Modelling and analysis of eclipsing binary V1385 Ori

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We present preliminary results obtained by spectroscopic and photometric observations of the previously not studied eclipsing binary V1385 Ori. Spectroscopic observations were performed with the Poznań Spectroscopic Telescope (PST). Photometric data used in the following work were taken from All Sky Automated Survey (ASAS). We have collected spectroscopic data to cover most of phases of the orbital motion. Data reduction was performed with the IRAF package. In order to determine radial velocities of components, one-dimensional cross-correlation technique has been used. The results of the orbital solution from radial velocity curves are combined with those derived from the light curve analysis to calculate orbital and stellar parameters. PHOEBE - a code based on Wilson-Devinney binary modelling method was applied for that analysis. As a result we determined the absolute parameters: mass, radius and temperature as well as the age and distance to the system.

1 Spectroscopy

Spectroscopic observations were performed with the Poznan Spectroscopic Telescope (PST)[1], located at Borowiec Astrogeodynamic Observatory near Poznań, Poland. PST is equipped with fiber-fed echelle spectrograph of resolution R $\sim$ 35000, which spectral range covers wavelengths from 4280 to 7500 Å, arranged in 57 echelle orders. Description of PST telescope and spectrograph can be found in Baranowski et al. (2009). The data reduction was performed with IRAF package[2]. For determination of radial velocities of binary components, one-dimensional cross-correlation technique has been used (IRAF FXCOR). The results are presented in Fig. 1. We correlated the observed V1385 Ori spectra with a synthetic spectrum, calculated for a solar metallicity star of $T_{eff} = 6800$ K and rotational velocity of 20 km/s. In the observed V1385 Ori spectra one can distinguish H_α, H_β, H_γ absorption lines, as well as other strong lines visible in this type of spectra: the sodium D-lines, Fe I, Mg I, Ca I and He I. The behaviour of cross-correlation function is shown in Fig. 1 and can be explained by the presence of two stars. Fitted RV curve can be seen in Fig. 2.

[1] http://www.astro.amu.edu.pl/GATS/
[2] http://iraf.noao.edu/

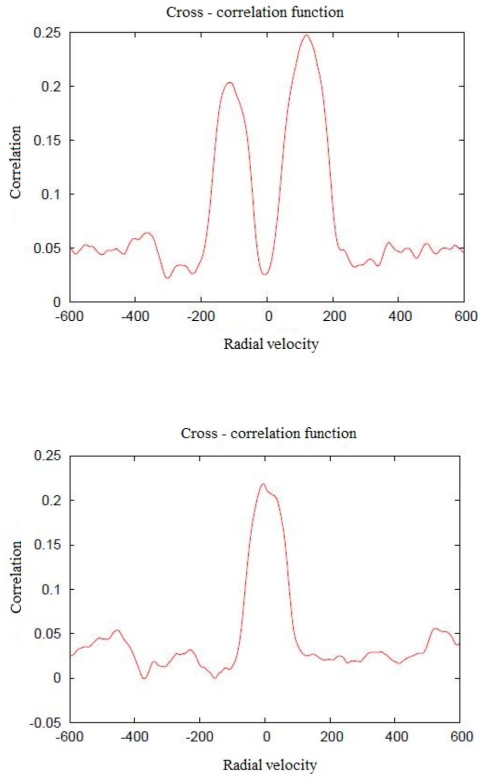

Fig. 1: Diagrams show maxima of cross – correlation function for 0.5 phase (upper) and 0.25 phase (lower).

2 Modelling

The majority of the field stars, about 60-80%, are binary or multiple systems (Duquennoy & Mayor, 1991). The analysis of an eclipsing binary gives a unique possibility for precise determination of the stellar parameters. V1385 Ori system was previously mentioned in two publications (Malkov et al., 2006; Kazarovets et al., 1999). The object is described by ASAS (Pojmanski, 1997) as β Lyrae-type binary. Also this object is identified as semi - detached or detached eclipsing binary. V1385 Ori's spectral type is specified as A0, thus we assume that the temperature of the primary component is 9790 K. Magnitude of the system in V band is 7.45 mag in the Tycho catalogue or 7.44 mag in ASAS catalogue[3]. The trigonometric parallax was measured with the value of 2.74 ± 0.74 mass (van Leeuwen, 2007).The resulting light curve exhibits periodic eclipses with depth of 0.18 mag. We supplemented the long-term photometry from ASAS to calculate parameters of investigated object. Results of obtained light curve modelling can be seen in Fig. 2.

[3]http://www.astrouw.edu.pl/asas/

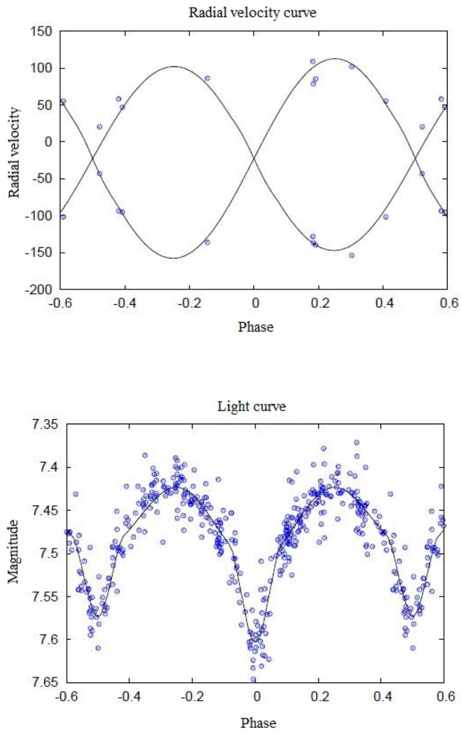

Fig. 2: The upper diagram shows RV curves derived using one-dimensional cross-correlation technique (IRAF FXCOR). For the analysis 10 echelle spectra of V1385 Ori obtained with PST during 9 different nights were used. The lower diagram presents ASAS light curve, which was modelled using PHOEBE software, based on Wilson-Devinney code.

For detailed analysis we used PHOEBE software (Prsa, 2006). Wilson-Devinney model was calculated based on the photometric and the radial velocity curves. We calculated V1385 Ori orbital period which is 2.2379017 days. A full compilation of stellar and orbital parameters of V1385 Ori obtained by using PHOEBE is presented in Table 1. Based on the data obtained from PHOEBE we calculated masses and radii of both V1385 Ori components. The result presented in Table 2 shows two very similar stars with masses $M_1 = 2.95 \pm 0.10\ M_\odot$ and $M_2 = 2.72 \pm 0.10\ M_\odot$, respectively. We also obtained mean radii of the components which are $R_1 = 4.18 \pm 0.02\ R_\odot$ and $R_2 = 3.65 \pm 0.01\ R_\odot$. Values of radii determined in different directions (point, side, back and pole) clearly show that components are distorted.

Table 1: Parameters of V1385 Ori system obtained with Wilson-Devinney method.

Parameter	Value
$a[R_\odot]$	12.84 ± 0.10
$V_\gamma[km/s]$	-22.5 ± 0.8
q	0.9217 ± 0.0035
$i[^\circ]$	64.3 ± 0.7
Ω_1	4.05 ± 0.07
Ω_2	4.32 ± 0.13
l_1	0.633 ± 0.011
l_2	0.367 ± 0.011
$T_1[K]$	9790 ± 30
$T_2[K]$	8948 ± 121
HJD_0	2452621.1290 ± 0.0025
P	2.2379017 ± 0.0000021

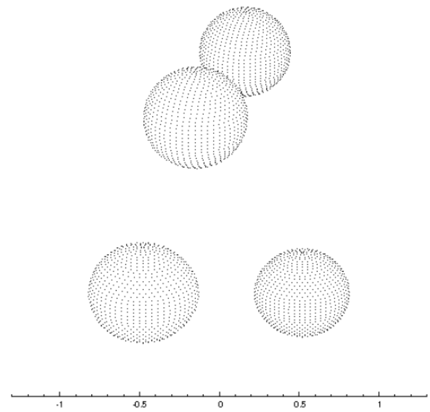

Fig. 3: The diagram shows 3D visualization of V1385 Ori system at the 0.45 phase (upper plot) and 0.25 phase (lower plot).

From trigonometric parallax we obtained distance to V1385 Ori which is 405 ± 78 pc. We used linear cosine formula for limb darkening calculations and Van Hamme coefficients (van Hamme, 1993). Limb darkening coefficients values are 0.42 and 0.46 for the primary and secondary component, respectively. Surface gravity acceleration is $\log g_1 = 3.666 \pm 0.018$ and $\log g_2 = 3.748 \pm 0.019$. Based on the results, we conclude that V1385 Ori can be considered as detached eclipsing binary. Fig. 3 shows the model of V1385 Ori system.

Parameter	Primary star	Secondary star
$\mathrm{M}[M_\odot]$	2.95 ± 0.10	2.72 ± 0.10
$R_{mean}[R_\odot]$	4.18 ± 0.02	3.65 ± 0.01
$R_{point}[R_\odot]$	4.530 ± 0.021	3.856 ± 0.015
$R_{side}[R_\odot]$	4.176 ± 0.019	3.647 ± 0.014
$R_{back}[R_\odot]$	4.367 ± 0.019	3.775 ± 0.014
$R_{pole}[R_\odot]$	4.045 ± 0.019	3.563 ± 0.014

Table 2: Absolute parameters of V1385 Ori system obtained with Wilson-Devinney method.

3 Comparison with stellar models

To verify the solution for both components we assummed standard solar metallicity of the system and compared them with current stellar evolution models (Yonsei - Yale evolutionary tracks) (Yi et al., 2001, 2003; Kim et al., 2002) for certain masses and checked if a single isochrone fits both stars simultaneously. According to our results the current location of V1385 Ori suggests the age of the system is about 0.3 Gyr and both components are still in the main sequence phase.

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