

A Puzzling Eclipsing Binary: KZ Virginis

S.H. Gürsoytrak–Mutlay and B. Gürol

Ankara University, Faculty of Science, Astronomy & Space Sciences Department,
Tandoğan, TR-06100, Ankara, Türkiye*Received February 13, 2024***ABSTRACT**

We present Transiting Exoplanet Survey Satellite (TESS) light curve analysis of KZ Vir. The TESS observations of KZ Vir were published in a total of three Sectors. TESS observations show some features that could not be observed with ground-based telescopes before. We refined the light elements of the system by using the times of minima found in the literature and the times observed with TESS. The TESS light curve was analyzed with the Wilson-Devinney code including geometric and physical parameters of the components obtained using published radial velocity data. We confirmed for the first time that the system is essentially a detached type eclipsing binary and obtained masses and radii of the primary and the secondary components: $M_1 = 1.596 \pm 0.022 M_\odot$, $M_2 = 1.319 \pm 0.019 M_\odot$ and $R_1 = 2.271 \pm 0.011 R_\odot$, $R_2 = 1.603 \pm 0.008 R_\odot$, respectively. We find that the components of KZ Vir are located above or on the TAMS.

Key words: *binaries: eclipsing – Stars: fundamental parameters – Stars: individual: KZ Vir – Methods: data analysis*

1. Introduction

KZ Vir (HD 114726, TIC 366786599, $V = 8.36$ mag, $\alpha_{2000} = 13^{\text{h}}12^{\text{m}}22^{\text{s}}.87$, $\delta_{2000} = 02^{\circ}39'13''.79$) is classified as a Spectroscopic Binary in the Simbad database and the spectral type and distance of the system are given as F3V (Houk and Swift 1999) and 177 pc (Gaia Collaboration *et al.* 2020), respectively. The system was first observed photoelectrically by Bond (1976) but no periodic variation could be obtained in the magnitude range of 0.05. In the Henry Draper Catalogue (Cannon and Pickering 1993), the spectral type of the system was given as F2.

The first light variation of KZ Vir was obtained by the Hipparcos satellite. The Hipparcos Catalog (Perryman *et al.* 1997) lists the following properties for this target: $V = 8.36$ mag, $\text{Amp} = 0.072$ mag, $(B - V) = 0.467 \pm 0.017$ mag, $d = 153.14 \pm 21.83$ pc and the variability type – W UMa (EW) with the light elements of $\text{HJD}_{\text{MinI}} = 2448500.3165 + 1^{\text{d}}.1318200 \times E$.

Afterward, Rucinski *et al.* (2001) included the system in their study of radial velocity observations of close binary stars and determined the orbital parameters.

The parameters given for KZ Vir are the system's velocity of the center of mass, $V_\gamma = -4.50 \pm 0.48$ km/s, and semi-amplitude of the primary and secondary component, $K_1 = 111.40 \pm 0.77$ km/s and $K_2 = 131.34 \pm 0.87$ km/s, respectively. According to these data, the mass ratio and mass function of the system were given: $q(m_2/m_1) = 0.848 \pm 0.008$ and $(M_1 + M_2) \sin^3 i = 1.681 \pm 0.034 M_\odot$, respectively.

Rucinski *et al.* (2001) argued that for late spectral type (F7V) with a relatively long orbital period of 1.13 d, the mass ratio is not typical for most contact binaries and puts the system among the rare systems. It is mentioned in the same work that the system is a close, but detached binary.

Using the radial velocity data published by Rucinski *et al.* (2001), Pourbaix *et al.* (2004) derived the system's orbital parameters: $a_1 \sin i = 1.73379 \times 10^6$ km, $a_2 \sin i = 2.04413 \times 10^6$ km, $m_1 \sin^3 i = 0.911 \pm 0.014 M_\odot$, and $m_2 \sin^3 i = 0.773 \pm 0.012 M_\odot$ (SB9: Catalogue of Spectroscopic Binary Orbits¹).

In the catalog of field contact binary stars (Pribulla *et al.* 2003) the system is coded as *B* which indicates that the components are in physical but not in thermal contact and the orbital period is $P = 1.^d13183250$. Additionally, the system is coded as *CWA – CB* (Late-type contact A system or near-contact system of unknown subclass) in the catalog of eclipsing variables published by Avvakumova *et al.* (2013).

In the *O – C* Gateway² the system was classified as W UMa and the light elements obtained by using four times of minima were given:

$$\text{HJD}_{\text{MinI}} = 2448500.3165 + 1.13183 \times E. \quad (1)$$

We found four different photometric observations of the system in the databases like Hipparcos (ESA 1977), ASAS (Pojmański 2002), ASAS-SN (Jayasinghe *et al.* 2018), and MASCARA (Burggraaff *et al.* 2018) which are plotted in Fig. 1 with shifting in magnitude axis to see the light curves clear. As can be seen, all of the light curves obtained show small amplitude periodic variation that resembles W UMa type eclipsing binary with some scattering.

An additional light curve of KZ Vir, published by Wraight *et al.* (2011) by using observations of NASA's Stereo Observatory, showed small-amplitude periodic variation like plotted in Fig. 1. We could not access these observational data but in the table of statistics published by Wraight *et al.* (2011) for 263 eclipsing binaries, the spectral type and orbital period of KZ Vir given as F2 and 1.^d13180, respectively.

According to the random forest automated supervised classification of Hipparcos periodic variable stars the system is classified as W UMa by Dubath *et al.* (2011). Although it was considered as a W UMa-type eclipsing variable in many studies (*e.g.*, D'Angelo *et al.* 2006, Deb and Singh 2011, Evcil 2013³), it was understood that the star differs from systems showing similar light variation. Here, we show that KZ Vir is essentially a detached type system.

¹<https://sb9.astro.ulb.ac.be/mainform.cgi>

²<http://var2.astro.cz/ocgate/>

³Master's Thesis, <http://nek.istanbul.edu.tr:4444/ekos/TEZ/50593.pdf>

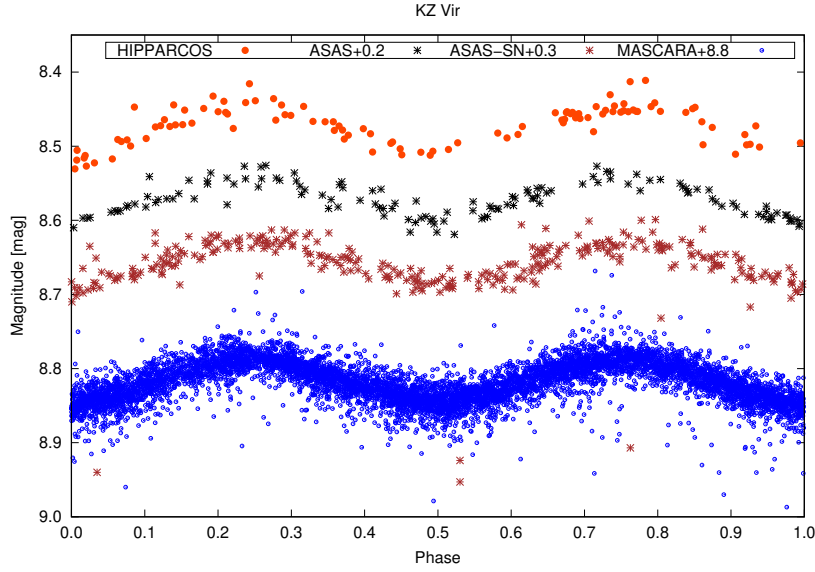


Fig. 1. Photometric observations of KZ Vir found in the Hipparcos, ASAS, ASAS-SN, and MASCARA databases. The phase values were obtained by using the light elements given in the *O – C* Gateway.

2. The TESS Data and Light Elements

The observations of KZ Vir were made by the Transiting Exoplanet Survey Satellite (TESS) (Ricker *et al.* 2015) at three sectors (23, 46 and 50). Each sector has ≈ 27.4 d of observations with nearly 2 min (SC: Short Cadence) exposure time. The TESS data are public in the MAST (Barbara A. Mikulski Archive for Space Telescopes⁴) archive. In this study, we prefer using the PDCSAP (pre-search data conditioning) data because the raw SAP (simple aperture photometry) data have extra scattering. A total of 48 206 observations of the system were obtained in approximately 763 d. The light elements of the system are given in the TESS Eclipsing Binary Catalog (Prša *et al.* 2022):

$$\text{BJD}_{\text{MinI}} = 2458930.130123(0.000058) + 1.1317802(0.0000621) \times E. \quad (2)$$

Upon examining Fig. 2, the system's light curve appears to exhibit a W UMa-type variation at first glance. But because of the high quality of the TESS data we see that especially at the primary and secondary minima, there are extra dips that cannot be seen in the ground based light curves (Fig. 1). The main variation seen in the light curve seems to be caused because of distortion of components and the extra dips are caused because of eclipse nature seen at low orbital inclinations. The depth of the minima seems to be around 0.008 mag in the TESS filter. With this

⁴<https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html>

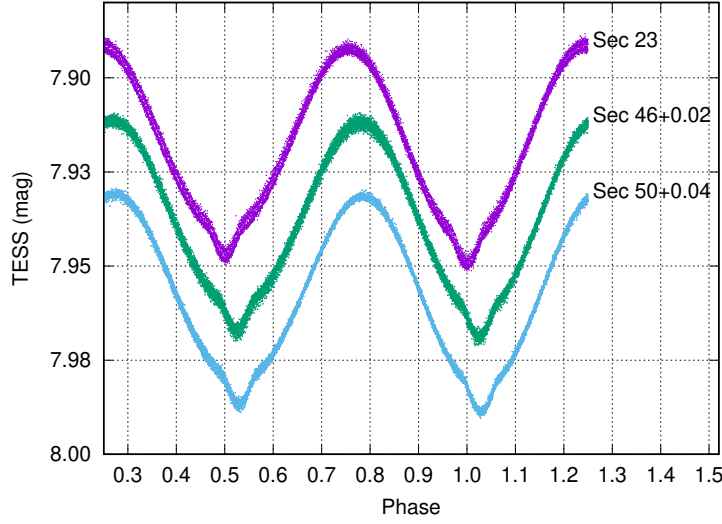


Fig. 2. Light curves of KZ Vir obtained by TESS. Magnitudes for different sectors are shifted by adding 0.02 mag relative to the previous sector. Phase values were obtained with the light elements given by Prša *et al.* (2022).

nature, we can confirm that the system is essentially a detached or semi-detached eclipsing binary. We see that Rucinski *et al.* (2001) correctly identified the system without knowing the real eclipse nature of the system.

Additionally, we see that the minima are shifted concerning each other using the light elements given above. First of all, we prefer to obtain new light elements of the system by using ($O - C$) analysis.

We obtained 63 primary and 61 secondary eclipse times. The eclipse times were calculated using the Minima27⁵ software published by Dr. Bob Nelson. In Table 1 we give the calculated minima times including the errors obtained with the same software. Additionally, we included the minimum times found in the literature. The minima times published in HJD converted to BJD using the algorithm published by Eastman *et al.* (2010)⁶. However, it should be noted here that the minimum times found in the literature are actually obtained by using the main light variation and do not exactly belong to the real eclipse times. Another interesting point is that although the system is bright enough, it has very few observations and minimum times in the literature.

By assuming the minima times obtained from literature are correct we obtained the ($O - C$) variation of the system as shown in Fig. 3. Using a linear fit to the ($O - C$) data and correcting the parameters we obtained new light elements:

$$\text{BJD}_{\text{MinI}} = 2458930.130422(0.000091) + 1.13182948(0.00000012) \times E. \quad (3)$$

⁵<https://www.variablestarssouth.org/resources/bob-nelsons-software-tools/software-by-bob-nelson>

⁶<https://astroutils.astronomy.osu.edu/time/hjd2bjd.html>

Table 1
The eclipse times of the KZ Vir system

No	Type	BJD (2450000+)	$\pm\sigma$	No	Type	BJD (2450000+)	$\pm\sigma$
1*	Min I	3110.26473	0.00090	63	Min II	9563.38906	0.00041
2**	Min I	5326.37879	0.00060	64	Min I	9563.95486	0.00011
3***	Min I	5687.44279	0.00300	65	Min II	9564.52092	0.00032
4	Min I	8928.99810	0.00020	66	Min II	9566.78470	0.00045
5	Min II	8929.56549	0.00019	67	Min I	9567.35072	0.00008
6	Min I	8930.13141	0.00044	68	Min II	9567.91627	0.00017
7	Min II	8930.69589	0.00043	69	Min I	9568.48292	0.00021
8	Min I	8931.26203	0.00027	70	Min II	9569.04861	0.00009
9	Min II	8931.82896	0.00005	71	Min I	9569.61385	0.00019
10	Min I	8932.39372	0.00013	72	Min II	9570.18046	0.00010
11	Min II	8932.96285	0.00037	73	Min I	9570.74618	0.00022
12	Min I	8933.52700	0.00056	74	Min II	9571.31272	0.00017
13	Min II	8934.09035	0.00481	75	Min I	9571.87729	0.00018
14	Min I	8934.65868	0.00154	76	Min II	9572.44381	0.00039
15	Min II	8935.22439	0.00259	77	Min I	9573.01001	0.00017
16	Min I	8935.78908	0.00175	78	Min II	9573.57551	0.00018
17	Min II	8936.35667	0.00013	79	Min I	9574.14106	0.00015
18	Min I	8936.92095	0.00015	80	Min II	9574.70820	0.00021
19	Min II	8937.48803	0.00031	81	Min I	9575.27305	0.00030
20	Min I	8938.05335	0.00030	82	Min II	9575.83898	0.00031
21	Min II	8938.61880	0.00030	83	Min I	9576.40572	0.00023
22	Min I	8939.18573	0.00005	84	Min II	9576.97082	0.00011
23	Min II	8939.75051	0.00083	85	Min I	9577.53710	0.00026
24	Min I	8940.31672	0.00031	86	Min II	9578.10304	0.00011
25	Min II	8942.01438	0.00033	87	Min I	9578.66851	0.00039
26	Min I	8943.71104	0.00048	88	Min I	9665.82056	0.00015
27	Min II	8944.27877	0.00016	89	Min II	9666.38659	0.00039
28	Min I	8945.97491	0.00029	90	Min I	9669.21497	0.00010
29	Min II	8946.54174	0.00083	91	Min II	9669.78067	0.00016
30	Min I	8947.10788	0.00022	92	Min I	9670.34691	0.00029
31	Min II	8947.67381	0.00026	93	Min II	9670.91294	0.00122
32	Min I	8948.24032	0.00021	94	Min I	9671.47837	0.00035
33	Min II	8948.80602	0.00028	95	Min II	9672.04323	0.00046
34	Min I	8949.37103	0.00108	96	Min I	9672.61045	0.00003
35	Min II	8949.93881	0.00015	97	Min II	9673.17664	0.00016
36	Min I	8950.50335	0.00006	98	Min I	9673.74218	0.00013
37	Min II	8951.06988	0.00009	99	Min II	9674.30814	0.00006
38	Min I	8951.63505	0.00028	100	Min I	9674.87478	0.00009
39	Min II	8952.20128	0.00026	101	Min II	9675.43955	0.00018
40	Min I	8952.76638	0.00031	102	Min I	9676.00520	0.00006

*Krajci (2005), **Liakos and Niarchos (2011), ***Cagas (2013). We excluded the minimum times obtained by Hipparcos data.

Table 1
Concluded

No	Type	BJD (2450000+)	$\pm\sigma$	No	Type	BJD (2450000+)	$\pm\sigma$
41	Min II	8953.33231	0.00012	103	Min II	9676.57127	0.00019
42	Min I	8953.89810	0.00029	104	Min I	9677.13820	0.00008
43	Min II	8954.46449	0.00038	105	Min II	9677.70376	0.00016
44	Min II	9552.06988	0.00031	106	Min I	9678.26941	0.00023
45	Min II	9553.20206	0.00029	107	Min I	9679.40044	0.00031
46	Min I	9553.76878	0.00015	108	Min II	9679.96765	0.00006
47	Min II	9554.33410	0.00011	109	Min I	9682.79677	0.00021
48	Min I	9554.90020	0.00017	110	Min II	9683.36257	0.00033
49	Min II	9555.46612	0.00063	111	Min I	9683.92886	0.00013
50	Min I	9556.03210	0.00014	112	Min II	9684.49438	0.00011
51	Min II	9556.59731	0.00020	113	Min I	9685.06011	0.00040
52	Min I	9557.16415	0.00035	114	Min II	9685.62696	0.00011
53	Min II	9557.72963	0.00033	115	Min I	9686.19187	0.00012
54	Min I	9558.29666	0.00020	116	Min II	9686.75824	0.00016
55	Min II	9558.86125	0.00006	117	Min I	9687.32384	0.00030
56	Min I	9559.42783	0.00012	118	Min II	9687.89063	0.00011
57	Min II	9559.99378	0.00023	119	Min I	9688.45536	0.00047
58	Min I	9560.55916	0.00017	120	Min II	9689.02258	0.00012
59	Min II	9561.12570	0.00033	121	Min I	9689.58753	0.00021
60	Min I	9561.69102	0.00018	122	Min II	9690.15493	0.00018
61	Min II	9562.25756	0.00016	123	Min I	9690.71964	0.00008
62	Min I	9562.82256	0.00035	124	Min II	9691.28563	0.00011

The absence of a permanent change in the $(O - C)II$ may indicate the stability of the system. For the rest of the calculation, we used the refined light elements obtained above.

3. Light Curve Analysis

To save the calculation time, we binned all observations for different sectors by averaging them at 0.001 phase intervals (Fig. 4). For the light curve analysis, we prefer to use the Wilson-Devinney code (2015 version to which the TESS band was added in 2019) which can solve light (and radial velocity) curves in magnitudes or in flux. The Wilson and Devinney method (Wilson and Devinney 1971, Wilson 1979, Wilson 1990) was applied to solve the light and radial velocity curves of the KZ Vir system.

In Table 2 we compiled effective temperature and distances published in different sources. Excluding the most divergent temperature given in Table 2 the median and standard deviation of the effective temperatures were obtained as 6355 ± 110 K and we prefer to use it as primary's temperature in the light curve analysis.

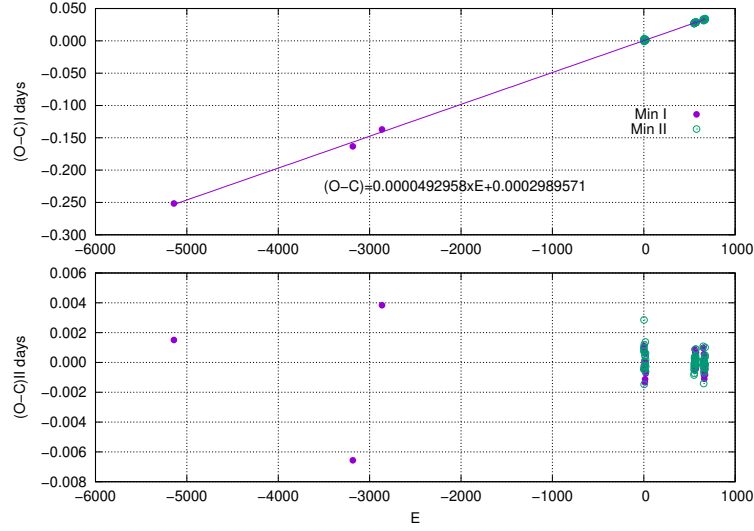


Fig. 3. *Top*: $(O-C)_I$ variation using light elements given by Prša *et al.* (2022) including the linear fit to the data. *Bottom*: $(O-C)_{II}$ variation using refined light elements obtained in this work for the KZ Vir system.

In addition to the radial velocity study made by Rucinski *et al.* (2001), we found the system's parameters in the catalog of Gaia DR3 Part 3 for non-single stars (Gaia Collaboration 2022). We found the system's velocity of the center of mass, $V_\gamma = -5.471 \pm 0.621$ km/s, semi-amplitude of the primary and secondary component, $K_1 = 109.4612 \pm 0.745$ km/s and $K_2 = 132.8956 \pm 1.862$ km/s, respectively. According to the values given in the Gaia DR3 catalog the mass ratio of

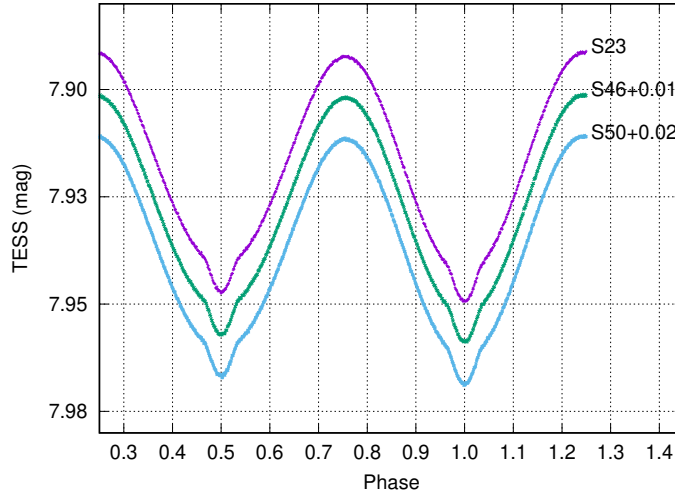


Fig. 4. Light curves of KZ Vir for three sectors. Magnitudes for consecutive sectors were shifted by adding 0.01 mag relative to the previous light curve. Normal points were obtained by averaging observations over a phase interval of 0.001. Data were phased with the light elements obtained in this work.

Table 2

Effective temperature (T_{eff}) and distance (d) values obtained from different sources for KZ Vir

T_{eff} [K]	d [pc]	References
6890	–	Wright <i>et al.</i> (2003)
6493	97	Ammons <i>et al.</i> (2006)
6200	187.27	McDonald <i>et al.</i> (2012)
6150	187.27	Chandler <i>et al.</i> (2016)
6434	–	Stevens <i>et al.</i> (2017)
6322	165.69	McDonald <i>et al.</i> (2017)
6296	–	Gaia Collaboration <i>et al.</i> (2018)
6296	–	Tonry <i>et al.</i> (2018)
6365	–	Bai <i>et al.</i> (2019)
6506	170.49	Stassun <i>et al.</i> (2019)
6436	187.27	Schofield <i>et al.</i> (2019)
6383	171.30	Montalto <i>et al.</i> (2021)
6345	–	Fouesneau <i>et al.</i> (2022)
6506	–	Prša <i>et al.</i> (2022)
6296	166.88	Gaia Collaboration (2022)
6296	–	Zheng <i>et al.</i> (2023)
6506	–	Green <i>et al.</i> (2023)

the system is $q(m_2/m_1) = 0.824$. The fact that both radial velocity solutions give such close results also strenghtens the reliability of the Gaia DR3 observations.

Considering that the light variation is mainly due to distortions of the components and that the real eclipsing nature occurs only in small phase intervals, we accept that the system is essentially detached or semi-detached as assumed by Pribulla *et al.* (2003).

In the light curve analysis of the KZ Vir, we used Mode 2 for appropriate detached type systems. Additionally, we select the starting parameters as $T_{\text{eff},1} = 6355 \pm 110$ K, $e = 0.0$, $P = 1.131829$ d and $i = 70^\circ$. Because the temperature of the primary component is lower than 7200 K we used the components' albedo and gravity darkening parameters of 0.5 and 0.32, respectively (von Zeipel 1924, Rucinski 1969).

By using the initial parameters (T_1 , q , i) as input values we solved the light and radial velocity curves until the solution converged. The convergent solution was obtained with the adjustable parameters by iteration until the correction on the parameters became smaller than the corresponding standard deviations.

The observed and model light and radial velocity curves calculated with the final elements are shown in Figs. 5 and 6, respectively, including the residuals of the fit with the observations. The parameters obtained from the light and radial velocity curve analysis are given in Table 3.

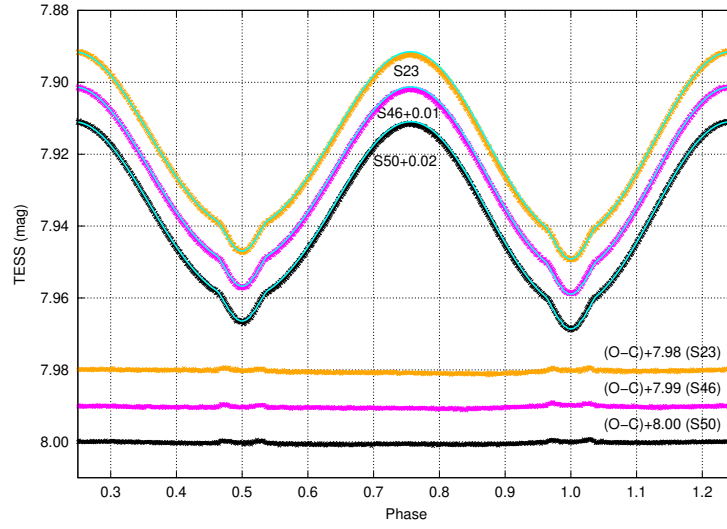


Fig. 5. Observational and model light curves (cyan colored lines) of KZ Vir including the residuals of the fit for different sectors.

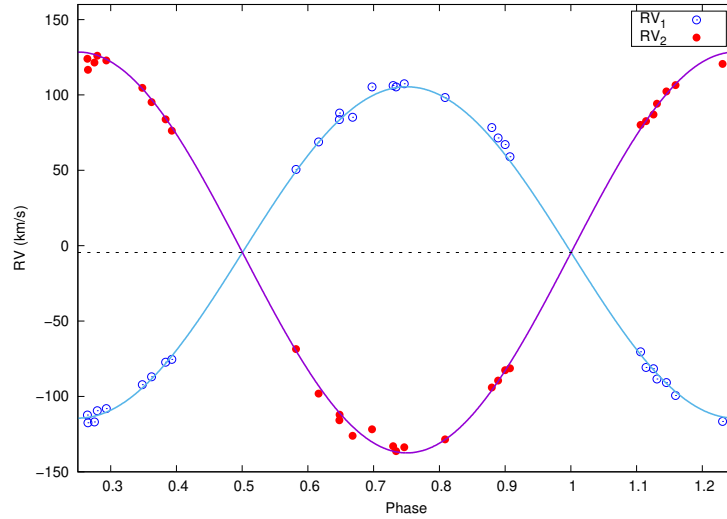


Fig. 6. Observational and model radial velocity curves of KZ Vir for primary (RV_1) and secondary (RV_2) components.

It can be seen that the light and radial velocity curves are modeled very well with the obtained solution parameters. The fact that the minimum depth is very shallow is caused by the low orbital inclination being at a critical value. If the orbital inclination were even a bit smaller, we could not see any visible eclipse for this system. Nevertheless, looking at the overall light variation we would still classify the system as a W UMa type.

The absolute parameters of the components obtained with the Wilson-Devinney LC code for the KZ Vir system are given in Table 4. Because the LC code does not

Table 3
Light curve solution of KZ Vir using TESS observations

Parameters	Solution	$\pm\sigma$
T_0 [BJD]	2458930.130422	0.000091
P [d]	1.13182948	0.00000012
a [$R_\odot$]	6.5472	0.0298
V_γ [km/s]	-4.497	0.637
K_1 [km/s]	109.895	0.770*
K_2 [km/s]	132.942	0.870*
$q(m_2/m_1)$	0.827	0.001
Phase Shift	-0.0001	—
e	0.00	—
i [deg]	56.259	0.011
T_1 [K]	6355*	110*
T_2 [K]	6261	110*
A_1	0.5	—
A_2	0.5	—
g_1	0.32	—
g_2	0.32	—
Ω_1	3.77762	0.00148
Ω_2	4.49079	0.00180
x_1 [bolo]	0.632	—
x_2 [bolo]	0.632	—
y_1 [bolo]	0.229	—
y_2 [bolo]	0.229	—
L_1/L_{tot} [TESS]	0.67746	0.00048
r_1 [mean]	0.34781	0.00006
r_2 [mean]	0.24540	0.00009
RV_1 [fit]	—	3.421
RV_2 [fit]	—	3.861
σ [fit]	—	5.6374E-07

Assumed values are marked with the * symbol.

produce any error for the absolute parameters, we estimated them from the input parameters. Since the light curve solution gives a tiny error for the secondary' temperature (like ± 10 K), we accepted the error as ± 110 K. The errors given here correspond to the propagated errors of the calculated parameters.

Using the semi-major axis and the mean fractional radii obtained by the light and radial velocity solution, we can find the radii of the components in the solar unit separately. The mean fractional radii of components were calculated with the formula, $r_{\text{mean}} = (r_{\text{pole}} \times r_{\text{side}} \times r_{\text{back}})^{1/3}$: 0.34781 ± 0.00006 and 0.24540 ± 0.00009 for primary and secondary components, respectively. Using those values we can calculate the radii of the components: $R_1 = a \times r_{1,\text{mean}} = (2.271 \pm 0.011) R_\odot$ and $R_2 = a \times r_{2,\text{mean}} = (1.603 \pm 0.008) R_\odot$.

Table 4
Absolute parameters of KZ Vir

Parameters	Primary	Secondary
Mass [$M_{\odot}$]	1.596 ± 0.022	1.319 ± 0.019
Radius [$R_{\odot}$]	2.271 ± 0.011	1.603 ± 0.008
Luminosity* [$L_{\odot}$]	7.580 ± 0.530	3.555 ± 0.252
$\rho(\rho_{\odot})$	0.136	0.320
M_{bol}	2.551 ± 0.076	3.373 ± 0.077
Bol.Corr. [TESS]	0.42 ± 0.07	0.44 ± 0.07
M_{TESS}	2.131 ± 0.228	2.935 ± 0.228
$\log g$ [cgs]	3.928 ± 0.007	4.149 ± 0.007
d [pc]	172.13 ± 7.85	172.20 ± 7.87

Calculated by using components' temperature and radius.

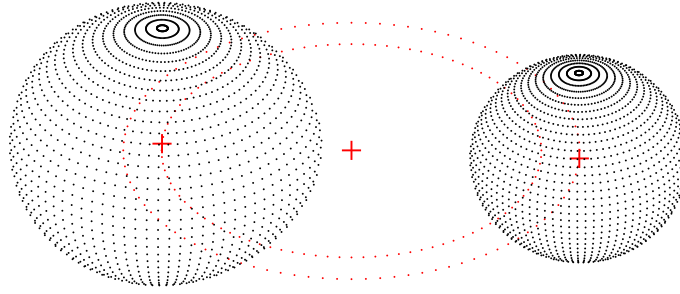


Fig. 7. Roche geometry of detached binary KZ Vir plotted by using BinaryMaker3 (Bradstreet and Steelman 2002).

The absolute parameters of $M_{\text{bol},2}$ and $L_{1,2}$ can be calculated using the well-known Eqs.(4) and (5) respectively,

$$M_{\text{bol},2} = 4.74 \text{ mag} - 5 \log(R_{1,2}/R_{\odot}) - 10 \log(T_{1,2}/T_{\odot}) \quad (4)$$

$$L_{1,2}(L_{\odot}) = (R_{1,2}/R_{\odot})^2 (T_{1,2}/T_{\odot})^4 \quad (5)$$

Adopting $T_{\odot} = 5772$ K, the bolometric magnitudes are found to be $M_{\text{bol},1} = 2.551 \pm 0.076$ and $M_{\text{bol},2} = 3.373 \pm 0.077$, and luminosities $L_1 = (7.580 \pm 0.530) L_{\odot}$ and $L_2 = (3.555 \pm 0.252) L_{\odot}$ for the primary and secondary component, respectively.

Using the $BC_{\text{TESS}} - T_{\text{eff}}$ relation given for main sequence stars by Eker and Bakış (2023) we obtained bolometric correction for the primary and secondary components: 0.42 ± 0.07 and 0.44 ± 0.07 , respectively. Since the bolometric magnitude of the components are known we can calculate the absolute magnitude of

the components separately using the formula $M_{\text{TESS}} = M_{\text{bol}} - BC_{\text{TESS}}$: $M_{\text{TESS,pri}} = 2.131 \pm 0.228$ mag and $M_{\text{TESS,sec}} = 2.935 \pm 0.228$ mag. Using the system's magnitude, $T = 7.918 \pm 0.004$ mag, and light ratios obtained from the light curve solution, $L_1/L_2(\text{TESS}) = 2.10039 \pm 0.00149$, we can obtain the magnitude of the primary and secondary components: $T_{\text{pri}} = 8.341 \pm 0.005$ and $T_{\text{sec}} = 9.147 \pm 0.006$, respectively. Using the color excess $E(B-V)$ value given by Kervella *et al.* (2022), 0.015 mag, the interstellar extinction in the TESS filter can be obtained with the relation given by Stassun *et al.* (2019): $A(\text{TESS}) = 2.06 \times E(B-V) = 0.0309$ mag. Using this value we can calculate the distance of the primary and secondary components:

$$d_1 = 10^{[(T_{\text{pri}} - A(T) - M_{\text{TESS,pri}} + 5)/5]} = 172.13 \pm 7.85 \text{ pc}, \quad (6)$$

$$d_2 = 10^{[(T_{\text{sec}} - A(T) - M_{\text{TESS,sec}} + 5)/5]} = 172.20 \pm 7.87 \text{ pc}. \quad (7)$$

The distance of the system evaluated from the light curve solution is consistent with the distances given in Table 2 and in the Simbad database ($d = 177$ pc). Additionally, the fact that both components are found to be at the same distance implies the accuracy of the solution. This compatibility can be considered as a support for the reliability of the light curve solution.

In Fig. 8 we plot our results in the Hertzsprung-Russell diagram (HRD) with the data given for detached eclipsing systems compiled by Torres *et al.* (2010). It seems that the primary and secondary components are located above and on the Terminal Age Main Sequence (TAMS), respectively. At this stage, if the primary component fills its Roche lobe, we can expect to see significant changes in the light curve and possibly in the orbital period of the system. However, due to the lack of data, we cannot see whether the orbital period has changed or not. The current $(O-C)$ variation does not show any sign of period variation.

4. Result and Discussions

We derived for the first time the absolute and geometrical parameters of the eclipsing binary KZ Vir using TESS photometry and radial velocity observations. The results of light-curve modeling reveal that KZ Vir is essentially a detached eclipsing binary, contrary to previous assumptions that it was a W UMa-type system. Using the semi-amplitudes of the radial velocity data of the system from the literature and our light curve solution we found the physical and geometric parameters of the components.

We refined the light elements of the system by using all of the times of minima published in the literature with the TESS observations. It seems that there is no secular variation in the $(O-C)$ which indicates the stability of the system at least during the time the observations were made. Because we did not find any eccentricity and no markable difference between consecutive light curves, we concluded that the components are orbiting in a synchronized orbit.

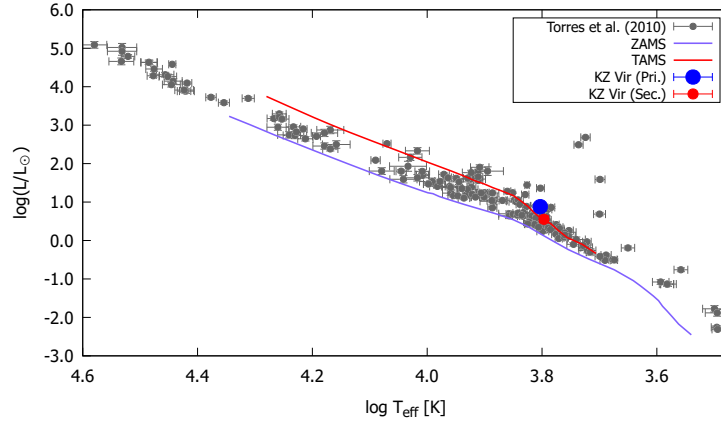


Fig. 8. Position of the primary and secondary components of KZ Vir on HRD (blue and red points), respectively. The effective temperature and luminosity of the stars were taken from Torres *et al.* (2010). Blue and red continuous lines representing the boundaries of ZAMS and TAMS for solar metallicity composition were taken from Girardi *et al.* (2000). The symbols of the components are drawn to scale relative to each other. The error bars of components are smaller than the plotted symbols.

The traditional view of the origin of contact binaries is that W UMa systems are formed from detached binaries of comparable periods through orbital decay by Angular Momentum Loss (AML) (Vilhu 1981, Rahunen and Vilhu 1981, Paczyński *et al.* 2006). We find that the components of KZ Vir are located above and on the TAMS and the next step of the evolution of the components is the subgiant branch of the HRD. Probably at this stage the primary component will fill its Roche lobe – going first to a semi-detached configuration and then to a W UMa-type configuration, in a relatively short time concerning the main sequence lifetime.

In this sense, we conclude that the system will make an important contribution to the literature. Thanks to the high quality TESS observations, the real nature of this system, which has been considered as a W UMa-type since its discovery, was revealed for the first time.

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