Contrib. Astron. Obs. Skalnaté Pleso **55/3**, 517 – 520, (2025)
https://doi.org/10.31577/caosp.2025.55.3.517

Photometric and spectroscopic analysis of the eccentric eclipsing binary BD+72 780

M. Yılmaz[1,2], İ. Özavcı[1], E. Bahar[1], H.V. Şenavcı[1] and B.S. Azizoglu[2]

[1] *Ankara University, Department of Astronomy and Space Sciences, TR-06100, Tandogan, Ankara, Türkiye (E-mail: mesutyilmaz@ankara.edu.tr)*

[2] *Ankara University, Astronomy and Space Sciences Research and Application Center (Kreiken Observatory), TR-06837, Ahlatlıbel, Ankara, Türkiye*

Received: October 18, 2024; Accepted: January 9, 2025

Abstract. In this study, we present the first radial velocity measurements of the eclipsing binary BD+72 780. We simultaneously modeled TESS light curves with our radial velocity data to derive the orbital and absolute parameters of the system. The analysis shows that the system is a detached binary with two different spectral types of components, and the orbit is slightly eccentric ($e \sim 0.07$).

Key words: stars – eclipsing binary – radial velocity

1. Introduction

Close binary stars allow us to accurately determine stellar masses through simultaneous spectroscopic and photometric analyses. These analyses also provide other fundamental parameters such as orbital inclination, eccentricity, semi major-axis, radii and luminosity, which help us better understand binary star evolution. These parameters are also essential for providing reliable data for statistical studies of both single and binary stars.

The literature on the BD+72 780 system (TIC 441739153, α: 17h 17m 42.16s, δ: $+72^\circ\ 06'\ 09.72''$) is quite sparse and limited. The orbital period is obtained to be 3.21 days (Shi et al., 2022) and the spectral type is derived as A2 (Cannon & Pickering, 1993). The first light curve characteristic was determined by Prša et al. (2022) based on morphological classification of the light curves. According to these results, this system reported as detached eclipsing binary.

In this context, we investigate the spectroscopic and photometric properties of the eclipsing binary systems BD+72 780 to derive physical and orbital characteristics.

2. Observations

We collected the TESS data of BD+72 780 from the MAST Portal. The system was observed from sectors 14 to 26 of the TESS observations in short cadence (2-min) mode. During the light curve analysis we used the data from sector 15. Photometry was performed by SPOC pipeline (Jenkins et al., 2016) and we used PDCSAP-FLUX data during the simultaneous light and radial velocity curve analysis. We also checked photometric apertures for light/background contamination if exists or not.

Spectroscopic observations of the system were performed using the Whopp-shel echelle spectrograph attached to the T80 telescope at the Ankara University Kreiken Observatory (AUKR). We obtained 13 spectra of BD+72 780 between March 25 and December 10, 2023, using the exposure time of 1800 s. Our spectra cover a wavelength range from 3950 Å to 7400 Å with a mean spectral resolution of R ˜ 14000. The average SNR values of the data vary between 50 and 80, which is sufficient to obtain the radial velocities of both components of BD+72 780. The radial velocity measurements of the system were carried out by broadening functions routine (Rucinski, 1992).

3. Analysis and Results

We simultaneously analysed the light and radial velocity curves of the eclipsing binary BD+72 780 using the PyWD2015 code (Güzel & Özdarcan, 2020), which is a graphical user interface (GUI) that is based on the 2015 version of the Wilson–Devinney (WD) code (Wilson & Devinney, 1971). We assumed the system as an detached binary and therefore selected Mode-2 in PyWD2015. We adjusted the orbital inclination (i), semi-major axis (a), eccentricity (e), mass ratio (q), center of mass velocity (V_γ), temperature of the secondary component (T_2), surface potentials (Ω_1, Ω_2), and luminosity of the primary (L_1); while fixing the temperatures of the primary component (T_1) as constant values according to their spectral types. We also fixed the albedo and the gravity brightening parameters to based on the assumed natures of the system. Since there is a slight difference between the maxima levels on phases 0.25 and 0.75 of the light curve of BD+72 780, we assumed one stellar cool spot available on the secondary component during the iterations.The observed light and radial data, and best model fits as well as their residuals are given in Figs. 1. The geometric representations of BD+72 780 are also illustrated bottom in Figs. 1. The parameters obtained from the simultaneous light and radial velocity curve modelling as well as the absolute parameters are summarized in Table 1.

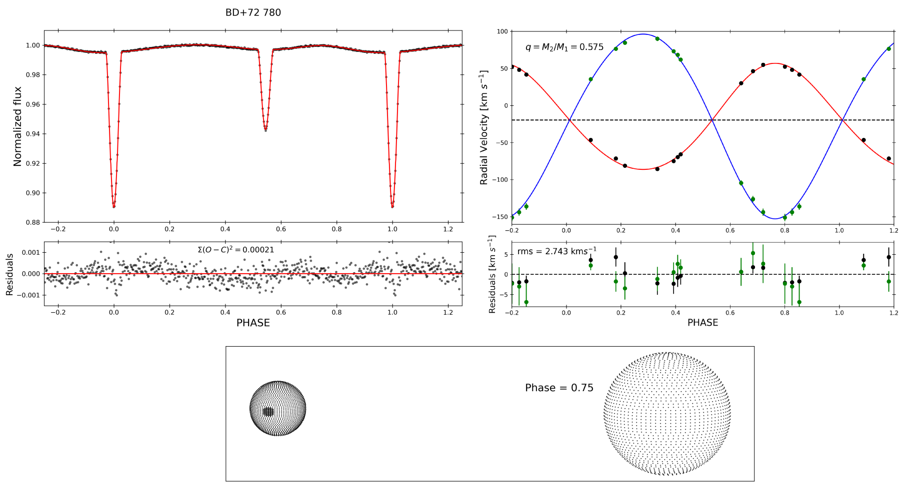

Figure 1. Phase-folded TESS light from Sector 15 and radial velocity curve of BD+72 780 as well as the best model fits (solid lines) obtained using Mode-2. The panels below shows the residuals from the theoretical models and bellow the geometric model of the system is given for phase 0.75.

Table 1. Results from the light and radial curve analysis.

Parameter	**Value**	**Parameter**	**Value**
i [°]	81.75 ± 0.04	M_1 $[M_\odot]$	2.02 ± 0.02
a $[R_\odot]$	13.325 ± 0.136	M_2 $[M_\odot]$	1.05 ± 0.07
e	0.074 ± 0.001	R_1 $[R_\odot]$	2.06 ± 0.05
ω [°]	10.47 ± 0.02	R_2 $[R_\odot]$	0.94 ± 0.05
V_γ [km/s]	-21.77 ± 0.80	L_1 $[L_\odot]$	11.651 ± 0.008
$q = M_2/M_1$	0.515 ± 0.005	L_2 $[L_\odot]$	0.925 ± 0.009
T_1 [K]	7894	ϕ [°]	90.0
T_2 [K]	5522 ± 124	λ [°]	255.88 ± 0.58
Ω_1	7.006 ± 0.023	θ [°]	14.18 ± 0.57
Ω_2	8.858 ± 0.036	T_{sp}/T_2	0.676 ± 0.008

4. Conclusions

In this study, TESS light curves and first ground based spectroscopic observation of the eclipsing binary BD+72 780 were simultaneously analysed using the WD code. The orbital and absolute parameters of the system first time obtained in this study. According to the Mode 2 solutions, the system is detached, and each component has not yet filled its inner Roche lobe. The absolute parameters obtained in the study are given in Table 1. The present analysis showed that one spot located on the secondary component is needed to fit light curves. The effective temperature of the secondary significantly lower than that of the primary. Therefore, its contribution to the total system light is less than 1%. Hence, spotted area on the secondary leads to comparatively small photometric effect. The solution also shows that the system has an orbit with a slightly low eccentricity ($e \sim 0.07$).

Acknowledgements. The data in this study were obtained with the T80 telescope at the Ankara University Astronomy and Space Sciences Research and Application Center (Kreiken Observatory) with project number of 23A.T80.01. The TESS data presented in this paper were obtained from the Mikulski Archive for Space Telescopes (MAST) at the Space Telescope Science Institute (STScI). This paper includes data collected by the TESS mission. Funding for the TESS mission is provided by the NASA's Science Mission Directorate.

References

Cannon, A. J. & Pickering, E. C. 1993, VizieR Online Data Catalog: Henry Draper Catalogue and Extension (Cannon+ 1918-1924; ADC 1989), VizieR On-line Data Catalog: III/135A. Originally published in: Harv. Ann. 91-100 (1918-1924)

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

Jenkins, J. M., Twicken, J. D., McCauliff, S., et al., The TESS science processing operations center. 2016, **9913**, 99133E, DOI:10.1117/12.2233418

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., Spectral-Line Broadening Functions of WUMa-Type Binaries. I. AW UMa. 1992, *Astronomical Journal*, **104**, 1968, DOI:10.1086/116372

Shi, X.-d., Qian, S.-b., & Li, L.-J., New Pulsating Stars Detected in EA-type Eclipsing-binary Systems Based on TESS Data. 2022, *Astrophysical Journal, Supplement*, **259**, 50, DOI:10.3847/1538-4365/ac59b9

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