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“Constant” eclipsing binary in the instability strip

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HIGHLIGHTS

- Taking into account the results, I discuss the nature of OO Peg.
- Analyses of the light and radial curves led to determination of stellar parameters.
- I show the location of the components in effective temperature–luminosity diagram.
- About six single stars and OO Peg components do not show any pulsational frequencies.
- They are apparently constant stars lie within the pulsation instability region.

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ABSTRACT

The eclipsing binary OO Peg consist of two late-A type stars in circular orbit with a period of 2.985 days. I use the high-resolution spectroscopic and extensive light curves from the *ASAS* and *Hipparcos* survey to measure the physical properties of the system. Previous attempts to model the light and radial velocity curves of the system have met with limited success, primarily because of the lack of a accurate photometric data. The system shows no signs of stellar activity, it is slowly rotating, has not been detected period changes, and there is no pulsational signs in the photometric data. I show the location of the components in effective temperature vs. luminosity diagram compared to the instability region limits established from eclipsing binary components. While more than 25 system have been plotted to diagram, about six single stars and OO Peg components do not show any pulsational frequencies. They are apparently constant stars lie within the pulsation instability region. I speculate as to the possible causes of this picture.

1. Introduction

The analysis of photometric and spectroscopic observations of double-lined detached eclipsing binaries (dEBs) usually yield fundamental parameters like masses and radii which are too important to match the predictions of theoretical stellar evolutionary models. The other use of dEBs is to investigate the physical processes at work in single stars. This is particularly useful if one or both components belongs to a class of peculiar or poorly understood stars, for example eclipsing binaries with at least one of the components located in the δ Scuti region of the *Cepheid* instability strip described by Soydugan et al. (2006). In this work I present the investigation of an eclipsing binary is already reported by Soydugan et al. (2006) and indicate that at least one of the component is a possible δ Scuti star.

The eclipsing nature of OO Peg (ASAS214138 + 1439.5, HIP107099) was detected by using the *Hipparcos* satellite (Perryman et al., 1997), photometry from which showed two eclipses of nearly the same depth and an orbital period of 2.985 days. The orbit is circular and eclipses are compared to the orbital period. Since then, OO Peg was the subject of several extensive studies based on both ground-based spectroscopy and multi-survey photometry.

Munari and Zwitter (1997) used *Hipparcos* observations plus presented 21 radial velocities for the components obtained with the 1.82 m telescope operated by Osservatorio Astronomico di Padova atop Mt. Ekar (Asiago). They combined *Hipparcos* photometry with the spectroscopic data to refine the orbital solution and to determine precise physical properties of both binary components.

In this paper I obtain and analyze the new high-resolution spectroscopic observations, and used the ASAS (Perryman, 1997) survey data to improve the photometric model and directly determine the high-precision absolute masses and radii of the

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components. I also investigate the suggestion of OO Peg is the potential candidate binaries with δ Scuti-type pulsating components.

2. Observations

2.1. Photometry

The system was observed by several automatic and robotized telescopes and surveys. Besides the old *Hipparcos* data, there exist also high precision photometry of OO Peg obtained by the ASAS survey (Pojmanski, 2002). OO Peg was observed by ASAS-3 survey between 2002 December–2008 May in V-band. All the data were split into separate data sets according to the seasonal gaps in observations and folded with the orbital period calculated by using Analysis of Variance algorithm of Schwarzenberg-Czerny (1989) described in next section.

2.2. Echelle spectroscopy

Spectroscopic observations were performed with the FRESCO échelle spectrograph at the 91-cm telescope of Catania Astrophysical Observatory. The spectrograph is fed by the telescope through an optical fiber (UVNIR, 100 μ m core diameter) and is located in a stable position in the room below the dome level. Spectra were recorded on a CCD camera equipped with a thinned back-illuminated SITe CCD of 1024 × 1024 pixels (size 24 × 24 μm). The resolution is 24,000, as deduced from the full width at half maximum of the lines of the Th-Ar calibration lamp. The spectra cover the wavelength range from 4300 to 6650 Å, split into 19 orders. In this spectral region there are several lines useful for measuring radial velocity and for the star classification, mainly located in the blue portion of the spectrum. The data reduction was performed by using the ECHELLE task of IRAF[1] package following the standard steps: background subtraction, division by a flat field spectrum given by a halogen lamp, wavelength calibration using the emission lines of a Th–Ar lamp, and normalization to the continuum through a polynomial fit.

Fifteen spectra of OO Peg were collected during the 22 observing nights in the observational season in 2008. Typical exposure times for the object spectroscopic observations were between 2400 and 3600 s. The signal-to-noise ratio (S/N) achieved was between 80 and 130, depending on the atmospheric conditions. α Lyr (A0V), 59 Her (A3IV), 50 Ser (F0V) and ι Psc (F7V) were observed during each run as radial velocity standard stars. The slowly-rotating star HD 27962 (A2IV) was observed as a template for the measurements of rotational velocity. The average S/N at continuum in the spectral region of interest was 170–350 for the standard stars.

3. Period determination and O–C evolution

Many astronomical phenomena exhibit patterns that have periodic behavior. Detecting their period and the periodic exemplary they exhibit an important task toward understanding their behavior. An important effort has been devoted to the analysis of light curves from periodic variable stars.

Firstly, I searched for periods shorter than 0.5 days using data combined from the *Hipparcos* and ASAS surveys. Analysis of Variance (AoV) algorithm of Schwarzenberg-Czerny (1989), as implemented in the VarTools light curve analysis program (Hartman et al., 2008). There were small peaks in the power spectra which were detected at a significance greater than 3σ. There is no evidence for a light modulation of the system with a period less than 0.9 day. I then searched for periodic signals in the range 0.5–10 days using the same procedure explained in the VarTools manuel. I show the resulting power spectra in Fig. 1 for combined data. I obtained the period and *False Alarm Probability* of peaks which are significant at a level greater than 3σ. I detect significant peaks in the power spectra at periods between 1 and 4 days, the most significant being at 1.49 days. The light and radial velocity curve of the system is phased with the 2.98465082(2) days period. I can estimate the expected uncertainty on the period using Eq. (25) of Schwarzenberg-Czerny (1989): $\Delta P \sim P^2 \sqrt{\frac{3\sigma^2 D}{T^3}}$, where P is the period, σ is the noise in units of the signal amplitude, D is the average correlation timescale for the residuals from the model periodic signal (equal to the sampling time for the case of pure Gaussian white noise with a perfect sinusoidal signal), and T is the time baseline.

In order to construct the O–C diagram, the linear ephemerides HJD = 2,448,500.6400 + E × 2.98465082 were used. Six primary and a secondary minima (ESA, 1997; Ogloza et al., 2008; Paschke, 2013) at different times were collected from the literature. As can be seen in Fig. 2, no significant long-term changes in the period are appreciated.

4. Analysis

4.1. Spectral classification

High-resolution optical spectroscopy permits us to derive most of the fundamental stellar parameters, such as the projected rotational velocity ($v \sin i$), spectral type (S_p), luminosity class, effective temperature ($T_{\rm eff}$), surface gravity ($\log g$), and metallicity ([Fe/H]).

The width of the cross-correlation function (CCF) is a good tool for the measurement of projected rotational velocity ($v \sin i$) of a star. I use a method developed by Penny (1996) to estimate the $v \sin i$ of each star composing the investigated double-lined eclipsing binary (SB2) system from its CCF peak by a proper calibration based on a spectrum of a narrow-lined star with a similar spectral type. The rotational velocities of the components were obtained by measuring the FWHM of the CCF peak related to each component in five high-S/N spectra acquired near the quadratures, where the spectral lines have the largest Doppler-shift. The CCFs were used for the determination of $v \sin i$ through a calibration of the full-width at half maximum (FWHM) of the CCF peak as a function of the $v \sin i$ of artificially broadened spectra of slowly rotating standard star (ι Psc, $v \sin i \simeq 3$ km s^{-1}, e.g., Takeda et al., 2005) acquired with the same set up and in the same observing night as the target system. The limb darkening coefficient was fixed at the theoretically predicted values, 0.55 for the system (van Hamme, 1993). I calibrated the relationship between the CCF Gaussian width $v \sin i$ using the Conti and Ebbets (1977) data sample. This analysis yielded projected rotational velocities for the components of

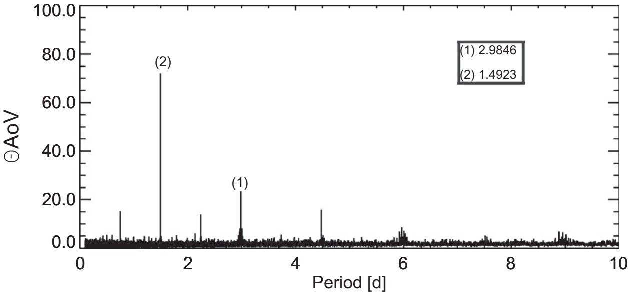

Fig. 1. Frequency analysis of object data combined from the *Hipparcos* and ASAS surveys. The known true period appears as the largest peak, signed with (2). The second period signed with (1) appears attenuated.

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