Observational signatures of past mass-exchange episodes in massive binaries

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1. Introduction

Mass and momentum exchanges in massive binaries can produce several observational signatures, such as asynchronous rotation and altered chemical compositions, that remain once the stars detach again. We have started to investigate these effects for a sample of detached massive O-star binaries that are thought to have previously experienced a Case A Roche Lobe Overflow. In this contribution, we present the first results of our analyses of HD149404 (O7.5If + ON9.7I).

2. Observations and system information

HD149404 :

- non-eclipsing O-star binary, member of the Ara OB1 association
- circular orbit with an orbital period of 9.81 days

(Rauw et al. 2001, A&A 368, 212; Thaller et al. 2001, ApJ 554, 1070)

- FEROS and Coralie echelle spectra used by Rauw et al. (2001)

3. Preliminary analysis

3.1 Disentangling

We separate the contributions from both stars through a disentangling method (Gonzalez & Levato 2006, A&A 448, 283).

3.2 Rotational velocities

Using a Fourier transform method on HeI 4026 Å, HeI 4922 Å, HeI 5016 Å, OIII 5592 Å, CIV 5801 Å and CIV 5812 Å, we have determined the rotational velocities of the stars of the system. The mean vsin(i) of the primary star is 90 km/s, while the one of the secondary is 63 km/s.
Using the radii determined by CMFGEN presented in Tab.2, we can thus see that the components of the system are not in synchronous rotation, but that the primary star rotates twice as fast as the secondary star. This may suggest that there has been a kinetic momentum transfer from the secondary to the primary star.

3.3 Macroturbulence velocities

A first approximation of the macroturbulence velocities has been made using the macroturbulent broadening formulation of David Gray (Gray 2008, "The Observation and Analysis of Stellar Photospheres", 3rd edition, Cambridge University Press) , leading to values of 70 and 80 km/s for the primary and secondary stars respectively.

3.4 Spectral types

Spectral types determined from equivalent width ratio of the spectral lines HeI 4471 Å and HeII 4542 Å, and SiIV 4089 Å and HeI 4143 Å from the disentangled spectra (van der Hucht 1996, "Wolf-Rayet stars in the framework of stellar evolution", Liege Astrophysics Colloquium, eds Vreux, Detal, Fraipont- Caro, Gosset, and Rauw, 1)

⇒ the primary star is a O7.5If star, while the secondary is a ON9.7I

3.5 Brightness ratio

To estimate the optical brightness ratio, we have measured the equivalent widths of HeI 4026 Å, HeII 4200 Å, Hγ, HeI 4471 Å and HeII 4542 Å on the disentangled spectra of the primary and secondary stars. From CIV 5801 Å and CIV 5812 Å lines, that are only present in the primary spectrum, we estimated the dilution of these lines. We thus derived an optical brightness ratio of 0.69 $\pm$ 0.24, smaller than the value found by Rauw et al. (2001).

4. Spectral analysis

4.1 Method

We then initiated the iterative study of the disentangled spectra with the atmosphere code CMFGEN (Hillier & Miller 1999, ApJ 519, 354) , starting from the stellar parameters obtained from the preliminary analysis hereabove and previous studies (Rauw et al. 2001). The first step has been to adjust the temperature and the surface gravity of the stars. As a first approximation, gravity, stellar mass, radius and luminosity were assumed equal to typical values of stars of the same spectral type (Martins et al. 2005, A&A 436, 1049) or taken from the study of Rauw et al. (2001). The mass-loss rate and wind velocity were then evaluated via the formalism of Muijres et al. (2012, A&A 537, A37). As the Hα and Hβ emission lines are strongly affected by extra emission from the wind-wind interaction, they cannot be used as diagnostics of the mass-loss rate and clumping factor.

Once the fundamental stellar parameters had been established or fixed, we could then investigate the CNO abundances through the strengths of the associated lines.

4.2 Results

We present in Fig.1 the current best fits of the primary and secondary spectra obtained by CMFGEN. In Tab.1 the corresponding chemical abundances are compared with solar ones and in Tab.2 we present the stellar parameters determined with CMFGEN compared to the ones computed by Rauw et al. in 2001.

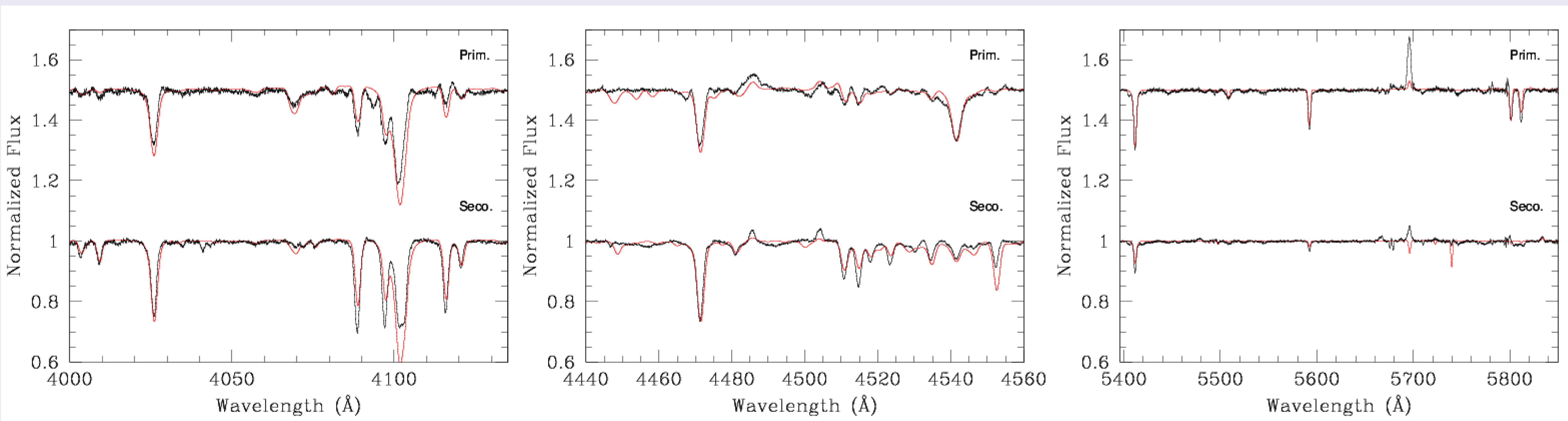

FIGURE 1 : Part of the primary (top) and secondary (bottom) spectra (black) and CMFGEN modelised spectra (red).

	Primary	Secondary	Sun
He/H	0.1	0.1	0.089
C/H	$2.5 * 10^{-4}$	$3.0 * 10^{-5}$	$2.69 * 10^{-4}$
N/H	$1.5 * 10^{-4}$	$5.5 * 10^{-4}$	$6.76 * 10^{-5}$
O/H	$7.0 * 10^{-4}$	$8.0 * 10^{-5}$	$4.90 * 10^{-4}$

TABLE 1 : Chemical abundances of primary and secondary stars as obtained with CMFGEN, compared with the solar abundances (Asplund et al. 2009, ARAA 47, 481).

	Rauw et al. 2001		This study	
	Prim.	Seco.	Prim.	Seco.
M (M_{sun})	54.8	33.0	45.9	37.8
R (R_{sun})	24.3	28.1	19.3	25.9
T_{eff} ($10^4 K$)	3.51±0.1	3.05±0.04	3.40	2.80
L (L_{sun})	$7.94 * 10^5$	$6.03 * 10^5$	$4.79 * 10^5$	$4.07 * 10^5$

TABLE 2 : Stellar parameters of primary and secondary stars as obtained with CMFGEN, compared with the parameters obtained by Rauw et al. 2001.

4.3 Discussion

We can see on the Fig.1 that the He lines and the CIII 4070 Å line seem rather well modelised for both stars. The N lines are well modelised in primary spectra and could be slightly improved for the secondary spectra, as they suggest a slightly higher N abundance. The O abundance is quite problematic, since OIII 5592 Å is really well adjusted whilst several OIII lines are present in the CMFGEN spectra (OIII 4448 Å, 4454 Å and 4458 Å for example) and barely visible in the disentangled spectra.

The large abundance of N in the secondary spectrum suggests that this star was formerly the more massive one and that it transferred mass and momentum to the present-day primary via a Roche Lobe Overflow (Vanbeveren 2011 BSRSL 80, 530 ; Pols 2010, ASPC 435, 393).