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The first light curve analysis of marginally eclipsed binary KZ Vir using TESS data

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Abstract. In this study, we present the first analysis of the light curve of the eclipsing binary KZ Vir. The light curve of KZ Vir were obtained from the TESS database, while radial velocity measurements were taken from the literature. By utilizing simultaneous light and radial velocity curve analysis, we determined the absolute parameters of the system and discussed the evolutionary status of its components. Our analysis revealed that the orbital inclination of the KZ Vir system is $i \sim 57^{\circ}$, and it exhibits marginal eclipses.

Key words: binaries: close – binaries: eclipsing – stars: individual (KZ Vir) – stars: fundamental parameters

1. Introduction

Binary stars play a crucial role in stellar astrophysics. Through simultaneous analysis of light and radial velocity curves, key parameters (e.g., orbital inclination, masses, radii, and temperatures of the component stars) can be determined. These parameters are essential for providing reliable data for statistical studies of both single and binary stars, enabling more accurate predictions about stellar structure and evolution.

KZ Vir (HD 114726) was first noticed by Bond (1976) to exhibit light variation; however, due to its low light variation amplitude ($0^m.05$), its period and light curve could not be determined. The spectral type of the system was identified as F3V (Houk & Swift, 1999), and it was classified as a suspected eclipsing binary based on HIPPARCOS observations Kazarovets et al. (1999). The first radial velocity study in the literature was performed by Rucinski et al. (2001) and the spectroscopic mass ratio of the system was determined as 0.848(8). This study also emphasized that the system is unlikely to be a contact binary and that both components may be distorted detached stars. They attributed the low

light variation amplitude to the system's low orbital inclination. Although light curves of KZ Vir obtained from various survey missions such as HIPPARCOS (ESA, 1997), ASAS (Pojmanski, 2002), ASAS-SN (Jayasinghe et al., 2018) and MASCARA (Burggraaff et al., 2018) exist in the literature, the nature of its variability has not been fully understood due to the low amplitude of brightness variation. However, thanks to the high-precision data provided by the TESS space telescope, a detailed light curve analysis can be performed.

2. Data and analyses

The TESS light curves used in this study were obtained from the MAST database, and the radial velocity data were taken from Rucinski et al. (2001). We conducted a simultaneous analysis of KZ Vir's light and radial velocity curves using the PyWD2015 code (Güzel & Özdarcan, 2020), which was developed in Python and is based on the 2015 version of the Wilson-Devinney (WD) code (Wilson & Devinney, 1971) with a graphical user interface (GUI).

During the analyses with PyWD2015, Mode-2 for detached systems was used, as suggested by Rucinski et al. (2001) and Avvakumova & Malkov (2014). The effective temperature of the primary component was fixed to $T_1 = 6436$ K, as provided by Schofield et al. (2019), which was derived from color-temperature relationships using dereddened (B-V) colors and validated against spectroscopic temperatures from the PASTEL catalog (Soubiran et al., 2016), as well as interferometric and asteroseismic data. The gravity darkening and the albedo coefficients were set to 0.32 and 0.5, respectively. The limb darkening coefficients were interpolated automatically from the van Hamme (1993) tables under the linear-cosine law assumption. We adjusted the effective temperature of the secondary component (T_2), orbital inclination (i), surface potential of components (Ω_1, Ω_2), the system mass ratio (q), the luminosity of the primary component (L_1), semi-major axis (a), and the gamma velocity (V_γ) during the simultaneous analysis. Due to the time difference between the radial velocity data and the light curve data, both datasets were phased using different ephemeris, as given in Rucinski et al. (2001) and Prša et al. (2022), respectively.

3. Results and discussion

The radial velocity and light curve analyses are presented in Fig. 1, illustrates the Roche geometry of the system and the graphic representation of the model in Fig. 2, illustrates the evolutionary status of the components in Fig. 3. The obtained parameters are listed in Table 1.

Both components are slightly evolved, but the primary component is more evolved. This situation explains the low light variation outside of eclipses, which is attributed to the distortion of the primary component (see Fig. 2 left panel.

Also, as can be seen in the right panel of Fig. 2, a marginal eclipse occurs with only a slight occultation of the primary component.

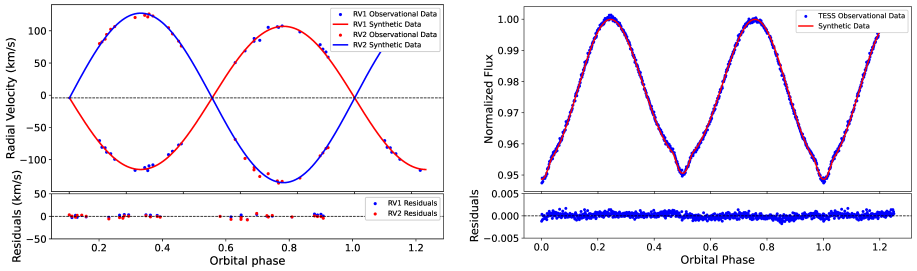

Figure 1. The left panel shows RV curves of the KZ Vir system (red and blue dots) and RV fits with PyWD2015 (red and blue lines), right panel shows LC curves from TESS of the KZ Vir system (blue dots) and LC fits with PyWD2015 (red line).

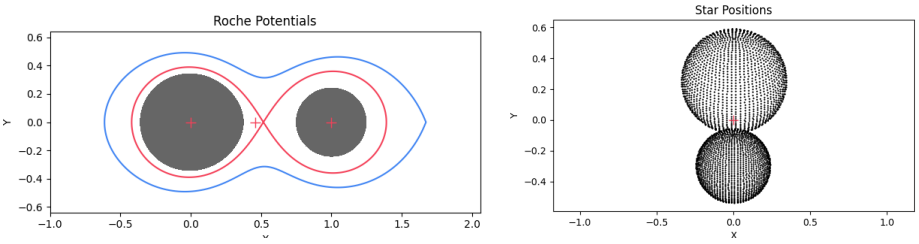

Figure 2. The left panel illustrates the Roche geometry of the system, and the right panel presents a 3D visualization of the stellar components at phase 0.0.

Table 1. Results from the light curve analysis (with formal errors from the WD code) and the absolute parameters of KZ Vir.

Parameter	Value	Parameter	Value
i [°]	56.69 ± 0.78	M_1 [$M_\odot$]	1.59 ± 0.03
a [$R_\odot$]	6.537 ± 0.028	M_2 [$M_\odot$]	1.35 ± 0.04
V_γ [km/s]	-4.18 ± 0.41	R_1 [$R_\odot$]	2.24 ± 0.01
$q = M_2/M_1$	0.850 ± 0.003	R_2 [$R_\odot$]	1.58 ± 0.02
T_1 [K]	6436	L_1 [$L_\odot$]	7.72 ± 0.09
T_2 [K]	6471 ± 10	L_2 [$L_\odot$]	3.94 ± 0.11
Ω_1	3.840 ± 0.006	$\log g_1$ [cgs]	3.938 ± 0.003
Ω_2	4.620 ± 0.017	$\log g_2$ [cgs]	4.168 ± 0.004

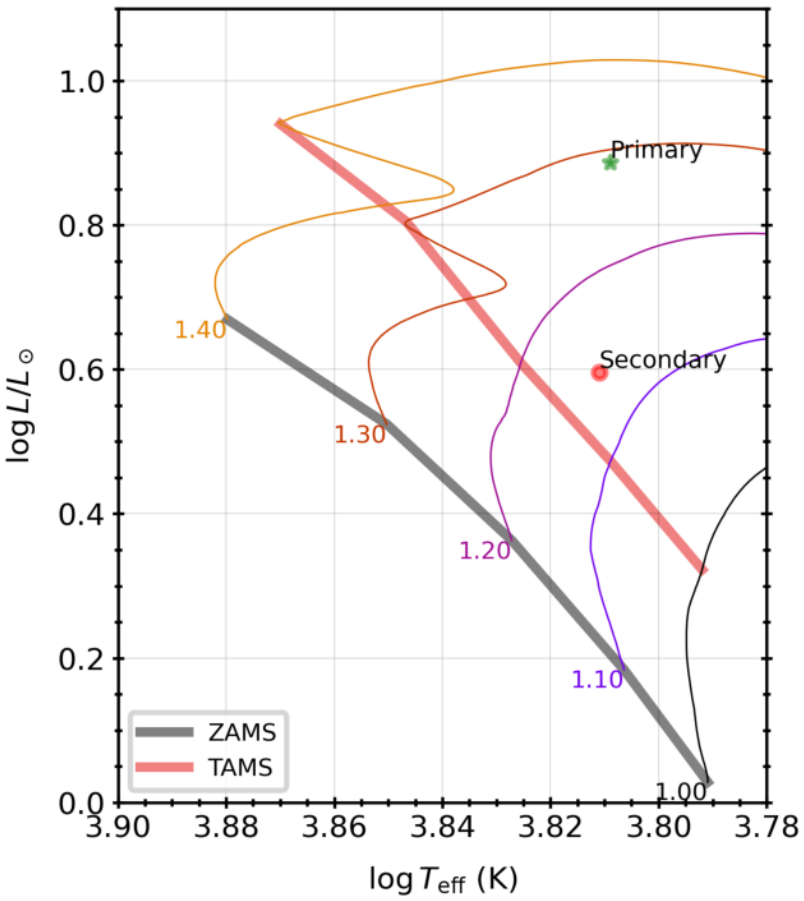

Figure 3. The positions of the components of KZ Vir on H–R diagram ($\log T_{\rm eff}$ - $\log L/L_\odot$). The green star shape and red dot represent the primary and secondary components, respectively.

References

Avvakumova, E. A. & Malkov, O. Y., Assessment of evolutionary status of eclipsing binaries using light-curve parameters and spectral classification. 2014, *Monthly Notices of the RAS*, **444**, 1982, DOI:10.1093/mnras/stu1572

Bond, H. E., Eclipsing Binaries Found Spectroscopically III. HD 199497. 1976, *Information Bulletin on Variable Stars*, **1214**, 1

Burggraaff, O., Talens, G. J. J., Spronck, J., et al., Studying bright variable stars with the Multi-site All-Sky CAmeRA (MASCARA). 2018, *Astronomy and Astrophysics*, **617**, A32, DOI:10.1051/0004-6361/201833142

ESA, ed. 1997, ESA Special Publication, Vol. **1200**, *The HIPPARCOS and TYCHO catalogues. Astrometric and photometric star catalogues derived from the ESA HIPPARCOS Space Astrometry Mission*

Güzel, O. & Özdarcan, O., PyWD2015 - A new GUI for the Wilson-Devinney code. 2020, *Contributions of the Astronomical Observatory Skalnate Pleso*, **50**, 535, DOI:10.31577/caosp.2020.50.2.535

Houk, N. & Swift, C., Michigan catalogue of two-dimensional spectral types for the HD Stars, Vol. 5. 1999, *Michigan Spectral Survey*, **5**, 0

Jayasinghe, T., Kochanek, C. S., Stanek, K. Z., et al., The ASAS-SN catalogue of variable stars I: The Serendipitous Survey. 2018, *Monthly Notices of the RAS*, **477**, 3145, DOI:10.1093/mnras/sty838

Kazarovets, E. V., Samus, N. N., Durlevich, O. V., et al., The 74th Special Name-list of Variable Stars. 1999, *Information Bulletin on Variable Stars*, **4659**, 1

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

Prša, A., Kochoska, A., Conroy, K. E., et al., TESS Eclipsing Binary Stars. I. Short-cadence Observations of 4584 Eclipsing Binaries in Sectors 1-26. 2022, *Astrophysical Journal, Supplement*, **258**, 16, DOI:10.3847/1538-4365/ac324a

Rucinski, S. M., Lu, W., Mochnacki, S. W., Ogłoza, W., & Stachowski, G., Radial Velocity Studies of Close Binary Stars. V. 2001, *Astronomical Journal*, **122**, 1974, DOI:10.1086/323106

Schofield, M., Chaplin, W. J., Huber, D., et al., The Asteroseismic Target List for Solar-like Oscillators Observed in 2 minute Cadence with the Transiting Exoplanet Survey Satellite. 2019, *Astrophysical Journal, Supplement*, **241**, 12, DOI:10.3847/1538-4365/ab04f5

Soubiran, C., Le Campion, J.-F., Brouillet, N., & Chemin, L., The PASTEL catalogue: 2016 version. 2016, *Astronomy and Astrophysics*, **591**, A118, DOI:10.1051/0004-6361/201628497

van Hamme, W., New Limb-Darkening Coefficients for Modeling Binary Star Light Curves. 1993, *Astronomical Journal*, **106**, 2096, DOI:10.1086/116788

Wilson, R. E. & Devinney, E. J., Realization of Accurate Close-Binary Light Curves: Application to MR Cygni. 1971, *Astrophysical Journal*, **166**, 605, DOI:10.1086/150986