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First determination of the system parameters in five contact binaries

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Abstract. We present solutions of the BVRI-light curve numerical modeling for five low-mass ratio totally eclipsing contact binary stars. One object required the introduction of a cool star spot to the best-fitting model. Only one object returned a solution with a hotter secondary component. None of the objects required the introduction of a third component.

Key words: stars – binaries: close – binaries: eclipsing

1. Introduction

The W UMa-type contact binary stars are canonically described as binary systems consisting of two main-sequence stars that share a common convective envelope. A consequence of such a configuration is an equalized surface temperature and, in the case of eclipsing systems, a light curve with brightness minima of nearly equal depths (Lucy, 1968). This feature allowed us to compose a catalog of suspected contact binaries (Debski & Walczak, 2022), which subsequently are observed and studied in the Krakow Observatory.

The common outer envelope in contact binaries is very well described with the Roche geometry (Kopal, 1959), which makes these systems good targets for the light curve numerical modeling studies (Debski, 2022). On the other hand, the degeneracy between the system inclination, effective temperature, and the mass ratio poses a serious problem for the modeling process. The surface temperature can be derived from the color of the system, but the search for the latter two parameters must be done under very specific circumstances. One of such is that the mass ratio could be obtained from radial velocity studies and then put into the photometric modeling. The other way is to study the totally eclipsing systems only. Pribulla et al. (2003) and Terrell & Wilson (2005) have shown that the inclination-mass ratio entanglement breaks when the Roche model is constrained with total eclipses. Since most of our targets are faint and lack spectroscopical data, we, therefore, decided to focus on totally eclipsing systems in our photometric studies.

Table 1. The parameters of the observed objects: coordinates and brightness (top row); best-fitting model results (middle rows) and the calculated physical parameters (bottom rows).

Parameter	KR 00017	KR 00036	KR 00059	KR 00085	KR 00225
RA [h m s]	06 29 57.7	15 58 54.2	02 34 25.0	06 50 47.2	20 40 03.6
DEC [° ' "]	76 42 59.7	46 35 49.0	79 37 39.4	73 21 32.7	63 59 34.5
P_{orb} [d]	0.314556	0.272030	0.346980	0.338555	0.352281
Max. mag, V	13.04(1)	13.37(1)	13.19(1)	13.10(3)	10.70(2)
i [°]	77(2)	77(3)	86(2)	80(1)	88(1)
T_1 [K]	5628	5673	6184	5808	6618
T_2 [K]	5554(11)	5712(9)	5796(11)	5543(12)	6435(11)
Ω [K]	2.004(39)	2.075(52)	2.080(48)	1.986(11)	1.985(41)
q [M_2/M_1]	0.117(21)	0.154(19)	0.161(11)	0.132(2)	0.125(9)
Dist. [pc]	517(3)	602(4)	756(6)	627(4)	271(1)
M_V	4.26(4)	4.41(3)	3.47(4)	3.78(4)	3.18(4)
M_1 [$M_\odot$]	1.36(25)	1.33(26)	1.84(37)	1.75(33)	1.74(29)
M_2 [$M_\odot$]	0.16(5)	0.20(6)	0.30(8)	0.23(7)	0.22(6)

2. The objects

The sample of objects studied in this work is a result of the individual tutoring program commenced by the Jagiellonian University at the Jordan Youth Center in Krakow. The objects selected for this study come from the precompiled list of suspected contact binaries[1]. The temperatures of the primary components were adopted from the TESS Input Catalogue (TIC), v8.2 (Paegert et al., 2021). The distances to the objects were calculated using the Gaia DR3 (Gaia Collaboration et al., 2023) parallaxes. The absolute magnitudes, M_V, were derived from the distances, D, and observed brightness m_V (collected by us), corrected by the interstellar extinction adopted from TIC.

3. Observations and Analysis

The photometric data used for this study were taken with the Apogee Alta U42 camera in the D9 casing mounted on the Cassegrain telescope (aperture 500 mm, effective focal length 6650 mm) at the Astronomical Observatory of the Jagiellonian University in Krakow. The light curves of all objects were taken in the Bessel B, V, R and I filters. The light curve numerical modeling was conducted using a modified Wilson-Devinney code (Wilson & Devinney, 1971; Zola et al., 1997; Debski, 2022). The physical parameters were calculated by incorporating the total brightness and the modeling result to the Stefan-Boltzman Law

[1] `http://bade.space/ew/`

and then using the derived orbital separation to the Third Kepler's Law. The individual masses were then calculated with the use of the mass ratio obtained from numerical modeling.

4. Results

This study presents first-time obtained physical parameters for five low-mass ratio contact binaries. The observational parameters, as well as the best-fitting model parameters and the calculated physical parameters for all objects, are compiled in the Table 1. One system (KR 00017) needed the introduction of a cool ($T_{spot} = 0.75\,T_1$) spot on the back of the primary component. The spot was fixed at the stellar equator.

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