



The photometric investigation of the newly discovered W UMa type binary system GSC 03122-02426



Zhou X. ^{a,b,c,*}, Qian S.-B. ^{a,b,c}, He J.-J. ^{a,b}, Zhang J. ^{a,b}, Zhang B. ^{a,b,c}

^a Yunnan Observatories, Chinese Academy of Sciences, PO Box 110, 650216 Kunming, China

^b Key Laboratory of the Structure and Evolution of Celestial Objects, Chinese Academy of Sciences, PO Box 110, 650216 Kunming, China

^c Graduate University of the Chinese Academy of Sciences, Yuquan Road 19, Sijingshang Block, 100049 Beijing, China

HIGHLIGHTS

- The first multi-color CCD light curves of the eclipsing binary GSC 03122-02426 are analyzed using the W–D method.
- GSC 03122-02426 is a W-subtype shallow contact binary system.
- The absolute physical parameters of the two components in GSC 03122-02426 are estimated.
- The formation and evolutionary scenario of GSC 03122-02426 is discussed.

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ABSTRACT

The $B V R_c I_c$ bands light curves of the newly discovered binary system GSC 03122-02426 are obtained and analyzed using the Wilson–Devinney (W–D) code. The solutions suggest that the mass ratio of the binary system is $q = 2.70$ and the less massive component is 422 K hotter than the more massive one. We conclude that GSC 03122-02426 is a W-subtype shallow contact (with a contact degree of $f = 15.3\%$) binary system. It may be a newly formed contact binary system which is just under geometrical contact and will evolve to be a thermal contact binary system. The high orbital inclination ($i = 81.6^\circ$) implies that GSC 03122-02426 is a total eclipsing binary system and the photometric parameters obtained by us are quite reliable. We also estimate the absolute physical parameters of the two components in GSC 03122-02426, which will provide fundamental information for the research of contact binary systems. The formation and evolutionary scenario of GSC 03122-02426 is discussed.

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1. Introduction

W UMa type binary systems are cool short-period binary systems in which both of its two components fill the critical Roche lobes and share a common convective envelope. Their EW-type light curves vary continuously and the depths of the primary and secondary minima are almost equal. It is found that about 95% of the eclipsing binaries around the solar system are W UMa type contact binary systems (Shapley, 1948). Binnendijk (1970) divided the W UMa type binary systems into two subclasses: A-subtype and W-subtype. The A-subtype W UMa systems are also called early-type contact binaries with their spectral types usually earlier than F0 and the more massive stars are the hotter ones. The W-subtype systems are also called late type contact binaries with

their spectral types to be F and G type or even later. The less massive components are the hotter ones in the W-subtype systems. The formation and evolutionary theories of contact binaries are still open issues. W UMa type systems are very important targets in this research field. Therefore, more and more fundamental information about W UMa type systems, both photometric and spectroscopic analysis, are urgently needed.

GSC 03122-02426, also named UCAC4 652-064817 or 2MASS J18454487+4017197, is a newly discovered W UMa type contact binary system detected in the field of view of V563 Lyr. There is neither photometric solution nor spectroscopic observation about this target published before. In the present work, $B V R_c$ and I_c bands light curves of GSC 03122-02426 are analyzed with the Wilson–Devinney (W–D) code for the first time. The basic physical parameters of this system is obtained and its formation and evolutionary scenario are figured out, which will improve our understanding on the W UMa type binary systems.

* Corresponding author. Tel.: +8613658806295; fax: +86087167395095.

E-mail address: zhouxiaophy@ynao.ac.cn (Z. X.).

Table 1
Coordinates of GSC 03122-02426 and the comparison star.

Targets	name	α_{2000}	δ_{2000}	V_{mag}
Variable	GSC 03122-02426	$18^h45^m44^s.9$	$+40^\circ17'20''.2$	14.5
The comparison	GSC 03122-00809	$18^h45^m36^s.4$	$+40^\circ08'05''.5$	11.6

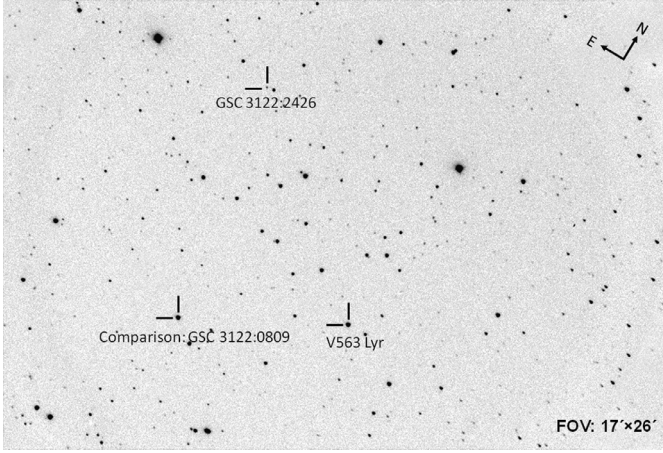


Fig. 1. The identification map of GSC 03122-02426 in the field of view of V563 Lyr.

2. The CCD photometric observations of GSC 03122-02426

The CCD photometric observations of the eclipsing binary GSC 03122-02426 were carried out over 7 nights on September and October 2012 (HJD 2456199 to HJD 2456207) using an SBIG ST-10XME CCD camera attached to the 0.4 m Cassegrain reflecting telescope in the University of Athens Observatory, Greece (Gazeas, 2015). During the observations, the broadband Johnson–Cousins $B V R_c I_c$ filters were used. GSC 03122-00809 was chosen as the comparison star. A total of 358 points in B filter, 395 in V filter, 383 in R_c filter and 417 in I_c filter were collected, respectively. The coordinates and brightness (in V band) of the variable, the comparison stars are listed in Table 1. The identification map of GSC 03122-02426 in the field of view of V563 Lyr is shown in Fig. 1.

The first linear ephemeris of GSC 03122-02426 is obtained

$$Min.I(HJD) = 2456200.2458(7) + 0^d.30050(9) \times E. \quad (1)$$

3. Photometric solutions of GSC 03122-02426

GSC 03122-02426 is a newly detected binary system with EW type light curves. To understand its geometrical structure and evolutionary state, the $B V R_c$ and I_c bands light curves covering complete phase ranges are analyzed simultaneously using the W–D code of version 2013 (Wilson and Devinney, 1971; Van Hamme and Wilson, 2007; Wilson et al., 2010). The phases applied in the W–D code are calculated with Eq. (1).

Since GSC 03122-02426 is a newly discovered binary system, there isn't any information about spectral type on this target published before. Therefore, we can't determine the effective temperature of the binary system directly. Considering the color index of $J - H = 0.42$ given by the fourth US Naval Observatory CCD Astrograph Catalog (UCAC4), we fix the effective temperature of the primary star (star eclipsed at the primary minimum light) to be $T_1 = 5230K$ (Cox, 2000). It means that GSC 03122-02426 is a late-type contact binary with convective envelopes. Thus the gravity-darkening coefficients $g_1 = g_2 = 0.32$ (Lucy, 1967) and the bolometric albedo $A_1 = A_2 = 0.5$ (Ruciński, 1969) are used. To account for the limb darkening in detail, logarithmic functions are used. The corresponding bolometric and passband-specific

Table 2
Photometric solutions of GSC 03122-02426.

Parameters	Values
$T_1(K)$	5230(fixed)
g_1	0.32(fixed)
g_2	0.32(fixed)
A_1	0.50(fixed)
A_2	0.50(fixed)
$q (M_2/M_1)$	$2.70 (\pm 0.07)$
$i(^{\circ})$	$81.6 (\pm 0.5)$
$\Omega_1 = \Omega_2$	$6.1168 (\pm 0.0883)$
$T_2(K)$	$4808 (\pm 11)$
$\Delta T(K)$	$422 (\pm 11)$
T_2/T_1	$0.919 (\pm 0.002)$
$L_1/(L_1 + L_2) (B)$	$0.432 (\pm 0.003)$
$L_1/(L_1 + L_2) (V)$	$0.402 (\pm 0.003)$
$L_1/(L_1 + L_2) (R)$	$0.380 (\pm 0.003)$
$L_1/(L_1 + L_2) (I)$	$0.365 (\pm 0.003)$
$r_1(pole)$	$0.2834 (\pm 0.0021)$
$r_1(side)$	$0.2964 (\pm 0.0023)$
$r_1(back)$	$0.3342 (\pm 0.0029)$
$r_2(pole)$	$0.4469 (\pm 0.0080)$
$r_2(side)$	$0.4798 (\pm 0.0110)$
$r_2(back)$	$0.5090 (\pm 0.0151)$
f	$15.3\% (\pm 14.4\%)$
$\Sigma\omega(O - C)^2$	0.00826

limb-darkening coefficients are chosen from Van Hamme (1993)'s table. Synchronous rotation and a circular orbit are assumed during the solution processes.

As there isn't any radial velocity study about GSC 03122-02426, a q -search method is used to determine the initial input mass ratio for the light curves. During the calculating, it is found that the solution converges at mode 3 (contact model), and the adjustable parameters are: the mass ratio $q (M_2/M_1)$; the orbital inclination i ; the effective temperature of star 2 (T_2); the monochromatic luminosity of star 1 (L_{1B}, L_{1V}, L_{1R} and L_{1I}); the dimensionless potential of star 1 ($\Omega_1 = \Omega_2$ in mode 3 for contact configuration). Solutions with mass ratio from 0.1 to 4.8 are investigated, and the relation between the resulting sum of weighted square deviations Σ and q is plotted in Fig. 2. The minimum values are found at $q = 2.65$, which indicates that GSC 03122-02426 is a W-subtype (Binnendijk, 1970) contact binary. Then $q = 2.65$ is set as the initial value and considered as an adjustable parameter. The final photometric solutions are listed in Table 2 and the corresponding theoretical light curves are displayed in Fig. 3. The contact configurations of GSC 03122-02426 are displayed in Fig. 4.

4. Discussions and conclusions

The CCD photometric light curves of GSC 03122-02426 in $B V R_c I_c$ bands are analyzed simultaneously with the W–D code (Version 2013). Our solutions suggest that GSC 03122-02426 is a W-subtype shallow contact ($f = 15.3\%$) binary system with its mass ratio to be $q = 2.70$, where "shallow" is defined when the degree of contact is lower than 20% (Liu et al., 2016). The temperature difference between its two components is 422 K which may imply that GSC 03122-02426 is a newly formed contact binary system. It is just under geometrical contact and will evolve to be a thermal contact binary system. The less massive star contributes about 40% of the total luminosity in the binary system. During the calculations, we also set l_3 as an adjustable parameter in the W–D code. However, we haven't detected the contribution of the third light in the light curves. The high orbital inclination ($i = 81.6^\circ$) implies that GSC 03122-02426 is a total eclipsing binary system and the photometric parameters obtained by us are quite reliable. By assuming that the primary star in GSC 03122-02426 is a

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