as a marginal Am (Am:) star with a spectral type of kA3hF1mA5 IV-V identified through the MKCLASS program. The observed light curves were analyzed through the Wilson-Devinney code. The final photometric solutions show that TYC 6408–989–1 is a marginal contact binary with a low mass ratio ($q = 0.27$). The temperature of the secondary component derived through the light curve analysis is significantly higher than main sequence stars. In addition, TYC 6408–989–1 is a poor thermal contact binary. The temperature differences between the two components is about 1800 K. TYC 6408–989–1 should be located in the oscillation stage predicted by the thermal relaxation oscillations theory (TRO) and will evolve into the shallow contact stage eventually. The very short period (less than one day), marginal Am peculiarity and quite large rotational velocity ($v \sin i \simeq 160$ km s$^{-1}$) make TYC 6408–989–1 become a challenge to the cut-off of rotation velocities and periods of Am stars. We have collected the well known eclipsing Am binaries with absolute parameters from the literature.

**Key words:** stars: chemically peculiar — stars: binaries: eclipsing — stars: binaries: general (TYC 6408–989–1) — stars: evolution

## 1 INTRODUCTION

Among the chemically peculiar (CP) stars, metallic-line A-type stars (Am stars for short) attract the attention of the astronomical researchers, because of their extremely strong or weak element lines, high binary frequency and other characteristics. Almost all Am stars are A or F type stars. Am stars show the following common characteristic: slow rotation compared with the normal A or F type stars (less than 120 km s$^{-1}$) (Abt & Moyd 1973); the spectra will show some remarkably characteristics as follows: weaker Ca II, K line (Titus & Morgan 1940; Roman et al. 1948) but enhanced Sr II line; the scandium and calcium elements are under-abundant while the iron-group elements, Y, Ba, and the rare earth elements are over-abundant (Conti 1970). The researchers found that almost all Am stars (more than 90%) are the components of binaries (Abt 1961, 1965; Hubrig et al. 2010). It is generally accepted that the largest rotational velocity of Am stars is about 120 km s$^{-1}$ (Abt & Moyd 1973; Abt 2000). There is a lack of very short periods ($P_{\rm orb} < 1.2$ days) Am type binaries (Budaj 1996), and the general explanation is synchronism in such systems would force the primary to rotate faster than 120 km s$^{-1}$. Nevertheless, Am peculiarity may have no significant correlation with rotational velocity (Monier & Richard 2004; Monier 2005). In addition, there are some normal A0-A3 type slow rotators without reasonable explanation (Abt & Moyd 1973; Wolff & Preston 1978; Royer et al. 2007). It is not clear yet whether slow rotation should be one necessary condition for the formation of an Am star, or slow rotation is an individual result of the Am phenomenon. It seems like the Am peculiarity can also depend on evolutionary status (or age) (Burkhart & Coupry 2000; Monier & Richard 2004; Monier 2005), atmospheric parameters (Kunzli & North 1998; Hui-Bon-Hoa 2000) or orbital elements in a binary system (Budaj 1996, 1997; Iliev et al. 1998; Fenovcík et al. 2004) as well. In classical Am stars, the spectral types inferred from the Ca II K line (Sp(K)) are early than that inferred from the metal lines (Sp(m)) with about five or more spectral subclasses. While stars in which the difference of spectral type ($\Delta = Sp(K) - Sp(m)$) is less ($1 \leq \Delta < 5$) are often referred to as ‘marginal Am’ (or Am:) stars. Many Am stars show anomalous luminosity effect, i.e. the luminosity criteria in certain spectral regions will indicate that the target should be a giant or even supergiant star, whereas in other regions the luminosity will indicate it as a dwarf or even lower luminosity star.

Some theories were presented to expound the origin of the Am phenomenon. The radiative diffusion occurred in a strong magnetic field will likely lead to chemical peculiarities of Ap stars (Michaud 1970), while when the magnetic field is absent, the diffusion will cause the Am phenomenon (Watson 1971). The slow rotation will further assist the diffusion to segregate the elements (Michaud et al. 1983). The spin braking may be a efficient process for the Am phenomenon in close binaries, but it is difficult to explain that the phenomenon occurred in single stars. Furthermore, the significantly weak but observable magnetic fields were found rarely in Am stars (e.g., Sirius A (Petit et al. 2011), $\beta$ UMa and $\theta$ Leo (Blazère et al. 2016)). Taking the radiative acceleration and atomic diffusion into consideration, Richer et al. (2000) developed the stellar evolutionary models. These models can produce alike abundance anomalies, resembling to that of Am stars with much larger value. We should note that the standard stellar evolution theory, the accretion process’s effects of interstellar and the circum stellar gases should all be taken into account for the investigation of the atmospheric chemical abundances of Am stars in the binary systems. As proposed, the accretion processes may strongly influence the surface abundances, such as the mass transfer from the evolved companion (Fowler et al. 1965; Proffitt & Michaud 1989). Fowler et al. (1965) proposed that the peculiar A and B type stars have evolved into an advanced phase, Such stars have evolved through the giant phase and returned to the vicinity of the main sequence. In other words, such a process has occurred in one component of the close binary and mass transfer has happened from the evolved component to the peculiar star.

Near contact binaries (NCBs) were defined as eclipsing binaries with the following common characteristics: continuous EB-type light variations, facing surface less than 0.1 orbital radius apart, short periods (less than one day) and one or two component at or near their Roche lobes (RLs) (Shaw 1994). NCBs actually were classified into the following subclasses: semi-detached, marginal contact and marginal detached systems (Zhu & Qian 2006). The mass transfer frequently happened in NCBs. NCBs have been significant targets to study the transition between the tidal-locked detached stage and W UMa type overcontact stage, occurring in binary systems.

TYC 6408–989–1 (ASAS J235103-1904.5, NSVS 14636842, GSC 06408-00989) is an EB type Am type eclipsing binary with a period of 0.470796 day (Renson et al. 1991; Slettebak & Brundage 1971; Renson & Manfroid 2009; Smalley et al. 2014). The spectral type of the primary component is A4m (Smalley et al. 2014). Slettebak & Brundage (1971) found some early type stars including this target near the south galactic pole. The period of TYC 6408–989–1 is the shortest among the well known Am type eclipsing binaries (Renson & Manfroid 2009; Torres et al. 2012, 2015). Smalley et al. (2014) presented the light curve of this target obtained by the Super WASP(SWASP) survey without photometric solutions. No detailed investigation on this target has been carried out.

The first $BV$ bands light curves and low resolution spectra of TYC 6408–989–1 were obtained in this study. The detailed light curve analysis and spectral fitting were presented. We collected all well known Am type eclipsing binaries with absolute parameters from the literature. The relationships between these parameters are summarized. Furthermore, the evolutionary stage of these systems and the reason of the chemical peculiarities are discussed.

## 2 OBSERVATION AND DATA REDUCTION

### 2.1 Photometric Observations

The first $BV$ bands light curves of Am type eclipsing binary TYC 6408–989–1 were observed with the 70 *cm* Sino-Thai telescope at Lijiang Observing Station of Yunnan Observatories (YNO), Chinese Academy of Sciences (CAS) on 2015 December 9, 11, 13 and 24. The PHOT package of IRAF was used to process all the observations. The comparison star and the check star were chosen to determine the differential magnitudes. The information of the comparison and check stars along with the target TYC 6408–989–1 are listed in Table 1. In the table, the $V$ band magnitudes of the variable star and the comparison star Ch1 were taken from Hoffman et al. (2008) and Munari et al. (2014), respectively. The $G$ band magnitudes of other comparison stars and check stars were acquired from the Gaia DR2 data (Gaia Collaboration et al. 2018). The observed CCD image of TYC 6408–989–1 was shown in Figure 1, in which the variable star was marked with ‘V’, and the comparison, check stars were marked as C1, C2, C3 and Ch1, Ch2, Ch3, respectively. The mean flux of comparison stars C1,C2,C3 (regarded as the comparison flux) and the mean flux of the check stars Ch1, Ch2, Ch3 (regarded as the check flux) were used to obtain the final differential

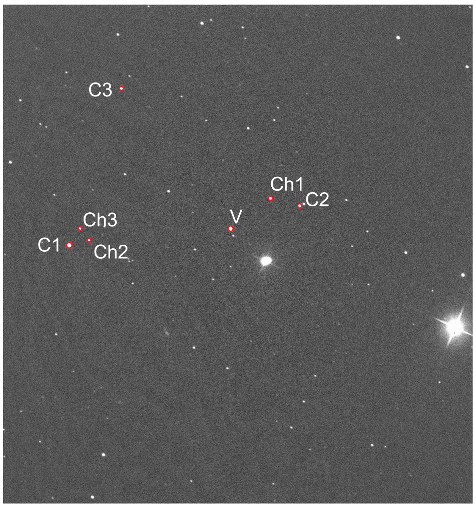

**Fig. 1** Observed CCD image of TYC 6408–989–1. ‘Variable star’ is marked with ‘V’. C1, C2, C3 mark the comparison stars and Ch1, Ch2, Ch3 represent the check stars.

magnitudes of TYC 6408–989–1, which show the light curves in Figure 2. In the figure, different colors marked the data observed on different nights. The magnitude differences between the comparison stars and the check stars are shown at the bottom of the figure.

### 2.2 Spectral Observations

The spectrum of TYC 6408–989–1 was observed on 2016 December 23 with the Beijing Faint Object Spectrograph and Camera (BFOSC) mounted to the 2.16 *m* telescope of Xinglong station of National Astronomical Observatories of China (NAOC), Chinese Academy of Sciences (CAS). The low-dispersion spectrometer BFOSC and grating G7 were used during the observations. The slit width and line dispersion of grating G7 are 1.8 arcsec and 95 Å $\mathrm{mm}^{-1}$, respectively. The observable wavelength range is 4000–6800 Å. The observations process and spectra extraction were done using IRAF. The fluxes were normalized and the atmospheric absorption lines were corrected. In such a low resolution, the observed spectra only show the spectral lines of the primary component. The observed spectrum was shown in the upper panel of Figure 3 with a black line. The University of Lyon Spectroscopic analysis Software (ULySS) (Koleva et al. 2009) was employed to acquire the atmospheric parameters through the full spectra fitting with the model spectra generated by an interpolator with the ELODIE library (Prugniel & Soubiran 2001). The fit spectrum was shown in the upper panel of Figure 3 with a red line. The obtained atmospheric parameters are as follows: $T_{\rm eff} = 6990 \pm 117$ K, $\log g = 4.25 \pm 0.26$ cm $\mathrm{s}^{-2}$, $[\mathrm{Fe/H}] = -0.55 \pm 0.03$ dex. The primary star contributes the most light to the total system and the above atmospheric parameters were commonly applied to show the atmospheric characteristics of the primary star.

The spectroscopic data of TYC 6408–989–1 are available in European Southern Observatory (ESO) archives. The data were observed with the spectrometer Faint Object Spectrograph and Camera (EFOSC2) (Buzzoni et al. 1984) mounted at the New Technology Telescope (NTT) at La Silla Paranal Observatory. During the observation, a 600 g $\mathrm{mm}^{-1}$ grating (i.e., grism 14) was used. Grism 14 has a resolving power of 7.54 Å and a spectral range of 3095–5058 Å. The slit width and the dispersion of grism 14 are 1.0 arcsec and 0.93 Å $\mathrm{pixel}^{-1}$. The observations process and spectra extraction were conducted by us using IRAF. An overview of the ESO spectrum was shown in the bottom panel of Figure 3. The ESO spectra were used to identify the spectra type through the MKCLASS program (Gray & Corbally 2014), which was designed to classify stellar spectra on the MK Spectral Classification system in a way similar to humans–by direct comparison with the MK classification standards. The standard library $libr18$ was used in our classification progress, which consists of 1.8 Å resolution rectified spectra with a spectral range from 3800–4600 Å. The spectra in standard library $libr18$ were obtained with a 1200 g $\mathrm{mm}^{-1}$ grating on the GM spectrograph of the Dark Sky Observatory (Appalachian State University).

A comparison of the blue-violet spectrum (3800–4600 Å) of TYC 6408–989–1 (kA3hF1mA5 IV-V) and part of the spectrum of two MK standards Bet Leo (A3 V) and HD 23194 (A5 V) are shown in Figure 4. It is clearly that the Ca II K line of TYC 6408–989–1 is slightly weaker in strength than that of the A3V and A5V MK standards. The spectral type derived from the MKCLASS is kA3hF1mA5, and the index of spectral type difference $\Delta$ is 2. Therefore, we conclude that TYC 6408–989–1 is a marginal Am (Am:) star with a spectral type of kA3hF1mA5 IV-V.

## 3 LIGHT CURVE ANALYSES

The first $BV$ bands light curves of TYC 6408–989–1 were phased with following linear ephemeris:

$$\begin{aligned} \mathrm{Min}I = &\ \mathrm{HJD}\,2457366.05772(.00037) \\ &+ 0.470796^{d} \times E. \end{aligned} \tag{1}$$

In the equation, the period was obtained from Smalley et al. (2014). The Wilson-Devinney (W-D) program (Wilson & Devinney 1971; Wilson 1990, 2012) was used for the light curves analysis. The temperature of the primary component was estimated as $T_1 = 6990$ K

**Table 1** Information of TYC 6408–989–1, the Comparison Stars and the Check Stars

| Targets | Name | $\alpha_{2000}$ | $\delta_{2000}$ | Mag |
|---|---|---|---|---|
| Variable(V) | TYC 6408–989–1 | $23^h51^m03^s.5689$ | $-19°04'29''.1076$ | $V$ =12.064 |
| Comparison(C) | C1(UCAC2 24500817) | $23^h51^m06^s.2789$ | $-19°11'40''.3554$ | $V$ =12.390 |
|  | C2(Gaia DR2 2390141539218676096) | $23^h50^m59^s.6221$ | $-19°01'24''.8279$ | $G$ =13.8351 |
|  | C3(Gaia DR2 2390132433888003200) | $23^h50^m38^s.6209$ | $-19°09'17''.6696$ | $G$ =13.6923 |
| Check(Ch) | Ch1(Gaia DR2 2390135560624200320) | $23^h50^m58^s.2628$ | $-19°02'42''.6827$ | $G$ =14.0021 |
|  | Ch2(Gaia DR2 2390130509742663808) | $23^h51^m05^s.3924$ | $-19°10'47''.3473$ | $G$ =15.4127 |
|  | Ch3(Gaia DR2 2390130475382925568) | $23^h51^m03^s.3342$ | $-19°11'11''.0596$ | $G$ =14.966 |

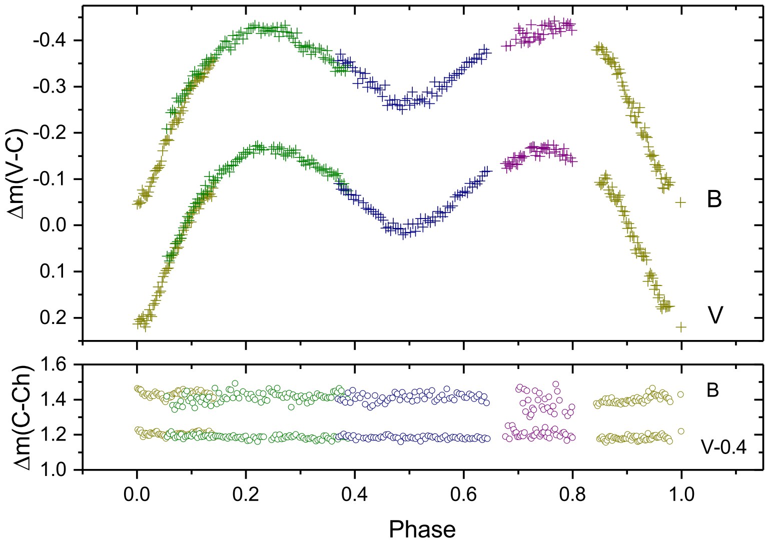

**Fig. 2** Light curves of TYC 6408–989–1 on $BV$ bands observed with the 70 *cm* Sino-Thai telescope.

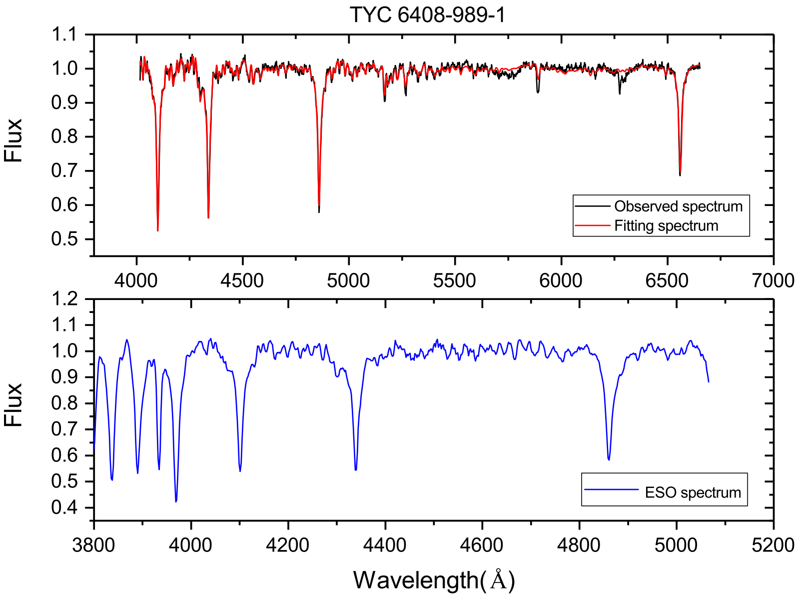

**Fig. 3** Observed spectrum of TYC 6408–989–1. The *black* and *red lines* in the upper panel represent the observed and fitted spectra, respectively. The *blue line* in the bottom panel shows an overview of the ESO spectrum.

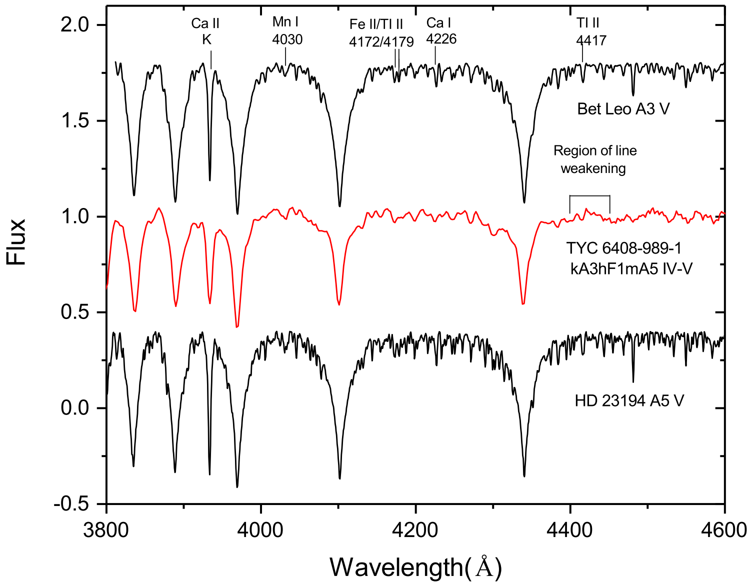

**Fig. 4** A comparison of the blue-violet spectrum $(3800 - 4600\text{Å})$ of TYC 6408–989–1 (kA3hF0mA5 IV-V) and part of the spectrum of two MK standards Bet Leo (A3 V) and HD 23194 (A5 V). Note the difference in Ca II K line strength between TYC 6408–989–1 and the two MK standards.

through the spectral fit. The light curves with all modes of WD have been tried. The finally convergent solutions were achieved with mode 3 (over-contact mode). The gravity-darkening coefficients of both components are $g_1 = g_2 = 0.32$ and bolometric albedos are $A_1 = A_2 = 0.5$ (Lucy 1967; Ruciński 1969). The bandpass limb-darkening coefficients (van Hamme 1993) and the logarithmic bolometric coefficients were applied during the WD modelling. There are some adjustable parameters in mode 3: the monochromatic luminosity of the primary star, $L_{1B}$, $L_{1V}$; the orbital inclination, $i$; the mean temperature of the secondary star, $T_2$; and the dimensionless potential of the primary star,$\Omega_1 = \Omega_2$. The third light $L_3$ was an adjustable parameter, but no converged result was obtained. The value of the third light is negative and keeps decreasing, which means that there is no third light that can be detected through the light curve analysis.

The mass ratio search (q-search) was a common technique to acquire the mass ratio. The photometric solutions were obtained with some assumed mass ratio values from 0.01 to 1 with the differential correction program. The step of the search is 0.01. The relation between the sums of weighted square deviations ($\sum (O-C)_i{}^2$) and mass ratio ($q$) are shown in Figure 5. The minimal value achieved at $q = 0.27$, which means that the solution at $q = 0.27$ is the best fit. Then the mass ratio $q$ was adjustable. The final converged photometric solutions are listed in Table 2. The uncertainty in the mass ratio in the table was given by the WD program with the standard method. In addition, the q-search curve bottom can be used to confirm the uncertainty of the mass ratio. It can be seen from Figure 5 that the q-search bottom is clearly narrow around 0.270(3) (visually, from 0.25 to 0.28) and the uncertainty is approximately 0.04. The theoretical light curves of TYC 6408–989–1 were shown in Figure 6 with black lines. The standard deviations of the residuals on $BV$ bands are both about 0.012 magnitudes. The geometric structure in 3D view is plotted in Figure 7.

**Table 2** Photometric Solutions of TYC6408–989–1

| Parameters | Values | Parameters | Values |
|---|---|---|---|
| Mode | Mode 3 | $L_1/L_{\text{total}\,V}$ | 0.93683(16) |
| $g_1 = g_2$ | 0.32(fixed) | $f$ | 0.003(29) |
| $A_1 = A_2$ | 0.5(fixed) | $r_1$(pole) | 0.46460(71) |
| q ($M_2/M_1$ ) | 0.270(3) | $r_1$(side) | 0.50088(94) |
| $i(^\circ)$ | 69.31(26) | $r_1$(back) | 0.5255(11) |
| $T_1$(K) | 6990 | $r_2$(pole) | 0.2541(32) |
| $T_2$(K) | 5089(50) | $r_2$(side) | 0.2646(38) |
| $\Omega_1$ | 2.3985(49) | $r_2$(back) | 0.2975(68) |
| $\Omega_2$ | 2.3985 | $R_2/R_1$ | 0.5480(55) |
| $L_1/L_{\text{total}\,B}$ | 0.959822(89) | $\sum(O-C)^2$ | 0.0054 |

## 4 DISCUSSION AND CONCLUSIONS

The $BV$ light curves of TYC 6408–989–1 were obtained firstly. The light curves show $\beta$ Lyrae characteristics. The atmospheric parameters of the primary star are estimated through the low resolution spectral fit as follows: $T_{\text{eff}} =$

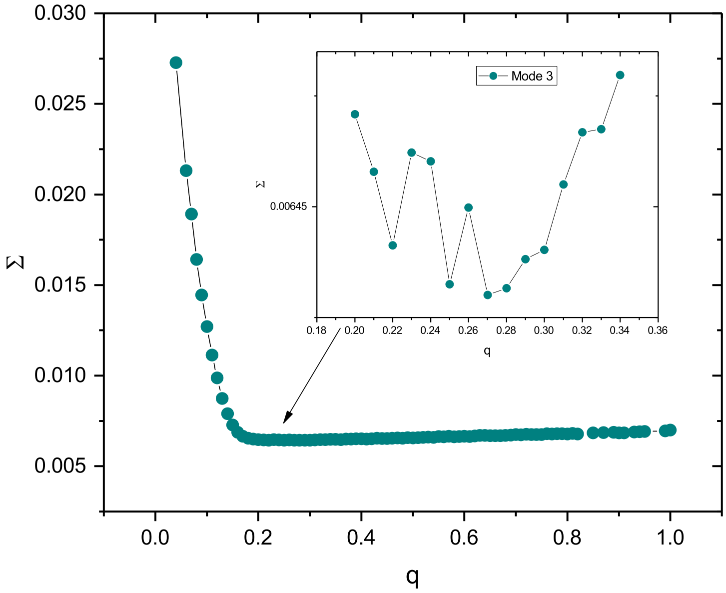

**Fig. 5** $\sum -q$ curve of TYC 6408–989–1.

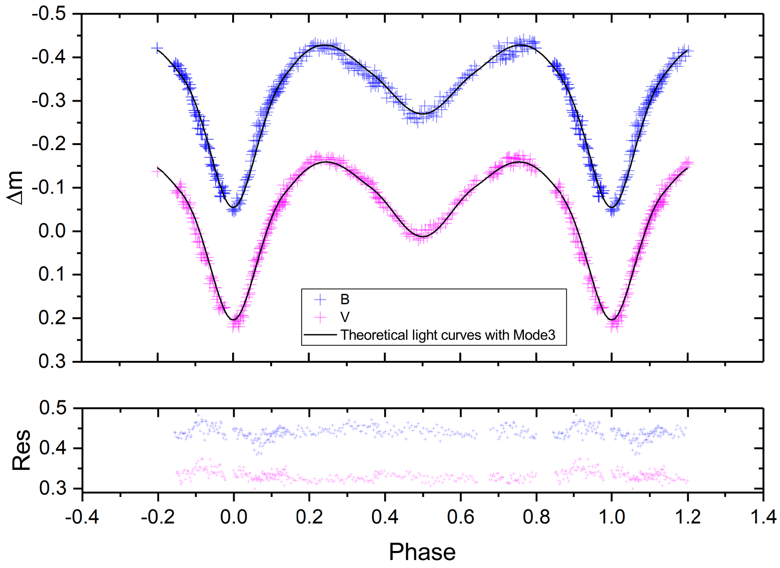

**Fig. 6** The theoretical light curves of TYC 6408–989–1.

$6990 \pm 117$ K, $\log g = 4.25 \pm 0.26$ cm s$^{-2}$, $[\mathrm{Fe/H}] = -0.55 \pm 0.03$ dex. The light curves analysis were done using the WD program. The contact degree factor of TYC 6408–989–1 is 0.003(29), which is extremely low and the error is quite large. That means that TYC 6408–989–1 should be a marginal contact binary, in which both components has nearly filled their critical RLs, just like UX Eri (Qian et al. 2007), AS Ser (Zhu et al. 2008), DD Com (Zhu et al. 2010) and DI Hya (Liao et al. 2017). TYC 6408–989–1 is one of the three well known Am type marginal contact binaries, the others are V1073 Cyg (Tian et al. 2018) and V2782 Ori (Tian et al. 2019). The orbital inclination of this target is $i = 69.31(26)^{\circ}$. The mass ratio was estimated as about $q = 0.270(3)$ through the mass ratio search progress. TYC 6408–989–1 was concluded as a marginal Am (Am:) star with a spectral type of kA3hF1mA5 IV-V. The difference between Sp(K) and Sp(M) is two subclasses (i.e., $\Delta = 2$). TYC 6408–

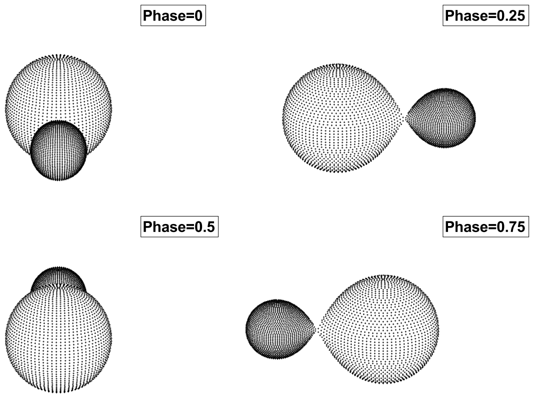

**Fig. 7** Geometrical structure of TYC 6408–989–1 in 3D view.

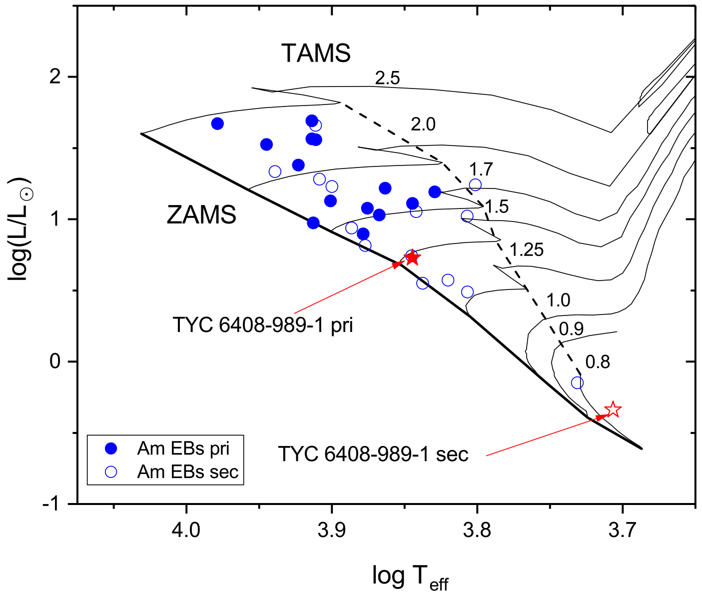

**Fig. 8** The temperature-luminosity diagram of Am type EBs.

989–1 consists of an F1 type primary star with $M_1 = 1.56(12)\ M_\odot$ (Cox & Pilachowski 2000). The spectra of the secondary star should be K0 type, which can be inferred from the temperature. Based on the photometric solutions, the absolute parameters of TYC 6408–989–1 were calculated as follows: $M_2 = 0.42(10)\ M_\odot$, $R_1 = 1.581(3)\ R_\odot$, $R_2 = 0.874(2)\ R_\odot$, $L_1 = 5.360(378)\ L_\odot$, $L_2 = 0.459(3)\ L_\odot$. TYC 6408–989–1 should be a B subtype contact binary with temperature difference between the two stars (which is about 1860 K), larger than 1000 K (Lucy & Wilson 1979; Csizmadia & Klagyivik 2004), like V2787 Ori(Tian et al. 2019).

Using the Kepler's third law and the photometric solutions with mode 3, the mean densities of the primary and secondary star were calculated as $\rho_1 = 0.388\rho_\odot$ and $\rho_2 = 0.636\rho_\odot$, respectively. The corresponding logarithmic values are $\log \rho_1/\rho_\odot = -0.411$ and $\log \rho_2/\rho_\odot = -1.97$. The mean densities of both components (especially the secondary star) are significantly lower than main sequence stars with the same spectral type (Cox & Pilachowski 2000), which indicates that the components of TYC 6408–989–1 may have evolved away from the Zero Age Main Sequence (ZAMS) line and the secondary star may have a higher degree of evolution. The luminosity class of the

**Table 3** Parameter of Some Known Am Type Eclipsing Binaries

| Star<br>- | Renson | Period<br>(d) | $q(M_2/M_1)$ | $M_1$<br>$(M_\odot)$ | $M_2$<br>$(M_\odot)$ | $T_1$<br>(K) | $T_2$<br>(K) | $L_1$<br>$(L_\odot)$ | $L_2$<br>$(L_\odot)$ | Type | Ref |
|---|---|---|---|---|---|---|---|---|---|---|---|
| V1073 Cyg | 56830 | 0.7858506 | 0.303 | 1.810(4) | 0.549(1) | 7300 | 6609(18) | 16.51 | 3.74 | W UMa | [1] |
| V2787 Ori | 11387 | 0.810979 | 0.120(2) | 1.44 | 0.17(1) | 6993(82) | 5386(29) | 12.93 | 0.71 | W UMa | [2] |
| TYC 6408–989–1 | 61280 | 0.470796 | 0.230(3) | 1.56(12) | 0.42(10) | 6990 | 5089(50) ) | 5.36(38) | 0.459(3) | W UMa | This study |
| TX Her | 44140 | 2.05984 | 0.895 | 1.61 | 1.44 | 8180 | 7536(20 | 9.44 | 6.56 | Algol | [3] |
| YZ Cas | 1140 | 4.4672235 | 0.585(2) | 2.263(12) | 1.325(7) | 9520(120) | 6880(240) | 46.989 | 3.556 | Algol | [4][5] |
| WW Aur | 12320 | 2.52501941 | 0.9235(27) | 1.964(7) | 1.814(7) | 7960(420) | 6411(410) | 13.458 | 10.544 | Algol | [6] |
| GZ CMa | 15390 | 4.80085 | 0.909 | 2.200(25) | 2.000(25) | 8810 | 8694 | 33.496 | 21.627 | Algol | [7] |
| V624 Her | 45460 | 3.894977 | 0.8326 | 2.270(14) | 1.870(13) | 8147 | 7943 | 36.308 | 16.982 | Algol | [8] |
| DV Boo | 35946 | 3.782624 | 0.75 | 1.64(2) | 1.23(2) | 7370(80) | 6410(74) | 10.715 | 3.090 | Algol | [9] |
| V885 Cyg | 50855 | 1.69478781 | 1.114 | 2.005(29) | 2.234(26) | 8375(150) | 8150(150) | 23.988 | 45.709 | Algol | [10] |
| EI Cep | 57180 | 8.4393522 | 0.9483 | 1.7716(66) | 1.6801(62) | 6750(100) | 6950(100) | 15.596 | 11.350 | Algol | [11] |
| EE Peg | 57410 | 2.628 | 0.6186 | 2.15(2) | 1.33(1) | 8709 | 6456 | – | – | Algol | [12] |
| SW CMa | – | 10.091988 | 0.9397 | 2.239(14) | 2.104(18) | 8200(150) | 8100(150) | 36.813 | 19.099 | Algol | [13] |
| HW CMa | – | 21.1178329 | 0.9665(43) | 1.721(11) | 1.781(12) | 7560(150) | 7700(150) | 7.907 | 8.710 | Algol | [13] |
| AN And | 60340 | 3.219566 | 0.53 | 2.48 | 1.32 | 8200 | 6330 | 49.2 | 17.5 | $\beta$ Lyr | [14] |
| V501 Mon | – | 7.02 | 0.8865 | 1.6455(43) | 1.4588(25) | 7510(100) | 7000(90) | 11.940 | 5.534 | Algol | [15] |

[1] Tian et al. (2018); [2] Tian et al. (2019); [3] Zhu et al. (2019); [4] Pavlovski et al. (2014); [5] Lastennet et al. (2000); [6] Southworth et al. (2005); [7] Popper et al. (1985); [8] Popper (1984); [9] Carquillat et al. (2004); [10] Lacy et al. (2004); [11] Torres et al. (2000); [12] Lacy & Popper (1984); [13]Torres et al. (2012); [14] Tremko & Bakos (1978); [15] Torres et al. (2015).

target from IV to V indicates that the primary should be an evolved subgiant.

The components in very short period NCB systems like TYC 6408–989–1 are likely rotating synchronously. For a circular orbit, the following equation can be used to obtain the synchronism rotational velocity: $v = 50.6(R/R_\odot)/(P/\mathrm{d})\ \mathrm{km\,s^{-1}}$ (Carquillat & Prieur 2007), in which $R$ is the radius of the considered component, $P$ is the orbital period, $v$ is its equatorial rotational velocity. The synchronous rotation velocity $v \sin i$ of the primary should be about 160 $\mathrm{km\,s^{-1}}$. TYC 6408–989–1 is a very especial Am type eclipsing binary with very short period (less than one day), marginal Am peculiarity and quite large rotational velocity, which make it became a challenge to the cut-off of rotation velocities and periods of Am stars, like V1073 Cyg ($v \sin i = 150\ \mathrm{km\,s^{-1}}$) (Budaj 1996).

According to the thermal relaxation oscillation theory (Lucy 1976; Flannery 1976; Robertson & Eggleton 1977; Lucy & Wilson 1979), W UMa type systems must undergo oscillations around the state of marginal contact. TYC 6408–989–1 should be a particular target like other marginal contact binaries lying in the TRO stage (Qian & Zhu 2002; Zhu et al. 2009, 2012). Such targets are very important for the investigation of the formation between detached and contact phase of binaries, which are quite rarely in observation. The light curves of these systems show $\beta$ Lyrae-type light-variation characteristics. In the evolutionary process, the systems may be in a semidetached phase with the more massive star filling the RL, and then evolve into a marginal-contact phase with poor thermal contact. TYC 6408–989–1 should be lying on the poor thermal contact stage. It is another promising candidate located in such a rare evolutionary stage, it will evolve to become a shallow contact binary with true thermal contact (e.g., Liao et al. 2012; Qian et al. 2013, 2014 and Liao & Sarotsakulchai 2019).

Some eclipsing Am binaries with known parameters were collected and tabulated in Table 3. The temperature-luminosity diagram of Am type EBs are plotted in Figure 8. In the figure, the ZAMS and terminal-age main sequence (TAMS) lines are obtained from Schaller et al. (1992) at $Z = 0.020$. From the figure, we can see that both components of Am type EBs are located in the main sequence. According to Fowler et al. (1965), one component in the Am type binary may has evolved through the giant phase, it may have striped most of the hydrogen shell and the stellar shell were exposed leading to higher temperature, then it will returned to main sequence. The statistical result support the above theory well. The accretion processes (such as mass transfer) may be very important for the formation of Am peculiarity in binaries. The mass transfer from the evolved component of Am type eclipsing binaries will recombine the chemical elements in the atmosphere of the companion stars and may result in chemical anomalies composition, such as the marginal contact binary V1073 Cyg (Tian et al. 2018), V2787 Ori (Tian et al. 2019) and TYC 6408–989–1, which are lying on the thermal relaxation oscillation state (Lucy 1976; Robertson & Eggleton 1977; Lucy & Wilson 1979). Mass transfer between the components may play an important role in the formation and evolution of Am stars in binaries. More observation evidence is needed to support this discussion. The research on individual Am type binaries including the binaries with very short periods (less than one day) will be very important and indispensable for exploring the formation and evolution of the Am star.

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