# Pulsating EL Cvn system

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## Introduction

The EL CVn-type systems are eclipsing binaries consisting of an A- or F-type main sequence (MS) star and a low-mass helium white dwarf [1,2]. The EL CVn-type binaries gained attention with the discovery of 17 helium white dwarf precursors [1]. Further studies found that these variables contain oscillating components. [3] first observed multi-periodic pulsations in the He WD companion of WASP 0247-10, marking a significant milestone in understanding EL CVn-type binaries. Several studies suggest that not only pre-He WD companions but also MS companions could exhibit pulsation behavior [4,5]. Since these initial discoveries, the number of EL CVn-type stars has steadily increased, aided by the analysis of their characteristic light curves. Given that EL CVn binaries contain a low-mass helium white dwarf and may exhibit multi-periodic pulsations, they serve as significant targets for comprehending the structure and formation of white dwarf stars. Therefore, in this study, we present the comprehensive photometric and spectroscopic analysis of TIC 469979014 which is one of the EL CVn-type binary and its $\delta$ Scuti-type pulsations were uncovered by [6]. The orbital elements of the system were derived with the analysis of radial velocity changes. The atmospheric parameters and chemical abundances of the pulsating component were estimated. The pulsational structure of TIC 469979014 was examined as well.

## Spectroscopic studies

The spectra of TIC 469979014 were gathered from ESO Science Archive Facility[a]. TIC 469979014 has fourhteen spectra taken with the Ultraviolet and Visual Échelle Spectrograph (UVES, R∼40 000 − 115 000) [7]. UVES provides spectra in different wavelength ranges which are called blue and red arms. In our analysis, we preferred to use spectra taken with the blue arm as in that part of spectra there are more lines that would be useful for the spectroscopic analysis. The signal-to-noise ratio of the spectra varied from around 50 to 90; on average, its value is ∼65. The blue arm observations of TIC 469979014 were taken with around 50 000 resolving power in the 328.2-456.3 nm wavelength range between May and July 2014.

### Radial velocity analysis

To calculate the radial velocity ($v_r$) variation the FXCOR task of IRAF program [8] was considered. In our $v_r$ estimation we utilized a synthetic spectrum as a template. This synthetic spectrum was generated using the local thermodynamic equilibrium ATLAS9 model [9] and SYNTHE code [10] considering the estimated effective temperature ($T_{\mathrm{eff}}$) values of the binary components in the study of [1]. The $v_r$ measurements were subsequently examined utilizing the `rvfit` software[b]. The consistency between the theoretical and observational $v_r$ changes is shown in Fig. 1. The result of the analysis is given in Table 1.

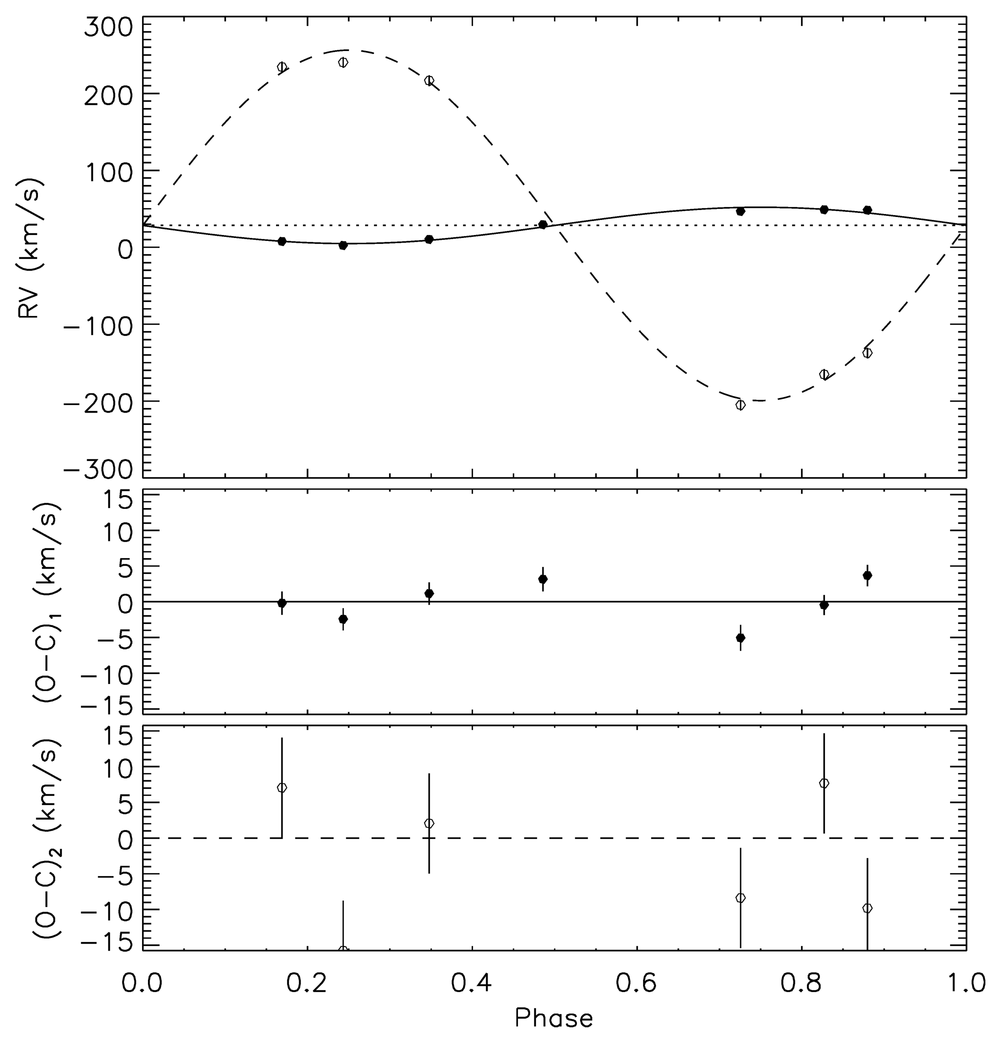


Figure 1. The theoretical $v_r$ curve fit for the measured $v_r$ values (upper panel) and the residuals (O-C) (middle and lower panels). The subscripts "1" and "2" represent the primary (more luminous star) and the secondary components, respectively.

Table 1. The result of $v_r$ analysis of TIC 469979014. The subscripts "1" and "2" represent the primary (more luminous star) and the secondary components, respectively.

| Parameters | Value |
|---|---|
| $P_{orb}$ (d) | 1.16260± 0.0004 |
| $T_0$ (HJD) | 2458000.1872 ± 0.0041 |
| $e$ | 0 |
| $\omega$ (deg) | 90 |
| $V\gamma$ (km/s) | 28.37 ± 0.58 |
| $K_1$ (km/s) | 23.63 ± 0.74 |
| $K_2$ (km/s) | 228.29 ± 2.96 |
| $M_1 \sin^3 i$ ($M_\odot$) | 1.74 ± 0.06 |
| $M_2 \sin^3 i$ ($M_\odot$) | 0.18 ± 0.08 |
| $q = M_2/M_1$ | 0.103 ± 0.003 |
| $a_1 \sin i$ ($R_\odot$) | 0.54 ± 0.02 |
| $a_2 \sin i$ ($R_\odot$) | 5.24 ± 0.07 |

### Determination of atmospheric parameters

We employed the ATLAS9 model [9] and SYNTHE code [10] in the examination. During the primary total eclipse, the pre-helium white dwarf is obscured by the main-sequence star. Thus, a spectrum obtained during the total eclipse can be utilized to estimate the atmospheric parameters of the main-sequence star. Consequently, we analyzed the spectrum taken around the primary eclipse following the same methods as [11]. The estimated parameters are listed in Table 2.

Table 2. The results of the spectroscopic analysis of the main sequence component of TIC 469979014.

| $T_{\mathrm{eff}}$ (K) | $\log g$ (cgs) | $\xi$ (km s$^{-1}$) | $v \sin i$ (km s$^{-1}$) | $\log \epsilon$ (Fe) |
|---|---|---|---|---|
| 7500 ± 200 | 4.0 ± 0.2 | 2.5 ± 0.2 | 86 ± 3 | 7.04 ± 0.17 |

[a]http://archive.eso.org/cms.html
[b]http://www.cefca.es/people/riglesias/rvfit.html

## Photometric studies

The TESS photometric data of TIC 469979014 were taken in five distinct sectors (1, 27, 28, 76). The 120-second TESS data were gathered from the Milkuski Archive for Space Telescopes (MAST)[a] in SAP flux and used in the study.

### Binary modelling

For the binary modeling, we used the well-known binary modeling code of Wilson-Devinney (W-D) [12] that combined with Monte Carlo simulation [13]. We fixed $T_{\mathrm{eff}}$ and $q$ parameters in addition to the bolometric albedos [14], the bolometric gravity-darkening coefficient [15], and the logarithmic limb darkening coefficient [16] during the modeling. The result of the analysis is listed in Table 3 and the consistency between the binary model and observation is demonstrated in Fig. 2.

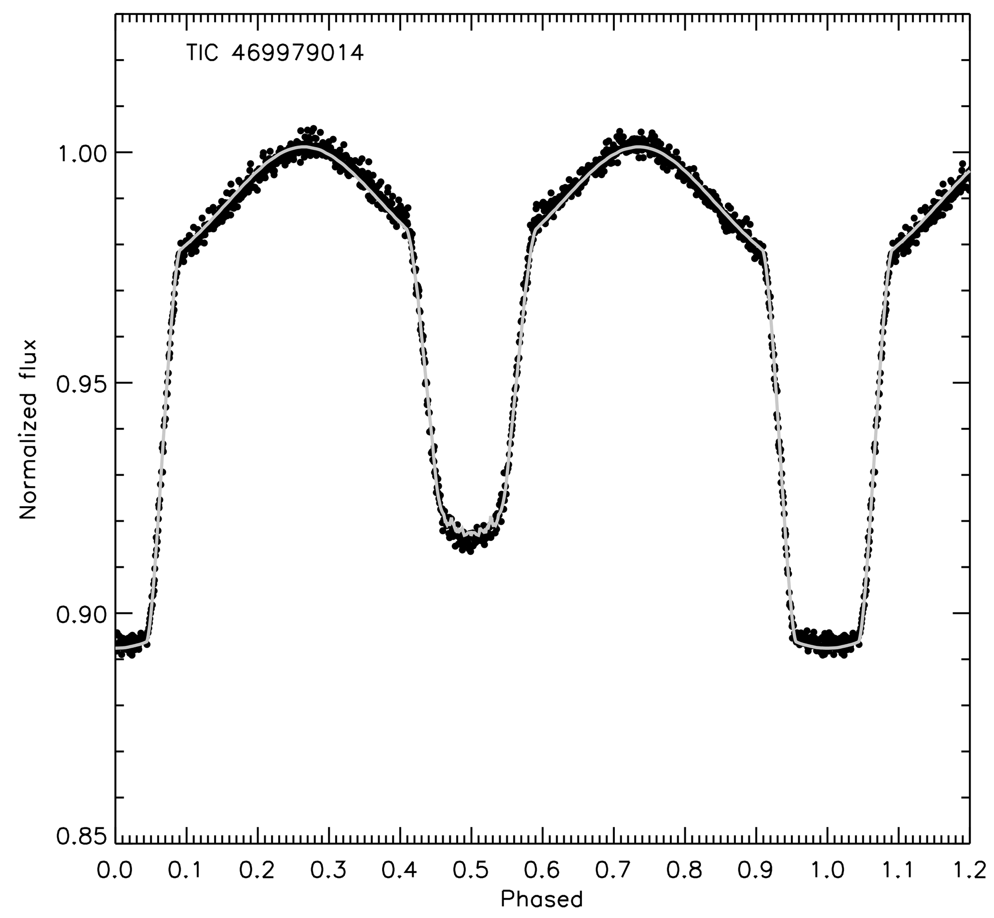


Figure 2. Theoretical binary model (gray solid line) fitted to the phase-folded, binned observational data (dots).

Table 3. Results of the binary modeling and the fundamental stellar parameters. The subscripts 1, 2 and 3 represent the primary, secondary, and third binary components, respectively. * shows the fixed parameters.

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| $i$ ($^o$) | 78.22 ± 0.05 | $M_1$ ($M_\odot$) | 2.21 ± 0.01 |
| $T_1$* (K) | 7500 ± 200 | $M_2$ ($M_\odot$) | 0.23 ± 0.01 |
| $T_2$ (K) | 8420 ± 240 | $R_1$ ($R_\odot$) | 2.86 ± 0.02 |
| $\Omega_1$ | 18.826 ± 0.014 | $R_2$ ($R_\odot$) | 0.69 ± 0.01 |
| $\Omega_2$ | 18.682 ± 0.009 | log ($L_1/L_\odot$) | 1.37 ± 0.05 |
| Phase shift | -0.0002 ± 0.0001 | log ($L_2/L_\odot$) | 0.34 ± 0.01 |
| $q$* | 0.103 ± 0.003 | $\log g_1$ (cgs) | 3.86 ± 0.02 |
| $r_1$ (mean) | 0.4566 ± 0.0027 | $\log g_2$ (cgs) | 4.11 ± 0.07 |
| $r_2$ (mean) | 0.1108 ± 0.0008 | $M_{bolo1}$ (mag) | 1.32 ± 0.04 |
| $L_1$ / ($L_1$+$L_2$) | 0.92 ± 0.002 | $M_{bolo2}$ (mag) | 3.89 ± 0.06 |
| $L_2$ /($L_1$+$L_2$) | 0.08 ± 0.002 | $M_{V1}$ (mag) | 1.27 ± 0.02 |
| $l_3$ | 0.0 | $M_{V2}$ (mag) | 3.92 ± 0.03 |
| Distance (pc) | 1814 ± 51 | | |

### Pulsation analysis

The Period04 program [17] and all TESS data of TIC 469979014 were used in the analysis. The highest amplitude frequency of the system was obtained to be 22.1814 d$^{-1}$ which shows that the main sequence component of the system is a $\delta$ Scuti variable. The amplitude spectrum of the system is shown in Fig. 3.

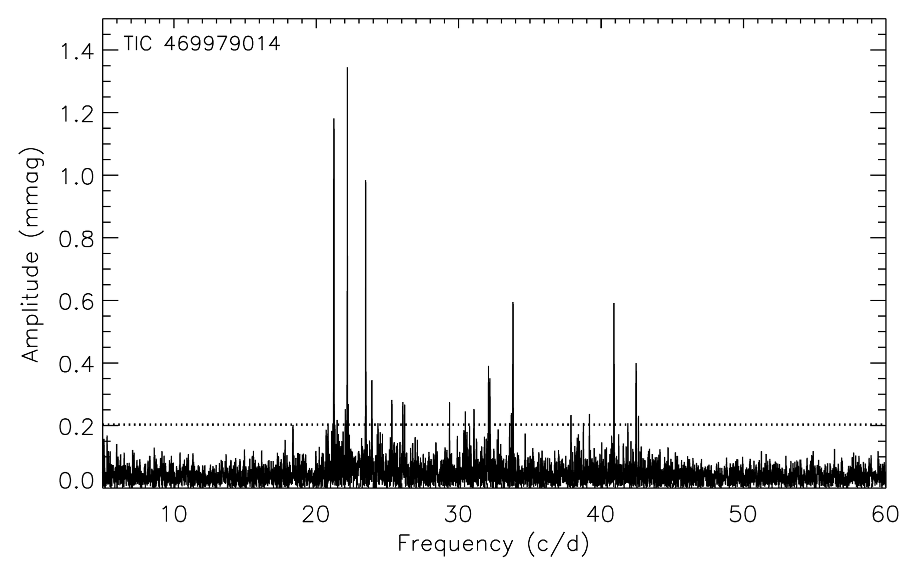


Figure 3. Amplitude spectrum of the pulsating component of TIC 469979014.

## Conclusions

With this study, for the first time, the detailed investigation of TIC 469979014 is given. It is binarity, atmospheric, and pulsational structures were obtained. As a future investigation, we plan to examine the evolutionary status and understand the nature of the system.

## References

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