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# Absolute parameters and physical nature of two W-UMa type binaries: V1123 Tau and V1128 Tau *

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**Abstract** We present high-precision, multi-band CCD photometry of two less-studied close binaries V1123 Tau and V1128 Tau. Complete covered light curves and a number of new times of light minima of the two eclipsing systems were obtained, based on which, revised orbital elements and new ephemerides were given. By adopting the Wilson-Devinney method, the light curves were analyzed. The photometric solutions confirm the W UMa-type nature of the binary systems. With the less-massive secondary slightly cooler than the primary, V1123 Tau could be classified as an A-type contact system. While V1128 Tau is typically considered a W-type W UMa star, the surface temperature of its secondary component is determined to be absolutely higher than the primary by about 270 K. Combining with the results of radial-velocity solutions, we determined absolute parameters of the two systems. The mass, radius and luminosity for each component of V1123 Tau were derived as: $1.36 \pm 0.05M_{\odot}$, $1.37 \pm 0.02R_{\odot}$, and $2.01 \pm 0.07L_{\odot}$ and $0.40 \pm 0.02M_{\odot}$, $0.80 \pm 0.01R_{\odot}$, and $0.67 \pm 0.04L_{\odot}$, respectively. For V1128 Tau, the absolute parameters were computed to be $1.09 \pm 0.03M_{\odot}$, $1.01 \pm 0.01R_{\odot}$, and $1.34 \pm 0.06L_{\odot}$ and $0.58 \pm 0.01M_{\odot}$, $0.76 \pm 0.01R_{\odot}$, and $0.91 \pm 0.05L_{\odot}$, respectively. Based on these results, the evolutionary status and the physical nature of the two binary systems are discussed, while also connecting with the theoretical models.

**Key words:** binaries: eclipsing — stars: late-type — stars: activity — stars: individual (V1123 Tau, V1128 Tau)

## 1 INTRODUCTION

W UMa-type systems are a group of contact binaries consisting of solar-type stars. Because of their peculiar observational properties, such as the so-called light-curve paradox, W UMa stars have been a challenge to the current theory of stellar structure and evolution since the 1960s (Lucy 1968a,b; Mochnacki 1981; Rucinski 1993; Eggleton 1996). How these systems formed and evolved is still

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an open issue, although W UMa stars are the most common kind of close binaries in the solar neighborhood. To answer these questions, precisely determined absolute parameters for more contact samples are needed.

V1123 Tau is a member of the visual double system WDS 03350+1743. It is accompanied by a fainter, late-type companion separated by about four arcsec. The variability of this star was discovered by HIPPARCOS (ESA 1997). In the Hipparcos Variable Star Annex, V1123 Tau is classified as a $\beta$ Lyrae-type eclipsing binary, while it is listed as a W UMa-type system by Kazarovets et al. (1999). Ozdarcan et al. (2006) published the first and only ground-based photoelectric photometry of V1123 Tau. The authors obtained two sets of UBVR light curves of the binary in 2003 and 2005, respectively, and confirmed its W UMa-type nature. Based on the observed color index, Ozdarcan et al. (2006) assigned a spectral type of G6V to the binary system, but it was recently revised to be G0V by Rucinski et al. (2008) and confirmed by Gutiérrez (2009).

V1128 Tau is another eclipsing binary discovered during the HIPPARCOS satellite mission. It also has a wide visual companion, BD +12 511B, separated by 14 arcsec. Tas et al. (2003) presented the first ground-based B and V band light curves of the binary star. The subsequent light-curve modeling indicated that V1128 Tau could be a totally eclipsing contact system of W-type with a mass ratio of 0.48 and a high orbital inclination of about 85 degrees. These were mostly confirmed later by Hawkins et al. (2005) based on five-band (UBVRI) CCD photometry.

These observations show that both V1123 Tau and V1128 Tau could be very interesting samples for studying W UMa-type stars. Rucinski et al. (2008) published high-precision spectroscopy of the two binary stars. The systems were both found to be double-lined. Thus their mass-ratios and mass functions were accurately determined by the authors through the radial-velocity solutions. This enables us to precisely determine the absolute parameters of the two binaries and discuss their physical nature in detail. We have therefore performed high-precision, multi-band CCD photometry of the two stars. We present the results of these observations in this paper.

## 2 OBSERVATIONS AND DATA REDUCTION

All the observations were carried out at the Xinglong Station of the National Astronomical Observatories, Chinese Academy of Sciences by using the 85 cm telescope. Data were collected with a PI MicroMAX 1024 BFT CCD camera, which provides a field of view of about $16.5' \times 16.5'$, corresponding to an image scale of 0.96 arcsec per pixel (Zhou et al. 2009). Four standard Johnson-Cousin-Bessell filters in the $B$, $V$, $R$ and $I$ bands were employed.

The star V1123 Tau was first observed on two nights from Nov. 28 to 29 in 2008. However, the quality of the photometry was not good enough for a precise light-curve analysis as we found later during the data reduction; we therefore observed the star again over two nights from Nov. 20 to 21 in 2009. We have obtained about 800 useful frames in each band, which completely cover four eclipses during this run. V1128 Tau was monitored from Nov. 30 to Dec. 15 in 2008. Useful data were obtained on four nights (Nov. 30, Dec. 13, 14 and 15). A total number of 1100 CCD images in each band was recorded.

The preliminary processing of the CCD frames was performed with the standard routines of CCDPROC in the IRAF package. Photometry was extracted using the DAOPHOTII package (Stetson 1987). For differential photometry, we used a nearby star located at $\alpha(2000) = 03^{\rm h}34^{\rm m}16^{\rm s}$, $\delta(2000) = +17°50'14''$ as the comparison star of V1123 Tau, and another one at $\alpha(2000) = 03^{\rm h}34^{\rm m}35^{\rm s}$, $\delta(2000) = +17°50'56''$ as the check star. For V1128 Tau, the star TYC664+751–1 was used as the comparison star since its color index was found to be close to the target and it appeared to be constant within 0.01 mag during all the observing nights, although it was fainter than the maximum light of the variable by about 1.6 mag in all the $B$, $V$, $R$, and $I$ bands. The star TYC664–751–1 was employed as the check star.

## 3 THE ORBITAL ELEMENTS

A total of five eclipses, including two primary and three secondary light minima, were recorded in all the $B$, $V$, $R$ and $I$ bands for V1123 Tau during the two observing sessions. By using the K-W method (Kwee & van Woerden 1956), the epochs of these light minima were determined as given in Table 1.

**Table 1** Photoelectric and CCD Times of Minima of V1123 Tau and the Residuals Computed from the Derived Ephemeris

| JD (Hel) (2400000+) | $E$ | $(O-C)1$ (d) | $(O-C)2$ (d) | Reference |
|---|---|---|---|---|
| 51832.5518 | –8310.0 | –0.0019 | –0.0014 | Hegedus et al. (2003) |
| 51837.3523 | –8298.0 | –0.0008 | –0.0003 | Hegedus et al. (2003) |
| 51877.5481 | –8197.5 | 0.0003 | 0.0007 | Hegedus et al. (2003) |
| 52591.4541 | –6412.5 | –0.0002 | –0.0002 | Tas et al. (2004) |
| 52606.4543 | –6375.0 | 0.0020 | 0.0020 | Derman & Kalci (2003) |
| 52634.4492 | –6305.0 | 0.0006 | 0.0005 | Derman & Kalci (2003) |
| 52963.4075 | –5482.5 | 0.0020 | 0.0018 | Tas et al. (2004) |
| 52964.4052 | –5480.0 | –0.0002 | –0.0004 | Tas et al. (2004) |
| 52976.4034 | –5450.0 | –0.0004 | –0.0006 | Tas et al. (2004) |
| 53001.4001 | –5387.5 | –0.0005 | –0.0006 | Tas et al. (2004) |
| 53020.5985 | –5339.5 | 0.0005 | 0.0003 | Nelson (2005) |
| 53020.5977 | –5339.5 | –0.0003 | –0.0005 | Dvorak (2005) |
| 53624.5198 | –3829.5 | 0.0009 | 0.0006 | Ozdarcan et al. (2006) |
| 53625.5179 | –3827.0 | –0.0009 | –0.0011 | Ozdarcan et al. (2006) |
| 53649.5159 | –3767.0 | 0.0003 | 0.0000 | Ozdarcan et al. (2006) |
| 53658.5151 | –3744.5 | 0.0006 | 0.0004 | Ozdarcan et al. (2006) |
| 53716.3052 | –3600.0 | –0.0017 | –0.0019 | Hubscher et al. (2006) |
| 53716.5067 | –3599.5 | –0.0002 | –0.0004 | Hubscher et al. (2006) |
| 54016.4684 | –2849.5 | 0.0009 | 0.0006 | Hubscher & Walter (2007) |
| 54800.1651 | –890.0 | 0.0002 | 0.0003 | Present study |
| 55156.1184 | 0.0 | 0.0002 | 0.0005 | Present study |
| 55156.3171 | 0.5 | –0.0011 | –0.0008 | Present study |
| 55157.1172 | 2.5 | –0.0009 | –0.0006 | Present study |
| 55157.3187 | 3.0 | 0.0006 | 0.0010 | Present study |

In addition, we have collected another 19 minimum times of the star from publications. With all data listed in Table 1, linear and quadratic ephemerides were derived for the binary system by the least square fitting.

$$\mathrm{Min.I(HJD)} = 2455156.1821(3) + 0^{\mathrm{d}}.39994759(5) \times E. \tag{1}$$

$$\mathrm{Min.I(HJD)} = 2455156.1178(3) + 0^{\mathrm{d}}.39994730(11) \times E - 3.8(1.9) \times 10^{-11} \times E^2. \tag{2}$$

This gives a revised orbital period slightly shorter than that given by Ozdarcan et al. (2006). The $O-C$ residuals for all the times of minimum light with respect to the two ephemerides were computed as given in Table 1 and plotted in Figure 1. The combined data show no obvious orbital period changes of the system during the past decade.

For V1128 Tau, we have also determined five precision mean epochs of minimum light from eclipse timings in the $B$, $V$, $R$ and $I$ bands. They are compiled in Table 2 along with all available timings of light minima of the star. A linear fit to these data gives

$$\mathrm{Min.I(HJD)} = 2454801.1230(3) + 0^{\mathrm{d}}.30537184(5) \times E. \tag{3}$$

Since the $O-C$ plot showed a probable intrinsic period change for the binary system, we have also calculated a quadratic fitting to all available timings, which resulted in a quadratic ephemeris

$$\mathrm{Min.I(HJD)} = 2454801.1213(3) + 0^{\mathrm{d}}.30537068(11) \times E - 1.21(11) \times 10^{-10} \times E^2. \tag{4}$$

**Table 2** Times of Light Minima of V1128 Tau and the Residuals with Respect to the Derived Linear and Quadratic Ephemerides

| JD (Hel) (2400000+) | $E$ | $(O-C)1$ (d) | $(O-C)2$ (d) | Reference |
|---|---|---|---|---|
| 51822.5237 | –9754.0 | –0.0024 | –0.0004 | Hegedus et al. 2003 |
| 51830.4633 | –9728.0 | –0.0024 | –0.0005 | Hegedus et al. 2003 |
| 51830.6165 | –9727.5 | –0.0019 | –0.0000 | Hegedus et al. 2003 |
| 52236.4578 | –8398.5 | 0.0002 | 0.0007 | Tas et al. 2003 |
| 52236.6099 | –8398.0 | –0.0004 | 0.0001 | Tas et al. 2003 |
| 52240.4273 | –8385.5 | –0.0001 | 0.0004 | Tas et al. 2003 |
| 52248.3671 | –8359.5 | –0.0000 | 0.0005 | Tas et al. 2003 |
| 52254.3203 | –8340.0 | –0.0016 | –0.0011 | Tas et al. 2003 |
| 52258.2906 | –8327.0 | –0.0011 | –0.0006 | Tas et al. 2003 |
| 52258.4442 | –8326.5 | –0.0002 | 0.0003 | Tas et al. 2003 |
| 52263.3300 | –8310.5 | –0.0003 | 0.0001 | Tas et al. 2003 |
| 52263.4819 | –8310.0 | –0.0011 | –0.0007 | Tas et al. 2003 |
| 52277.2234 | –8265.0 | –0.0013 | –0.0009 | Tas et al. 2003 |
| 52277.3768 | –8264.5 | –0.0006 | –0.0002 | Tas et al. 2003 |
| 52313.2582 | –8147.0 | –0.0004 | –0.0001 | Tas et al. 2003 |
| 52314.3272 | –8143.5 | –0.0002 | 0.0001 | Tas et al. 2003 |
| 52315.2437 | –8140.5 | 0.0002 | 0.0005 | Tas et al. 2003 |
| 52536.4872 | –7416.0 | 0.0018 | 0.0015 | Tas et al. 2003 |
| 52563.5118 | –7327.5 | 0.0010 | 0.0007 | Tas et al. 2003 |
| 52565.3432 | –7321.5 | 0.0001 | –0.0002 | Tas et al. 2003 |
| 52565.4972 | –7321.0 | 0.0014 | 0.0012 | Tas et al. 2003 |
| 52608.2479 | –7181.0 | 0.0001 | –0.0003 | Tas et al. 2003 |
| 52608.4012 | –7180.5 | 0.0007 | 0.0003 | Hawkins et al. 2005 |
| 52998.6665 | –5902.5 | 0.0008 | –0.0001 | Hawkins et al. 2005 |
| 53000.6523 | –5896.0 | 0.0017 | 0.0007 | Hawkins et al. 2005 |
| 53000.8044 | –5895.5 | 0.0011 | 0.0002 | Ogloza et al. 2008 |
| 53305.7179 | –4897.0 | 0.0008 | –0.0003 | Ogloza et al. 2008 |
| 53315.6411 | –4864.5 | –0.0006 | –0.0017 | Ogloza et al. 2008 |
| 53315.7964 | –4864.0 | 0.0020 | 0.0010 | Ogloza et al. 2008 |
| 53320.6811 | –4848.0 | 0.0008 | –0.0003 | Ogloza et al. 2008 |
| 53321.7496 | –4844.5 | 0.0005 | –0.0006 | Ogloza et al. 2008 |
| 53326.6372 | –4828.5 | 0.0021 | 0.0011 | Ogloza et al. 2008 |
| 53326.7905 | –4828.0 | 0.0027 | 0.0017 | Ogloza et al. 2008 |
| 53327.7054 | –4825.0 | 0.0015 | 0.0005 | Ogloza et al. 2008 |
| 53328.6207 | –4822.0 | 0.0007 | –0.0004 | Ogloza et al. 2008 |
| 53328.7742 | –4821.5 | 0.0015 | 0.0005 | Ogloza et al. 2008 |
| 53329.6894 | –4818.5 | 0.0006 | –0.0005 | Ogloza et al. 2008 |
| 53339.6151 | –4786.0 | 0.0017 | 0.0007 | Ogloza et al. 2008 |
| 53347.7071 | –4759.5 | 0.0014 | 0.0003 | Ogloza et al. 2008 |
| 53366.6353 | –4697.5 | –0.0035 | –0.0046 | Ogloza et al. 2008 |
| 53706.3658 | –3585.0 | 0.0008 | –0.0001 | Hubscher et al. 2006 |
| 53707.7406 | –3580.5 | 0.0015 | 0.0006 | Nelson 2006 |
| 54083.4987 | –2350.0 | –0.0005 | –0.0008 | Hubscher & Walter 2007 |
| 54500.3313 | –985.0 | –0.0005 | 0.0002 | Hubscher et al. 2009 |
| 54801.1216 | –0.0 | –0.0014 | 0.0003 | Present study |
| 54801.2735 | 0.5 | –0.0022 | –0.0005 | Present study |
| 54814.1006 | 42.5 | –0.0007 | 0.0010 | Present study |
| 54815.0144 | 45.5 | –0.0031 | –0.0013 | Present study |
| 54816.0854 | 49.0 | –0.0009 | 0.0009 | Present study |

The $O-C$ residuals for all the times of minimum light with respect to the linear and quadratic ephemerides are computed as given in Table 2.

Figure 2 illustrates the quadratic fit to the linear $O-C$ residuals from the second ephemeris. It clearly indicates that the binary system could have undergone a rapid orbital period decrease during the past two decades, though the timings only cover about 10 000 cycles. This confirms the

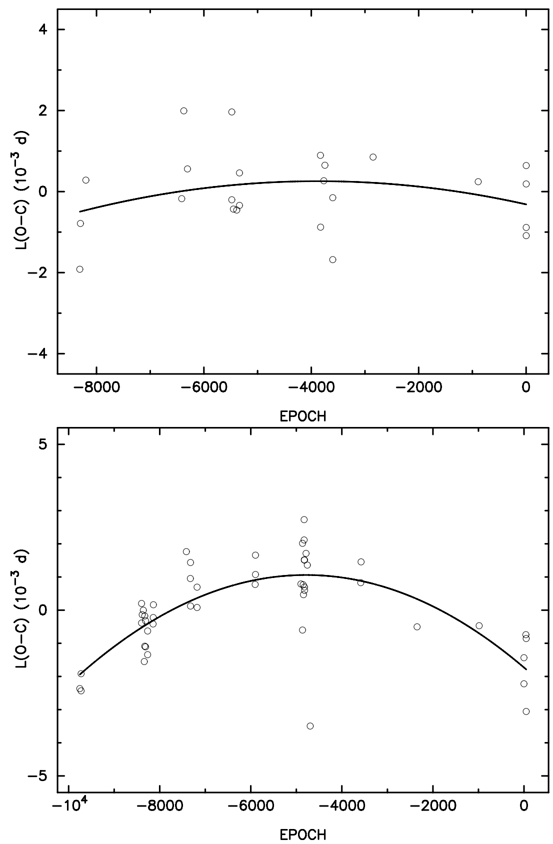


**Fig. 1** Period analysis of V1123 Tau and V1128 Tau.

result of Hawkins et al. (2005). The rate of period decrease turns out to be about $dP/dE = -2.41 \times 10^{-10}$ d cycle$^{-1}$ or $dP/dt = -2.89 \times 10^{-7}$ d yr$^{-1}$. This will be discussed in detail later in Section 5.

## 4 LIGHT CURVE ANALYSIS

### 4.1 V1123 Tau

With the derived linear ephemeris, phases of all the measurements of V1123 Tau were computed. With the data obtained in 2009, we constructed the phased light curves of V1123 Tau as plotted in Figure 2. The general feature of the light curves of V1123 Tau is typical of W UMa systems with nearly equal minima. The primary eclipse is slightly deeper than the secondary one by 0.024, 0.018, 0.014 and 0.012 mag in the $B$, $V$, $R$ and $I$ bands, respectively. The depths of the primary minima with respect to the primary light maxima (Max I, at phase 0.25) were measured to be 0.376, 0.358, 0.347 and 0.339 mag in the $B$, $V$, $R$ and $I$ filters, respectively. In comparison to the previously published light curves by Ozdarcan et al. (2006), the asymmetry of the light curves outside the eclipses appears to be more obvious. The secondary maxima (at phase 0.75) were measured to be brighter than the primary ones by 0.051 mag in B, 0.037 mag in $V$, 0.029 mag in $R$ and 0.024 mag in $I$ band, respectively. The marked distortion and changes in the light curves could be caused by the probable strong spot activity on the star's surface, considering the very late spectral type of the system.

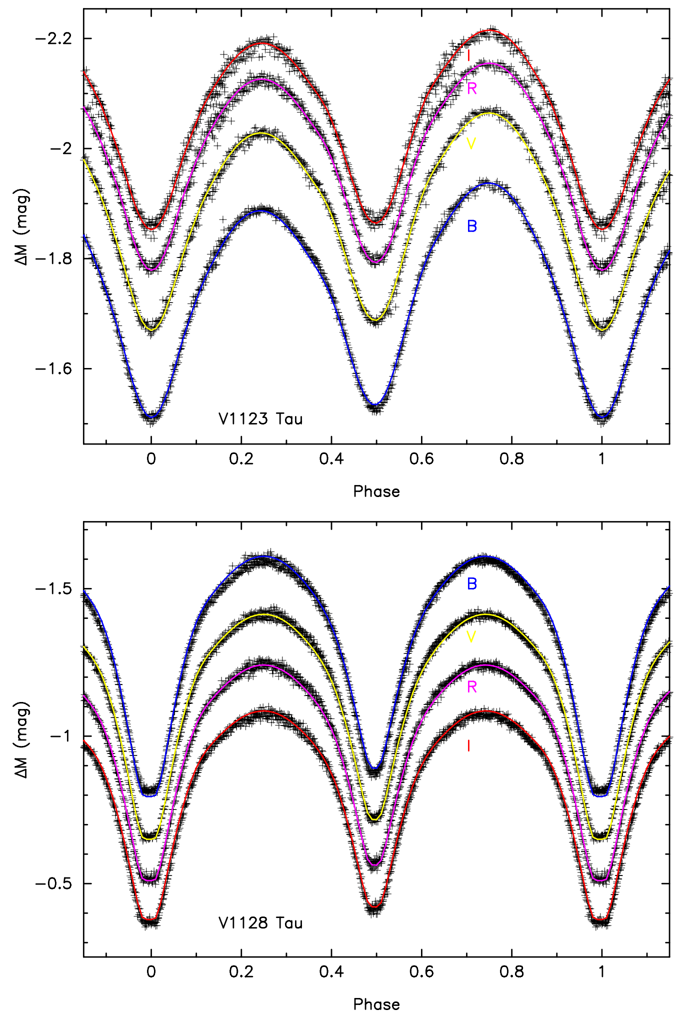


**Fig. 2** Observed $B$, $V$, $R$ and $I$ light curves of V1123 Tau and V1128 Tau plotted along with their theoretical synthesis.

With the completely covered $B$, $V$, $R$ and $I$ band light curves, photometric solutions of the eclipsing system were computed. The numerical light curve analysis was made by using the 2003 version of the Wilson-Devinney code with the Kurucz atmospheres (Wilson & Devinney 1971; Wilson 1979, 1990, ). A nonlinear limb-darkening law with a logarithmic form was applied in the light curve synthesis. Considering the probable close distance between the components, the effect of reflection was taken into account. The initial bolometric ($X_1$, $X_2$, $Y_1$, $Y_2$) and monochromatic ($x_1$, $y_1$, $x_2$, $y_2$) limb-darkening coefficients of the components were taken from van Hamme (1993). The gravity darkening exponents were set to be $g_1$=$g_2$=0.32 according to Lucy (1967), and bolometric albedos were given as $A_1$=$A_2$=0.5 following Ruciński (1969).

In modeling the light curves of V1123 Tau, we set $T_1 = 5940\,\mathrm{K}$ according to the spectral type of G0 through the calibration of Cox (2000). The mass ratio of the system was fixed at $q = M_2/M_1 = 0.279$ according to Rucinski et al. (2008). Since the light curves are markedly asymmetric outside the eclipses, we could not obtain a satisfactory fit to both the quadratures of the light curves with the unspotted synthesis. At the outset, we set the weights of the measurements with phases between 0.6 and 0.9 to be zero and only fit the first quadrature of the light curves. In this way we derived the approximate geometrical system parameters. After that, the weights for all the measurements were reset to be one, and a one-spot model was applied to perform further analysis.

In general, the asymmetry of the light curves can be synthesized by either a cool spot or a hot spot model. Inspecting the light curves, along with those from Ozdarcan et al. (2006), in detail, one can find that the light distortions and variations all occurred in the second quadrature. Meanwhile, we noted that the light asymmetry varies depending on the bandpass. The largest light excess at MAX. II appears in $B$, and the lowest appears in the $I$-band light curve. These suggest that the asymmetry of the light curves of V1123 Tau could very probably be caused by a hot spot rather than a cool one on the surface of one component; we therefore placed an assumed hot spot on the primary component and adjusted the spot parameters along with the adjustable system parameters. The preliminary spot longitude could be found approximately from the phases of spot distortion in the light curves. The other three parameters were calculated by adjusting the theoretical light curve to approximately fit the observed distorted light curve. The spot parameters were then adjusted along with the adjustable system parameters. Finally, we derived the photometric solution with the best fit. Table 3 lists the results from the best-fit solution. The light curve synthesis was illustrated by Figure 2. In Figure 3, a geometric presentation of the system along with the cool spot based on the solutions is displayed.

**Table 3** Photometric Solutions for V1123 Tau and V1128 Tau

| Parameters | V1123 Tau Best-fit value (Error) | V1128 Tau Best-fit value (Error) |
|---|---|---|
| $q = m2/m1$ | 0.297 | 1.873 |
| $g_1 = g_2$ | 0.32 | 0.32 |
| $A_1 = A_2$ | 0.50 | 0.50 |
| $X_{\rm bol1}, X_{\rm bol2}$ | 0.644, 0.642 | 0.639, 0.640 |
| $Y_{\rm bol1}, Y_{\rm bol2}$ | 0.224, 0.214 | 0.241,0.232 |
| $x_{1B}, y_{1B}$ | 0.827, 0.177 | 0.806, 0.232 |
| $x_{1V}, y_{1V}$ | 0.743, 0.255 | 0.710, 0.275 |
| $x_{1R}, y_{1R}$ | 0.650, 0.269 | 0.617, 0.284 |
| $x_{1I}, y_{1I}$ | 0.557, 0.260 | 0.526, 0.271 |
| $x_{2B}, y_{2B}$ | 0.834, 0.131 | 0.815, 0.206 |
| $x_{2V}, y_{2V}$ | 0.757, 0.235 | 0.725, 0.266 |
| $x_{2R}, y_{2R}$ | 0.666, 0.259 | 0.632, 0.277 |
| $x_{2I}, y_{2I}$ | 0.572, 0.255 | 0.540, 0.266 |
| $T_1$ (K) | 5940 | 6519(4) |
| $T_2$ (K) | 5925(5) | 6250 |
| $i$ ($^\circ$) | 68.92(5) | 85.55(10) |
| $\Omega_1 = \Omega_2$ | 2.4309(9) | 4.9827(28) |
| $L_1/(L_1 + L_2)$ $(B)$ | 0.7545(10) | 0.4216(8) |
| $L_1/(L_1 + L_2)$ $(V)$ | 0.7530(8) | 0.4065(6) |
| $L_1/(L_1 + L_2)$ $(R)$ | 0.7524(7) | 0.3974(5) |
| $L_1/(L_1 + L_2)$ $(I)$ | 0.7515(5) | 0.3904(5) |
| $r_1, r_2$ (pole) | 0.4627(2),0.2668(2) | 0.3129(3),0.4165(3) |
| $r_1, r_2$ (side) | 0.4991(3),0.2787(2) | 0.3280(3),0.4435(3) |
| $r_1, r_2$ (back) | 0.5262(3),0.3165(4) | 0.3657(5),0.4751(4) |
| fill-out | 15.5(5)% | 14.7(5)% |
| Spot parameters | | |
| Latitude ($^\circ$) | 111.8 (7) | |
| Longitude ($^\circ$) | 248.8 (1.0) | |
| Radius ($^\circ$) | 43.5 (4) | |
| $T_{\rm spot}/T_1$ | 1.0338(4) | |

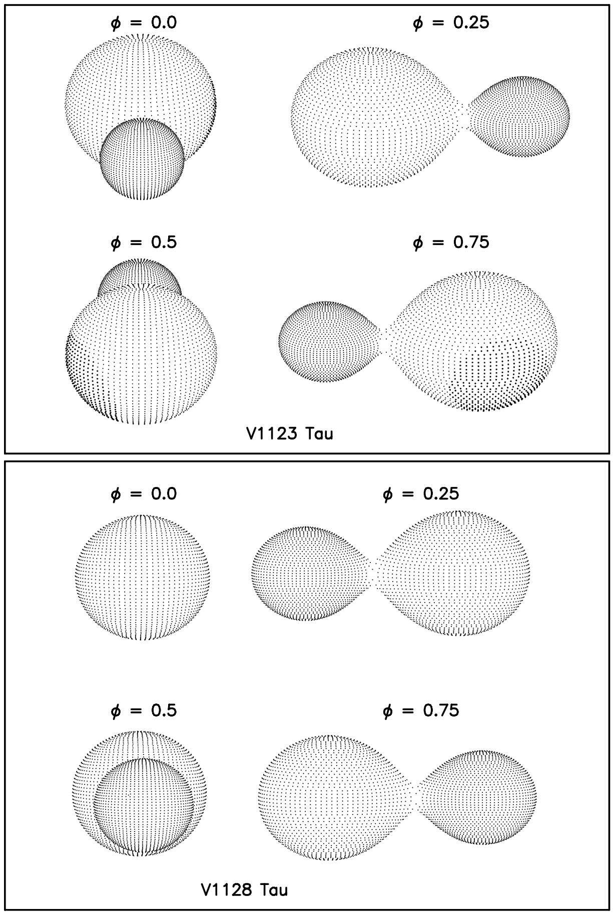


**Fig. 3** Geometric configurations illustrated for V1123 Tau and V1128 Tau.

The hot-spot model can fit the light curves in all filters fairly well. To check the reliability of the hot-spot model, we also tried to model the light curves with a cool spot, but the final synthesis is very poor. We do not present the results of this trial here.

## 4.2 V1128 Tau

The light curves of V1128 Tau as shown in Figure 2 are of EW type with very deep eclipses implying a very high orbital inclination angle of the eclipsing system. The depths of the primary light minima were measured to be about 0.814 mag in $B$, 0.763 mag in $V$, 0.731 mag in $R$ and 0.707 mag in $I$ bands. The primary eclipse is obviously deeper than the secondary one by about 0.095, 0.067, 0.052, and 0.042 mag in $B$, $V$, $R$, and $I$ filters respectively. The primary eclipse possesses flat light minima lasting about 16 min, indicating that V1128 Tau could be a totally eclipsing system. Since the total eclipse exists at phase 0.0, which corresponds to the eclipse of the less-massive star by the massive companion, it strongly suggests that the less-massive component could be hotter than the massive one. That is to say that V1128 Tau is very likely a W UMa system of W subtype as indicated by the previous photometric solutions (Tas et al. 2003; Hawkins et al. 2005).

As a late-type binary system, V1128 Tau could be magnetically active. The O'Connell effect among the light curves has been reported by both Tas et al. (2003) and Hawkins et al. (2005). However, the newly derived light curves show no asymmetry outside the eclipses. The two light maxima have nearly equal brightness in all the $B$, $V$, $R$ and $I$ bands. We guess that the star might be in its quiet period at present.

Also with the Wilson-Devinney method, a photometric solution of V1128 Tau was determined. Since the binary has been as a W-subtype system, we therefore designated star 1 as the less-massive component, and star 2 as the massive component during the light curve synthesis. The temperature of star 2, the luminous component, was assigned to be $T_2 = 6250\,\mathrm{K}$ corresponding to the spectral type of F8V assigned by Rucinski et al. (2008); the mass ratio of the system was fixed at $q = M_2/M_1 = 1.873$, and the inverse value of $M_1/M_2 = 0.534$ was given by the same authors. Adopting the solutions derived by Hawkins et al. (2005), the converged solution was rapidly reached. The results of the best-fit solution were obtained as given in Table 3. The theoretical light curves computed from the solution are plotted in the lower panel of Figure 2 along with the observations, in which the light curves have been shifted by 0.15, 0.3, and 0.45 mag in the $V$, $R$, and $I$ filters for clarity, respectively. A geometric configuration of the system is shown in Figure 3.

## 5 RESULTS AND DISCUSSION

The photometric solutions confirm the W UMa-type nature for both V1123 Tau and V1128 Tau. With the secondary slightly cooler than the primary, V1123 Tau could be classified as an A-type contact binary. V1128 Tau is typically a W UMa system of W subtype as predicted from the shape of the light curves. The surface temperature derived for its less-massive secondary component is higher than the primary by about 270 K. In addition, the fill-out factors of the two contact binaries were computed to be about 15.5% and 14.7%, indicating that they are both in shallow contact.

The observed asymmetry among the light curves of V1123 Tau is fairly well synthesized by a hot spot on the primary component rather than a cool one. The hot spot could be explained by a gas stream between the components (Rucinski 1997) or a white light plage due to the magnetic activity as predicted from the frequent light curve changes. Comparing the light curves of V1128 Tau with those previously published by Tas et al. (2003) and Hawkins et al. (2005), marked changes are clearly seen. This suggests that V1128 Tau could also be a solar-like active star, although it seems to be quiet at present.

Combining the results of our photometric solutions with the spectroscopic solutions given by Rucinski et al. (2008), we computed the absolute parameters including mass, radius and luminosity for each of the components of the two contact binaries, as given in Table 4.

**Table 4** Absolute Parameters of V1123 Tau and V1128 Tau

| | V1123 Tau | V1128 Tau |
|---|---|---|
| $M_1/M_\odot$ | 1.36±0.05 | 0.58±0.01 |
| $M_2/M_\odot$ | 0.40±0.02 | 1.09±0.03 |
| $R_1/R_\odot$ | 1.37±0.02 | 0.76±0.01 |
| $R_2/R_\odot$ | 0.80±0.01 | 1.01±0.01 |
| $L_1/L_\odot$ | 2.01±0.07 | 0.91±0.05 |
| $L_2/L_\odot$ | 0.67±0.04 | 1.34±0.06 |

The values of mass and radius determined for the primary component of V1128 Tau roughly match its spectral type of F8V, while those for V1123 Tau are quite large in comparison with values of a normal G0V star. To discuss the evolutionary status of the two systems, we plot the components of the two binaries on the M-L and M-R diagrams in Figure 4. In the plot, the solid lines represent the zero- and terminal-aged main sequence (TAMS) from Girardi et al. (2000) for the Population I

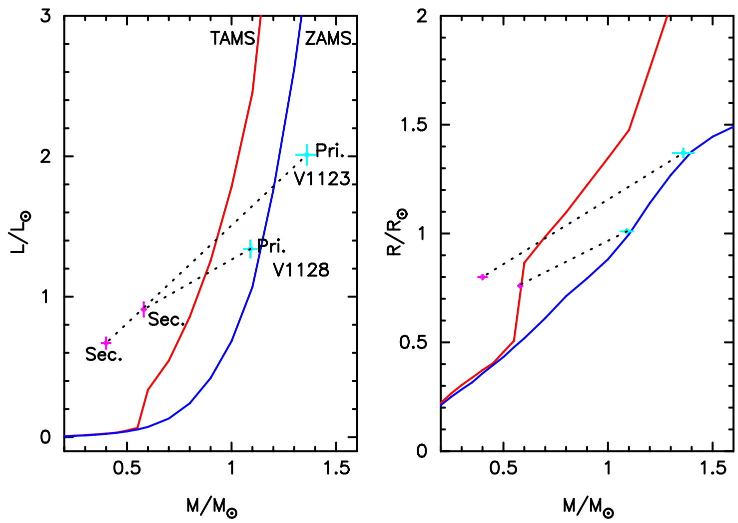


**Fig. 4** Locations of the components of V1123 Tau and V1128 Tau on the mass-luminosity and mass-radius diagrams. Solid lines represent the ZAMS and TAMS from Girardi et al. (2000) with solar chemical composition.

stars. In comparison with the theoretical models, the secondary components of the two systems both appear to be quite evolved with over-luminosity and over-radius. Their positions on the M-L and M-R diagrams are both obviously outside the main-sequence zone. On the other hand, the primary stars show little to no evolution. On the M-R diagram, they are both located right on the zero-age main sequence (ZAMS); on the M-L diagram, the primary component of V1128 Tau is positioned slightly above the ZAMS, but that of V1123 Tau is clearly far below the ZAMS, implying that the star could be less evolved than a ZAMS star with the same mass. Such an extreme under-luminosity phenomenon of the primary star has also been noted among other contact binary systems (Li et al. 2008).

The result shows that the components of contact systems should not be treated like normal main-sequence stars. Their peculiar evolutionary status suggests that they may have a very different interior structure, which may not be interpreted by energy transfer from the primary to the secondary components according to the theory of contact binaries (Lucy 1968a,b). In a previous work concerning another W UMa-type binary TX Cnc, which is also a member of the Praesepe cluster, Zhang et al. (2009) noted similar phenomena regarding the evolutionary states of the components, and attributed the effect to the process of mass exchange during the initial formation of the detached or semi-detached system. For the case of V1123 Tau and V1128 Tau, since we have no information about their age and metallicity, we will not discuss this in detail.

The orbital period analysis indicated that V1128 Tau is undergoing a rapid decrease in orbital period, which could be interpreted as the result of mass transfer from the massive primary to the secondary component. If the estimate of mass exchange is conservative, the rate of mass transfer could be calculated to be about $1.19 \times 10^{-7}\ M_{\odot}$ yr$^{-1}$. The time scale of the probable mass transfer can be estimated to be $9.2 \times 10^{6}$ yr, however, it would absolutely be shorter than the thermal time scale of the donor, which is about $2.6 \times 10^{7}$ yr. Considering the strong magnetic activity of the star, we agree with the suggestion of Hawkins et al. (2005) that the variable, decreasing period of V1128 Tau could be attributed to the effect of the Applegate-mechanism (Applegate 1992) due to the variable magnetic activity. To confirm this behavior, further observations are needed.

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