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The early-type near-contact binary system V337 Aql revisited

M. Tüysüz [a,*], F. Soydugan [a], S. Bilir [b], E. Soydugan [a], T. Şenyüz [a], T. Yontan [b]

[a] Çanakkale Onsekiz Mart University, Faculty of Sciences and Arts, Physics Department, 17100 Çanakkale, Turkey
[b] Istanbul University, Faculty of Sciences, Department of Astronomy and Space Sciences, 34119 Istanbul, Turkey

HIGHLIGHTS

- New BVR light curves of V337 Aql have been obtained.
- Long-term orbital period variation of the system has been studied.
- The multi-color light curves together with published radial velocities were analyzed.
- Absolute parameters of the components were estimated.

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ABSTRACT

The close binary V337 Aql consists of two early B-type components with an orbital period of 2.7339 d. New multi-band photometric observations of the system together with published radial velocities enabled us to derive the absolute parameters of the components. The simultaneous light and radial velocity curves solution yields masses and radii of $M_1 = 17.44 \pm 0.31\,M_\odot$ and $R_1 = 9.86 \pm 0.06\,R_\odot$ for the primary and $M_2 = 7.83 \pm 0.18\,M_\odot$ and $R_2 = 7.48 \pm 0.04\,R_\odot$ for the secondary component. Derived fundamental parameters allow us to calculate the photometric distance as 1355 ± 160 pc. The present analysis indicates that the system is a near-contact semi-detached binary, in which a primary star is inside its Roche lobe with a filling ratio of 92% and the secondary star fills its Roche lobe. From $O–C$ data analysis, an orbital period decrease was determined with a rate of $-7.6 \times 10^{-8}\,\mathrm{yr}^{-1}$. Kinematic analysis reveals that V337 Aql has a circular orbit in the Galaxy and belongs to a young thin-disc population.

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1. Introduction

V337 Aql (HD 177284, BD -02 4840, SAO 142979, $V = 8^{\mathrm{m}}.64$) is a β Lyr type eclipsing binary system with an orbital period of ~2.7339 days. The first estimation of the photometric parameters of the system based on its photographic light curve analysis was given by Wright and Dugan (1936). Using several plate spectra, Feast and Thackeray (1963) measured the radial velocities and classified the system as a double-line spectroscopic binary. In the study of Catalano et al. (1971), the first complete photoelectric light curve of the system was published and reported asymmetries and variations on its light curve. They also announced that the orbital period of the system was decreasing. Alduseva (1977) mentioned the amplitude variations and instabilities on the *UBV* light curves of V337 Aql as being connected with mass exchange between the components and also, using radial velocity measurements, estimated the masses of the components to be $M_1 \sim 16M_\odot$ and $M_2 \sim 10M_\odot$. *B* and *V* light curves obtained by Alduseva (1977) were also solved by Giuricin and Mardirossian (1981); however, their results strongly differed from those of Catalano et al. (1971). Mayer (1987) reported the changes in the orbital period related with the light–time effect. A study on the orbital period variation of V337 Aql was published by Šimon (1999), in which, although the data in the $O–C$ diagram indicated scattering, he suggested a possible decrease in the orbital period, which corresponded to $\Delta P/P \approx -6.5 \times 10^{-10}\,\mathrm{days}^{-1}$. Lastly, Mayer et al. (2002) measured the radial velocities of the components of V337 Aql based on high resolution echelle spectra and gave the orbital parameters. They also analyzed the light curve published by Catalano et al. (1971) and reported the absolute parameters of the components.

In this study, new photometric analysis of the early-type eclipsing binary system V337 Aql is presented. After presenting information and background studies of the system, new photometric data are described in Section 2, followed by analysis of the orbital period variation. In the next section, the simultaneous solution of *BVR* light curves together with published radial velocity curves is outlined. In the last section, the results and discussion, which

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[*] Corresponding author. Fax: +90 286 218 05 33.
E-mail address: mehmettuysuz@comu.edu.tr (M. Tüysüz).

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include absolute parameters of the components, comparing the system with the similar eclipsing binaries and also kinematic properties are presented.

2. Observations

New photometric observations of V337 Aql were performed at the Çanakkale Onsekiz Mart University Observatory over 22 nights in the observation season of 2012. During the observations of the system, a 60-cm Cassegrain telescope, equipped with Apogee ALTA U42 CCD camera and Bessell *BVR* filters, was used. The camera is of 13.5 × 13.5 microns pixel size and provides an effective field of view (FOV) of $17'.5 \times 17'.5$. The total number of the points obtained was 9880 in all filters. TYC 5132-878-1 and TYC 5128-840-1 were used as comparison and check stars, respectively. Reductions of the CCD images and aperture photometry were made using the C-Munipack[1] software package in the standard mode. The difference magnitude between the comparison and check stars did not indicate any significant light variation. The errors of individual observational points were estimated as about $0^m.01$ in all the filters. Fig. 2 represents the *BVR* light curves of the system. The orbital phase in the figure was computed according to the following light elements given by Kreiner (2004):

$$HJD\ (MinI) = 2452500.334 + 2^d.733882(1) \times E \quad (1)$$

All observational data shown in Fig. 2 was used the light curve synthesis given in Section 4.

3. Orbital period variation

The *O–C* diagram of V337 Aql in the database of the *O–C* Atlas of Eclipsing Binaries (Kreiner et al., 2001) indicates orbital period change. Although the visual (v) and photovisual (p) minima times contain relatively large errors and also large scatter, the orbital period variation can be studied using photographic (pg), photoelectric (pe) and CCD minima times. We collected the data from the *O–C* Atlas of Eclipsing Binaries (Kreiner et al., 2001) and combined them with three minima times (one primary and two secondary) determined from the new data listed in Table 1. New minima times were calculated using the Kwee and van Woerden (1956) method. For the *O–C* analysis, 20 photographic, 8 photoelectric and 3 CCD minima times were used, while their weights were selected as per the following: pg = 5, pe and CCD = 10. The *O–C* values were plotted against the epoch number in Fig. 1. As shown in Fig. 1, the general trend of *O–C* data can be represented by a downward parabola indicating a long-term orbital period decrease. Hence, by applying a weighted least-squares fitting, the following quadratic ephemeris with errors is derived:

$$HJD\ (MinI) = 2434896.8712(7) + 2^d.7338836(1) \times E - 7.8(2) \times 10^{-10} \times E^2 \quad (2)$$

Using the quadratic term, the rate of orbital period decrease can be derived to be $dP/dt = -7.6 \times 10^{-8}\ \mathrm{yr}^{-1}$. As can be seen in Fig. 1, the downward parabolic term represents the general trend of the *O–C* data well and the last three minima times obtained in this study also support the variation.

4. Light curve synthesis

The *BVR* light curves obtained in this study and the radial velocities given by Mayer et al. (2002) of V337 Aql were solved simultaneously using the Wilson–Devinney (W–D) program (Wilson and Devinney, 1973). The difference magnitudes (867 points in *B*, 1152 points in *V* and 957 points in *R* filters) for each filter were converted to intensity units using the mean magnitudes at 0.25 orbital phase. Although a semi-detached configuration was suggested for V337 Aql (Catalano et al., 1971, Alduseva, 1977, Giuricin and Mardirossian, 1981, Mayer et al., 2002), firstly, the detached mode (Mode 2 in W-D code) was used to check whether the surface potentials of the components reached their Roche limits or not. After trials, it was seen that the secondary component filled its Roche lobe and it was concluded that the semi-detached system configuration should be taken into account. Therefore, Mode 5 in W-D code was selected for the analysis.

In the light curve solutions, some parameters were fixed as the following: The effective temperature of the primary component was adopted as 28000 K (Popper, 1980) for the B0.5 spectral class suggested by Roman (1956) and Mayer et al. (2002). The bolometric albedos $A_{1,2}$ were taken from Rucinski (1969) to be 1.0 for the components with radiative envelope. The bolometric gravity-darkening coefficients $g_{1,2}$ were set to 1.0 for radiative atmospheres from von Zeipel (1924). The corresponding logarithmic bolometric and monochromatic limb-darkening coefficients used were from van Hamme (1993) tables. The secondary minimum is seen at 0.5 phase and the ascent and descent duration of the secondary and primary minimum are the same, therefore, a circular orbit ($e = 0$) was assumed. The third light ($l_3 = 0$) was fixed to zero since no evidence was found during trials. The adjusted parameters are the semi-major axis of orbit (a), radial velocity of the system's mass center (V_γ), phase shift (ϕ), orbital inclination (i), surface temperature of the secondary component (T_2), non-dimensional surface potential of primary component (Ω_1), mass ratio (q) and

Table 1
Minima times obtained in this study for V337 Aql.

HJD + 2400000	Error	Type	Filters
56114.4964	±0.0004	Primary	*BVR*
56110.3951	±0.0005	Secondary	*BVR*
56140.4627	±0.0004	Secondary	*BVR*

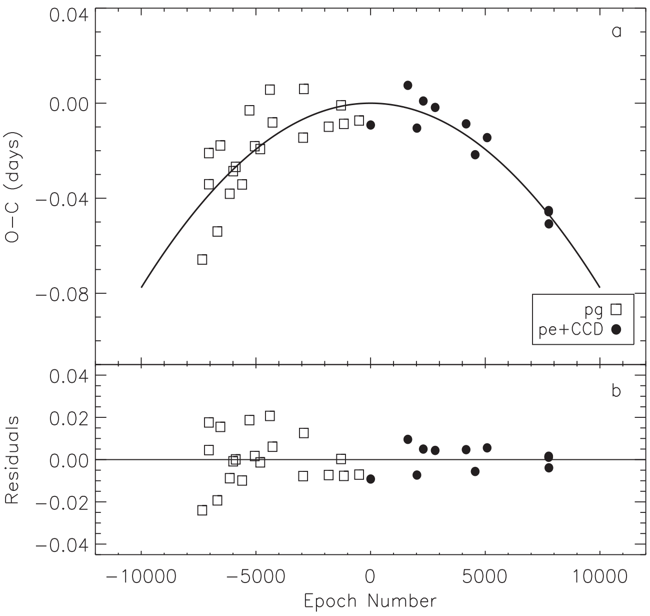

Fig. 1. *O–C* diagram of V337 Aql showing (a) downward parabolic representation (solid line) of *O-C* changes in the system and (b) residuals from the best theoretical curve (b).

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[1] http://c-munipack.sourceforge.net/

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