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Improved model of Delta Orionis

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Abstract. We present an improved model of triple star Delta Orionis A. For the first time we were able to disentangle the very weak spectral lines of the secondary in the blue parts of the optical spectrum and derive a reliable mass ratio $q = 0.415$. Along with light-curve solutions, based on photometry from the *SMEI*, *MOST* and *BRITE* satellites, we obtained realistic masses and radii of both components of the close binary.

Key words: eclipsing binary stars – spectroscopic analysis – light curves

1. Introduction

The object δ Ori A (HD 36486, HIP 25930, HR 1852; $V = 2.23$ mag.; average position angle 162.35° Niesten, 1904) is a triple star in the multiple star system δ Orionis (Mintaka, ADS 4134) in the constellation of Orion (for the structure of the system see Harvin et al., 2002). The star δ Orionis A consists of an eclipsing binary with the orbital period of $P = 5.732$ d and a distant tertiary with an orbital period of the order of several thousand days.

The binary system has been studied many times. Harvin et al. (2002) carried out a tomographic separation of UV and optical spectra and concluded that the components have unexpectedly low masses: $M_1 = 11.2\,\mathcal{M}^{\rm N}_\odot$ and $M_2 = 5.6\,\mathcal{M}^{\rm N}_\odot$. Than Mayer et al. (2010) pointed out that the second system of spectral lines in Harvin's study belongs to a tertiary and showed that primary and tertiary dominate the optical spectra. They concluded that the system has normal masses and estimated a mass ratio of about 0.4. Harmanec et al. (2013) indeed reported a similar mass ratio, detecting the secondary in the He I 6678 Å line. A series of detailed studies was published by Corcoran et al. (2015), Nichols et al. (2015), Pablo et al. (2015) and Shenar et al. (2015).

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† Pavel Mayer passed away on the day of his 86th birthday Nov. 7, 2018

2. Observational material used and data analysis

All electronic spectra covering the blue and green spectral region (RJD between 50031 and 58405) obtained at the Ondřejov 2-m reflector were used. These were complemented by spectra from the Haute Provence Observatory Elodie echelle spectrograph and the ESO LaSilla Feros echelle spectrograph. The space-based photometric data was obtained with instruments on board *SMEI*, *MOST* and *BRITE*[1] (RJD between 52676 and 56995).

Normalization of spectra, removal of residual cosmic rays and radial-velocity (RV) measurements were carried out with the program `SPEFO` (Horn et al., 1996; Škoda, 1996), developed by Mr. J. Krpata (Krpata, 2008). We disentangled the spectra in `KOREL` (Hadrava, 2004) in two steps: we first disentangled the strong spectra of the primary and tertiary and then we disentangled the spectrum of the faint secondary in the residual spectra from the first step. They were then fitted by interpolated synthetic spectra with the help of the program `PYTERPOL`[2] to fit the profiles of the components (see Fig. 1). For the final combined RV and light-curve solutions we used the program `PHOEBE` 1[3] (Prša & Zwitter, 2005).

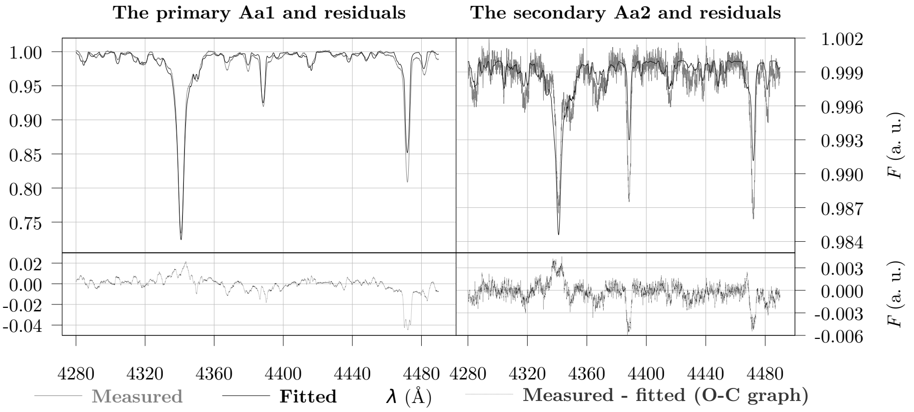

Figure 1. Comparison of disentangled spectra of the primary and secondary with the best-fit synthetic spectra found by `PYTERPOL`.

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[1] Based on data collected by the *BRITE* Constellation satellite mission, designed, built, launched, operated and supported by the Austrian Research Promotion Agency (FFG), the University of Vienna, the Technical University of Graz, the University of Innsbruck, the Canadian Space Agency (CSA), the University of Toronto Institute for Aerospace Studies (UTIAS), the Foundation for Polish Science & Technology (FNiTP MNiSW), and National Science Centre (NCN).

[2] https://github.com/chrysante87/pyterpol/wiki

[3] http://phoebe-project.org/1.0

3. Results

The final elements are in Table 1. It was found that the solution based on the *SMEI* data led to a high inclination and an anomalously small radius for the secondary. A realistic solution was found with the *BRITE* and *MOST* photometry together. Fig. 2 displays the fitted light curves. Using *SMEI* we arrived at reasonable masses and radii for both the primary (cf. Martins et al., 2005) and secondary (see Harmanec, 1988).

Table 1. Solution

Parameters	BRITE	SMEI
$a/\mathcal{R}^{\mathrm{N}}_{\odot}$	41.91 ± 0.18	40.71 ± 0.21
$\omega/^{\circ}$	148.73 ± 1.49	158.37 ± 0.71
$\gamma/\mathrm{km\ s^{-1}}$	21.96 ± 0.33	22.28 ± 0.41
$i/^{\circ}$	78.1 ± 0.3	91.6 ± 0.4
$M_1/\mathcal{M}^{\mathrm{N}}_{\odot}$	21.1	19.4
$M_2/\mathcal{M}^{\mathrm{N}}_{\odot}$	8.8	8.1
$R_1/\mathcal{R}^{\mathrm{N}}_{\odot}$	13.6	10.4
$R_2/\mathcal{R}^{\mathrm{N}}_{\odot}$	3.7	1.71
$M_{\mathrm{bol}_1}/\mathrm{mag}$	-8.28	-7.69
$M_{\mathrm{bol}_2}/\mathrm{mag}$	-4.55	-2.87
L_{R_1}	0.690	0.712
L_{R_2}	0.037	0.014
$\log_{10} g_1$	3.50	3.70
$\log_{10} g_2$	4.24	4.88
χ^2_{N}	11.389	1.008

Fixed param.	Values
P/d	5.732436*
$\dot{\omega}/^{\circ}\ \mathrm{d}^{-1}$	0.004220*
$q = M_2/M_1$	0.41549**
e	0.07583**
$T_{\mathrm{eff}_1}/\mathrm{K}$	31401***
$T_{\mathrm{eff}_2}/\mathrm{K}$	25442***
L_{R_3}	0.273***

* Mayer et al. (2010)
** from `KOREL`
*** from `PYTERPOL`

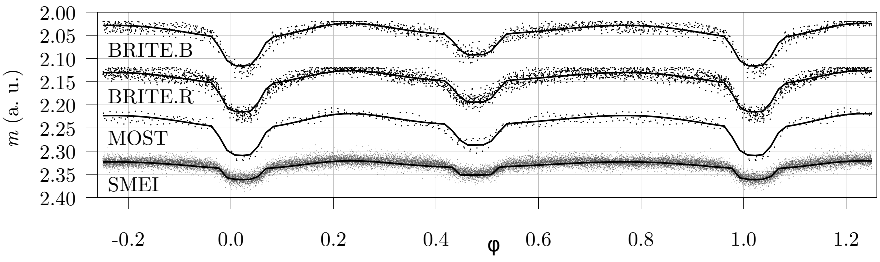

Figure 2. Fitted light curves (from the program `PHOEBE`)

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