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Oscillating classical Algol-type binary XZ Aql

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HIGHLIGHTS

- First comprehensive investigation of XZ Aql was carried out based on new CCD photometric data.
- Oscillating behaviour of the primary component was determined for the first time.
- Orbital period variations of the system were analysed and interpreted using possible mechanisms.
- Absolute properties of the components were estimated.

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ABSTRACT

New CCD photometric observations of the neglected classical Algol-type binary XZ Aql were obtained over 53 nights during the observing season of 2011. Photometric elements were determined from analysis of multi-colour light curves. This first comprehensive investigation of the system revealed that the system is in semi-detached configuration with a mass ratio of 0.204 ± 0.02 and a filling ratio of the primary of 50%. Absolute parameters of components and distance of the system were estimated. Based on all eclipse timings, the (O–C) variation indicating orbital period behaviour can be represented by a periodic term superimposed on an upward parabola. Secular increase with a rate of $dP/dt = 7.82 \times 10^{-7}$ day yr^{-1} is due to mass transfer from the less massive to more massive component. A possible third body around the eclipsing pair and also magnetic activity of the late-type component were used to interpret cyclic variation in the orbital period. Short-period light variations out-of-eclipse imply that XZ Aql is an oscillating eclipsing binary with a pulsating, mass gainer component. From Fourier analysis, two frequencies were detected as 30.6325 c/d and 34.5009 c/d. Pulsational properties and estimated absolute parameters indicate that the primary component may be classified as a δ Scuti type variable.

1. Introduction

Current studies on eclipsing binaries with pulsating components provide more information than those of single pulsating stars. These systems show both binary nature and pulsation properties at the same time. Accurate measurement of the light and radial velocity variations of the eclipsing binaries enables us to determine the most sensitive absolute parameters (e.g. mass, radii). In addition, if one or both components of the binary systems are within the instability strip of pulsation stars, we can detect pulsational behaviour in these systems. Only nine systems were known as eclipsing binary systems with δ Scuti component in the year 2000 (Rodríguez and Breger, 2001). However, many more have been discovered in the last ten years, particularly after the catalogue of close binaries located in the instability strip was published by Soydugan et al. (2006b). Recently, Zhang et al. (2013) reported that the number of these systems has reached 69 with the new discoveries made by Hambsch et al. (2010), Liakos and Niarchos (2011), Southworth et al. (2011), Liakos et al. (2012) and Liakos and Niarchos (2013).

One of the eclipsing binaries with a δ Scuti component is XZ Aql (=HD 193740, BD −07° 5271) with an orbital period of $2^d.139$ (Samolyk, 1996). The light variations for the system were discovered by Ceraski (1929) using photographic plates. The spectral types of the hot and cool components were estimated to be A2 and G5IV, respectively (Svechnikov and Kuznetsova, 1990). There is neither a published photometric study nor a spectroscopic of the system in the literature except for some studies relating to orbital period variations. Studies on orbital period changes of XZ Aql were presented by Prikhod'Ko (1961), Kreiner (1971), Pokorny and Zlatuska (1976), Samolyk (1996), Kreiner et al. (2001) and Soydugan et al. (2006a). While Pokorny and Zlatuska (1976) and Samolyk (1996) revealed parabolic period variations, Kreiner et al. (2001)

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denoted complex variability. Detailed O–C analysis and discussion of parabolic and cyclic variations were carried out by Soydugan et al. (2006a).

The aim of this study is to present the first detailed photometric investigation of semi-detached system XZ Aql with a pulsating component. Analysis of multi-colour light curves is given in Section 3, after reporting observational data. Orbital period variation is outlined in Section 4, while frequency analysis and its interpretations are considered in Section 5. The final section contains a summary of results and discussions.

2. Observations

The photometric data on XZ Aql were collected between June and September 2011 at the Çanakkale Onsekiz Mart University Observatory (ÇOMUO). During observations, we used 40-cm Schmidt–Cassegrain and 122-cm Cassegrain–Nasmyth telescopes equipped with CCD camera Apogee U47 and U42, respectively. Photometric observations were carried out over 53 nights. Data on a total of 135 h (122-cm telescope) and 88 h (40-cm telescope) were acquired and a total of 6119, 6192 and 6143 observational points were collected in Bessell *B, V* and *R* photometric filters, respectively. GSC 5174-00186 and GSC 5174-00433, which were selected as the comparison and check stars, respectively, did not indicate light variations during the observational runs. Reductions of all CCD frames were made with C-Munipack[1] code. While the average probable error of the observations was calculated to be about $0^m.01$ for the 40-cm Schmidt–Cassegrain telescope, standard deviations were about $0^m.008$ in B filter and $0^m.006$ in both V and R filters for the 122-cm Cassegrain–Nasmyth telescope. Orbital phases in light curves were calculated according to initial epoch T_0 (HJD) = 2452501.0890 and orbital period $P_{\rm orb}$ = 2.139204 days, taken from Kreiner (2004). As seen in Fig. 2, there are light variations caused by pulsations at the maxima phases and secondary minima of the light curves.

3. Simultaneous solution of multi-colour light curves

In order to determine the physical and geometrical parameters of the components and orbital properties of XZ Aql, Wilson–Devinney (WD) program (Wilson and Devinney, 1971; van Hamme and Wilson, 2003) were used. The system has been suggested as a classical Algol-type binary (Budding et al., 2004; Malkov et al., 2006) and the shape of its light curves appears similar to classical Algol type binaries. However, in this study, analysis commenced using two approaches, detached (in Mode 2) and semi-detached (in Mode 5) configuration, with a view to first establishing the configuration of the system. Considering the dimensionless potential value of its secondary component during trials of the solutions, it was decided that the secondary component of the system filled its Roche lobe. Therefore, we applied Mode 5, corresponding to a semi-detached configuration in WD code, throughout the light curve analysis in order to obtain the best theoretical curves consistent with observational curves.

Before the analysis, magnitudes values were converted to relative intensities and normalized to a unit corresponding to the mean magnitudes ($-1^m.38$ for *B*, $-0^m.97$ for *V* and $0^m.72$ for *R* filters) around an orbital phase of 0.25. Some parameters were selected as fixed; namely, temperature of the primary component, the bolometric albedos taken from Rucinski (1969) as 1.0 for radiative envelopes (primary component) and 0.5 for convective envelopes (secondary component), and the bolometric gravity-darkening coefficients derived from von Zeipel (1924) and

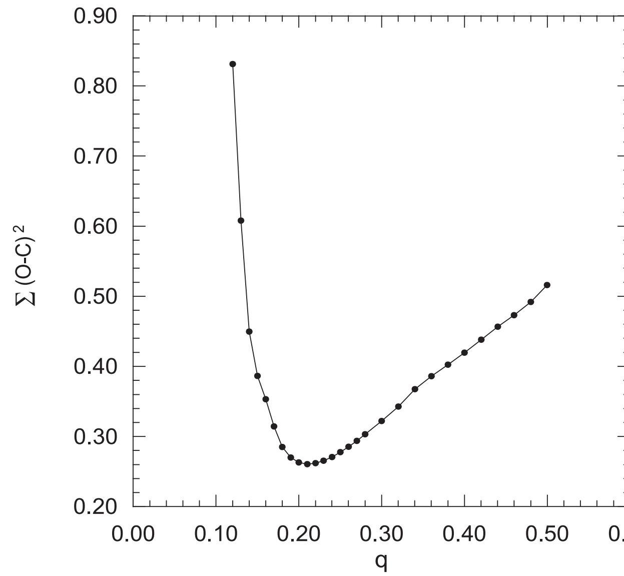

Fig. 1. Sum of squared residuals as a function of mass ratio (q) for XZ Aql.

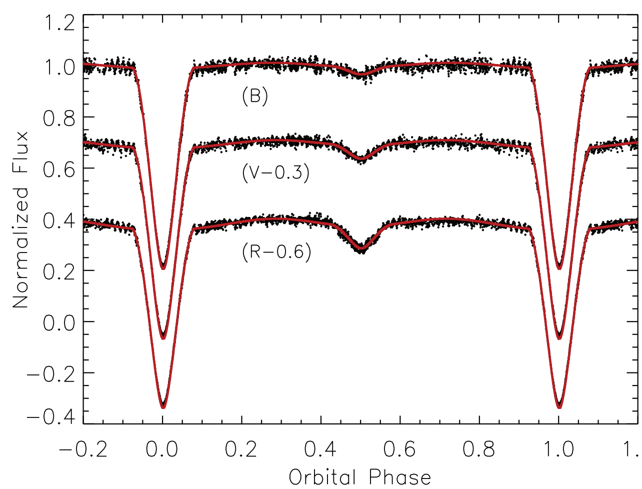

Fig. 2. Best theoretical fits to light curves of XZ Aql.

Lucy (1967) to be 1.0 for radiative atmospheres and 0.32 for convective atmospheres, respectively. The other parameters of orbital inclination (i), surface temperature of secondary (T_c), dimensionless potential of primary (Ω_h), phase shift (Φ), mass ratio (q) and fractional luminosity of primary component (L_h), were accepted as adjustable parameters. The secondary minima of XZ Aql are at 0.5 phase and their light curves appear not to be asymmetrical. Also, their ascent and descent duration are equal for the primary and secondary minima. Hence, we assumed a circular orbit ($e = 0$), which can be expected in classical Algols such as XZ Aql due to their evolutionary state. Synchronous rotation was also assumed for the components ($F_1 = F_2 = 1$). The temperature of the primary component, corresponding to A2 spectral type (Svechnikov and Kuznetsova, 1990; Malkov et al., 2006) was adopted as 8770 K (Popper, 1980). In order to search the initial value of q, we determined behaviour of the sum of the squared residuals ($\Sigma(O-C)^2$) for the corresponding q values, which is shown in Fig. 1. As seen in the figure, the minimum value of the $\Sigma(O-C)^2$ was found around $q = 0.21$. This value was used later as the input value for the mass ratio. In order to check whether the light contribution of a third body (l_3) to the total light existed or not, l_3 was selected as a free parameter in the solution. After initial runs, we found that l_3 light

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