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Photometric observations of an extreme mass ratio overcontact binary

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Abstract. Our R_C and I_C light curves of CSS J135012.1+272259 were analyzed with the Wilson-Devinney (W-D) program. The results reveal that CSS J135012.1+272259 is an extreme mass ratio overcontact binary with mass ratio $q = 0.147$. It may be in the final evolutionary stage of cool short-period binaries and merge into a single rapid-rotation star to form a blue straggler or FK Com type star. Also, 25 extreme mass ratio overcontact binary systems ($q \leq 0.15$) are collected for long-term monitoring. These targets will improve understanding of the pre-outburst state of overcontact binaries and enrich knowledge of the merger mechanism.

Key words: binaries: eclipsing – binaries: photometry – light curves – stellar mergers

1. Introduction

Stellar mergers are estimated to be common events in the Galaxy. Theoretical models predict that an overcontact (OC) binary system will merge when its mass ratio reaches $q \approx 0.07 - 0.09$ (Arbutina, 2012). Only a handful of these transients have been noted in the Milky Way: V4332 Sgr (Hayashi et al., 1994), V838 Mon (Brown et al., 2002), V1309 Sco (Nakano et al., 2008), and OGLE-2002-BLG-360 (Tylenda et al., 2013). The red nova V1309 Sco is the best studied stellar merger case to date. The discovery of V1309 Sco (Nova Scorpii 2008) and the fact that its progenitor is an extreme mass ratio OC system with a rapidly decreasing orbital period triggered our interest on extreme mass ratio OC systems. Photometric and spectrometric data on OC binaries have been accumulating rapidly over the past few decades, owing to large sky survey projects

such as the Optical Gravitational Lensing Experiment (Rucinski, 1997), the All Sky Automated Survey (Jayasinghe et al., 2019), the Large Sky Area Multi-Object Fibre Spectroscopic Telescope (Qian et al., 2019) and the *Gaia* mission (Gaia Collaboration et al., 2016). Also, many extreme mass ratio OC systems or potential stellar merger candidates have been reported.

2. Photometric investigations of CSS J135012.1+272259

CSS J135012.1+272259 is a short period OC system. R_C and I_C light curves were obtained on March 8th, 2018 with the 2.4-m telescope at Thai National Observatory, National Astronomical Research Institute of Thailand (Soonthornthum, 2018). The ephemeris is:

$$\text{Min.I(HJD)} = 2458186.4009 + 0.232465 \times E. \quad (1)$$

The effective temperature is 6137 K, as given by the LAMOST survey. The Wilson-Devinney program (Wilson & Devinney, 1971; Van Hamme & Wilson, 2007; Wilson & Van Hamme, 2014) of version 2013 was applied to model the light curves, with solutions in Table 1. A q-search diagram and light curves are in Fig. 1.

Table 1. CSS J135012.1+272259 Phorometric Solutions

Parameters	Values without l_3	Values with l_3
$T_1(K)$	6137(fixed)	6137(fixed)
q (M_2/M_1)	0.114(±0.004)	0.147(±0.011)
$i(^\circ)$	75.9(±1.3)	79.1(±1.6)
$\Omega_1 = \Omega_2$	1.98(±0.01)	2.06(±0.03)
$T_2(K)$	5838(±43)	5891(±55)
$\Delta T(K)$	299	246
T_2/T_1	0.951(±0.007)	0.960(±0.009)
$L_1/(L_1+L_2)$ (R_c)	0.8931(±0.0004)	0.863(±0.009)
$L_1/(L_1+L_2)$ (I_c)	0.8905(±0.0004)	0.860(±0.009)
$L_1/(L_1+L_2+L_3)$ (R_c)		0.705(±0.036)
$L_1/(L_1+L_2+L_3)$ (I_c)		0.702(±0.038)
$L_3/(L_1+L_2+L_3)$ (R_c)		0.183(±0.039)
$L_3/(L_1+L_2+L_3)$ (I_c)		0.184(±0.041)
$r_1(pole)$	0.530(±0.003)	0.518(±0.005)
$r_1(side)$	0.590(±0.005)	0.572(±0.008)
$r_1(back)$	0.610(±0.005)	0.596(±0.008)
$r_2(pole)$	0.202(±0.015)	0.223(±0.032)
$r_2(side)$	0.211(±0.018)	0.234(±0.039)
$r_2(back)$	0.247(±0.040)	0.278(±0.092)
f	18.6 %(±20.1 %)	34.0 %(±30.8 %)
$\Sigma\omega(O-C)^2$	0.0051	0.0045

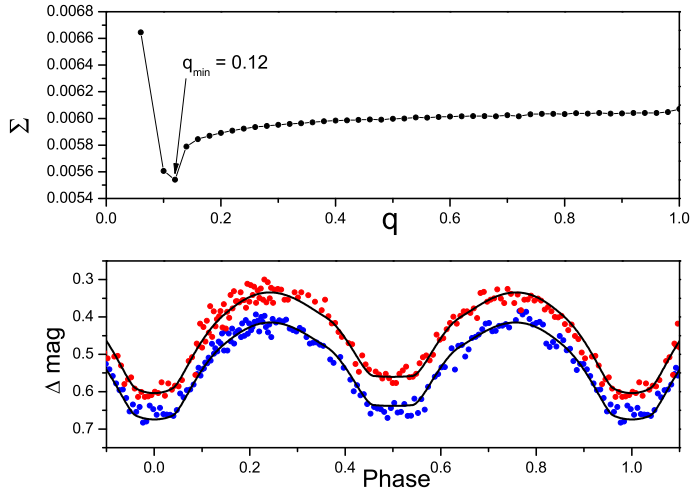

Figure 1. In the upper panel, the minimum mass ratio is determined to be $q_{min} = 0.12$ with the q-search method. In the lower panel, the red and blue circles are R_C and I_C light curves, respectively. The black lines are theoretical light curves.

3. Discussion and conclusions

Photometric solutions show that CSS J135012.1+272259 is an A-subtype extreme mass ratio OC binary with mass ratio $q = 0.147$ that is predicted to merge and make a blue straggler or FK Com type star in the center (Tylenda et al., 2011; Ferreira et al., 2019). A-type is a sub-type of the W UMa's, and the W UMa's are a sub-type of the OCs (Binnendijk, 1970). More observations of extreme mass ratio OC systems are needed since only a few stellar merger events have been reported and there are some discrepancies between observed features and theoretical models. Thus, 25 targets with mass ratio $q \leq 0.15$ have been collected: V857 Her, ASAS J083241+2332.4, SX Crv, V53 (a member of the Globular Cluster M4), AW UMa, ZZ Ps, V870 Ara, AW CrB, DN Boo, ASAS J082243+1927, V1191 Cyg, CK Boo, GR Vir, FG Hya, AL Lep, V776 Cas, V345 Gem, V410 Aur, V710 Mon, DZ Psc, HV Aqr, CSS J135012.1+272259, XY LMi, EM Psc, and TYC 4157-683-1. All of these targets will be monitored long-term.

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