Contrib. Astron. Obs. Skalnaté Pleso **54/2**, 58 – 69, (2024)
https://doi.org/10.31577/caosp.2024.54.2.58

Low-mass contact binaries as probes of stellar merging events

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Received: November 13, 2023; Accepted: January 8, 2023

Abstract. Gravitational interaction is important for nearly every aspect of Astrophysics. Theoretical models are tough tested in cases where strong, stellar winds, angular momentum loss, and mass transfer take place in the course of stellar evolution within a common envelope. Stellar interaction impacts the formation and evolution of diverse types of binary and multiple stellar systems. Therefore, evolution in a binary (and a multiple) stellar environment is still an open question in Astrophysics while contact binaries are challenging the well-established and solid theories that concern thermal equilibrium and orbital stability. There is a vast number of such systems observed in the Milky Way and the Magellanic Clouds. Systematic (independent or combined) observations, all-sky surveys, ground-based and space telescopes have offered very detailed photometric and spectroscopic information about these systems. Special attention is given when extreme cases are observed, such as ultra-short orbital period contact binaries or extremely low mass ratio systems. These cases can give insights into the physical and orbital parameters of low-mass contact binaries and their temporal variations. For example, one can investigate the orbital period modulation, the spot activity, and the possibility of contact binaries to host planets, as well as predict a stellar merger, red nova events, and a possible connection with exotic stellar populations such as blue stragglers. The purpose of this work is to present the recent developments in observations of low-mass contact binaries, highlighting the most important findings, in combination with existing theories. The research of such systems, at an international level, is constantly challenging our current knowledge of stellar interactions and advances our understanding of stellar dynamics in common envelope and contact phases.

Key words: Stars: low-mass – Stars: evolution – (Stars:) binaries (including multiple): close – (Stars:) binaries: eclipsing

1. Introduction

Binarity in nature is something very common, expressed in a wide range of scales, from binary asteroids and dwarf planets to binary stars, clusters, and galaxies. Kepler's law and the two-body theory can be simply applied to understand the orbital behavior of the involved objects, assuming that there is no intrinsic variability or evolution that alters their physical properties. Consequently, the binary system behavior is dominated by the stellar interaction between the two components. This process is the dominant mechanism that leads the individual components and the system itself through the paths of binary evolution. Although most of the eclipsing binaries are observed to be members of triple, quadruple, or multiple systems in general, they are formed in a hierarchical configuration. Stellar evolution in a contact binary system is different than a single-star evolution in many aspects. Evolution alters the physical parameters of single (solar-type) stars in a timescale of 5–10 Gyr. On the contrary, the current theoretical models support that evolution within a binary environment can be even slower, exceeding the timescale of 10–15 Gyr (Gazeas & Stępień, 2008). Therefore, what we see today as a contact binary stellar system is just a snapshot of this long-lasting process.

Stellar evolution theories indicate that we should be able to observe stellar merging events (Webbink, 1976; Stępień, 2006) due to the gradual coalescence of contact binaries. However, this has not been the case until the detection of the merging event of V1309 Sco in 2008 (Tylenda et al., 2011). Even in this case, the contact binary nature of the progenitor was discovered only after the red nova event (Nova Sco 2008). Numerous observations of V1309 Sco are available in the OGLE-III and IV surveys (Udalski, 2003) before the red nova event and they helped to identify the nova progenitor as a low mass ratio contact binary in deep contact configuration with an orbital period of about 1.4 days.

A merging event is presumed to be driven by the instability of the two involved stellar components. A contact binary system can experience mass and angular momentum loss via mass outflow from the Lagrange point L_2 or via stellar wind and magnetic activity (e.g. flares). The system can be also unstable if the orbital angular momentum is less than three times the total spin angular momentum (Hut, 1980), also known as "Darwin instability". Systematic studies of such systems started to appear only very recently, suggesting that low mass ratio contact binary systems are promising merger candidates (Li et al., 2022; Wadhwa et al., 2023b,a; Liu et al., 2023).

2. Challenging theoretical models

From the observational aspect, there are efforts to increase the sample of well-studied systems, derive their physical and orbital parameters with high accuracy, and eventually understand the nature of the contact binary configuration. Fortunately, there is a vast number of contact binary systems in the Milky Way and the Magellanic Clouds, and the majority of them (over 60%) are accompanied by tertiary members, as shown in past and recent studies (D'Angelo et al., 2006), (Loukaidou et al., 2022). Low-mass and low-temperature contact binaries are the most frequently observed types of eclipsing binary systems. Their components have smaller sizes in comparison with other main-sequence stars, and they belong to the old stellar population group (Rucinski, 2000).

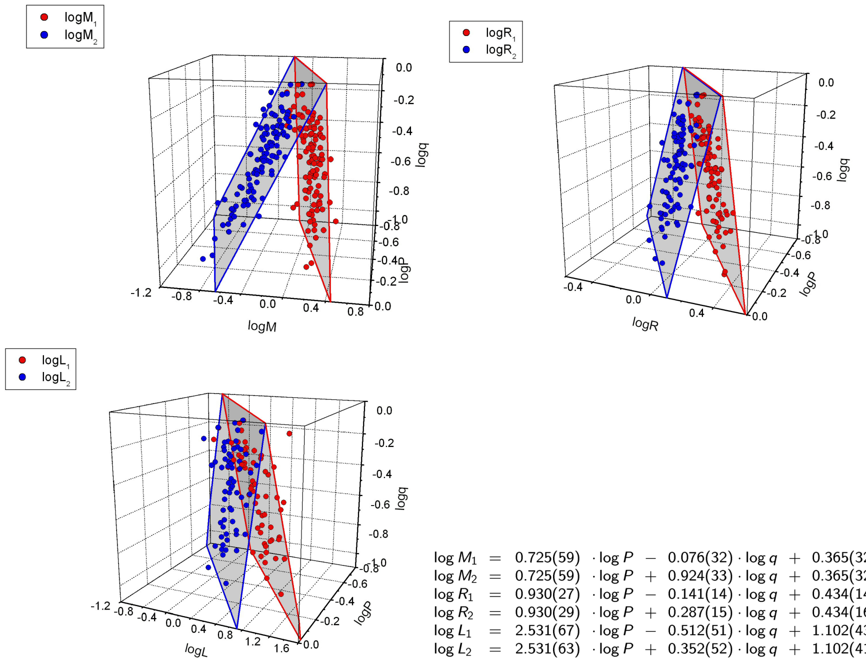
In parallel to the observations, there are several attempts to understand the evolution processes within a binary environment. We have more than a century of knowledge of the existence of contact binary systems. In the early 50's and 60's, we had the first attempts to understand the physics within a common envelope environment. It was only after the 80's that the first statistical studies showed that low-mass contact binaries share common orbital and physical characteristics. It was also found that the members in such systems are surrounded by a common convective envelope that lies between the inner and outer critical Roche surfaces.

In most of cases, low-mass contact binaries are low-temperature Main Sequence (MS) stars of F, G, and K spectral type. They have solar-type characteristics and they belong to the old population group of our Galaxy, confirming that they are old stars that did not evolve towards the Red Giant Branch (RGB), remaining at the MS together with the rest of the young dwarf (single) stars. According to (Bilir et al., 2005) contact binaries have a kinematic age of 5–12 Gyr. Observations also show that there are several low-mass contact binaries with their total mass close to 1–1.4 $M_\odot$ (Gazeas & Niarchos, 2006; Gazeas & Stępień, 2008). Magnetic activity (expressed by cool photospheric spots or even hot chromospheric flares) is something expected in cool stars with convection zone. Low-mass contact binaries are among the binary systems with the highest level of chromospheric activity. Therefore, they lose angular momentum and mass by the magnetized wind, as is observed in single, highly active stars. Cool spots can explain the observed asymmetries in light curves sufficiently. In addition, the heavily covered surface of the components by cool spots is the most likely explanation of the so-called 'W–phenomenon' (Stepien, 1980; Eaton et al., 1980; Zola et al., 2010).

Their contact configuration puts several constraints on their physical properties due to the Roche geometry. In addition, there is a link between the orbital and the physical properties, i.e. the mass, radius, temperature, and luminosity. This is how the first empirical relations started to appear in literature, correlating the physical parameters with quantities that are directly derived from observations, such as the orbital period or the mass ratio, as shown in Fig. 1.

3. Why contact binaries are so interesting?

A low-mass contact binary is formed when a short orbital period system undergoes stable mass transfer between its components. Angular momentum is lost due to stellar wind and magnetic braking phenomena, while both stars overflow their Roche lobes. This process eventually leads towards a contact configuration. The components of low-mass and low-temperature contact binaries follow



$$
\begin{aligned}
\log M_1 &= 0.725(59) \cdot \log P - 0.076(32) \cdot \log q + 0.365(32)\\
\log M_2 &= 0.725(59) \cdot \log P + 0.924(33) \cdot \log q + 0.365(32)\\
\log R_1 &= 0.930(27) \cdot \log P - 0.141(14) \cdot \log q + 0.434(14)\\
\log R_2 &= 0.930(29) \cdot \log P + 0.287(15) \cdot \log q + 0.434(16)\\
\log L_1 &= 2.531(67) \cdot \log P - 0.512(51) \cdot \log q + 1.102(43)\\
\log L_2 &= 2.531(63) \cdot \log P + 0.352(52) \cdot \log q + 1.102(41)
\end{aligned}
$$

Figure 1. The above 3D diagrams show that there is a direct correlation of the absolute physical parameters (M, R, L) with the directly observed parameters (orbital period P and mass ratio q) of low mass contact binary systems. The extracted empirical relations express the equations of the shaded flat surfaces (Gazeas, 2009).

certain empirical relationships, which closely correlate physical parameters with each other, due to the Roche geometry. As a result, contact binaries are excellent astrophysical tools for the determination of the fundamental physical parameters (mass, radius, luminosity) of low-temperature stellar components, that can be used to trace their evolutionary paths. They are of great interest to the study of stellar populations since they provide an excellent opportunity to investigate stellar merging scenarios. They can be very successfully used as distance indicators, a fact that was proposed and tested in several studies in the past (Rucinski, 1997; Rubenstein & Bailyn, 1996; Edmonds et al., 1996; Yan & Mateo, 1994). They provide an excellent opportunity to investigate evolution paths such as stellar merging, while their parameters can be measured or derived in a highly accurate way. This leads to the close monitoring of the orbital (and physical) parameter modulations, which can provide evidence of evolution toward merging.

Following careful methodology in data treatment, negligible modulation of parameters can be traced and therefore their temporal variation can be mon-

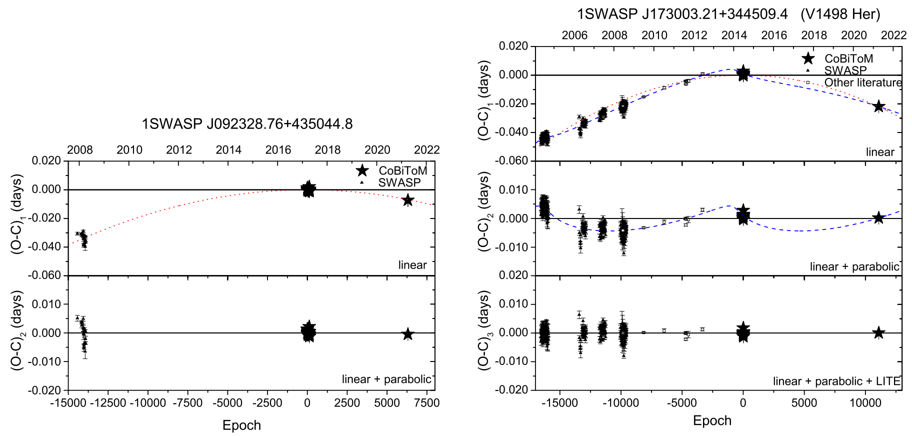


Figure 2. The diagrams present the observed (O) minus the calculated (C) value of orbital period in two low mass contact binaries with ultra-short orbital period (Loukaidou et al., 2022). Both systems show an orbital period decrease (expressed as a negative parabolic trend), while the second one additionally shows the existence of a tertiary component orbiting the close binary.

itored. For example, Fig. 2 shows the O–C diagrams of two selected contact binaries with ultra-short orbital period (Loukaidou et al., 2022). Both systems exhibit a negative parabolic trend on their orbital period modulation, which is translated as an orbital shrinkage. On top of that, 1SWASP J173003.21+344509.4 shows an additional periodic modulation, as a consequence of a tertiary component orbiting the contact binary. The diagrams are so sensitive, that even tiny fluctuations of the orbital parameters can be detected. The overall trend, as derived from the diagrams, can quantify the orbital shrinkage, and therefore the merging timescale. Angular momentum and mass loss of the system via stellar wind may be the dominating mechanism, that explains the observed orbital period modulation. In addition, mass transfer between the components may alter the orbital period, and it can reverse the mass ratio between the two components (Stępień & Gazeas, 2008).

4. Physical and orbital properties of contact binaries

An alternative model of stellar evolution in a binary environment was proposed by Stępień & Gazeas (2012). The model is based on the idea that a detached binary system with an orbital period of ∼1.5-2 days loses angular momentum through stellar wind. Such a process can be dramatically accelerated through Kozai-Lindov cycles (Kozai, 1962), by the existence of a tertiary component that pumps angular momentum out of the close binary. The angular momentum loss shrinks the orbit and the two components come in contact, sharing a common photosphere, and therefore sharing thermal energy. However, such a process requires an exceptional amount of time, of about 10-12 Gyr. To have a good agreement of the model with the observed parameters in low mass contact binary systems as we observe them today, the angular momentum loss rate, as well as the mass loss rate, should be constrained within narrow limits (Fig. 3).

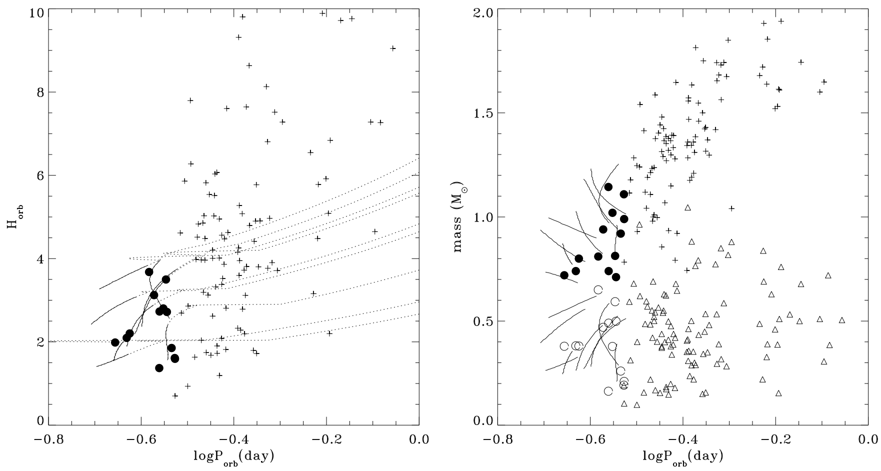


Figure 3. Left panel: The distribution of angular momentum of 112 contact binaries in cgs units ($\times 10^{51}$). Evolutionary tracks of models given by Stępień & Gazeas (2012) are also shown. Parts of the tracks plotted with dotted lines correspond to pre-contact phases and those plotted with solid lines describe binary evolution while in contact configuration. Right panel: The components of low-mass contact binaries (open and filled circles) and of other contact binary systems ('plus' signs and triangles). These values are compared with parameters derived after direct observations of contact binaries (Gazeas & Stępień, 2008).

5. Observations of low mass contact binaries

Information about the properties of contact binaries comes almost explicitly from photometric and spectroscopic observations. Dedicated observing campaigns collect high-resolution data, to provide analytical solutions to match theoretical models with the observations.

Space telescopes provide ultra-high precision photometric data for a long uninterrupted period of time, which is essential for the orbital period determination and its modulation. However, in most cases, space-borne spectroscopic data are still limited to low-resolution data, which are adequate for temperature determination, but not for radial velocity measurements.

On the other hand, ground-based sky surveys can also contribute to the long-term monitoring of the contact binaries with several photometric data and (again) limited spectroscopic observations. Large telescope facilities are needed for high-resolution spectra, which is not always easy, since long-term photometric observations are almost impossible, due to the limited observing time and availability in large aperture telescopes.

Small telescope networks can contribute significantly to this field. Some examples are AAVSO (Watson et al., 2006), ASAS (Pojmanski, 2002), ASAS-SN (Jayasinghe et al., 2019), CoRoT (Deleuil et al., 2018), CSS (Drake et al., 2014), GCVS (Samus et al., 2018), Kepler (Kirk et al., 2016), LAMOST (Qian et al., 2020), OGLE (Szymański et al., 2001), SWASP (Norton et al., 2011), WISE (Petrosky et al., 2021), and ZTF (Chen et al., 2020). Survey observations can provide a uniform data set for the long-term monitoring of such systems and their study can trace the orbital and physical parameter modulations for decades.

6. CoBiToM Project

The Contact Binaries Towards Merging (*CoBiToM* Project, Gazeas et al. (2021)) was initiated in 2012 under the idea of the long-term monitoring of low mass contact binaries and the modulations of their physical parameters. The ultimate goal is to investigate stellar coalescence and merging processes towards red nova events, as the final state of stellar evolution of low-mass contact binary systems. The program aspires to give insights into their physical and orbital parameters and their temporal variations, e.g. the orbital period modulation, spot activity, etc. The innovation of *CoBiToM* Project is based on a multi-method approach and a detailed investigation, that will shed light on the origin of stellar mergers and rapidly rotating stars for the first time. *CoBiToM* Project is closely connected with the *WUMa* program (Kreiner et al., 2003), which was initiated in 2002 and resulted in a list of 160 contact binary systems with high-resolution spectroscopy and mass ratio determination.

Fig. 4 shows the mass distribution over the orbital period of 118 well-studied contact binaries with combined photometric and spectroscopic techniques. The current investigation, in the frame of *CoBiToM* Project, focuses on the study of ultra-short orbital period systems (extreme left part of the plot), and investigates the systems with an extremely small secondary component, and therefore ultra-low mass ratio (systems with the smallest mass at the lower part of the plot). The preliminary results show that the ultra-short orbital period contact binaries are very stable systems, while over 60% of them are hosted within triple or multiple systems. In addition, half of them present orbital period modulation.

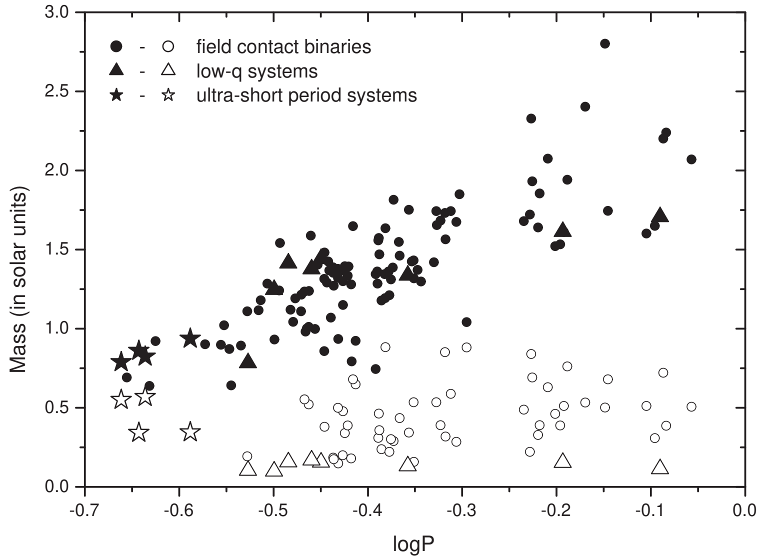


Figure 4. The mass distribution for the two components of all 118 contact binaries in our sample. The mass of the primary components is plotted with full circles, while the mass of the secondary ones is plotted with open circles. Triangles represent the low-q systems with secondary components of very small mass. Note that the mass of the secondaries lies within the range of 0–1 $M_{\odot}$, while the mass of the primaries gradually increases proportionally to logP (Gazeas & Niarchos, 2006).

7. Observing challenges and future goals

The current and future trend of the research on low mass contact binaries is to further study the ultra-short orbital period systems and the prominent cut-off limit, detect systems with significant orbital period modulation via the O-C diagrams, investigate the ultra-low mass ratio systems, and search for possible unstable orbits among them. Furthermore, the study of contact binaries as common envelope systems investigates the possibility of discovering exoplanets hidden within the circumbinary material and the stellar ejecta from the stellar wind and the mass loss processes. Dedicated observing programs seek for red nova progenitors and future merger candidates and aspire to connect the merger results with fast rotating stars, such as the population of Blue Stragglers.

8. Summary

The evolution of low-mass contact binaries is mostly driven by mass transfer and angular momentum loss via the magnetized wind, which shrinks the orbit and makes both components overflow their outer Roche lobes. It is known that all low-mass contact binaries are old, with a typical age of 7–8 Gyr, although their contact phase lasts less than 1 Gyr, leading into coalescence (Stępień & Gazeas, 2012). There is an obvious need for dedicated sky surveys focusing on high-resolution spectroscopy on such systems. Ground-based surveys and telescope networking, play an important role in time-domain Astrophysics and this is a key aspect for future research in this field. Long-term observing campaigns and active Pro-Am collaborations in data acquisition are essential for monitoring temporal modulations of physical and orbital parameters.

References

Bilir, S., Karataş, Y., Demircan, O., & Eker, Z., Kinematics of W Ursae Majoris type binaries and evidence of the two types of formation. 2005, *Monthly Notices of the RAS*, **357**, 497, DOI: 10.1111/j.1365-2966.2005.08609.x

Chen, X., Wang, S., Deng, L., et al., The Zwicky Transient Facility Catalog of Periodic Variable Stars. 2020, *Astrophysical Journal, Supplement*, **249**, 18, DOI: 10.3847/1538-4365/ab9cae

D'Angelo, C., van Kerkwijk, M. H., & Rucinski, S. M., Contact Binaries with Additional Components. II. A Spectroscopic Search for Faint Tertiaries. 2006, *Astronomical Journal*, **132**, 650, DOI: 10.1086/505265

Deleuil, M., Aigrain, S., Moutou, C., et al., Planets, candidates, and binaries from the CoRoT/Exoplanet programme. The CoRoT transit catalogue. 2018, *Astronomy and Astrophysics*, **619**, A97, DOI: 10.1051/0004-6361/201731068

Drake, A. J., Djorgovski, S. G., García-Álvarez, D., et al., Ultra-short Period Binaries from the Catalina Surveys. 2014, *Astrophysical Journal*, **790**, 157, DOI: 10.1088/0004-637X/790/2/157

Eaton, J. A., Wu, C. C., & Rucinski, S. M., Ultraviolet colors of W UMa : gravity darkening, temperature differences and the cause of W-type light curves. 1980, *Astrophysical Journal*, **239**, 919, DOI: 10.1086/158179

Edmonds, P. D., Gilliland, R. L., Guhathakurta, P., et al., Stellar Variability in the Central Populations of 47 Tucanae from WF/PC Observations with the Hubble Space Telescope. II. Binary Systems. 1996, *Astrophysical Journal*, **468**, 241, DOI: 10.1086/177687

Gazeas, K. & Stępień, K., Angular momentum and mass evolution of contact binaries. 2008, *Monthly Notices of the RAS*, **390**, 1577, DOI: 10.1111/j.1365-2966.2008.13844.x

Gazeas, K. D., Physical parameters of contact binaries through 2-D and 3-D correlation diagrams. 2009, *Communications in Asteroseismology*, **159**, 129

Gazeas, K. D., Loukaidou, G. A., Niarchos, P. G., et al., CoBiToM project - I. Contact binaries towards merging. 2021, *Monthly Notices of the RAS*, **502**, 2879, DOI: 10.1093/mnras/stab234

Gazeas, K. D. & Niarchos, P. G., Erratum: Masses and angular momenta of contact binary stars. 2006, *Monthly Notices of the RAS*, **372**, L83, DOI: 10.1111/j.1745-3933.2006.00229.x

Hut, P., Stability of tidal equilibrium. 1980, *Astronomy and Astrophysics*, **92**, 167

Jayasinghe, T., Stanek, K. Z., Kochanek, C. S., et al., The ASAS-SN catalogue of variable stars - II. Uniform classification of 412 000 known variables. 2019, *Monthly Notices of the RAS*, **486**, 1907, DOI: 10.1093/mnras/stz844

Kirk, B., Conroy, K., Prša, A., et al., Kepler Eclipsing Binary Stars. VII. The Catalog of Eclipsing Binaries Found in the Entire Kepler Data Set. 2016, *Astronomical Journal*, **151**, 68, DOI: 10.3847/0004-6256/151/3/68

Kozai, Y., Secular perturbations of asteroids with high inclination and eccentricity. 1962, *Astronomical Journal*, **67**, 591, DOI: 10.1086/108790

Kreiner, J. M., Rucinski, S. M., Zola, S., et al., Physical parameters of components in close binary systems. I. 2003, *Astronomy and Astrophysics*, **412**, 465, DOI: 10.1051/0004-6361:20031456

Li, K., Gao, X., Liu, X.-Y., et al., Extremely Low Mass Ratio Contact Binaries. I. The First Photometric and Spectroscopic Investigations of Ten Systems. 2022, *Astronomical Journal*, **164**, 202, DOI: 10.3847/1538-3881/ac8ff2

Liu, X.-Y., Li, K., Michel, R., et al., The study of 11 contact binaries with mass ratios less than 0.1. 2023, *Monthly Notices of the RAS*, **519**, 5760, DOI: 10.1093/mnras/stad026

Loukaidou, G. A., Gazeas, K. D., Palafouta, S., et al., CoBiToM Project - II. Evolution of contact binary systems close to the orbital period cut-off. 2022, *Monthly Notices of the RAS*, **514**, 5528, DOI: 10.1093/mnras/stab3424

Norton, A. J., Payne, S. G., Evans, T., et al., Short period eclipsing binary candidates identified using SuperWASP. 2011, *Astronomy and Astrophysics*, **528**, A90, DOI: 10.1051/0004-6361/201116448

Petrosky, E., Hwang, H.-C., Zakamska, N. L., Chandra, V., & Hill, M. J., Variability, periodicity, and contact binaries in WISE. 2021, *Monthly Notices of the RAS*, **503**, 3975, DOI: 10.1093/mnras/stab592

Pojmanski, G., The All Sky Automated Survey. Catalog of Variable Stars. I. 0 h - 6 hQuarter of the Southern Hemisphere. 2002, *Acta Astronomica*, **52**, 397, DOI: 10.48550/arXiv.astro-ph/0210283

Qian, S., Zhu, L., Liu, L., et al., Contact binaries at different evolutionary stages. 2020, *Research in Astronomy and Astrophysics*, **20**, 163, DOI: 10.1088/1674-4527/20/10/163

Rubenstein, E. P. & Bailyn, C. D., A W UMa Contact Binary in the Globular Cluster NGC 6397. 1996, *Astronomical Journal*, **111**, 260, DOI: 10.1086/117778

Rucinski, S. M., Eclipsing Binaries in the OGLE Variable Star Catalog.II.Light Curves of the W UMA-Type Systems in Baade's Window. 1997, *Astronomical Journal*, **113**, 1112, DOI: 10.1086/118329

Rucinski, S. M., W UMA-Type Binary Stars in Globular Clusters. 2000, *Astronomical Journal*, **120**, 319, DOI: 10.1086/301417

Samus, N. N., Durlevich, O. V., Kazarovets, E. V., Kireeva, N. N., & Pastukhova, E. N., Version 5.1 of the General Catalogue of Variable Stars for the Constellation Cepheus. 2018, *Astronomy Reports*, **62**, 1050, DOI: 10.1134/S1063772918140019

Stępień, K., The Low-Mass Limit for Total Mass of W UMa-type Binaries. 2006, *Acta Astronomica*, **56**, 347

Stępień, K. & Gazeas, K., Evolutionary scenario for W UMa-type stars. 2008, in IAU Symposium, Vol. **252**, *The Art of Modeling Stars in the 21st Century*, ed. L. Deng & K. L. Chan, 427–428

Stępień, K. & Gazeas, K., Evolution of Low Mass Contact Binaries. 2012, *Acta Astronomica*, **62**, 153

Stepien, K., SW Lac and the SPOT activity on W UMa stars. 1980, *Acta Astronomica*, **30**, 315

Szymański, M., Udalski, A., Kubiak, M., et al., OGLE Survey - Microlensing in the Milky Way. 2001, in Astronomical Society of the Pacific Conference Series, Vol. **228**, *Dynamics of Star Clusters and the Milky Way*, ed. S. Deiters, B. Fuchs, A. Just, R. Spurzem, & R. Wielen, 277

Tylenda, R., Hajduk, M., Kamiński, T., et al., V1309 Scorpii: merger of a contact binary. 2011, *Astronomy and Astrophysics*, **528**, A114, DOI: 10.1051/0004-6361/201016221

Udalski, A., The Optical Gravitational Lensing Experiment. Real Time Data Analysis Systems in the OGLE-III Survey. 2003, *Acta Astronomica*, **53**, 291

Wadhwa, S. S., Arbutina, B., Petrović, J., et al., A Study of Six Extreme Low Mass Ratio Contact Binary Systems. 2023a, *Publications of the ASP*, **135**, 094201, DOI: 10.1088/1538-3873/acf40d

Wadhwa, S. S., Arbutina, B., Tothill, N. F. H., et al., A Study of Twelve Potential Merger Candidate Contact Binary Systems. 2023b, *Publications of the ASP*, **135**, 074202, DOI: 10.1088/1538-3873/ace3f5

Watson, C. L., Henden, A. A., & Price, A., The International Variable Star Index (VSX). 2006, *Society for Astronomical Sciences Annual Symposium*, **25**, 47

Webbink, R. F., The evolution of low-mass close binary systems. I. The evolutionary fate of contact binaries. 1976, *Astrophysical Journal*, **209**, 829, DOI: 10.1086/154781

Yan, L. & Mateo, M., Primordial Main sequence Binary Stars in the Globular Cluster M71. 1994, *Astronomical Journal*, **108**, 1810, DOI: 10.1086/117194

Zola, S., Gazeas, K., Kreiner, J. M., et al., Physical parameters of components in close binary systems - VII. 2010, *Monthly Notices of the RAS*, **408**, 464, DOI: 10.1111/j.1365-2966.2010.17129.x