The user wants me to translate a Chinese academic paper title and abstract (or part of it) to English. The title is “BSN: The First Photometric Analysis of Contact Binary Systems V1961 Cyg and V0890 Lyr 后印本”. Let me break down the requirements: 1. Preserve ALL LaTeX commands and placeholders exact…

Authors: Sabrina Baudart and Atila Poro

Date: 2025-01-07T00:00:00+00:00

Abstract

The user wants me to translate a Chinese text to English. Let me analyze the requirements:

1. This is a scientific/academic text about binary star systems
2. I need to preserve LaTeX commands and MATH placeholders exactly
3. I need to preserve citation commands ([?], **??**, (**??**), etc.) exactly
4. I need to preserve ALL …paragraph wrapper tags EXACTLY
5. Maintain academic tone and formal scientific writing style
6. Use precise technical terminology - obey the glossary strictly
7. Preserve section structure and paragraph organization
8. Translate all content completely - do not omit any information

Looking at the input text, I see: - It’ s about photometric analysis of V1961 Cyg and V0890 Lyr binary systems - Mentions BSN Project, PHOEBE Python code, MCMC method - Discusses O-C diagrams, light curve solutions, starspots - Mentions mass ratios, empirical relationships, absolute parameters - Classifies them as W-type contact binary systems - Mentions M-L, M-R diagrams

The glossary provided is: 机器学习 => machine learning 深度学习 => deep learning

But these terms don’ t appear in the text. The text is already in English! Wait, let me re-read the instructions.

The user says “Translate from Simplified Chinese to English” but the text provided is already in English. This is confusing. Let me check if there’ s any Chinese text that I missed.

Looking at the input again: “We presented the first photometric analysis of the V1961 Cyg and V0890 Lyr binary systems. We observed and analyzed these systems at an observatory in France as part of the Binary Systems of South and North (BSN) Project. We extracted and collected the times of minima from the observations and literature and presented a new ephemeris for each system. Due to the few observations about these systems over the years, both O-C diagrams were fitted linearly. The PHysics Of Eclipsing BinariEs (PHOEBE) Python code and the Markov Chain Monte Carlo (MCMC) method were used for light curve solutions. The light curve solution required a cold starspot on the hotter component in the V1961 Cyg binary system. We compared and have close agreements between our mass ratios’ results from the light curve analysis processes and a new method based on the light curve derivative. We estimated the absolute parameters using an empirical relationship between the semimajor axis and orbital period for contact binary systems. The results show V1961 Cyg and V0890 Lyr are W-type contact binary systems. We displayed stars and systems’ positions in the M-L, M-R”

This is all

Full Text

Preamble

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BSN: The First Photometric Analysis of Contact Binary Systems V1961 Cyg and V0890 Lyr

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Abstract

We present the first photometric analysis of the V1961 Cyg and V0890 Lyr binary systems. We observed and analyzed these systems at an observatory in France as part of the Binary Systems of South and North (BSN) Project. We extracted and collected times of minima from both our observations and the literature, and derived new ephemerides for each system. Due to the limited number of observations of these systems over the years, both O-C diagrams were fitted linearly. The PHysics Of Eclipsing BinariEs (PHOEBE) Python code and the Markov Chain Monte Carlo (MCMC) method were used for light curve solutions. The light curve solution required a cold starspot on the hotter component in the V1961 Cyg binary system. We compared our mass ratio results from the light curve analysis with those from a new method based on the light curve derivative and found close agreement. We estimated the absolute parameters using an empirical relationship between the semimajor axis and orbital period for contact binary systems. The results show that V1961 Cyg and V0890 Lyr are W-type contact binary systems. We display the positions of the stars and systems in the M–L, M–R, and other diagrams. We also present a new relationship between mass ratio and luminosity ratio.

Key words: (stars:) binaries: eclipsing -methods: observational -stars: individual (V1961 Cyg, V0890 Lyr)

1. Introduction

W Ursae Majoris (W UMa) eclipsing contact binary systems consist of two late-type stars with short orbital periods. In these systems, the two components overfill their critical Roche lobes and share a common envelope (Kopal 1959). The effective temperature difference between the component stars in contact binary systems is low, and they typically have minima of similar or equal depth (Kuiper 1941; Yakut & Eggleton 2005).

W UMa contact binaries are generally classified into two categories: A-subtype and W-subtype (Binnendijk 1970). The subtype of a system cannot be recognized from its light curve shape alone; absolute parameters, including the masses of the stars, are required for classification (Guo et al. 2022). The stars in contact systems transfer mass to each other (Lucy & Wilson 1979), and this process can alter their orbital periods. The orbital period of contact systems plays a role in relations with absolute parameters and influences the evolutionary process of these systems (Latković et al. 2021; Loukaidou et al. 2022; Poro et al. 2024b, 2024c). Several studies have investigated the upper and lower cut-offs of these systems' orbital periods (Zhang & Qian 2020).

Asymmetric light curves from contact and near-contact binaries are commonly observed over time, particularly at phases 0.25 and 0.75. This phenomenon is generally referred to as the O' Connell effect (O' Connell 1951), which is crucial for studying a star' s magnetic activity. This asymmetry in the light curves is typically modeled with one or more starspots, which presents a challenge in the modeling process.

In this work, we investigated V1961 Cyg (2MASS J21243169+3957197) and V0890 Lyr (2MASS J19184581+3708166), which are binary star systems classified as EW type in variable star catalogs and databases such as ASAS-SN, GCVS, ZTF, and VSX. The variability of V1961 Cyg was discovered by Kulagin & Shugarov (1989). Based on Gaia Data Release 3 (DR3), V1961 Cyg has coordinates of R.A.: 321°.1320 and decl.: 39°.9554 in the Cygnus constellation. This system ranges from 13.88 to 14.6 mag in the V filter, according to the VSX database. The orbital period of V1961 Cyg was reported to be 0.286008 days in the Kulagin & Shugarov (1989) study and 0.2860135 days in the ASAS-SN catalog of variable stars.

V0890 Lyr was identified in a survey of Two Micron All Sky Survey (2MASS) and Northern Sky Variability Survey (NSVS) data (Gettel et al. 2006). This system is located in the constellation Lyra with coordinates of R.A.: 289°.6909 and decl.: 37°.1379, according to the Gaia DR3 database. The VSX database reported a magnitude range of 11.38–11.71 mag in the V filter and an orbital period of 0.3884152 days for V0890 Lyr.

We aim to investigate two contact binary systems that have not been previously studied in detail. Different systems have their own characteristics, and their analysis can lead to a better understanding of contact binary evolution. Additionally, investigating new contact binary systems expands the sample of studied targets, which could be used to develop future empirical relationships between parameters. This paper is structured as follows: Section 2 describes the observational data and methods used for data reduction. Section 3 presents the new ephemerides of each contact binary system. Section 4 presents the light curve analysis solutions, while Section 5 provides the estimated absolute parameters of each target system. Finally, Section 6 gives our discussion and conclusion.

2. Observation and Data Reduction

We observed V1961 Cyg and V0890 Lyr at a private observatory located in Toulon, France (longitude 05°54\$ '35' '\$ E, latitude 43°8\$' 59'' \$ N, altitude 68 m above sea level). The photometric observations were made using the standard V filter for both target systems. We employed an apochromatic refractor telescope with a 102 mm aperture and a ZWO ASI 1600MM CCD camera. The binning of the images was 1 × 1, and the average temperature during the observations was −15°C.

V1961 Cyg was observed for three nights on July 2nd, 9th, and 13th, 2023, accumulating 499 images with 110 s exposure time. We used Gaia DR2 1965471833170939904 as a comparison star, which has a magnitude of V = 12.795(28) mag and coordinates R.A.: 21h24m21.976, decl.: +39°59\$' 36.83.$GaiaDR2 1965424588530688256 waschosenasacheckstarwithamagnitudeofV = 13.621(34) magandcoordinatesR.A. : 21h24m22.725, decl. : +39°55'$ \$27.37 (Figure 1, left). The average signal-to-noise ratio (SNR) of our observations is 15.49 decibels (dB), which indicates a 0.03 mag uncertainty for V1961 Cyg.

V0890 Lyr was observed for two nights on August 19th and 20th, 2023. These observations resulted in 484 images with an exposure time of 80 s. Gaia

DR2 2051151521582207232 (R.A.: 19h17m06.764, decl.: +37°06$' 03.74, $V =$ 12.672(140)*mag*)*wasusedasacomparisonstar*, *andGaiaDR*22051169835322822912(*R.A.* : 19*h*17*m*21.475, *decl.* : +37°11' $52.05, V = 11.439(119) mag) as a check star (Figure 1, right). Our data analysis indicates that the average SNR is 24.56 dB, which corresponds to an uncertainty of 0.004 mag for V0890 Lyr. The field-of-view of the target systems with comparison and check stars is shown in Figure 1.

We determined the apparent magnitude at maximum brightness for each light curve based on our observations, resulting in $V_{\max} = 14.15$ mag for V1961 Cyg and $V_{\max} = 11.45$ mag for V0890 Lyr. The data reduction process for both binary systems involved standard calibration techniques, including bias correction using offset frames, dark frame subtraction to eliminate thermal noise, and division by flat-field frames to correct for uneven illumination. These standard processes were executed using version 1.2.0 of the Siril software.

3. New Ephemeris

Data derived from our ground-based observations were used to extract primary and secondary times of minima. We utilized a Python program to fit a Gaussian distribution and extract minima from the ground-based data. We used an online tool to convert the times of minima gathered from the literature, which were given in Heliocentric Julian Day (HJD), to Barycentric Julian Date and Barycentric Dynamical Time (BJDTDB). The times of minima are listed in Table 1.

A reference ephemeris was used to calculate the epoch and O-C values of each system. We chose $t_0(\text{BJDTDB}) = 2453259.38056 \pm 0.00240$ from Hubscher et al. (2005) and $P_0 = 0.2860135$ days from the ASAS-SN catalog for V1961 Cyg. For V0890 Lyr, $t_0(\text{BJDTDB}) = 2457944.979491$ and $P_0 = 0.3884152$ days were taken from the VSX database. O-C diagrams of the systems are presented in Figure 2. The O-C diagram of each system was fitted linearly based on the limited observations available for these target systems. The computed new ephemerides are given by Equations (1) and (2):

V1961 Cyg:

$$\text{Min. I} = 2453259.38056(24) + 0.28601330(13) \times E \quad (1)$$

V0890 Lyr:

$$\text{Min. I} = 2457944.97949(37) + 0.3884144(4) \times E \quad (2)$$

where E is the number of orbital cycles after the reference mid-eclipse time.

4. Light Curve Solutions

We employed the PHysics Of Eclipsing BinariEs (PHOEBE) 2.4.9 Python code and the Markov Chain Monte Carlo (MCMC) method in this investigation (Prša et al. 2016; Conroy et al. 2020) to provide the first light curve analysis of the binary systems V1961 Cyg and V0890 Lyr. We selected a contact mode in the PHOEBE code based on the classification given to both systems in the catalogs and the typical shape of their light curves. The assumed gravity-darkening coefficients and bolometric albedo in this study are $g_h = g_c = 0.32$ (Lucy 1967) and $A_h = A_c = 0.5$ (Rucinski 1969), respectively. A stellar atmosphere model was applied using the Castelli & Kurucz (2004) method, and limb-darkening coefficients were determined by PHOEBE.

We adopted the Gaia DR3 reported temperature of 5386 K for the hotter component of V1961 Cyg as an initial value based on the light curve morphology. TESS reported a temperature for V1961 Cyg of 5157 ± 224 K. For the V0890 Lyr system, we set the effective temperature provided by the TESS database (6876 K) for the hotter component. Gaia DR3 did not report a temperature for V0890 Lyr, while Gaia Data Release 2 (DR2) indicates a temperature of 6911 K. We then used the depth difference between the primary and secondary minima of the light curve to determine the temperature ratio of each system.

We determined the initial value of the mass ratio using photometric data by performing a q-search with a step size of 0.1, ranging from 0.1 to 10. Figure 3 illustrates that each q-search curve has a clear minimum in the sum of squared residuals. We then attempted to obtain a good initial theoretical fit to the observational data.

The light curve of the V1961 Cyg contact binary system shows asymmetry in peak brightness. The difference between the maxima of the light curve for V1961 Cyg is 0.068 mag. This is a sign of the O’ Connell effect, for which one explanation might be the existence of a starspot due to magnetic activity on the star’ s surface (O’ Connell 1951). Accordingly, we added one cold starspot to the hotter component of the V1961 Cyg system. The starspot position and characteristics are described in Table 2, and it is visible in the three-dimensional representation of V1961 Cyg in Figure 7.

We then used PHOEBE’ s optimization tool to improve the theoretical fit. Finally, we applied the MCMC approach, which is based on the emcee package (Foreman-Mackey et al. 2013) in PHOEBE, to determine the values of the parameters together with their uncertainties (Hogg & Foreman-Mackey 2018). This process considered a normal Gaussian distribution within the solution ranges for inclination (i), mass ratio (q), fillout factor (f), effective temperatures for both components ($T_{1,2}$), and the luminosity of the primary star (l_1). Four starspot parameters were also included for the V1961 Cyg system in the MCMC process. The MCMC approach was employed with 96 walkers and 1500 iterations for V1961 Cyg, and 96 walkers and 1000 iterations for V0890 Lyr.

The photometric light curve solution results are listed in Table 2, and the corner plots produced by the MCMC modeling for each system are shown in Figures 4 and 5. The observational and synthetic light curves for the V1961 Cyg and V0890 Lyr systems are displayed in Figure 6.

5. Absolute Parameters

The empirical relationship between the semimajor axis (a) and orbital period (P) from the Poro et al. (2024a) study was utilized as the foundation for estimating the absolute parameters of each target system (Equation 3):

$$a(R_\odot) = 3.804 \times P^{2/3} \quad (3)$$

We adopted the orbital periods of the systems as 0.28601330(13) days for V1961 Cyg and 0.3884144(4) days for V0890 Lyr. Using these values, we computed a from Equation (3). Equation (4) was used to estimate the radii of the stars based on the $r_{\mathrm{mean}(h,c)}$ values resulting from the light curve solutions and the value of a:

$$R_{(h,c)} = r_{\mathrm{mean}(h,c)} \times a \quad (4)$$

The effective temperature of each component was determined from the light curve solutions. Considering blackbody emission, we computed the luminosity $L_{(h,c)}(L_\odot)$ from the radius of each component and its effective temperature using Equation (5):

$$L_{(h,c)} = \left(\frac{R_{(h,c)}}{R_\odot}\right)^2 \left(\frac{T_{(h,c)}}{T_\odot}\right)^4 \quad (5)$$

The mass ratio and Kepler' s third law were used to estimate each component' s mass. The stellar masses were computed using Equations (6) and (7):

$$M_h = \frac{M_{\mathrm{tot}}}{1+q} \quad (6)$$

$$M_c = M_{\mathrm{tot}} - M_h \quad (7)$$

where M_{tot} is the total mass derived from the orbital period and semimajor axis. Next, the surface gravity of each star was determined using its mass and radius via Equation (8):

$$g_{(h,c)} = \frac{GM_{(h,c)}}{R^2_{(h,c)}} \quad (8)$$

Finally, using the Pogson (1856) relation, we computed the absolute bolometric magnitudes ($M_{\mathrm{bol}(h,c)}$) of each component (Equation 9):

$$M_{\mathrm{bol}(h,c)} = M_{\mathrm{bol}\odot} - 2.5\log_{10}\left(\frac{L_{(h,c)}}{L_\odot}\right) \quad (9)$$

We adopted the solar bolometric magnitude value reported in the Torres (2010) study, which is $M_{\mathrm{bol}\odot} = 4.73$ mag. Table 3 lists the values of the estimated absolute parameters. The uncertainties of each absolute parameter in this study were computed using the uncertainties from the a-P relationship and the light curve solution parameters ($r_{\mathrm{mean}(h,c)}$, $T_{(h,c)}$, and q).

6. Discussion and Conclusion

We employed ground-based photometric observations to investigate two W UMa-type contact binary systems. V1961 Cyg and V0890 Lyr were observed during five nights in 2023 at an observatory in France. We extracted four primary and secondary times of minima from our data for both target systems and presented new ephemerides.

The first light curve analysis of these systems was performed using PHOEBE and MCMC. We used the q-search method on photometric data to determine the initial mass ratio. The final parameters and uncertainties were obtained after performing the MCMC process. The companion temperature differences are 287 K and 238 K for V1961 Cyg and V0890 Lyr, respectively. The spectral types of stars in V1961 Cyg and V0890 Lyr were determined to be G8-K1 and F1-F2, respectively, based on the Eker et al. (2018) and Cox (2015) studies.

We used a new method to examine the mass ratios resulting from our light curve solutions. Kouzuma (2023) presented a method for estimating the photometric mass ratio of overcontact binaries using derivatives of the light curve. This method can be applied to most overcontact systems and is based on derivation at various orders of the photometric light curve. The light curve should show at least two maxima after derivation. A parameter named W is obtained after the third-order derivative, and according to Kouzuma (2023), there is a strong relationship between W and q. We applied this method to V1961 Cyg and V0890 Lyr, obtaining mass ratios of $1/q = 0.681(72)$ and $1/q = 0.268(43)$, respectively. We found close agreement with our light curve analysis results, with discrepancies of $\Delta q = 0.023$ and $\Delta q = 0.003$ for V1961 Cyg and V0890 Lyr, respectively. Figure 8 shows the derivative process of the light curves.

The absolute parameters were estimated using the relationship between the semimajor axis and the orbital period. Based on these estimated absolute parameters, we displayed the evolutionary state of the target systems on Mass-Luminosity (M-L) and Mass-Radius (M-R) diagrams. The theoretical Zero-Age Main Sequence (ZAMS) and Terminal-Age Main Sequence (TAMS) lines from Girardi et al. (2000) are also shown in the M-L and M-R diagrams (Figure 9). In these diagrams, the hotter star of V1961 Cyg is near the TAMS line, whereas for V0890 Lyr it is above the TAMS. The cooler star is located between ZAMS and TAMS for both target systems.

The orbital angular momentum (J_0) was computed for V1961 Cyg and V0890 Lyr to be $\log J_0 = 51.56 \pm 0.20$ and $\log J_0 = 51.56 \pm 0.17$, respectively, based on the orbital period, mass ratio, and total mass of the systems. We estimated J_0 using Equation (10) from the Eker et al. (2006) study:

$$J_0 = \frac{M_h M_c}{M_{\text{tot}}} \sqrt{G M_{\text{tot}} a (1 - e^2)} \quad (10)$$

The $\log M_{\text{tot}}$-$\log J_0$ diagram (Figure 10) shows the systems' positions and indicates that both are located in the region of contact binary systems.

In the literature, there are studies about the empirical relationship between the mass ratio (q) and the luminosity ratio (L_{ratio}) for contact binary systems. We have listed some of these relationships in Table 4. We updated the q-L_{ratio} relationship based on a carefully selected sample. We chose our sample from the Latković et al. (2021) study, selecting only studies that had or used spectroscopic results. We excluded from the sample any results that contained a third light component (l_3), or if l_3 was present in subsequent studies of that system. We also excluded studies that used low-resolution spectroscopic observations. The systems used for this sample include both A- and W-subtypes. As a result, we compiled a sample of 88 contact binary systems, which are listed in Table 5.

We performed a linear fit to the data points, yielding the following equation:

$$\frac{1}{q} = 0.78(2) \times \frac{1}{L_{\text{ratio}}} + 0.15(1) \quad (11)$$

The mass ratio and luminosity ratio in Equation (11) are expressed as $1/q$ and $1/L_{\text{ratio}}$, respectively, a form that has not been utilized in previous studies (Table 4). This formulation appears to produce less scatter in the data points compared to other samples. Additionally, other literature samples contain mass ratios from both photometric and spectroscopic data. The positions of V1961 Cyg and V0890 Lyr in Figure 11 are in agreement with other contact systems that have been analyzed with spectroscopic data.

We used the relationship from the Sun et al. (2020) study to determine that the target systems are partially or totally eclipsing. V1961 Cyg, with $i = 88.57^\circ$, is a total eclipsing system, while V0890 Lyr, with $i = 67.00^\circ$, is a partial eclipsing system. Based on the discussion in Terrell & Wilson (2005), systems with total and partial eclipses and high orbital inclinations can yield reliable photometric mass ratios. Additionally, according to the mass ratios from the light curve solutions in the MCMC process, the mass ratio results using the Kouzuma (2023) method, and their position in the empirical q-L_{ratio} relationship, the obtained mass ratios are reliable for both systems.

According to the mass ratios, fillout factors, and orbital inclinations of the target systems, we can conclude that V1961 Cyg and V0890 Lyr are contact binary systems. Based on the fillout factor, there are three categories: deep ($f > 50\%$), medium ($25\% < f < 50\%$), and shallow ($f < 25\%$) eclipsing contact binary stars (Li et al. 2022). Therefore, V1961 Cyg is a shallow system, and V0890 Lyr is a medium system. Additionally, contact binaries are divided into A- and W-subtypes (Binnendijk 1970). In the A-subtype, the more massive component is the hotter star, while in the W-subtype, the less massive component has a higher effective temperature. Based on the results of the light curve solutions and the estimated absolute parameters, both systems are categorized as W-subtype since the less massive components have higher effective temperatures.

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Data Availability: Ground-based data will be made available on request.

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References

Albayrak, B., Djurašević, G., Selam, S. O., Atanacković-Vukmanović, O., & Yılmaz, M. 2005, NewA, 10, 163
Alton, K. B., Nelson, R. H., & Boyd, D. R. S. 2018a, AcA, 68, 159
Alton, K. B., Nelson, R. H., & Terrell, D. 2018b, IBVS, 6256, 1
Alvarez, G. E., Sowell, J. R., Williamon, R. M., & Lapasset, E. 2015, PASP, 127, 742
Awadalla, N. S., & Hanna, M. A. 2005, JKAS, 38, 43
Baran, A., Zola, S., Rucinski, S. M., et al. 2004, AcA, 54, 195
Binnendijk, L. 1970, VA, 12, 217
Çalışkan, Ş., Latković, O., Djurašević, G., et al. 2014, AJ, 148, 126
Castelli, F., & Kurucz, R. 2004, A&A, 419, 725
Chochol, D., van Houten, C. J., Pribulla, T., & Grygar, J. 2001, CoSka, 31, 5
Conroy, K. E., Kochoska, A., Hey, D., et al. 2020, ApJS, 250, 34
Copeland, H., Jensen, J. O., & Jorgensen, H. E. 1970, A&A, 5, 12
Cox, A. N. 2015, Allen' s Astrophysical Quantities (Berlin: Springer)
Csák, B., Kiss, L. L., Vinkó, J., & Alfaro, E. J. 2000, A&A, 356, 603
Deb, S., & Singh, H. P. 2011, MNRAS, 412, 1787
Djurašević, G., Rovithis-Livaniou, H., Rovithis, P., Erkapić, S., & Milovanović, N. 2001, A&A, 367, 840
Djurašević, G., Yılmaz, M., Baştürk, Ö., et al. 2011, A&A, 525, A66
Eker, Z., Bakış, V., Bilir, S., et al. 2018, MNRAS, 479, 5491
Eker, Z., Demircan, O., Bilir, S., & Karataş, Y. 2006, MNRAS, 373, 1483
Ekmekçi, F., Elmaslı, A., Yılmaz, M., et al. 2012, NewA, 17, 603
Erdem, A., & Özkardeş, B. 2006, NewA, 12, 192

Foreman-Mackey, D., Hogg, D. W., Lang, D., & Goodman, J. 2013, PASP, 125, 306
Gazeas, K. D., Baran, A., Niarchos, P., et al. 2005, AcA, 55, 123
Gazeas, K. D., Niarchos, P. G., Zola, S., Kreiner, J. M., & Rucinski, S. M. 2006, AcA, 56, 127
Gettel, S. J., Geske, M. T., & McKay, T. A. 2006, AJ, 131, 621
Girardi, L., Bressan, A., Bertelli, G., & Chiosi, C. 2000, A&AS, 141, 371
Guo, D.-F., Li, K., Liu, F., et al. 2022, MNRAS, 517, 1928
Gürol, B. 2016, NewA, 47, 57
Gürol, B., Bradstreet, D. H., Demircan, Y., & Gürsoytrak, S. H. 2015a, NewA, 41, 26
Gürol, B., Bradstreet, D. H., & Okan, A. 2015b, NewA, 36, 100
Gürol, B., Gökay, G., Saral, G., et al. 2016, NewA, 46, 31
Gürol, B., Gürsoytrak, S. H., & Bradstreet, D. H. 2015c, NewA, 39, 9
Gürol, B., Terzioğlu, Z., Gürsoytrak, S. H., Gökay, G., & Derman, E. 2011, AN, 332, 690
Habets, G. M. H. J., & Heintze, J. R. W. 1981, A&AS, 46, 193
Hasanzadeh, A., Farsian, F., & Nemati, M. 2015, NewA, 34, 262
Hogg, D. W., & Foreman-Mackey, D. 2018, ApJS, 236, 11
Hubscher, J., Paschke, A., & Walter, F. 2005, IBVS, 5657, 1
Kamalifar, Z., Abedi, A., & Roobiat, K. Y. 2020, NewA, 78, 101354
Kjurkchieva, D., Stateva, I., Popov, V. A., & Marchev, D. 2019, AJ, 157, 73
Kopal, Z. 1959, Close Binary Systems (London: Chapman & Hall)
Köse, O., Kalomeni, B., Keskin, V., Ulaş, B., & Yakut, K. 2011, AN, 332, 626
Kouzuma, S. 2023, ApJ, 958, 84
Kreiner, J. M., Rucinski, S. M., Zola, S., et al. 2003, A&A, 412, 465
Kuiper, G. P. 1941, ApJ, 93, 133
Kulagin, Y. V., & Shugarov, S. Y. 1989, ATsir, 1541, 11
Latković, O., Čeki, A., & Lazarević, S. 2021, ApJS, 254, 10
Lee, J. W., Lee, C.-U., Kim, S.-L., Kim, H.-I., & Park, J.-H. 2011, PASP, 123, 34
Lee, J. W., Youn, J.-H., Park, J.-H., & Wolf, M. 2015, AJ, 149, 194
Li, H.-L., Wei, J.-Y., Yang, Y.-G., & Dai, H.-F. 2016a, RAA, 16, 2
Li, K., Gao, D. Y., Hu, S. M., et al. 2016b, Ap&SS, 361, 63
Li, K., Gao, X., Liu, X.-Y., et al. 2022, AJ, 164, 202
Li, K., Hu, S., Guo, D., et al. 2015a, NewA, 41, 17
Li, K., Hu, S. M., Guo, D. F., et al. 2015b, AJ, 149, 120
Li, K., Hu, S. M., Jiang, Y. G., Chen, X., & Ren, D. Y. 2014, NewA, 30, 1
Li, K., & Qian, S. B. 2013, NewA, 21, 46
Liu, L., Qian, S.-B., He, J.-J., et al. 2012, PASJ, 64, 48
Liu, L., Qian, S. B., Zhu, L. Y., He, J. J., & Li, L. J. 2011, AJ, 141, 147
Lohr, M. E., Hodgkin, S. T., Norton, A. J., & Kolb, U. C. 2014, A&A, 563, A34
Loukaidou, G. A., Gazeas, K. D., Palafouta, S., et al. 2022, MNRAS, 514, 5528
Lucy, L. B. 1967, ZA, 65, 89
Lucy, L. B. 1968a, ApJ, 153, 877
Lucy, L. B. 1968b, ApJ, 151, 1123

Lucy, L. B., & Wilson, R. E. 1979, ApJ, 231, 502
Mitnyan, T., Bódi, A., Szalai, T., et al. 2018, A&A, 612, A91
Molnar, L. A., Van Noord, D. M., Kinemuchi, K., et al. 2017, ApJ, 840, 1
Nelson, R. H., Şenavci, H. V., Baştürk, Ö., & Bahar, E. 2014, NewA, 29, 57
Nelson, R. H., & Robb, R. M. 2015, IBVS, 6134, 1
O' Connell, D. 1951, MNRAS, 111, 642
Oh, K. D., Kim, C. H., Kim, H. I., & Lee, W. B. 2007, in ASP Conf. Ser. 362, The Seventh Pacific Rim Conference on Stellar Astrophysics, ed. Y. W. Kang et al. (San Francisco, CA: ASP), 82
Ostadnezhad, S., Delband, M., & Hasanzadeh, A. 2014, NewA, 31, 14
Özkardeş, B., & Erdem, A. 2012, NewA, 17, 143
Pagel, L. 2022, AIAAJ, 60, 1
Paki, E., & Poro, A. 2024, Ap, 67, 316
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., et al. 2017, AJ, 154, 260
Pogson, N. 1856, MNRAS, 17, 12
Poro, A., Hedayatjoo, M., Nastaran, M., et al. 2024b, NewA, 110, 102227
Poro, A., Paki, E., Alizadehsabegh, A., et al. 2024c, RAA, 24, 015002
Poro, A., Tanriver, M., Michel, R., & Paki, E. 2024a, PASP, 136, 024201
Prša, A., Conroy, K. E., Horvat, M., et al. 2016, ApJS, 227, 29
Qian, S. B., Yang, Y. G., Soonthornthum, B., et al. 2005, AJ, 130, 224
Rovithis-Livaniou, H., Rovithis, P., & Bitzaraki, O. 1992, Ap&SS, 189, 237
Rucinski, S. 1969, AcA, 19, 245
Sarotsakulchai, T., Qian, S. B., Soonthornthum, B., et al. 2018, AJ, 156, 199
Sarotsakulchai, T., Qian, S.-B., Soonthornthum, B., et al. 2019, PASJ, 71, 34
Selam, S. O., Esmer, E. M., Şenavcı, H. V., et al. 2018, Ap&SS, 363, 34
Şenavcı, H. V., Doğruel, M. B., Nelson, R. H., Yılmaz, M., & Selam, S. O. 2016, PASA, 33, e043
Şenavcı, H. V., Nelson, R. H., Özavcı, İ, Selam, S. O., & Albayrak, B. 2008, NewA, 13, 468
Sun, W., Chen, X., Deng, L., & de Grijs, R. 2020, ApJS, 247, 50
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
Tian, X.-M., Zhu, L.-Y., Qian, S.-B., Li, L.-J., & Jiang, L.-Q. 2018, RAA, 18, 020
Torres, G. 2010, AJ, 140, 1158
Ulaş, B., & Ulusoy, C. 2014, NewA, 31, 56
Yakut, K., & Eggleton, P. P. 2005, ApJ, 629, 1055
Yang, Y., & Liu, Q. 2003, AJ, 126, 1960
Yang, Y. G., Qian, S. B., Zhang, L. Y., Dai, H. F., & Soonthornthum, B. 2013, AJ, 146, 35
Yang, Y. G., Qian, S. B., & Zhu, C. H. 2004, PASP, 116, 826
Yildirim, M. F., Aliçavuş, F., & Soydugan, F. 2019, RAA, 19, 010
Zhang, X.-D., & Qian, S.-B. 2020, MNRAS, 497, 3493

Zola, S., Gazeas, K., Kreiner, J. M., et al. 2010, MNRAS, 408, 464
Zola, S., Kreiner, J. M., Zakrzewski, B., et al. 2005, AcA, 55, 389
Zola, S., Rucinski, S. M., Baran, A., et al. 2004, AcA, 54, 299

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