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CCD photometric investigation of a W UMa-Type binary GSC 0763–0572

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Abstract A photometric solution of an A-type W UMa binary, GSC 0763–0572, is examined with a revised orbital period. The overcontact degree is found to be $f = 40.66\%$, with a low mass ratio of $q = 0.2554$. The result demonstrates an unambiguous increase in the orbital period with a relative period change of $\Delta P/P = +5.69 \times 10^{-7}$ d yr^{-1}. This indicates that GSC 0763–0572 is undergoing a process of mass transfer from the secondary component to the primary one with a rate of relative mass change of $\Delta m_1/m = +5.18 \times 10^{-8}$ yr^{-1}, for a conservative model of mass transfer. We find that GSC 0763–0572 might transform into a rapidly rotating star, if total spin angular momentum increases until it is greater than one-third of the orbital angular momentum, without breaking the contact configuration.

Key words: stars: binaries: close — stars: binaries: eclipsing — stars: individual (GSC 0763–0572)

1 INTRODUCTION

W UMa type systems are one of the most interesting types of binaries, which can be found in many studies that investigate their evolutionary states. These systems are believed to be formed from detached binaries, which are losing angular momentum and decreasing orbital periods by a process called angular momentum loss (Vilhu 1981; Rucinski 1982; Guinan & Bradstreet 1988; Maceroni & van't Veer 1996; Paczyński et al. 2006). It is well-known that W UMa binaries are classified into two subtypes (Binnendijk 1970). A W UMa system is called A-subtype if the more massive component is eclipsed by the less massive one at primary minima. On the other hand, a system with the opposite feature is called W-subtype. Some authors suggested that W-subtype systems have evolved from A-subtype ones by mass loss (Gazeas & Niarchos 2006; Rucinski 1985), whereas others argued the opposite is true (Maceroni et al. 1985; Hilditch et al. 1988). However, van Hamme (1982) and Li et al. (2008) found that there is no evolutionary difference between both subtypes. Li et al. (2008) suggested that the dynamical evolution would cause W UMa binaries to evolve into lower mass ratio systems and the tidal instability forces these systems to merge into rapidly rotating single stars.

An A-subtype W UMa binary, GSC 0763–0572 ($\alpha_{\rm J2000}$=07$^{\rm h}$16$^{\rm m}$57$^{\rm s}$.32, $\delta_{\rm J2000}$=09°12′35″.5), was first discovered as a short-period variable by Bernhard (2002). Lloyd et al. (2003) reported five observations of light minima displaying characteristics of a W UMa binary with an orbital period of 0.426388 d. Yang et al. (2005) indicated that GSC 0763–0572 belongs to an A-subtype with a period of 0.4263947 d, slightly higher than that of Lloyd et al. (2003). A photometric solution suggested that the system is a low mass ratio contact binary with $q = 0.2401$, an orbital inclination of 79° and a contact degree of 29.5% (Yang et al. 2005).

This study presents a photometric study of GSC 0763–0572 with a revised orbital period and analysis of the period change and mass transfer rate. New observations and data reduction are first described in Section 2. The orbital period and the relative period change are examined in Section 3. Section 4 explains a light curve fit and a revised photometric solution of GSC 0763–0572. Finally, Sections 5 and 6 contain discussion and conclusions respectively.

2 OBSERVATIONS AND DATA REDUCTION

Imaging data of GSC 0763–0572 were obtained from the 0.5 m telescope at Sirindhorn Observatory, Chiang Mai University, Thailand. The observations were done for the BVR filter bands, using an SBIG CCD (Model of ST10-XME), with exposure times of 60 seconds. The photometric data were taken during three nights (2010 December 29–31), covering approximately 2.5 periods. We have obtained 294 observations per filter band. The data were reduced using the standard IRAF package.

BVR differential magnitudes were determined using GSC 0763–0291 ($\alpha_{\rm J2000} = 07^{\rm h}16^{\rm m}59^{\rm s}.49$, $\delta_{\rm J2000} = 09°16'57''.6$) and GSC 0763–0177 ($\alpha_{\rm J2000} = 07^{\rm h}16^{\rm m}38^{\rm s}.98$, $\delta_{\rm J2000} = 09°17'53''.0$) as the comparison and check stars, respectively. The amplitude of light curve variation is about 0.45 mag, and the magnitude difference between the primary and secondary eclipses is about 0.05 mag with almost the same level of light maxima.

3 ORBITAL PERIOD CHANGE

The new photometric data of GSC 0763–0572 display four times of light minima in the BVR filter bands. Light minimum times are determined in terms of HJD, using a least-squares method. New times of light minima are found as two primary and two secondary eclipses for each filter, listed in Table 1. The times of light minima in this study are combined with eight times from literature to estimate the orbital period, as shown in Table 2. The HJD at light minimum times are fitted with the linear least-squares method and the result yields the orbital period of 0.4263965(±0.0000002) d as shown in Equation (1).

$$\text{Min.I} = \text{HJD } 2455559.9439(\pm 0.0009) + 0.4263965(\pm 0.0000002) \times E. \tag{1}$$

Table 1 New Times of Light Minima

No.	Min	Filter	HJD	Error
1	II	B	2455560.1570	0.0010
	II	V	2455560.1572	0.0009
	II	R	2455560.1572	0.0008
2	I	B	2455560.3712	0.0016
	I	V	2455560.3700	0.0015
	I	R	2455560.3706	0.0007
3	I	B	2455561.2234	0.0011
	I	V	2455561.2239	0.0021
	I	R	2455561.2234	0.0005
4	II	B	2455561.4368	0.0014
	II	V	2455561.4369	0.0004
	II	R	2455561.4366	0.0007

Notes: Col. (1): the number of light minimum times. Col. (2): types of minima. Col. (3): filter bands. Col. (4): HJD at light minima. Col. (5): errors of HJD at light minima.

Table 2 All Light Minimum Times

HJD	Epoch	Min	$(O-C)$	Ref.
2452318.0524	–7603.0	I	0.0015	[1]
2452325.0886	–7586.5	II	0.0021	[1]
2452336.3876	–7560.0	I	0.0016	[1]
2452361.3321	–7501.5	II	0.0019	[1]
2452362.3974	–7499.0	I	0.0012	[1]
2453359.3092	–5161.0	I	–0.0019	[2]
2453361.2282	–5156.5	II	–0.0017	[2]
2453361.4387	–5156.0	I	–0.0044	[2]
2455560.1571	0.5	II	0.0006	[3]
2455560.3706	1.0	I	0.0009	[3]
2455561.2235	3.0	I	0.0011	[3]
2455561.4368	3.5	II	0.0012	[3]
2455599.3872	92.5	II	0.0023	[4]

Notes: Col. (1): HJD at light minima. Col. (2): epoch. Col. (3): types of minima. Col. (4): residuals of HJD at light minima. Col. (5): references for sources are as follows: [1] Lloyd et al. (2003); [2] Yang et al. (2005); [3] This study; [4] Hubscher (2011).

The orbital period of GSC 0763–0572 shows progressive lengthening from the values obtained by Lloyd et al. (2003), Yang et al. (2005) and our study. With this orbital period increase, the residuals $(O-C)$ are determined as listed in Table 2 and the least-squares fitting solution yields Equation (2). It is found that the orbital period increases with a relative change of $\Delta P/P = +5.69 \times 10^{-7}$ d yr^{-1}. However, the number of light minimum times is not very large. Thus, more observations are needed in the future.

$$(O-C) = 0.00032(\pm 0.00038) + 2.38(\pm 0.31) \times 10^{-6} E + 3.32(\pm 0.41) \times 10^{-10} E^2. \quad (2)$$

4 LIGHT CURVE FIT

Observed light curves in the BVR filter bands are fitted with the 2003 version of the Wilson-Devinney (W-D) code (Wilson & Devinney 1971; Wilson 1979, 1990; Wilson & Van Hamme 2003). The applied orbital period is 0.4263965 d. Total magnitudes of GSC 0763–0572 in the B and V filter bands from the Tycho-2 Catalog (Høg et al. 2000) are 11.423 and 10.673, respectively. Thus the color-temperature relation (Sekiguchi & Fukugita 2000; Ramírez & Meléndez 2005) gives the estimated temperature of the primary star of approximately 5300 K. Required parameters are adopted for the W-D code in mode 3, as listed in Table 3. The gravity darkening exponents of both components are equal, $g_1 = g_2 = 0.32$ (Lucy 1967), and the bolometric albedo coefficients of star 1 and star 2 are given as 0.50, $A_1 = A_2 = 0.50$ (Ruciński 1973). The limb darkening coefficients of star 1 and star 2 are adopted as $x_{1B} = 0.840$, $x_{2B} = 0.830$, $x_{1V} = x_{2V} = 0.750$ and $x_{1R} = x_{2R} = 0.670$ (Al-Naimiy 1978). The adopted adjustable parameters are the orbital inclination, i, estimated secondary temperature, T_2, mass ratio, q, the surface potential of the components, $\Omega_1 = \Omega_2$, and the monochromatic luminosity of star 1, L_1. The relative luminosity of star 2 is estimated using a model of stellar atmospheres (Kurucz 1993).

A good fit with the W-D code gives a mass ratio of q=0.2554 ($\pm$0.0035), and the overcontact degree of f=40.66% ($\pm$3.14%), which is higher than the previous study of f=29.5% (Yang et al. 2005). Meanwhile, radius parameters of the secondary component, r_2 (pole) = 0.2657 (0.0037), r_2 (side) = 0.2789 (0.0046) and r_2 (back) = 0.3276 (0.0106), slightly increase and are comparable to the values of Yang et al. (2005), while the radius parameters of the primary one do not significantly change. The temperature difference between the components is not very large (i.e. T_1=5300 K and T_2=5256 K). The sum of squares of residuals for input values, $\Sigma(O-C)^2$=0.0040, corresponding

Table 3 Photometric Solution for the Light Curve Fit of GSC 0763–0572

Parameters	Values
$i(^\circ)$	79.10(0.43)
$g_1 = g_2$	0.32
$A_1 = A_2$	0.50
$T_1(K)$	5300
$T_2(K)$	5256(30)
$\Omega_1 = \Omega_2$	2.3000(0.0051)
q	0.2554(0.0035)
$L_{1B}/(L_{1B} + L_{2B})$	0.7755(0.0023)
$L_{1V}/(L_{1V} + L_{2V})$	0.7779(0.0022)
$L_{1R}/(L_{1R} + L_{2R})$	0.7769(0.0022)
r_1 (pole)	0.4831(0.0014)
r_1 (side)	0.5263(0.0020)
r_1 (back)	0.5555(0.0029)
r_2 (pole)	0.2657(0.0037)
r_2 (side)	0.2789(0.0046)
r_2 (back)	0.3276(0.0106)
x_{1B}	0.840
x_{2B}	0.830
x_{1V}	0.740
x_{2V}	0.740
x_{1R}	0.670
x_{2R}	0.670
$\Sigma(O - C)^2$	0.0040
f (%)	40.66(3.14)

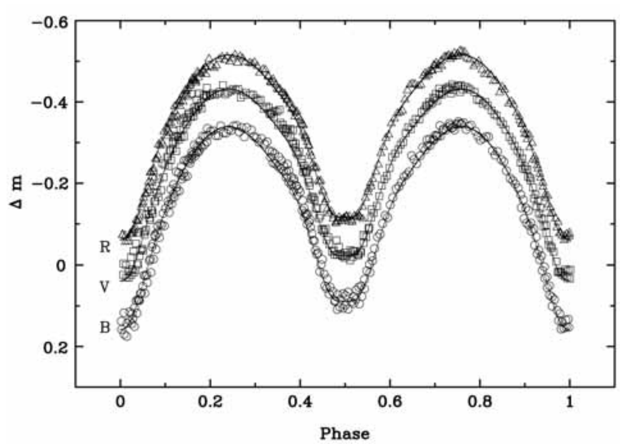

Fig. 1 Observed in the B (*circle*), V (*square*) and R (*triangle*) filter bands and theoretical (*solid lines*) light curves vs. orbital phase.

to the light curves, and all main parameters are listed in Table 3. Finally, the theoretical light curves are plotted, overlaid on the observed ones, as shown in Figure 1.

5 DISCUSSION

The photometric solution from W-D synthesis with $q = 0.2554$ ($\pm$0.0035) and the theoretical light curves in Figure 1 clearly show that GSC 0763–0572 is an A-subtype W-UMa binary, as Yang et al.

(2005) mentioned. The orbital period of GSC 0763–0572 is gradually increasing from 0.426388 d (Lloyd et al. 2003) and 0.4263947 ($\pm$0.0000003) d (Yang et al. 2005) to 0.4263965($\pm$0.0000002) d in this study.

The orbital period of GSC 0763–0572 increases at a rate of the relative period change $\Delta P/P = +5.69 \times 10^{-7}$ d yr^{-1}. This indicates that the system is undergoing mass transfer from the less massive secondary to the more massive primary component with a relative mass change, $\Delta m_1/m = +5.18 \times 10^{-8}$ yr^{-1}, for a conservative model of mass transfer (Pribulla 1998; Pribulla et al. 1999; Singh & Chaubey 1986), where Δm_1 is the mass increase of the more massive component ($\Delta m_1 = -\Delta m_2$) and m is total mass ($m = m_1 + m_2$). This process of mass transfer is similar to the results found in V700 Cyg (Yang & Dai 2009) and V345 Gem (Yang et al. 2009), and also in the Algol-type VW Hya (Zhang et al. 2009) and the β-Lyr type AI Cru (Zhao et al. 2010).

As the orbital period increases, the corresponding separation between both components spreads out. This process is caused by orbital angular momentum loss and the mass transfer forces the system to have a smaller mass ratio, thus increasing the spin angular momentum. It is possible that GSC 0763–0572 could satisfy the condition that the total spin angular momentum exceeds one-third of the orbital angular momentum, i.e. $3J_{\rm spin} > J_{\rm orb}$, so the system will be unstable (Hut 1980). The resulting tidal instability compels the system to evolve into a rapidly rotating single star (Li et al. 2008), similar to what was found in the analysis of QX And (Qian et al. 2007), V343 Ori (Yang 2009) and V345 Gem (Yang et al. 2009).

6 CONCLUSIONS

New photometric data of GSC 0763–0572 show four times of light minima. Combining the light minimum times from literature and using the least squares method, we give a revised orbital period of 0.4263965 ($\pm$0.0000002) d. Although the number of light minimum times is not very large, the result clearly exhibits an increase in the orbital period. The photometric solution of the A-subtype W UMa binary GSC 0763–0572 is deduced, providing some revised parameters (i.e. the mass ratio, $q = 0.2554$ and the overcontact degree, $f = 40.66\%$), which are higher than those in the literature.

The relative change of the orbital period of GSC 0763–0572 is found to be the rate of $\Delta P/P = +5.69 \times 10^{-7}$ d yr^{-1}. The period increase is being caused by mass transfer from the less massive component to the more massive one with a relative mass change of $\Delta m_1/m = +5.18 \times 10^{-8}$ yr^{-1}, for a conservative model. Because component separation increases while mass ratio decreases during expansion of the secondary, GSC 0763–0572 could evolve into a rapidly-rotating star when the system reaches the condition of Hut (1980). However, there are not many recorded times of light minima for this system, so more observations are still needed in the future to examine the long-term period change, which can more precisely confirm how GSC 0763–0572 evolves.

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References

Al-Naimiy, H. M. 1978, Ap&SS, 53, 181
Bernhard, K. 2002, vsney-newvar, 1395
Binnendijk, L. 1970, Vistas in Astronomy, 12, 217
Gazeas, K. D., & Niarchos, P. G. 2006, MNRAS, 370, L29
Guinan, E. F., & Bradstreet, D. H. 1988, in NATO ASIC Proc. 241, Formation and Evolution of Low Mass Stars, eds. A. K. Dupree, & M. T. V. T. Lago (Dordrecht: Kluwer), 345

Hilditch, R. W., King, D. J., & McFarlane, T. M. 1988, MNRAS, 231, 341
Høg, E., Fabricius, C., Makarov, V. V., et al. 2000, A&A, 355, L27
Hubscher, J. 2011, Information Bulletin on Variable Stars, 5984, 1
Hut, P. 1980, A&A, 92, 167
Kurucz, R. L. 1993, in Light Curve Modeling of Eclipsing Binary Stars, ed. E. F. Milone (New York: Springer-Verlag), 93
Li, L., Zhang, F., Han, Z., Jiang, D., & Jiang, T. 2008, MNRAS, 387, 97
Lloyd, C., Moschner, W., Kiyota, S., Bernhard, K., & Frank, W. 2003, Information Bulletin on Variable Stars, 5366, 1
Lucy, L. B. 1967, ZAp, 65, 89
Maceroni, C., Milano, L., & Russo, G. 1985, MNRAS, 217, 843
Maceroni, C., & van't Veer, F. 1996, A&A, 311, 523
Paczyński, B., Szczygieł, D. M., Pilecki, B., & Pojmański, G. 2006, MNRAS, 368, 1311
Pribulla, T. 1998, Contributions of the Astronomical Observatory Skalnate Pleso, 28, 101
Pribulla, T., Chochol, D., Rovithis-Livaniou, H., & Rovithis, P. 1999, A&A, 345, 137
Qian, S.-B., Liu, L., Soonthornthum, B., Zhu, L.-Y., & He, J.-J. 2007, AJ, 134, 1475
Ramírez, I., & Meléndez, J. 2005, ApJ, 626, 465
Ruciński, S. M. 1973, Acta Astronomica, 23, 79
Rucinski, S. M. 1982, A&A, 112, 273
Rucinski, S. M. 1985, in NATO ASIC Proc. 150: Interacting Binaries, eds. P. P. Eggleton, & J. E. Pringle, 13
Sekiguchi, M., & Fukugita, M. 2000, AJ, 120, 1072
Singh, M., & Chaubey, U. S. 1986, Ap&SS, 124, 389
van Hamme, W. 1982, A&A, 105, 389
Vilhu, O. 1981, Ap&SS, 78, 401
Wilson, R. E. 1979, ApJ, 234, 1054
Wilson, R. E. 1990, ApJ, 356, 613
Wilson, R. E., & Devinney, E. J. 1971, ApJ, 166, 605
Wilson, R. E., & Van Hamme, W. 2003, Computing Binary Stars Observables, the 4th Edition of the W-D Program
Yang, Y.-G. 2009, PASP, 121, 699
Yang, Y.-G., & Dai, H.-F. 2009, PASJ, 61, 577
Yang, Y.-G., Qian, S.-B., Zhu, L.-Y., & He, J.-J. 2009, AJ, 138, 540
Yang, Y.-G., Qian, S.-B., Zhu, L.-Y., He, J.-J., & Yuan, J.-Z. 2005, PASJ, 57, 983
Zhang, J., Qian, S.-B., & Soonthornthum, B. 2009, RAA (Research in Astronomy and Astrophysics), 9, 307
Zhao, E.-G., Qian, S.-B., Fernández Lajús, E., von Essen, C., & Zhu, L.-Y. 2010, RAA (Research in Astronomy and Astrophysics), 10, 438