

BSN-I: the first in-depth photometric study of seven total-eclipse contact binary systems

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ABSTRACT

This is the first in-depth study of seven total-eclipse W Ursae Majoris-type contact binary systems using photometric light curves. The ground-based observations were conducted with four observatories in the Northern and Southern hemispheres. We also used the *Transiting Exoplanet Survey Satellite* for four target systems. We presented the analysis of orbital period variations of six systems and found that they display parabolic variations. The material transfer rates between the stars of the systems were calculated. Also, the results show that four systems have a long-term increase, while two have a long-term decrease in their orbital periods. We analysed light curves using the PHysics Of Eclipsing BinariEs PYTHON code and the Markov chain Monte Carlo algorithm to estimate different parameters of target systems and their uncertainties. Six of the target systems required the addition of a cold or hot star-spot. We estimated absolute parameters using the empirical relationship between the orbital period and the semimajor axis ($P-a$). According to each component’s effective temperature and mass, it was recognized that the studied systems are W subtype. We examined the dynamic stability of two targets, which were low mass ratio contact binary systems. We also showed the evolution of stars in the $M-R$ and $M-L$ diagrams. Finally, we showed that the hotter stars in contact systems have a temperature difference of less than ≈ 400 K compared to the *Gaia* Data Release 3 temperature report.

Key words: binaries: eclipsing – binaries: close – stars: fundamental parameters – methods: data analysis – stars: individual: (Seven Contact Binary Stars).

1 INTRODUCTION

Among the extremely wide variety of binary stars, overcontact systems that exchange mass, angular momentum, and energy are important to assess the physical mechanisms at play, such as coalescence, spiralling, angular momentum loss, thermal relaxation oscillations, etc. (Lucy 1968; Bradstreet & Guinan 1994; Eggleton & Kiseleva-Eggleton 2002; Qian 2003; Yakut & Eggleton 2005; Stepien 2006, 2011; Eggleton 2012). W Ursae Majoris (W UMa)-type contact binaries have two main-sequence components of F to K spectral type, short ($< \text{day}$) periods, and a common convective envelope. The W UMa-type binaries are challenging to study. The minimum depths

of primary and secondary eclipses are similar, and the effective temperatures of the components are also close to each other (Kuiper 1941; Qian et al. 2014). Morphologically, their light curves are classified into two types: in the A subtype, the more massive component has a higher effective temperature, while in the second class, the W subtype, the reverse is true (Binnendijk 1970). W subtype systems also have shorter periods, later spectral types, and larger mass ratios. Some systems have transitioned from the A subtype to the W subtype in a few years (Latković, Čeki & Lazarević 2021).

The broadening and blending of spectral lines make it difficult to measure some contact systems’ mass ratios (q) spectroscopically, and hence the best estimates come from the photometric analysis of systems undergoing total eclipses. Also, estimating the mass ratio for systems where one of the companions has a small radius and mass is difficult and sometimes not possible with spectroscopic data,

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Table 1. Specifications of the target systems from the *Gaia* DR3.

System	RA [°] (J2000)	Dec. [°] (J2000)	<i>d</i> (pc)	<i>T</i> _{<i>Gaia</i>} (K)
BK Oct	295.766 0936	−74.858 2357	1040(16)	5722(10)
<i>Gaia</i> DR3 5842836641483889280 (G5842)	186.554 7148	−71.248 0380	1003(34)	4869(37)
ASAS J165337+1542.7 (J1653)	253.404 1846	15.710 4837	434(6)	5111(36)
CRTS J165528.6+294254 (J1655)	253.869 4590	29.715 0252	938(23)	4817(8)
NSVS 5902490 (N5902)	320.474 5956	39.536 9870	621(34)	5722(31)
NSVS 5905978 (N5905)	321.205 5036	40.132 9269	696(6)	5562(42)
V2825 Ori	93.608 0081	−0.528 0932	531(5)	5920(13)

and photometric analysis is an effective way to study them (Li et al. 2022, 2024b).

Many studies have been done about the orbital period of contact binary systems and its relationship with other physical parameters. So, the accurate determination of the orbital period can have an impact on other empirical parameter relationships to estimate the absolute parameters (Qian 2003).

One of the most prevalent features of contact binary systems is the well-known O’Connell effect (O’Connell 1951a). The asymmetry in the light-curve maxima of eclipsing binary stars indicates this effect. This phenomenon, which leads to the need to include the star-spot(s) in the light-curve solution, can be explained by the presence of magnetic activity at the star’s surface.

This study used photometric observations of seven W UMa-type contact binaries undergoing total eclipses to provide more accurate orbital and physical parameters. The ground-based observations were conducted by four observatories in the Binary Systems of South and North (BSN) project. This study is numbered with BSN-I. However, the BSN project has so far published observations and analyses of contact systems being investigated for the first time, which include Poro et al. (2021a, b, 2022a, b, 2023, 2024a, b, c, e, f), Paki, Baudart & Poro (2023), Alizadehsabegh et al. (2024), Sarvari, Fernández Lajús & Poro (2024), and Baudart & Poro (2024). The study is divided into seven sections. Section 2 recaps the basic known properties of the selected systems, while Section 3 reports the observations carried out at the different ground-based observatories and the *Transiting Exoplanet Survey Satellite* (*TESS*) mission. Section 4 analyses orbital period variations of the systems, while Section 5 presents the multicolour light-curve solutions. Absolute parameter estimations are discussed in Section 6. A discussion and summary of our results are included in Section 7.

2 TARGET SYSTEMS

We have analysed seven eclipsing binary stars, including BK Oct, *Gaia* DR3 5842836641483889280 (hereinafter G5842), ASAS J165337+1542.7 (hereinafter J1653), CRTS J165528.6+294254 (hereinafter J1655), NSVS 5902490 (hereinafter N5902), NSVS 5905978 (hereinafter N5905), and V2825 Ori. Table 1 presents some specifications for the target systems in the *Gaia* Data Release 3 (DR3) data base. We averaged the upper and lower temperature limits provided by *Gaia* DR3 for uncertainty in Table 1. The following are the target systems’ generalities:

(i) BK Oct: Hoffmeister (1963) and Kukarkin, Kholopov & Perova (1970) reported this system as a new variable from the Southern hemisphere. Then, Malkov et al. (2006) and Avvakumova, Malkov & Kniazhev (2013) classified BK Octans as a contact binary star. The General Catalogue of Variable Stars (GCVS) reported 14.30 mag as a maximum magnitude. The reported orbital periods of this system in the catalogue are very close to each other:

GCVS = 0.3686 d, the Zwicky Transient Facility (ZTF; Sánchez-Sáez et al. 2023) = 0.368 5127 d, the All-Sky Automated Survey for SuperNovae (ASAS-SN; Jayasinghe et al. 2018) = 0.368 51 d, and the *Wide-field Infrared Survey Explorer* (Chen et al. 2018) catalogue of periodic variable stars = 0.368 5174 d. It should be mentioned that the temperature difference reported from *Gaia* DR3 and *TESS* Input Catalog (TIC) v8.2 with 301 K is significant for this system.

(ii) G5842: This system was proposed for the first time in the study of Mowlavi et al. (2023) as a contact binary candidate. It is not listed in catalogues such as ASAS-SN and GCVS, and there is little information about it. Also, G5842 has not been observed by *TESS* yet.

(iii) J1653: It is located in the Hercules constellation in the Northern hemisphere. J1653 was discovered by the Robotic Optical Transient Search Experiment I telescope, which presented the first results of a search for periodic variable stars (Akerlof et al. 2000). The ZTF periodic variable stars’ catalogue presented an ephemeris for this system as $2458638.293583^{\text{HJD}} + 0.2809766 \times E$ (Chen et al. 2020). The ASAS and Variable Star Index (VSX) catalogues reported 13.20 and 13.16 mag for the maximum magnitude of this binary system. TIC reported a system temperature of 5337 ± 154 K, which is 226 K higher than *Gaia* DR3.

(iv) J1655: This binary system was discovered by Catalina Surveys Data Release 1 (CSDR1; Drake et al. 2014) in the Hercules constellation. The CSDR1, VSX, ZTF, and ASAS-SN catalogues reported J1655 as a contact system with an orbital period of 0.269 99 d. The VSX data base reported 16.40 mag for the maximum magnitude of this binary system. Also, the temperature difference between *Gaia* DR3 and TIC is only 80 K for this system ($T_{\text{TIC}} = 4737 \pm 165$ K).

(v) N5902: It was discovered as a W UMa binary system in the Northern Sky Variability Survey (NSVS; Hoffman, Harrison & McNamara 2009). It is classified in the ASAS-SN, ZTF, and Asteroid Terrestrial-impact Last Alert System (ATLAS) catalogues as a contact binary system. N5902 is located in the Cygnus constellation, and its maximum magnitude was reported at 12.67 mag by the VSX data base. The temperature of this system is not reported in TIC.

(vi) N5905: This binary system was discovered in the NSVS as a W UMa with an orbital period of 0.433 19 d. N5905 is in the Cygnus constellation, and the VSX data base presented $V_{\text{max}} = 13.623$ mag. The most important thing about this system is the huge temperature difference (911 K) reported by *Gaia* DR3 and TIC. As listed in Table 1, *Gaia* DR3’s temperature is 5562 ± 42 K and TIC reported 6473 ± 278 K.

(vii) V2825 Ori: Diethelm (2011) presented an ephemeris ($2454519.566^{\text{HJD}} + 0.346327 \times E$) for this binary system for the first time. V2825 Orion was classified as a contact binary by Kazarovets et al. (2015). Also, catalogues such as ATLAS, GCVS, and ASAS-SN introduced it as a contact binary system. GCVS and ASAS-SN have reported orbital period values of 0.346 327 and 0.346 33 d, respectively, which are close to each other. The ASAS

Table 2. Specifications of the ground-based observations.

System	Observation(s) date	Filter	Exposure time(s)	Observatory
BK Oct	2024 (Aug 9)	$BV R_c I_c$	$B(40), V(15), R_c(10), I_c(10)$	CASLEO
G5842	2023 (Mar 2)	R_c	$R_c(120)$	OBP-South
J1653	2024 (May 27)	$BV R_c I_c$	$B(70), V(50), R_c(35), I_c(30)$	SPM
J1655	2024 (May 21, June 1)	$BV R_c I_c$	$B(70), V(50), R_c(35), I_c(30)$	SPM
N5902	2023 (July 2, 9, 14)	V	$V(110)$	OASa
N5905	2023 (July 2, 9, 14)	V	$V(110)$	OASa
V2825 Ori	2024 (Mar 1, 6, 18)	V	$V(110)$	OASa

Table 3. List of the comparisons and check stars in the ground-based observations. Coordinates come from the *Gaia* DR3.

System	Star type	Star name	RA [°] (J2000)	Dec. [°] (J2000)
BK Oct	Comparison	2MASS 19421402–7453083	295.558 4457	–74.885 6418
BK Oct	Check	2MASS 19425752–7455468	295.739 7603	–74.929 7148
G5842	Comparison	Gaia DR3 5842837401701627520	186.559 7689	–71.239 6145
G5842	Check	Gaia DR3 5842837264262660608	186.473 6675	–71.258 8317
J1653	Comparison	Gaia DR3 4557874824155774848	253.348 9128	15.681 9645
J1653	Check	Gaia DR3 4557880596591908352	253.457 0287	15.744 3665
J1655	Comparison	Gaia DR3 1309731726953037056	253.905 7075	29.759 9072
J1655	Check	Gaia DR3 1309729562289519488	253.826 4715	29.680 8101
N5902	Comparison	Gaia DR2 1965471833170939904	321.091 5760	39.993 5854
N5902	Check	Gaia DR2 1965424588530688256	321.094 5478	39.924 2306
N5905	Comparison	Gaia DR2 1965424588530688256	321.094 5478	39.924 2306
N5905	Check	Gaia DR2 1965424588530688256	321.094 5478	39.924 2306
V2825 Ori	Comparison	Gaia DR2 3121651740485309312	93.621 6639	–0.546 6014
V2825 Ori	Check	Gaia DR2 3121187540419633792	94.058 3165	–1.095 5787

Catalog of Variable Stars and GCVS catalogues reported 12.71 and 12.75 mag for maximum magnitudes, respectively. Regarding the system temperature, TIC reported a temperature of 101 K higher than *Gaia* DR3 with an uncertainty of 315 K.

3 OBSERVATION AND DATA REDUCTION

Photometric observations and data reductions were conducted for seven target systems using standard filters at four Northern and Southern hemispheres' observatories: Complejo Astronomico El Leoncito (CASLEO), San Pedro Martir (SPM), Observatoire Astronomique de Sabichette (OASa), and Observatoire des Baronnies Provençales (OBP-South). Table 2 lists the observation characteristics of each target system, including the date of observation, filter used, exposure time, and name of the observatory. Also, the general characteristics of comparison and check stars in the observation processes are presented in Table 3.

3.1 CASLEO observatory

The 2.15-m Jorge Sahade telescope at the CASLEO observatory in Argentina (69°18' West, 31°48' South, 2552 m above sea level) was used to observe the BK Oct. The standard $BV R_c I_c$ filters and a CCD Versarray 2048B (Roper Scientific, Princeton Instruments) were employed. Moreover, binning 5×5 and a scale of 0.15 asec pix^{−1} were used for the observations. CCD reduction and aperture photometry were performed using the Image Reduction and Analysis Facility (IRAF¹) APPHOT photometry program (Tody 1986). Bias and flat-field images were used in these data reduction processes.

3.2 SPM observatory

The J1655 and J1653 binary systems were observed at the SPM observatory in Mexico (115°27'49" West, 31°02'39" North, and an altitude of 2830 m above sea level). A 0.84-m Ritchey–Chrétien telescope ($f/15$), a CCD detector from spectral instruments (e2v CCD42-40 chip with $13.5 \times 13.5 \mu\text{m}^2$ pixels, gain of 1.39e[−]/ADU, and readout noise of 3.54e[−]), and $BV R_c I_c$ filters were used for the observations. Photometric images were processed using IRAF routines (Tody 1986). The data reduction process was done using bias and flat-field images.

3.3 OASa observatory

We have observed the N5902, N5905, and V2825 Ori systems at the OASa observatory in Toulon, France (05°54'35" East, latitude 43°8'59" North, and altitude 68 m above sea level). We employed an apochromatic refractor telescope with a 102-mm aperture, a ZWO ASI 1600MM CCD, and a V standard filter for observations of these binary systems. During the observations, the CCD average temperature was −15 °C, and the image binning was set to 1×1 . We performed the data reduction process using the SIRIL software 1.2.0,² employing bias, dark, and flat-field images.

3.4 OBP-South observatory

The G5842 target system was observed at the OBP-South observatory located on site of the Deep Sky Chile, MPC code x07 (−30°31'35" South, −70°51'13.00" West, and altitude 1700 m above sea level). We used a RASA 14-inch ($f/2.2$) telescope, ASI ZWO 6200 MM pro

¹<http://iraf.noao.edu>

²<https://siril.org/fr/download/2023-09-15-siril-1.2.0/>

Table 4. Specifications of the *TESS* data used in this investigation.

System	TIC	<i>TESS</i> sector	Exposure time(s)	Obs. year
J1653	353179421	25	1800	2020
N5902	373662724	15-16-55-56-75	1800-1800-600-200-200	2020-2021-2023-2-23-2024
N5905	468470819	15-16-55-56-75	1800-1800-600-200-200	2020-2021-2023-2-23-2024
V2825 Ori	242128030	6-33	1800-600	2018-2020

Table 5. The times of minima extracted from our observations.

System	Min.(BJD _{TDB})	Error	Epoch	O-C
BK Oct	2460532.52764	0.030 99	0	0
	2460532.71410	0.035 27	0.5	0.002 20
G5842	2460005.69208	0.000 27		
	2460005.82596	0.000 21		
J1653	2460457.67965	0.000 35	−0.5	0.001 55
	2460457.81859	0.000 72	0	0
	2460457.96061	0.000 35	0.5	0.001 53
J1655	2460451.72475	0.000 54	−41	−0.000 70
	2460462.79512	0.000 29	0	0
	2460462.92888	0.000 26	0.5	−0.001 24
N5902	2460128.45307	0.000 30	−20	0.000 72
	2460135.47589	0.001 03	0	0
	2460139.51393	0.000 30	11.5	−0.000 49
N5905	2460128.52808	0.000 77	0	0
	2460135.45701	0.001 00	16	−0.001 99
	2460139.57193	0.000 29	25.5	−0.002 31
V2825 Ori	2460376.36072	0.000 35	0	0
	2460388.31173	0.000 24	34.5	0.002 62

(CMOS) CCD, and an R_c standard filter. During observations, the CCD average temperature was -15°C , and the image binning set to 1×1 . The data reduction processes were carried out using C-MUNIPACK 2.1.32 software³ and the bias, dark, and flat-field images.

3.5 *TESS* observations

NASA launched the *TESS* to discover exoplanets (Ricker et al. 2010, 2015). However, this telescope also gave researchers high-precision photometric data from binary systems (Stassun et al. 2018). This space telescope has four wide-field cameras that allow it to observe different sky regions. *TESS* spends 27.4 d per sector observing a specific area of the sky. We used time-series available *TESS* data for the J1655, N5902, N5905, and V2825 Ori target systems. The *TESS* data are available from the Mikulski Space Telescope Archive (MAST).⁴ *TESS*-style curves were extracted from the MAST using the LIGHTKURVE⁵ code. Data were detrended using the *TESS* Science Processing Operations Center pipeline (Jenkins et al. 2016). Table 4 lists the *TESS* sectors used in this study.

4 ORBITAL PERIOD VARIATIONS

In order to conduct further analysis on these targets, we strive to gather as many eclipsing times as we can from diverse photometric surveys, including the ASAS-SN (Shappee et al. 2014; Jayasinghe et al. 2018), the ZTF (Bellm et al. 2019; Masci et al. 2019), the *TESS* (Ricker et al. 2015), and Wide Angle Search for Planets

(SuperWASP; Butters et al. 2010). Through these eclipsing times, we analysed the orbital period variations for these seven targets. However, due to an insufficient number of eclipsing times collected for G5842, further analysis could not be conducted. In addition, we also collected data from the VarAstro⁶ data base. We calculated directly the eclipsing times for *TESS* 2-min, *TESS* 10-min, and SuperWASP data. However, for the *TESS* 30-min cadence data, ZTF, and ASAS-SN dispersed data, we need to apply the method suggested by Li et al. (2020) to shift the data into one period before obtaining the eclipsing times. After that, we use the Kwee & van Woerden (1956) method to calculate the eclipsing times.

Since our data contain both the Barycentric Julian Date in Barycentric Dynamical Time (BJD_{TDB}) and the Heliocentric Julian Date (HJD), to unify the time-scale, we used the online tool⁷ to convert HJD to BJD_{TDB}. The eclipsing times extracted from our observations are listed in Table 5. The online machine-readable format is available for the extracted and collected minima times of the BK Oct, J1653, J1655, N5902, N5905, and V2825 Ori binary systems. Then, we calculated the O-C values using the reference ephemeris,

$$\text{BJD} = \text{BJD}_0 + P \times E, \quad (1)$$

where BJD represents the observational eclipsing times, BJD₀ listed in the second column of Table 6 is the initial primary eclipsing time, and P listed in the third column of Table 6 is the orbital period. The calculated epoch and O-C values are listed in Table 5 and in machine-readable online format. The O-C diagrams are shown in Fig. 1.

³<https://c-munipack.sourceforge.net/>

⁴<https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html>

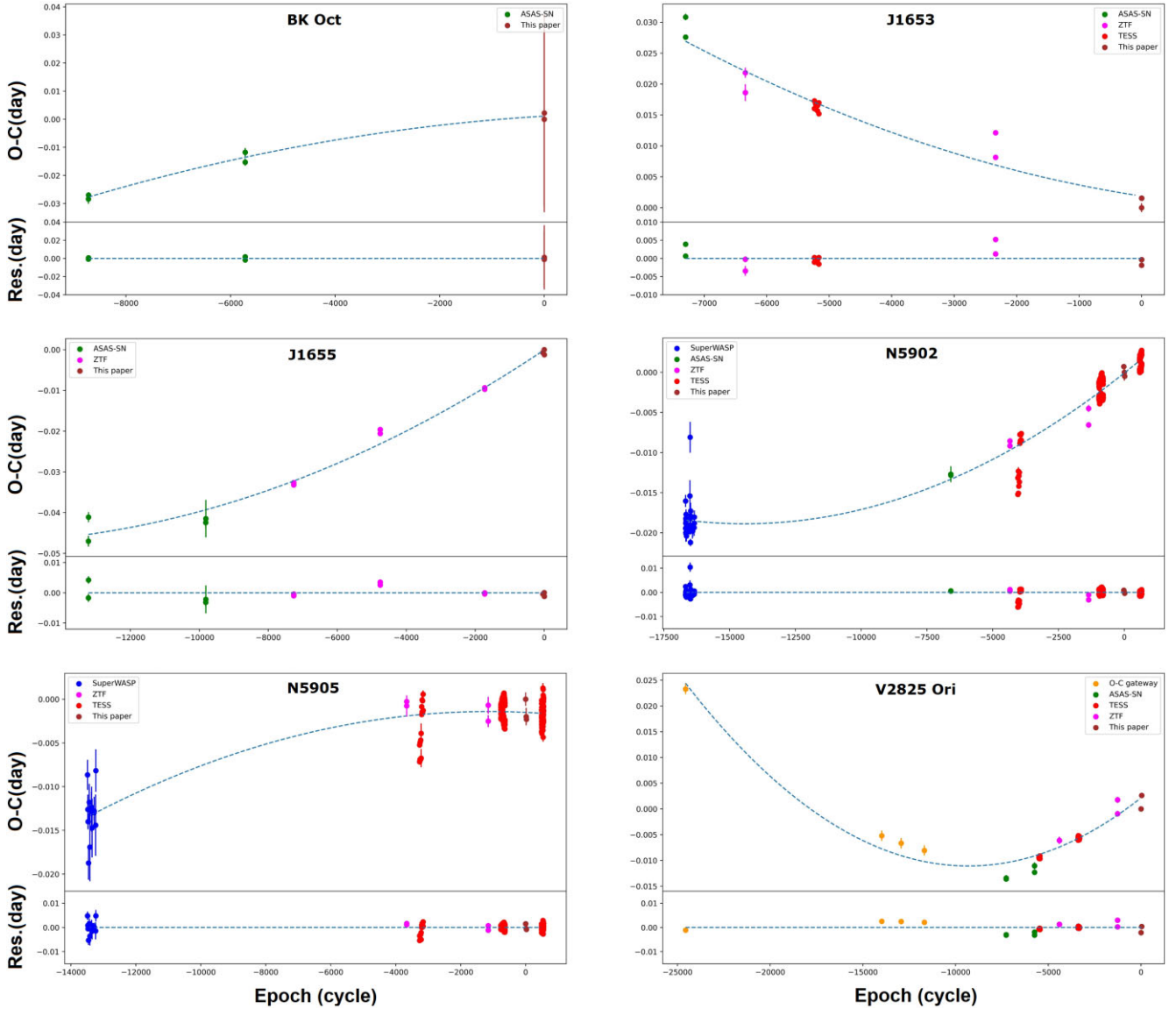
⁵<https://lightcurve.github.io/lightcurve/>

⁶<http://var.astro.cz>

⁷<https://astroutils.astronomy.osu.edu/time/hjd2bjd.html>

Table 6. Reference and new ephemeris of the systems. The referent times of minima (t_0) were obtained from our observations in this study.

System	Reference ephemeris		New ephemeris	
	t_0	Period/source	Corrected t_0	New period
BK Oct	2460532.5276(310)	0.368 5127/ASAS-SN	2460532.5287(25)	0.368 5138(16)
J1653	2460457.8186(7)	0.280 9786/ASAS-SN	2460457.8205(24)	0.280 9771(16)
J1655	2460462.7951(3)	0.269 9918/ASAS-SN	2460462.7951(25)	0.269 9975(10)
N5902	2460135.4759(10)	0.351 1768/ASAS-SN	2460135.4758(1)	0.351 1794(1)
N5905	2460128.5281(8)	0.433 1826/VSX	2460128.5266(1)	0.433 1824(2)
V2825 Ori	2460376.3607(4)	0.346 3300/ASAS-SN	2460376.3629(5)	0.346 3328(1)

**Figure 1.** The O-C diagrams of the seven binary systems.

We find that all targets display parabolic variations; hence, we utilize the following equation for the O-C fitting:

$$O - C = \Delta T_0 + \Delta P_0 \times E + \frac{\beta}{2} E^2. \quad (2)$$

The fitted parameters are shown in Table 7, and the corrected new ephemeris is shown in Table 6. We found that four stars show a

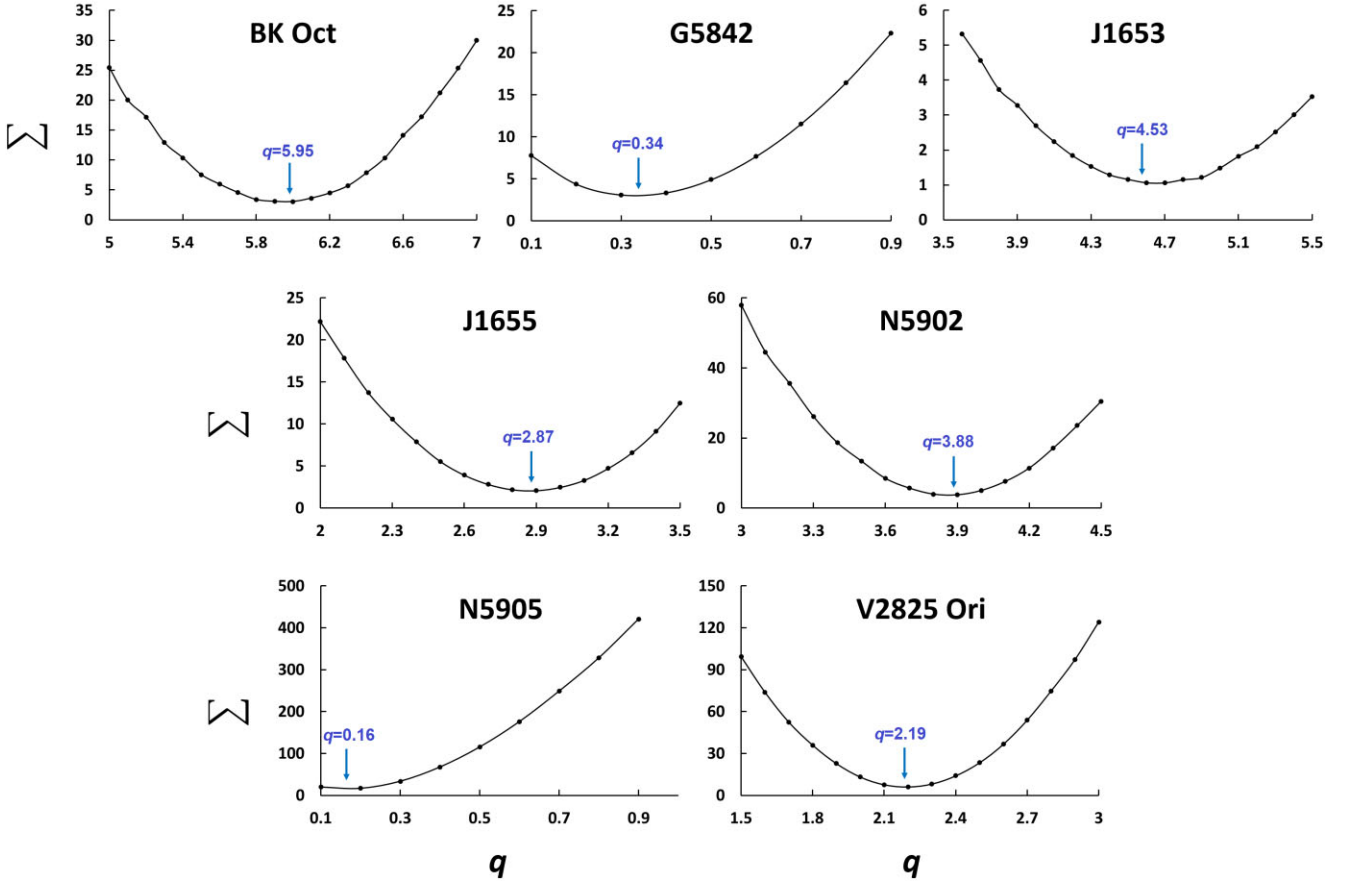
long-term increase in their orbital periods, while two stars show a long-term decrease.

5 LIGHT-CURVE SOLUTIONS

The light curve of the target binary systems was examined using the Physics Of Eclipsing Binaries (PHOEBE) PYTHON code version 2.4.9

Table 7. The O-C fitting coefficients and mass transfer rate.

Parameter	ΔT_0 ($\times 10^{-4}$ d)	Error	ΔP_0 ($\times 10^{-7}$ d)	Error	β ($\times 10^{-7}$ d yr $^{-1}$)	Error	dM_1/dt ($\times 10^{-7}$ M $_{\odot}$ yr $^{-1}$)	Error
BK Oct	11.00	25.15	11.36	15.71	-4.93	3.62	1.29	0.95
J1653	18.71	24.38	-15.44	15.69	6.73	5.81	-2.67	2.3
J1655	-0.56	24.53	56.54	9.79	4.56	2.02	-3.1	1.37
N5902	-1.00	1.36	26.00	1.36	1.87	0.17	-0.79	0.07
N5905	-15.04	1.49	-1.76	1.83	-1.33	0.24	-0.30	0.05
V2825 Ori	21.57	4.57	28.40	1.47	3.22	0.14	-2.86	0.12

**Figure 2.** Sum of the squared residuals as a function of the mass ratio.

and Markov chain Monte Carlo (MCMC) approach (Prša et al. 2016; Conroy et al. 2020). We used new ephemeris (Table 6) to convert time to phase in light curves. The contact mode was chosen for the light-curve solutions based on the light curves' appearance, the systems' type in catalogues, and the short orbital periods. We assumed that $g_1 = g_2 = 0.32$ (Lucy 1967) and $A_1 = A_2 = 0.5$ (Ruciński 1969) were the gravity-darkening coefficients and the bolometric albedo, respectively. The Castelli & Kurucz (2004) study was used to model the stellar atmosphere, and the limb darkening coefficients were included as a free parameter in PHOEBE.

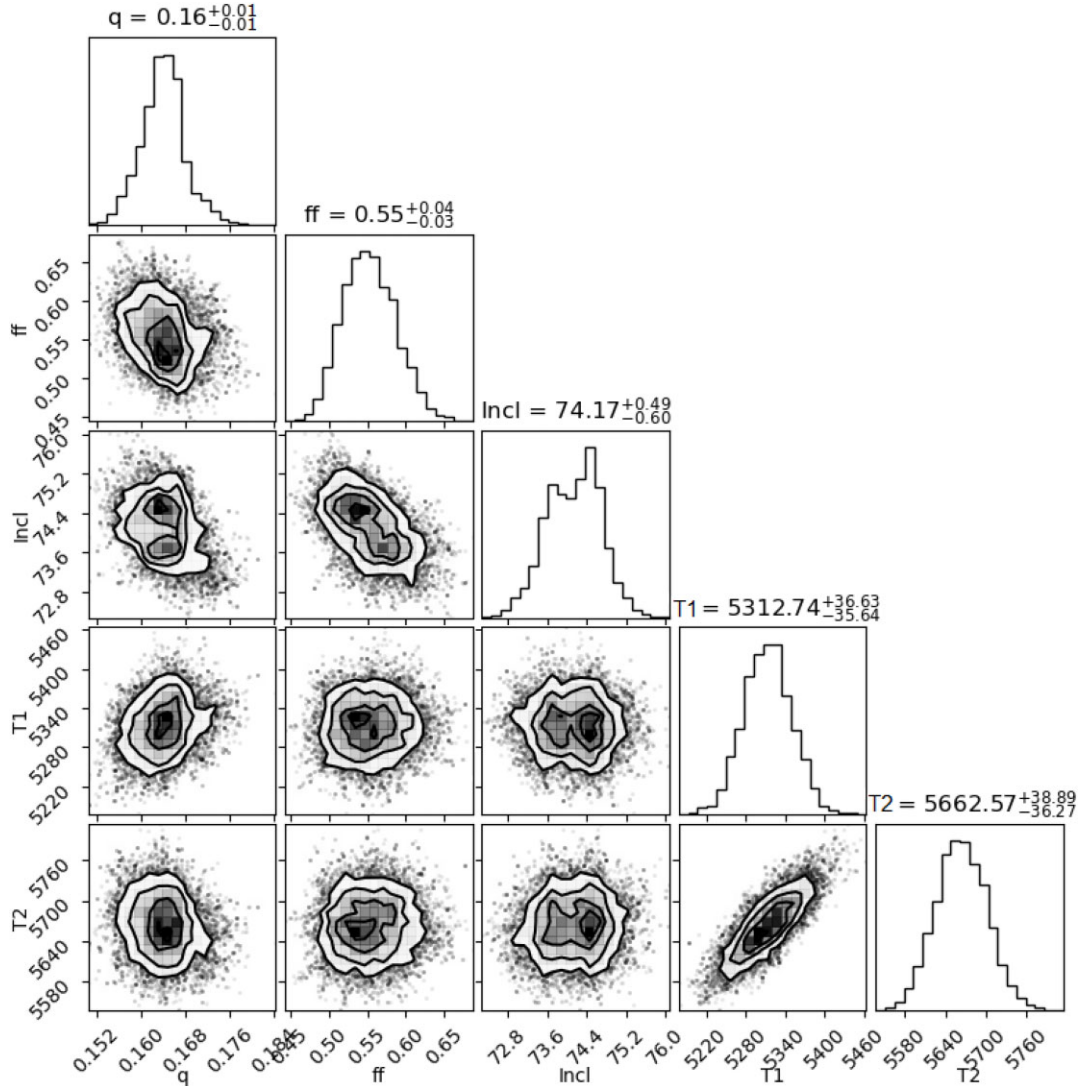
To begin the analysis, we used the *Gaia* DR3 data base to find the input effective temperature. We also checked the temperature provided by the TIC v8.2 during the analysis process. The systems' initial temperatures were placed on the hotter star based on the depth of the minima. So, we used the difference in depth between the primary and secondary minima of the light curves to determine the temperature of the cooler component.

We estimated the systems' initial mass ratio using the q -search method (Terrell & Wilson 2005). We searched a range of mass ratios between $q = 0.1$ and $q = 10$. Then, we shortened the interval and searched again according to the minimum sum of squared residuals. Fig. 2 illustrates that each q -search curve has a clear minimum sum of squared residuals. Also, the mass ratio of total systems in photometric analysis is more reliable based on theoretical and empirical studies (Li et al. 2021; Sarvari et al. 2024).

The maxima of the light curves (phases 0.25 and 0.75) show asymmetry in the light curve for six target systems (Table 8). The most probable explanation is that the magnetic activity of the components is causing the presence of the star-spot(s), which are introduced with the O'Connell effect (O'Connell 1951b; Sriram et al. 2017). So, the light-curve solution required a star-spot on a component. Table 8 lists the commonly recognized features of a star-spot, including colatitude, longitude, angular radius, and temperature ratio. The difference between the light curves' maximum I at phase

Table 8. Light-curve solutions of the target binary stars.

Parameter	BK Oct	G5842	J1653	J1655	N5902	N5905	V2825 Ori
T_1 (K)	5724^{+17}_{-15}	4756^{+33}_{-38}	5038^{+71}_{-71}	4816^{+80}_{-72}	5858^{+39}_{-39}	5313^{+37}_{-36}	5918^{+74}_{-75}
T_2 (K)	5646^{+17}_{-13}	4831^{+37}_{-40}	4904^{+73}_{-70}	4676^{+72}_{-68}	5568^{+39}_{-35}	5663^{+39}_{-36}	5744^{+70}_{-70}
$q = M_2/M_1$	5.95^{+3}_{-6}	0.34^{+1}_{-1}	4.53^{+9}_{-9}	2.87^{+8}_{-9}	3.88^{+8}_{-10}	0.16^{+1}_{-1}	2.19^{+4}_{-6}
i°	85.08^{+87}_{-58}	88.36^{+60}_{-59}	$85.18^{+1.62}_{-1.77}$	81.49^{+81}_{-92}	76.52^{+34}_{-28}	74.17^{+49}_{-60}	83.22^{+57}_{-56}
f	0.29^{+1}_{-2}	0.08^{+2}_{-2}	0.64^{+4}_{-4}	0.11^{+2}_{-4}	0.15^{+2}_{-2}	0.55^{+4}_{-3}	0.16^{+1}_{-1}
$\Omega_1 = \Omega_2$	10.15(32)	2.54(2)	8.17(23)	6.38(7)	7.66(10)	2.07(5)	5.42(10)
$l_1/l_{\text{tot}}(V)$	0.182(1)	0.707(4)	0.238(1)	0.319(1)	0.261(1)	0.792(3)	0.354(1)
$l_2/l_{\text{tot}}(V)$	0.818(5)	0.293(1)	0.762(4)	0.681(2)	0.739(4)	0.208(1)	0.646(2)
$r(\text{mean})1$	0.252(13)	0.481(5)	0.293(24)	0.299(7)	0.277(8)	0.564(21)	0.325(12)
$r(\text{mean})2$	0.549(11)	0.295(5)	0.545(19)	0.481(19)	0.509(7)	0.261(24)	0.461(11)
Col. $^\circ$ (spot)	95(1)		100(1)	86(1)	95(1)	77(1)	104(2)
Long. $^\circ$ (spot)	299(3)		84(1)	263(2)	29(1)	56(1)	289(2)
Radius $^\circ$ (spot)	15(1)		19(1)	24(2)	15(1)	12(1)	14(1)
$T_{\text{spot}}/T_{\text{star}}$	0.82(1)		0.87(1)	0.80(1)	0.79(1)	0.88(1)	0.91(1)
Component	Secondary		Secondary	Primary	Secondary	Primary	Secondary
MaxII-MaxI(V)	-0.028	0.001	0.063	0.037	0.031	-0.020	-0.015

**Figure 3.** The corner plots of the N5905 system were determined by MCMC modelling.

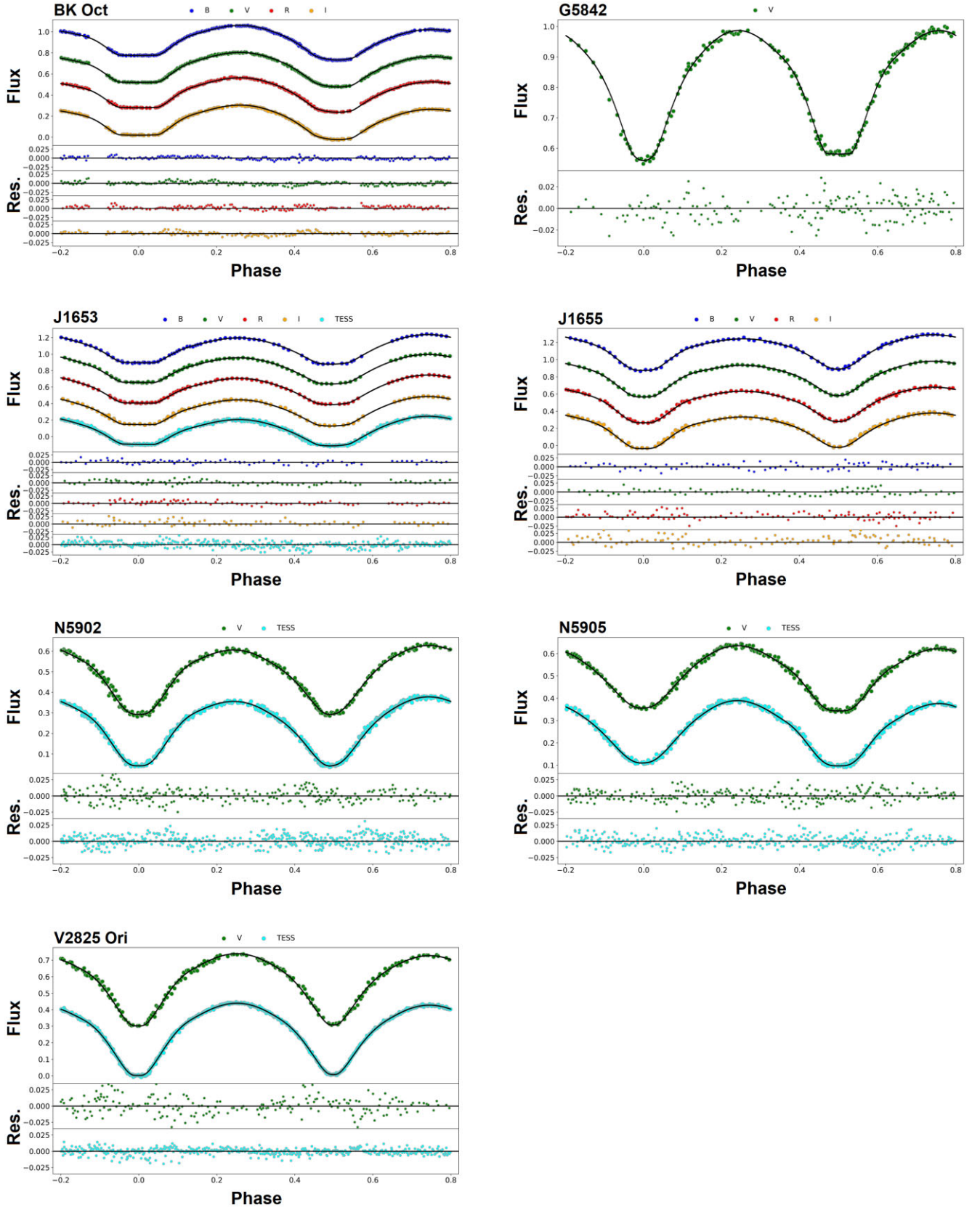


Figure 4. The dots show the observed light curves of the systems, and the synthetic light curves were generated using the light-curve solutions.

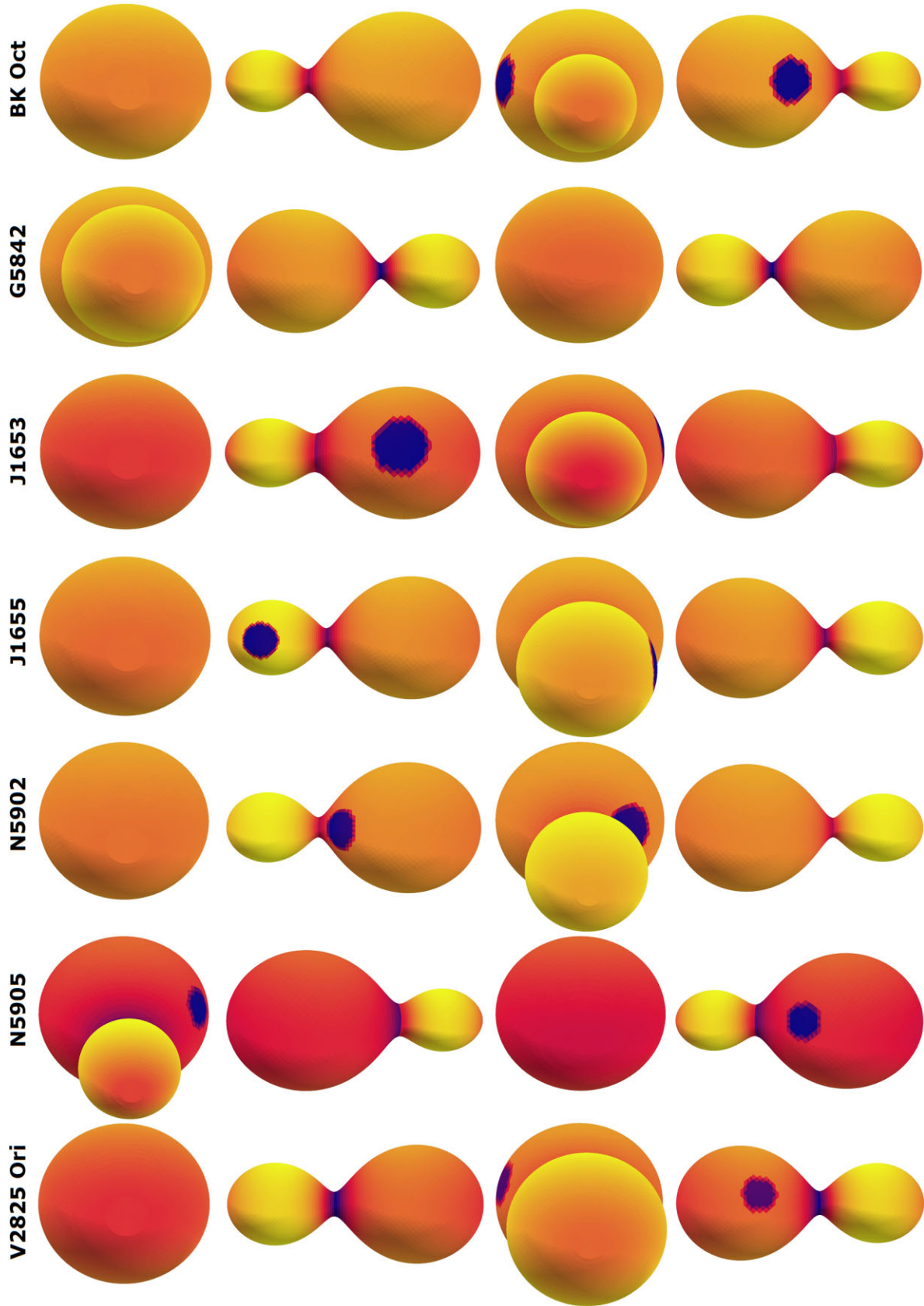


Figure 5. 3D view of stars in the target binary systems.

Table 9. Estimated absolute parameters of the systems.

Parameter	BK Oct	G5842	J1653	J1655	N5902	N5905	V2825 Ori
M_1 ($M_\odot$)	0.24(7)	1.04(33)	0.26(8)	0.36(12)	0.33(9)	1.56(41)	0.50(14)
M_2 ($M_\odot$)	1.41(39)	0.36(12)	1.17(37)	1.04(34)	1.27(37)	0.25(7)	1.09(32)
R_1 ($R_\odot$)	0.64(9)	0.94(10)	0.60(11)	0.59(7)	0.68(8)	1.65(20)	0.79(10)
R_2 ($R_\odot$)	1.40(15)	0.58(7)	1.11(15)	0.95(13)	1.25(13)	0.77(14)	1.12(13)
L_1 ($L_\odot$)	0.40(13)	0.41(11)	0.21(10)	0.17(6)	0.49(14)	1.97(57)	0.68(23)
L_2 ($L_\odot$)	1.80(43)	0.16(5)	0.64(23)	0.39(15)	1.35(33)	0.54(23)	1.22(37)
M_{bol1} (mag)	5.72(30)	5.71(26)	6.44(43)	6.67(32)	5.51(27)	4.00(28)	5.14(32)
M_{bol2} (mag)	4.09(23)	6.70(27)	5.21(34)	5.76(35)	4.41(24)	5.39(39)	4.51(29)
$\log(g)_1$ (cgs)	4.19(1)	4.51(3)	4.30(3)	4.46(2)	4.29(1)	4.19(1)	4.34(1)
$\log(g)_2$ (cgs)	4.29(2)	4.47(3)	4.42(1)	4.50(1)	4.35(3)	4.07(4)	4.38(2)
a ($R_\odot$)	2.55(22)	1.95(19)	2.03(19)	1.97(19)	2.45(21)	2.93(24)	2.42(21)
$\log J_0$ (cgs)	51.40(18)	51.42(20)	51.34(20)	51.43(20)	51.49(18)	51.48(17)	51.61(18)
A_V (mag)	0.173(1)	0.896(16)	0.191(1)	0.105(1)	0.401(16)	0.858(5)	0.501(3)

Table 10. Some conclusions regarding the target systems.

Systems	$\Delta T_{1,2}$ (K)	Sp. cat.	$1/q$	Subtype	T_{Gaia} (K)	M_{1i} ($M_\odot$)	M_{2i} ($M_\odot$)	M_{lost} ($M_\odot$)
BK Oct	78	G5-G7	0.17(1)	W	5722	0.93	1.68	0.96
G5842	75	K3-K2	–	W	4869	0.78	1.13	0.51
J1653	134	K1-K2	0.22(1)	W	5111	0.78	1.41	0.77
J1655	140	K2-K3	0.35(1)	W	4817	0.77	1.16	0.53
N5902	290	G3-G8	0.26(1)	W	5722	0.83	1.65	0.88
N5905	350	K0-G7	–	W	5562	1.04	1.78	1.02
V2825 Ori	174	G2-G5	0.46(1)	W	5920	0.74	1.56	0.70

0.25 and maximum II at phase 0.75 (MaxII-MaxI) for V -band data is presented in Table 8.

Then, we attempted to determine an acceptable theoretical fit on the observational data using the initial values. In addition, we used PHOEBE's optimization tool to improve light-curve solution output and provide the desired outcomes for the next phase.

The MCMC approach based on the EMCEE package (Foreman-Mackey et al. 2013) was used to determine the final values of the parameters and their uncertainty. Mass ratio q , inclination i , fillout factor f , and effective stars' temperatures $T_{1,2}$ were the five main parameters considered for the MCMC modelling process. We selected the Gaussian distribution that adequately encompasses the entire observational light curve and employed 28 walkers, 3000 iterations, and a 500 burn-in in the MCMC sampling. The light-curve analysis indicated that no target system displayed a third body l_3 .

Table 8 presents the outcomes of the light-curve solutions. The corner plot of one target system is displayed as an example in Fig. 3, and the corner plots for the other systems are available in the online version of this study. Fig. 4 displays the final and observed synthetic light curves of the binary systems. The binary systems' three-dimensional (3D) views are displayed in Fig. 5.

6 ABSOLUTE PARAMETERS' ESTIMATIONS

There are various methods to estimate the absolute parameters of the contact binary systems. When just photometric data are available, one method for this estimation is the *Gaia* DR3 parallax, which was explained in the Poro et al. (2024d) study. The accuracy of estimation of absolute parameters using *Gaia* DR3 parallax depends on the input parameters; however, with A_V higher than 0.4 mag, this method's results could be unreliable. Using the 3D dust map based on the *Gaia* DR3 distance, we computed A_V (Green et al. 2019). G5842, N5902,

N5905, and V2825 Ori show inappropriate values of A_V to use *Gaia* DR3 parallax to estimate absolute parameters (Table 9). Therefore, we used an empirical parameter relationship between the orbital period and the semimajor axis to estimate the absolute parameters of the target systems (Poro et al. 2024f). The P – a empirical relationship was updated by Poro et al. (2024e) utilizing 414 contact binary systems with orbital periods shorter than 0.7 d (equation 3):

$$a = (0.372^{+0.113}_{-0.114}) + (5.914^{+0.272}_{-0.298}) \times P. \quad (3)$$

The estimation process for the absolute parameters started with the calculation a ($R_\odot$) using P (d). We used the average uncertainty in equation (3). Then, Kepler's famous third law equation and the mass ratio (q) from the light-curve solutions were used to determine each star's mass and uncertainty (equations 4 and 5):

$$M_1 = \frac{4\pi^2 a^3}{GP^2(1+q)}, \quad (4)$$

$$M_2 = q \times M_1. \quad (5)$$

The radius (R) of each star was calculated using $r_{\text{mean},1,2}$ from the light-curve solutions and equation (6),

$$R = a \times r_{(\text{mean})}. \quad (6)$$

It is possible to estimate the luminosity of the components by having each star's radius and effective temperature using an astrophysics equation for stars (equation 7),

$$L = 4\pi R^2 \sigma T^4. \quad (7)$$

The absolute bolometric magnitude (M_{bol}) was calculated using the estimated luminosity and the relationship between the star parameters (equation 8). We set the Sun's absolute bolometric magnitude to be 4.73^{mag} based on the Torres (2010) study.

$$M_{\text{bol},1,2} = M_{\text{bol}\odot} - 2.5 \times \log \left(\frac{L_{1,2}}{L_\odot} \right). \quad (8)$$

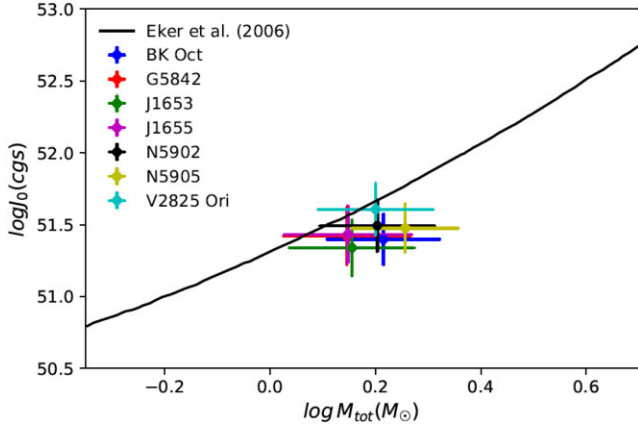


Figure 6. Location of the seven systems on the $\log(J_0)$ – $\log(M_{\text{tot}})$ diagram. Detached binaries are above the quadratic borderline and contact systems are below it.

We estimated the surface gravity (g) of the stars on a logarithmic scale using the mass and radius parameters of stars (equation 9):

$$g = G_{\odot}(M/R^2). \quad (9)$$

The orbital angular momentum (J_0) of each system was estimated using the Eker et al. (2006) study (equation 10),

$$J_0 = \frac{q}{(1+q)^2} \sqrt{\frac{G^2}{2\pi}} M^5 P, \quad (10)$$

where M is the total mass of the system and G is the gravitational constant.

The results of estimating seven binary systems' absolute parameters are presented in Table 9.

7 DISCUSSION AND CONCLUSION

We conducted the first in-depth photometric study on seven total-eclipse contact binary stars, including orbital period variations, light-curve solutions, and absolute parameter estimations. These target systems were observed at four Northern and Southern hemisphere observatories. Based on the results, the following are presented as discussions and conclusions:

(A) Based on the O-C diagram analysis, we obtained that the orbital periods of four targets show a long-term increase and two

targets show a long-term orbital period decrease. We assumed that the orbital period variations are caused by the conservative material transfer. Equation (11) (Kwee 1958),

$$\frac{\dot{P}}{P} = -3\dot{M} \left(\frac{1}{M_1} - \frac{1}{M_2} \right), \quad (11)$$

was used to calculate material transfer rates, and the results are shown in Table 7. Because the time span of the O-C diagram for all targets is very short, more observations are needed to confirm the present results in the future.

(B) Light-curve analysis was done with the PHOEBE PYTHON code and MCMC algorithm. The light-curve solutions of the six target systems required the addition of a cold or hot star-spot due to the asymmetry in the maxima. The star-spot is related to the O'Connell effect, an observational phenomenon mostly occurring in contact binary systems (O'Connell 1951b). According to the results, the target systems' stars have temperatures ranging from 4676 to 5918 K. It was found that the G5842 (75 K) and N5905 (350 K) systems have the minimum and maximum temperature differences (ΔT) between the two companion stars, respectively (Table 10). We identified the spectral category of the stars of the systems in Table 10 based on the studies of Cox (2015) and Eker et al. (2018). The temperature difference between two stars in contact binary systems is roughly 5 percent, which is true for our target systems.

(C) We used the empirical relationship P – a to estimate the absolute parameters of the systems. So, each star's mass and the system's total mass (M_{tot}) were calculated. The orbital angular momentum of each system was estimated using the orbital period, the total mass of the system, the mass ratio, and equation (10) from the Eker et al. (2006) study. We show the location of each system in the $\log J_0$ – M_{tot} diagram (Fig. 6) based on the results in Table 9. The area below the quadratic line in Fig. 6 is associated with contact binary stars, whereas the area above represents detached systems. Consequently, seven target systems are below the quadratic fit and in the contact binary region.

(D) We found that the target systems are eclipsing contact binary systems based on their light-curve solution results such as mass ratios, fillout factors, and orbital inclinations. Therefore, the subtype of each system is possible to identify based on the effective temperature and mass of the stars. W UMa contact binary stars are divided into A and W subtypes (Binnendijk 1970). So, if the less massive component has a higher effective temperature, the system is classified as a W

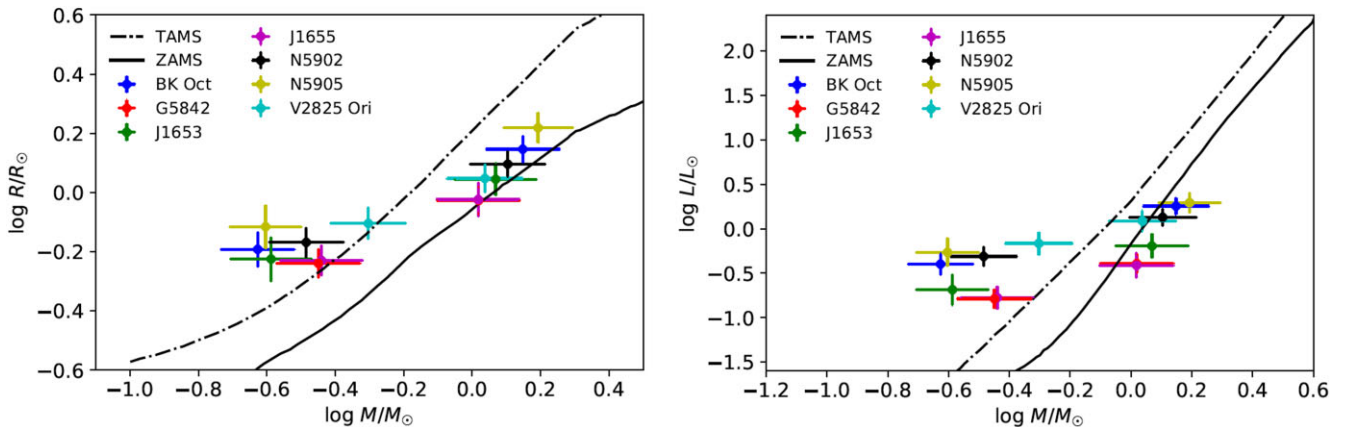


Figure 7. Position of both components on the M – R and M – L diagrams.

Table 11. The sample used to show the temperature uncertainty of the system's hotter star from the literature with the reported temperature of *Gaia* DR3 for them.

System	T_h	T_{Gaia}	Ref.	System	T_h	T_{Gaia}	Ref.	System	T_h	T_{Gaia}	Ref.
V757 Cen	6000	5771	1	TYC 2675-663-1	5534	5688	28	BX Dra	6980	7613	45
BW Dra	6164	5587	2	AC Boo	6250	5882	29	GSC 01511-00479	4500	4645	46
YY Eri	5600	5240	3	FG Hya	6519	5752	30	NSVS 13392702	4500	4901	46
HV UMa	7910	7089	4	RT LMi	6350	6103	30	AK Her	6500	6217	47
U Peg	5800	5928	5	QX And	6440	6145	31	HI Dra	7000	7300	47
V899 Her	5700	6442	6	V1167 Her	4900	4829	31	V2612 Oph	6280	5771	47
FN Cam	6848	6650	7	TZ Boo	5890	5789	32	AB And	5450	5349	48
AP Leo	6250	6202	8	AQ Psc	6250	6286	33	V1191 Cyg	6378	5862	49
RZ Tau	7300	6614	9	BV Eri	6881	6571	33	HI Pup	6500	5860	50
AO Cam	5900	5346	10	CK Boo	6250	6036	33	V1003 Her	6936	7258	51
SX Crv	6340	5970	11	DY Cet	6650	6313	33	LO And	6690	5874	52
V402 Aur	6775	6830	11	EE Cet	6250	6026	33	HH UMa	6550	5979	53
EL Aqr	6909	6771	12	NN Vir	7201	6922	33	V546 And	6517	5658	54
EZ Hya	6100	5608	13	OU Ser	5940	5640	33	HH Boo	5680	5571	55
AH Aur	6418	5981	14	TX Cnc	6250	5784	33	V921 Her	7700	7327	56
GM Dra	6450	6193	14	UX Eri	6093	5637	33	V781 Tau	6000	5640	57
GR Vir	6554	5700	14	V2357 Oph	5560	5684	33	V776 Cas	7000	6461	58
UV Lyn	6000	5830	15	V2377 Oph	5940	5665	33	AM Leo	6273	6325	59
V592 Per	6020	6769	15	V417 Aql	6381	5934	33	AW UMa	7410	6556	60
TV Mus	5980	5832	16	VY Sex	5960	5891	33	GW Cnc	5790	5785	61
HX UMa	6650	6100	17	XX Sex	6881	6529	33	V728 Her	6743	6728	62
V351 Peg	7580	7029	18	FT UMa	7178	6773	34	KIC 10618253	6118	6263	63
eps CrA	6678	6880	19	V1123 Tau	5920	5788	35	V502 Oph	6140	5872	64
RR Cen	6912	6903	19	V357 Peg	7000	6672	35	AD Phe	6155	6160	65
ET Leo	5500	5790	20	BO CVn	7191	7651	36	KIC 9832227	5920	5865	66
FP Boo	6980	6758	20	FU Dra	6100	5886	37	BN Ari	5278	5498	67
DX Tuc	6250	6250	21	V524 Mon	5560	5345	38	TY Pup	6915	6917	68
V870 Ara	6210	5772	21	EF Dra	6250	5736	39	V566 Oph	6456	6658	69
HN UMa	6252	6080	22	PY Vir	4830	4995	40	V972 Her	6522	6442	69
DN Boo	6095	6442	23	DU Boo	7850	7409	41	GSC 03334-00553	6514	5997	70
V345 Gem	6365	6630	24	VW LMi	6440	6533	41	NSVS 4161544	6016	5867	70
SS Ari	5860	5682	25	DZ Psc	6210	6244	42	RZ Com	5420	6045	71
V842 Her	6020	5795	26	FI Boo	5746	5726	43	CN And	6350	6288	72
CN Hyi	6500	6375	27	HV Aqr	6669	5792	44	BB Peg	6355	5525	73

Note. (1) Maceroni, Milano & Russo (1984), (2) Kaluzny & Rucinski (1986), (3) Yang & Liu (1999), (4) Csák et al. (2000), (5) Djurašević et al. (2001), (6) Özdemiir et al. (2002), (7) Pribulla et al. (2002), (8) Kreiner et al. (2003), (9) Yang & Liu (2003), (10) Baran et al. (2004), (11) Zola et al. (2004), (12) Wadhwa & Zealey (2004), (13) Yang, Qian & Zhu (2004), (14) Gazeas et al. (2005), (15) Zola et al. (2005), (16) Qian et al. (2005), (17) Selam et al. (2005), (18) Albayrak et al. (2005), (19) Yang et al. (2005), (20) Gazeas et al. (2006), (21) Szalai et al. (2007), (22) Oh et al. (2007), (23) Şenavcı et al. (2008), (24) Yang et al. (2009), (25) Liu et al. (2009), (26) Erdem & Özkardeş (2009), (27) Özkardeş, Erdem & Bakış (2009), (28) Caballero-García et al. (2010), (29) Nelson (2010), (30) Zola et al. (2010), (31) Djurašević et al. (2011), (32) Christopoulou, Parageorgiou & Chrysopoulos (2011), (33) Deb & Singh (2011), (34) Yuan (2011), (35) Ekmekçi et al. (2012), (36) Zola et al. (2012), (37) Liu et al. (2012), (38) He, Wang & Qian (2012), (39) Yang (2012), (40) Zhu et al. (2013), (41) Djurašević et al. (2013), (42) Yang et al. (2013), (43) Christopoulou & Papageorgiou (2013), (44) Li & Qian (2013), (45) Park et al. (2013), (46) Lohr et al. (2014), (47) Çalışkan et al. (2014), (48) Li et al. (2014), (49) Ostadnezhad, Delband & Hasanizadeh (2014), (50) Ulaş & Ulusoy (2014), (51) Papageorgiou et al. (2015), (52) Nelson & Robb (2015), (53) Yılmaz et al. (2015), (54) Gürol, Bradstreet & Okan (2015a), (55) Gürol et al. (2015b), (56) Zhou et al. (2016b), (57) Li et al. (2016), (58) Zhou et al. (2016a), (59) Gorda (2016), (60) Eaton (2016), (61) Gürol et al. (2016), (62) Erkan & Ulaş (2016), (63) Şenavcı et al. (2016), (64) Xiao et al. (2016), (65) Pi et al. (2017), (66) Molnar et al. (2017), (67) Alton, Nelson & Boyd (2018), (68) Sarotsakulchai et al. (2018), (69) Selam et al. (2018), (70) Kjurkchieva et al. (2019), (71) Nelson & Alton (2019), (72) Yildirim, Aliçavuş & Soyduğan (2019), and (73) Kamalifar, Abedi & Roobiat (2020).

subtype, and if the more massive component is a hotter star, it is classified as an A subtype. According to the definition, the seven studied systems are of the W subtype (Table 10).

(E) We displayed the evolution state of the systems on the logarithmic mass–radius (M – R) and mass–luminosity (M – L) diagrams (Fig. 7) based on the estimation of absolute parameters. The figures showed the star positions relative to the terminal-age main sequence (TAMS) and zero-age main sequence (ZAMS) lines from the Girardi et al. (2000) study. According to the light-curve analysis and estimation of absolute parameters, stars with lower mass and radius in target systems have a higher temperature. Since the stars' luminosity is more dependent on their radius (equation 7), our target has a smaller luminosity. Therefore, as shown in Fig. 7, the lower

mass components are located in the region above the TAMS. Also, the stars with more mass are around ZAMS.

(F) Many studies have been done on low mass ratio contact binary systems ($q \leq 0.25$), and there are still many questions (Li et al. 2022, 2024b). The investigations of contact binaries with low mass ratios are crucial to understanding the merging process and low mass ratio limit. BK Oct and N5905, with respective mass ratios of $1/q = 0.17$ and $q = 0.16$, are on the border of systems with extremely low mass ratios (Table 10; Li et al. 2024b).

Examining the dynamic stability of contact binaries requires knowing the ratio of the spin angular momentum (J_{spin}) to the orbital angular momentum (Hut 1980). Therefore, we used the following equation from the Yang & Qian (2015) study to determine the J_{spin}/J_0

for two target systems:

$$\frac{J_{\text{spin}}}{J_0} = \frac{1+q}{q} [(k_1 r_1)^2 + (k_2 r_2)^2 q]. \quad (12)$$

In equation (12), $k_{1,2}$ is the dimensionless gyration radius, and $r_{1,2}$ is the relative radius. We have adopted the values of $k_{1,2}$ from Li & Zhang (2006). We found that the values of J_{spin}/J_0 for BK Oct = 0.053 and N5905 = 0.049 and the perspective of the J_{spin}/J_0 for these two systems are dynamically stable (Li & Zhang 2006). According to the Wadhwa et al. (2021) study, our computation indicates that they must be unstable if their instability mass ratios q_{inst} are smaller than $q_{\text{inst}} = 0.055$ and $q_{\text{inst}} = 0.045$, for BK Oct and N5905, respectively.

(G) Determining each star's initial mass is required to understand how stars in the contact binary system have evolved (Li et al. 2022). We used Yildiz & Doğan (2013) method for these calculations. So, the initial mass of companion stars was obtained using two equations (13) and (15), respectively:

$$M_{2i} = M_2 + \Delta M = M_2 + 2.50(M_L - M_2 - 0.07)^{0.64}, \quad (13)$$

$$M_L = \left(\frac{L_2}{1.49} \right)^{1/4.216}, \quad (14)$$

$$M_{1i} = M_1 - (\Delta M - M_{\text{lost}}) = M_1 - \Delta M(1 - \gamma), \quad (15)$$

where in equations (13)–(15), M_1 and M_2 were the mass of the stars at present, M_{1i} and M_{2i} were the initial masses, M_L is the mass due to mass–luminosity relation (equation 14), M_{lost} is the mass lost by the binary system, and γ is the ratio $M_{\text{lost}}/\Delta M$. M_{1i} was computed using Yildiz & Doğan (2013)'s mean value of $\gamma = 0.664$. Also, we used the reciprocal mass ratio ($0 < 1/q < 1$) for these calculations. The calculations' outcome is listed in Table 10. We found that these results are consistent with those reported by Yildiz & Doğan (2013) and Yildiz (2014).

(H) Recently, studies have been published that include automatic light-curve analysis for determining some main parameters of contact systems using photometric light curves. These studies try to analyse a large number of contact systems and present parameters $T_{1,2}$, q , i , and f as an outcome, which is an important goal. However, the accuracy of the results of these studies is associated with doubts that have not been addressed.

The Li et al. (2024a) study presented the distributions of parameters of 11 111 short-period contact binary systems. This investigation included four of our target systems: J1653, N5902, N5905, and V2825 Ori. They used MCMC and neural networks to obtain the systems' mass ratio, orbital inclination, fillout factor, and temperature ratio. The accuracy of observational data is the most important factor in photometric analysis. The Li et al. (2024a) study used ASAS-SN V-band light curves. The majority of ASAS-SN data have scattered light curves; they utilized the Lafler–Kinman string length (LKSL) to select light curves. LKSL is a statistical measure that is used to quantify the degree of scatter in the light-curve data. A lower LKSL value indicates a more regular and consistent light curve (less scatter), while a higher LKSL value suggests greater variability and irregularity in brightness. The usage of LKSL cannot generally result in the selection of suitable light curves because it examines the entire light curve, and while there is little scatter in some parts of the light curve, a lot of scatter may be observed at the minima or maxima. For this reason, there is a large uncertainty in the orbital inclination in the results of Li et al. (2024a). Therefore, it is necessary to use data from other data bases (e.g. *TESS* and *Gaia*) in addition to the ASAS-SN so that the amount of dispersion does not affect the results of light-curve solutions.

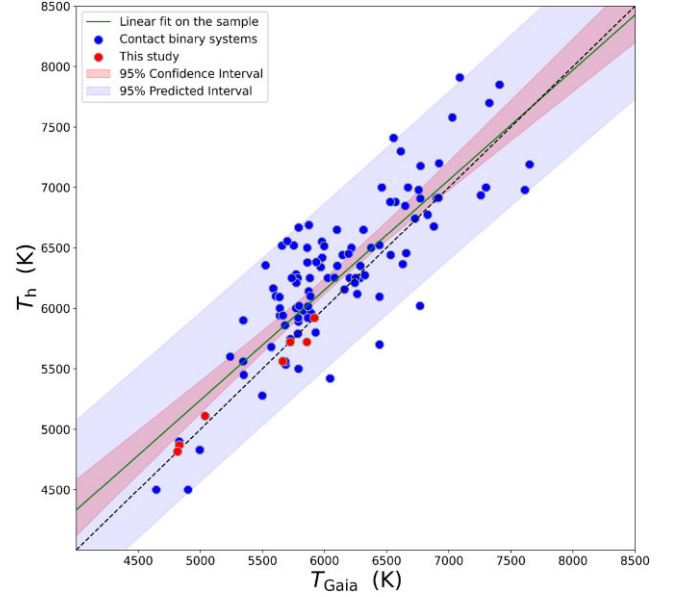


Figure 8. Hotter system star from the literature versus the temperature reported in *Gaia* DR3. The red dots are the results of this study. The one-to-one fit is displayed as a black dashed line.

Based on the Poro et al. (2024d) study, the difference between the calculated temperature in the light-curve solution and the reported temperature of *Gaia* DR3 is important in evaluating the accuracy of the light-curve analysis and absolute parameter outcomes. Li et al. (2024a) have used the period–temperature relationship or *Gaia* data base to obtain the effective temperature of the stars. According to their results, the difference between the hotter component and the reported temperature of *Gaia* DR3 was for J1653 = 770 K, N5902 = 286 K, N5905 = 334 K, and V2825 Ori = 237 K. It is necessary to measure the range of temperature difference resulting from light-curve analysis and *Gaia* DR3 to find out whether this difference is acceptable for the four target systems or not. We used a sample of 102 contact systems with spectroscopic and photometric analysis and estimated the initial temperature with various methods (Table 11). The hotter stars from the selected systems and the reported temperatures of *Gaia* DR3 are also listed in Table 11. As shown in Fig. 8 and based on a linear fit to the data (equation 16), the uncertainty is less than ≈ 400 K,

$$T_h = (0.91 \pm 0.05) \times T_{\text{Gaia}} + (691 \pm 334). \quad (16)$$

Therefore, the Li et al. (2024a) study for the J1653 system reports a large temperature and unacceptable difference with *Gaia* DR3. The difference between the temperature reported by *Gaia* DR3 (Table 10) and the light-curve analysis results in this study (Table 8) for seven target systems is lower ≈ 400 K.

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⁸<https://bsnp.info>

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DATA AVAILABILITY

Ground-based data, extracted minima, and corner plots are available in the paper's online supplement. We also used *TESS* photometric data in this study, which are available on the MAST portal.

REFERENCES

- Akerlof C. et al., 2000, *AJ*, 119, 1901
- Albayrak B., Djurašević G., Selam S. O., Atanacković-Vukmanović O., Yılmaz M., 2005, *New Astron.*, 10, 163
- Alizadehsabegh A., Lomoz F., Poro A., Narimani A., 2024, *Astrophysics*, 67, 128
- Alton K. B., Nelson R. H., Boyd D. R. S., 2018, *Acta Astron.*, 68, 159
- Avvakumova E. A., Malkov O. Y., Kniazev A. Y., 2013, *Astron. Nachr.*, 334, 860
- Baran A., Zola S., Rucinski S. M., Kreiner J. M., Siwak M., Drozd M., 2004, *Acta Astron.*, 54, 195
- Baudart S., Poro A., 2024, *Res. Astron. Astrophys.*, 24, 125013
- Bellm E. C. et al., 2019, *PASP*, 131, 068003
- Binnendijk L., 1970, *Vistas Astron.*, 12, 217
- Bradstreet D. H., Guinan E. F., 1994, in Shafter A., ed., ASP Conf. Ser. Vol. 56, Interacting Binary Stars. Astron. Soc. Pac., San Francisco, p. 228
- Butters O. W. et al., 2010, *A&A*, 520, L10
- Caballero-García M. D., Torres G., Ribas I., Rísquez D., Montesinos B., Mas-Hesse J. M., Domingo A., 2010, *A&A*, 514, A36
- Çalışkan Ş. et al., 2014, *AJ*, 148, 126
- Castelli F., Kurucz R., 2004, *A&A*, 419, 725
- Chen X., Wang S., Deng L., de Grijs R., Yang M., 2018, *ApJS*, 237, 28
- Chen X., Wang S., Deng L., de Grijs R., Yang M., Tian H., 2020, *ApJS*, 249, 18
- Christopoulou P. E., Papageorgiou A., 2013, *AJ*, 146, 157
- Christopoulou P. E., Papageorgiou A., Chrysopoulos I., 2011, *AJ*, 142, 99
- Conroy K. E. et al., 2020, *ApJS*, 250, 34
- Cox A. N., ed., 2015, *Allen's Astrophysical Quantities*. Springer, Berlin
- Csák B., Kiss L. L., Vinkó J., Alfaro E. J., 2000, *A&A*, 356, 603
- Deb S., Singh H. P., 2011, *MNRAS*, 412, 1787
- Diethelm R., 2011, *Inf. Bull. Var. Stars*, 5960, 1
- Djurašević G., Rovithis-Livanou H., Rovithis P., Erkapic S., Milovanović N., 2001, *A&A*, 367, 840
- Djurašević G., Yılmaz M., Baştürk Ö., Kılıçoğlu T., Latković O., Çalışkan Ş., 2011, *A&A*, 525, A66
- Djurašević G. et al., 2013, *AJ*, 145, 80
- Drake A. J. et al., 2014, *ApJS*, 213, 9
- Eaton J. A., 2016, *MNRAS*, 457, 836
- Eggleton P. P., 2012, *J. Astron. Space Sci.*, 29, 145
- Eggleton P. P., Kiseleva-Eggleton L., 2002, *ApJ*, 575, 461
- Eker Z., Demircan O., Bilir S., Karataş Y., 2006, *MNRAS*, 373, 1483
- Eker Z. et al., 2018, *MNRAS*, 479, 5491
- Ekmekçi F. et al., 2012, *New Astron.*, 17, 603
- Erdem A., Özkardeş B., 2009, *New Astron.*, 14, 321
- Erkan N., Ulaş B., 2016, *New Astron.*, 46, 73
- Foreman-Mackey D., Hogg D. W., Lang D., Goodman J., 2013, *PASP*, 125, 306
- Gazeas K. D. et al., 2005, *Acta Astron.*, 55, 123
- Gazeas K. D., Niarchos P. G., Zola S., Kreiner J. M., Rucinski S. M., 2006, *Acta Astron.*, 56, 127
- Girardi L., Bressan A., Bertelli G., Chiosi C., 2000, *A&AS*, 141, 371
- Gorda S. Y., 2016, *Astrophys. Bull.*, 71, 64
- Green G. M., Schlafly E., Zucker C., Speagle J. S., Finkbeiner D., 2019, *ApJ*, 887, 93
- Gürol B., Bradstreet D. H., Okan A., 2015a, *New Astron.*, 36, 100
- Gürol B., Bradstreet D. H., Demircan Y., Gürsoytrak S. H., 2015b, *New Astron.*, 41, 26
- Gürol B., Gökay G., Saral G., Gürsoytrak S. H., Cerit S., Terzioğlu Z., 2016, *New Astron.*, 46, 31
- He J.-J., Wang J.-J., Qian S.-B., 2012, *PASJ*, 64, 85
- Hoffman D. I., Harrison T. E., McNamara B. J., 2009, *AJ*, 138, 466
- Hoffmeister C., 1963, *Veroeff. Sternwarte Sonneberg*, 6, 1
- Hut P., 1980, *A&A*, 92, 167
- Jayasinghe T. et al., 2018, *MNRAS*, 477, 3145
- Jenkins J. M. et al., 2016, in Chiozzi G., Guzman J. C., eds, Proc. SPIE Conf. Ser. Vol. 9913, Software and Cyberinfrastructure for Astronomy IV. SPIE, Bellingham, p. 99133E
- Kaluzny J., Rucinski S. M., 1986, *AJ*, 92, 666
- Kamalifar Z., Abedi A., Roobiat K. Y., 2020, *New Astron.*, 78, 101354
- Kazarovets E. V., Samus N. N., Durevich O. V., Kireeva N. N., Pastukhova E. N., 2015, *Inf. Bull. Var. Stars*, 6151, 1
- Kjurkchieva D., Stateva I., Popov V. A., Marchev D., 2019, *AJ*, 157, 73
- Kreiner J. M. et al., 2003, *A&A*, 412, 465
- Kuiper G. P., 1941, *ApJ*, 93, 133
- Kukarkin B. V., Kholopov P. N., Perova N. B., 1970, *Inf. Bull. Var. Stars*, 480, 1
- Kwee K. K., 1958, *Bull. Astron. Inst. Neth.*, 14, 131
- Kwee K. K., van Woerden H., 1956, *Bull. Astron. Inst. Neth.*, 12, 327
- Latković O., Čeki A., Lazarević S., 2021, *ApJS*, 254, 10
- Li K., Qian S. B., 2013, *New Astron.*, 21, 46
- Li L., Zhang F., 2006, *MNRAS*, 369, 2001
- Li K., Hu S. M., Jiang Y. G., Chen X., Ren D. Y., 2014, *New Astron.*, 30, 64
- Li K., Gao D. Y., Hu S. M., Guo D. F., Jiang Y. G., Chen X., 2016, *Ap&SS*, 361, 63
- Li K., Kim C.-H., Xia Q.-Q., Michel R., Hu S.-M., Gao X., Guo D.-F., Chen X., 2020, *AJ*, 159, 189
- Li K. et al., 2021, *AJ*, 162, 13
- Li K., Gao X., Liu X.-Y., Gao X., Li L.-Z., Chen X., Sun G.-Y., 2022, *AJ*, 164, 202
- Li X.-Z., Zhu Q.-F., Ding X., Xu X.-H., Zheng H., Qiu J.-S., Liu M.-C., 2024a, *ApJS*, 271, 32
- Li K. et al., 2024b, *A&A*, 692, L4
- Liu L., Qian S. B., He J. J., Zhang J., Li L. J., 2009, *Ap&SS*, 321, 19
- Liu L., Qian S.-B., He J.-J., Liao W.-P., Zhu L.-Y., Zhao E., 2012, *PASJ*, 64, 48
- Lohr M. E., Hodgkin S. T., Norton A. J., Kolb U. C., 2014, *A&A*, 563, A34
- Lucy L., 1967, *Z. Astrophys.*, 65, 89
- Lucy L. B., 1968, *ApJ*, 151, 1123
- Maceroni C., Milano L., Russo G., 1984, *A&AS*, 58, 405
- Malkov O. Y., Oblak E., Snegireva E. A., Torra J., 2006, *A&A*, 446, 785
- Masci F. J. et al., 2019, *PASP*, 131, 018003
- Molnar L. A. et al., 2017, *ApJ*, 840, 1
- Mowlavi N. et al., 2023, *A&A*, 674, A16
- Nelson R. H., 2010, *Inf. Bull. Var. Stars*, 5951, 1
- Nelson R. H., Alton K. B., 2019, *Inf. Bull. Var. Stars*, 6266, 1
- Nelson R. H., Robb R. M., 2015, *Inf. Bull. Var. Stars*, 6134, 1
- O'Connell D. J. K., 1951a, *Publ. Riverview Coll. Obs.*, 2, 85
- O'Connell D., 1951b, *MNRAS*, 111, 642
- Oh K. D., Kim C. H., Kim H. I., Lee W. B., 2007, in Kang Y. W., Lee H. W., Leung K. C., Cheng K. S., eds, ASP Conf. Ser. Vol. 362, The Seventh Pacific Rim Conference on Stellar Astrophysics. Astron. Soc. Pac., San Francisco, p. 82
- Ostadezhad S., Delband M., Hasanzadeh A., 2014, *New Astron.*, 31, 14

⁹<http://www.cosmos.esa.int/gaia>

- Özdemir S., Demircan O., Erdem A., Çiçek C., Bulut İ., Soyduğan E., Soyduğan F., 2002, *A&A*, 387, 240
- Özkardeş B., Erdem A., Bakış V., 2009, *New Astron.*, 14, 461
- Paki E., Baudart S., Poro A., 2023, *Astrophysics*, 66, 452
- Papageorgiou A., Christopoulou P. E., Pribulla T., Vaňko M., 2015, *Ap&SS*, 357, 59
- Park J.-H., Lee J. W., Kim S.-L., Lee C.-U., Jeon Y.-B., 2013, *PASJ*, 65, 1
- Pi Q.-f., Zhang L.-y., Bi S.-l., Han X. L., Wang D.-m., Lu H.-p., 2017, *AJ*, 154, 260
- Poro A. et al., 2021a, *Res. Astron. Astrophys.*, 21, 203
- Poro A., Blackford M. G., Davoudi F., Mohandes A., Madani M., Rezaei S., Bozorgzadeh E., 2021b, *Open Astron.*, 30, 37
- Poro A. et al., 2022a, *Res. Astron. Astrophys.*, 22, 055020
- Poro A. et al., 2022b, *PASP*, 134, 064201
- Poro A., Fernández-Lajús E., Madani M., Sabbaghian G., Nasrollahzadeh F., Jahediparizi F., 2023, *Res. Astron. Astrophys.*, 23, 095011
- Poro A. et al., 2024a, *Res. Astron. Astrophys.*, 24, 045018
- Poro A. et al., 2024b, *Res. Astron. Astrophys.*, 24, 055001
- Poro A., Tanriver M., Keskin A., Bulut A., Rabieefar S., Gharghabi M. M., Walter F., Holy S., 2024c, *Astrophysics*, 67, 299
- Poro A. et al., 2024d, *New Astron.*, 110, 102227
- Poro A., Tanriver M., Michel R., Paki E., 2024e, *PASP*, 136, 024201
- Poro A. et al., 2024f, *AJ*, 168, 272
- Pribulla T., Chochol D., Vanko M., Parimucha S., 2002, *Inf. Bull. Var. Stars*, 5258, 1
- Prša A. et al., 2016, *APJS*, 227, 29
- Qian S., 2003, *MNRAS*, 342, 1260
- Qian S. B., Yang Y. G., Soonthornthum B., Zhu L. Y., He J. J., Yuan J. Z., 2005, *AJ*, 130, 224
- Qian S. B. et al., 2014, *ApJS*, 212, 4
- Ricker G. R. et al., 2010, in *American Astronomical Society Meeting Abstracts #215*, p. 450.06
- Ricker G. R. et al., 2015, *J. Astron. Telesc. Instrum. Syst.*, 1, 014003
- Ruciński S., 1969, *Acta Astron.*, 19, 245
- Sánchez-Sáez P. et al., 2023, *A&A*, 675, A195
- Sarotsakulchai T. et al., 2018, *AJ*, 156, 199
- Sarvari E., Fernández Lajús E., Poro A., 2024, *Res. Astron. Astrophys.*, 24, 105002
- Selam S., Albayrak B., Yilmaz M., Şenavcı H. V., Özavcı İ., Çetintaş C., 2005, *Ap&SS*, 296, 305
- Selam S. O., Esmer E. M., Şenavcı H. V., Bahar E., Yörükoğlu O., Yılmaz M., Baştürk Ö., 2018, *Ap&SS*, 363, 34
- Şenavcı H. V., Nelson R. H., Özavcı İ., Selam S. O., Albayrak B., 2008, *New Astron.*, 13, 468
- Şenavcı H. V., Doğruel M. B., Nelson R. H., Yılmaz M., Selam S. O., 2016, *Publ. Astron. Soc. Aust.*, 33, e043
- Shappee B. J. et al., 2014, *ApJ*, 788, 48
- Sriram K., Malu S., Choi C., Rao P. V., 2017, *AJ*, 153, 231
- Stassun K. G. et al., 2018, *AJ*, 156, 102
- Stepien K., 2006, *Acta Astron.*, 56, 347
- Stepien K., 2011, *Acta Astron.*, 61, 139
- Szalai T., Kiss L. L., Mészáros S., Vinkó J., Csizmadia S., 2007, *A&A*, 465, 943
- Terrell D., Wilson R. E., 2005, *Ap&SS*, 296, 221
- Tody D., 1986, in Crawford D. L., ed., *Proc. SPIE Conf. Ser. Vol. 627, Instrumentation in Astronomy VI*, SPIE, Bellingham, p. 733
- Torres G., 2010, *AJ*, 140, 1158
- Ulaş B., Ulusoy C., 2014, *New Astron.*, 31, 56
- Wadhwa S. S., Zealey W. J., 2004, *Ap&SS*, 291, 21
- Wadhwa S. S., De Horta A., Filipović M. D., Tothill N. F., Arbutina B., Petrović J., Djurašević G., 2021, *MNRAS*, 501, 229
- Xiao Z., Shengbang Q., Binghe H., Hao L., Jia Z., 2016, *PASJ*, 68, 102
- Yakut K., Eggleton P. P., 2005, *ApJ*, 629, 1055
- Yang Y.-G., 2012, *Res. Astron. Astrophys.*, 12, 419
- Yang Y., Liu Q., 1999, *A&AS*, 136, 139
- Yang Y., Liu Q., 2003, *AJ*, 126, 1960
- Yang Y.-G., Qian S.-B., 2015, *AJ*, 150, 69
- Yang Y. G., Qian S. B., Zhu C. H., 2004, *PASP*, 116, 826
- Yang Y.-G., Qian S.-B., Zhu L.-Y., He J.-J., Yuan J.-Z., 2005, *PASJ*, 57, 983
- Yang Y. G., Qian S. B., Zhu L. Y., He J. J., 2009, *AJ*, 138, 540
- Yang Y. G., Qian S. B., Zhang L. Y., Dai H. F., Soonthornthum B., 2013, *AJ*, 146, 35
- Yildirim M. F., Aliçavuş F., Soyduğan F., 2019, *Res. Astron. Astrophys.*, 19, 010
- Yıldız M., 2014, *MNRAS*, 437, 185
- Yıldız M., Doğan T., 2013, *MNRAS*, 430, 2029
- Yılmaz M., Baştürk Ö., Özavcı İ., Şenavcı H. V., Selam S. O., 2015, *New Astron.*, 34, 271
- Yuan J.-Z., 2011, *Res. Astron. Astrophys.*, 11, 1158
- Zhou X., Qian S. B., Zhang J., Jiang L. Q., Zhang B., Kreiner J., 2016a, *ApJ*, 817, 133
- Zhou X., Qian S.-B., Zhang J., Li L.-J., Wang Q.-S., 2016b, *Adv. Astron.*, 2016, 746897
- Zhu L. Y., Qian S. B., Liu N. P., Liu L., Jiang L. Q., 2013, *AJ*, 145, 39
- Zola S. et al., 2004, *Acta Astron.*, 54, 299
- Zola S. et al., 2005, *Acta Astron.*, 55, 389
- Zola S., Gazeas K., Kreiner J. M., Ogloza W., Siwak M., Koziel-Wierzbowska D., Winiarski M., 2010, *MNRAS*, 408, 464
- Zola S., Nelson R. H., Şenavcı H. V., Szymanski T., Kuźmicz A., Winiarski M., Jableka D., 2012, *New Astron.*, 17, 673

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