Observational signatures of past mass-exchange episodes in massive binaries : The cases of HD 17505 and HD 206267

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Definitions

- **Massive star** :
  - $M > 10\, M_{Sun}$, $T_{eff} > 20\ 000$ K, $L > 10^6 L_{Sun}$
  - $v_\infty \sim 2000 - 3000\, km/s$ and $\dot{M} \sim 10^{-6} - 10^{-5} M_{Sun}/year$

- Large fraction of massive stars in **binary or higher multiplicity** systems

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But multiplicity can also lead to **complications** :

- **Interactions** between the stellar **winds**

- **Transfer** of matter and kinetic momentum through a **Roche Lobe overflow** interaction **(Podsiadlowski et al. 1992; Wellstein et al. 2001; Hurley et al. 2002)**

⇒ Binarity significantly affects the spectra and the subsequent evolution of the components

HD 17505

- Multiple system composed of 7 visual companions, member of the Cas OB6 association
- Central object composed of three O-stars
- Low eccentricity orbit of the inner binary, e = 0.095, with an orbital period of 8.57 days
- Orbital period of the tertiary < 61 years

HD 206267

- Triple system O6.5 V((f)) + O9.5: V + OB of the Cep OB2 association
- Orbital period of the inner massive binary of 3.71 days
- Slightly eccentric orbit : $e = 0.119$
- Third component with constant radial velocity

Spectral disentangling

Previous determination of the orbital solution by Hillwig et al. (2006) for the inner binary + measures of the RVs of the third component

$\rightarrow$ Recover the individual spectra of both components via **disentangling**

(González & Levato 2006)

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This technique also has its **limitations** (González & Levato 2006)

- Broad spectral features are not recovered with the same accuracy as narrow ones
- Spectral disentangling does not yield the brightness ratio of the stars
- Small errors in the normalization of the input spectra lead to oscillations of the continuum in disentangled spectra
- Quality of the results depends on the RV ranges covered

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In the specific case of HD17505 : third component "pollutes" the observed spectra

Spectral disentangling

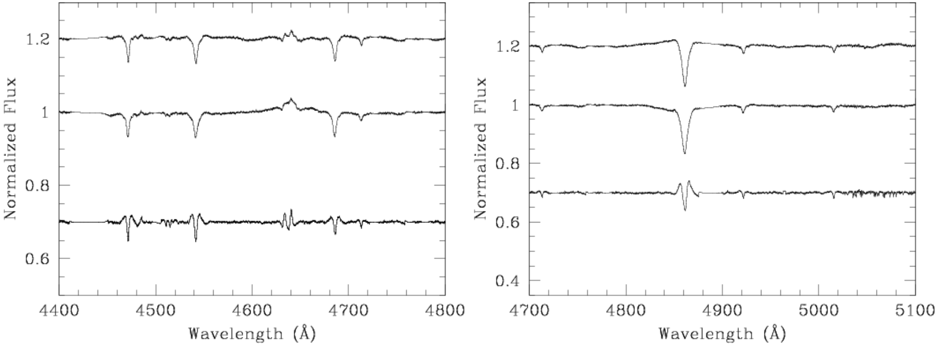


Figure 1 : Parts of a normalized disentangled spectra of the primary (top, shifted upwards by 0.2 continuum units), secondary (middle) and tertiary star (bottom, shifted downwards by 0.3 continuum units) of HD 17505.

Recombination

HD 17505

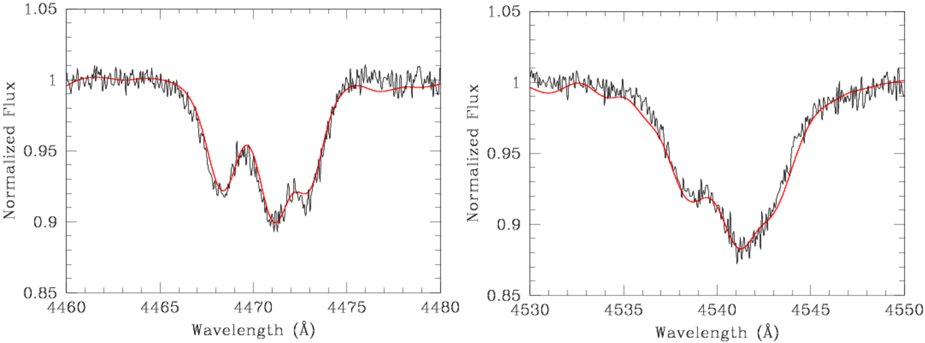


Figure 2 : Parts of a normalized spectrum of the triple system HD 17505 (black), along with the best-fit CMFGEN model spectra (red).

Spectral types and brightness ratio

Based on the reconstructed individual line spectra :

- Conti's quantitative classification criteria for O-type stars **(Conti & Alschuler 1971, Conti & Frost 1977, Mathys 1988, see also van der Hucht 1996)**

  $\Rightarrow$ Primary and secondary are **O7 V** stars

- $\frac{l_1}{l_2} = (\frac{EW_1}{EW_2})_{obs}(\frac{EW_{O7}}{EW_{O7}})_{mean} = (\frac{EW_1}{EW_2})_{obs}$

  $\Rightarrow$ Mean brightness ratio : $\mathbf{0.88 \pm 0.09}$

Good agreement with previous studies **(Hillwig et al. 2006)** :

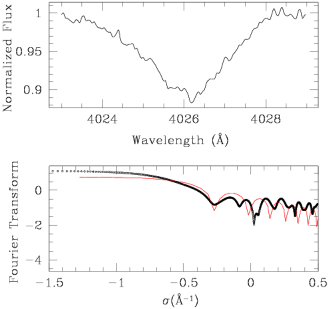
$$\text{O7.5V} + \text{O7.5V and } \frac{l_1}{l_2} \sim 1.00$$

Rotational velocities and macroturbulence

- **Rotational velocities**

  ⇒Determination of the **v sin(i)** of the stars of the system using a **Fourier transform method** (Gray 2008, Simón-Díaz & Herrero 2007)

  ⟹Mean vsin(i) = **62 and 68 kms^{-1}** for the P and S stars respectively



- **Macroturbulence**

  ⇒MACTURB (Gray, R.O. 2010, http://www.appstate.edu/~grayro/spectrum/spectrum276/node38.html)

  ⟹**60 and 65 kms^{-1}** for the P and S stars respectively

The CMFGEN code and method

Non-LTE model atmosphere code CMFGEN (Hillier & Miller 1998) :

Equations of radiative transfer and statistical equilibrium in the co-moving frame for plane-parallel or spherical geometries

First approximation of gravity, stellar mass, radius and luminosity **from literature** (Martins et al. (2005), Hillwig et al. (2006) and Muijres et al. (2012))

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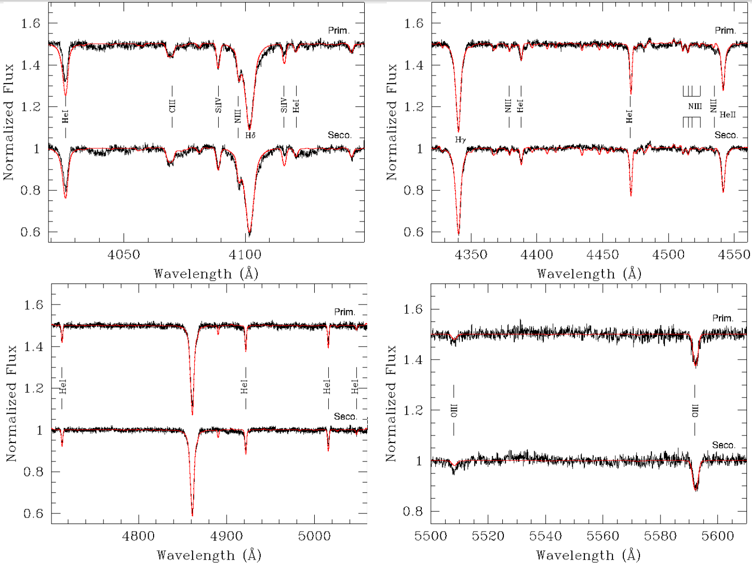
Iterative process that permits us to adjust these parameters :

1. The temperatures : relative strength of the He I λ 4471 and He II λ 4542 lines (Martins 2011)
2. Surface gravities : ~~through wings of Balmer lines~~
   Together with luminosities : iterative process through BC and $\frac{M_1}{M_2}$
3. Mass-loss rate and the clumping factor $\rightarrow$ Approximations
4. CNO abundances through the strengths of the associated lines

Results (1)

HD 17505



Results (2)

No significant overabundances :

$$[N/C] \simeq 3\,[N/C]_\odot$$
$$\& \ [N/O] \simeq 3\,[N/O]_\odot \text{ for the P star}$$
$$[N/C] \simeq 2\,[N/C]_\odot$$
$$\& \ [N/O] \simeq 1-2\,[N/O]_\odot \text{ for the S star}$$

vs.

$$[N/C] \simeq 100\,[N/C]_\odot$$
$$[N/O] \geq 5\,[N/O]_\odot$$

for the donor star in the case of a post-RLOF system

	Primary	Secondary	Sun[1]
He/H	0.1	0.1	0.089
C/H	$1.91^{+0.37}_{-0.40} \times 10^{-4}$	$1.97^{+0.40}_{-0.41} \times 10^{-4}$	2.69×10^{-4}
N/H	$1.37^{+0.25}_{-0.21} \times 10^{-4}$	$9.70^{+1.06}_{-0.84} \times 10^{-5}$	6.76×10^{-5}
O/H	$3.87^{+1.15}_{-0.93} \times 10^{-4}$	$4.73^{+2.19}_{-1.45} \times 10^{-4}$	4.90×10^{-4}

[1] (Asplund et al. 2009)

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No asynchronous rotation : $\frac{P_P}{\sin i} = 10.91$ and $\frac{P_S}{\sin i} = 10.12$ days

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$\Rightarrow$ No observational evidence of a past RLOF episode

Recombination

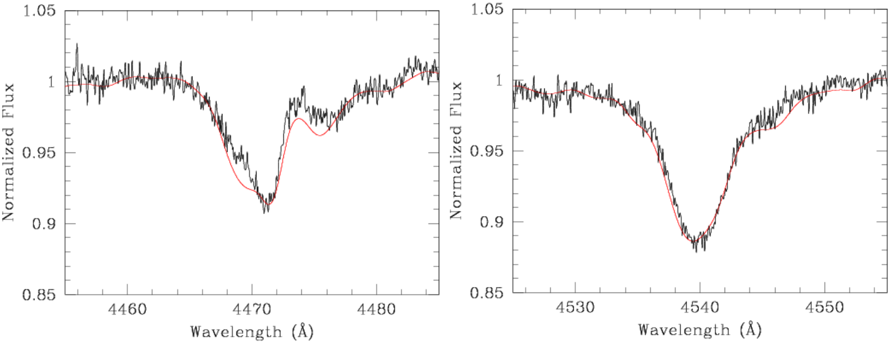

Figure 4 : Parts of a normalized spectrum of the triple system HD 206267 (black), along with a first fit with CMFGEN model spectra (red).

Conclusion

- Other targets that have been studied : HD 149404 & LSS 3074
  (Raucq et al. 2016, Raucq et al. 2017 (submitted))

→ First systems in a sample of binary systems with past mass-exchange episode

→ First step to better understand the interactions in massive binaries

- HD 17505 does not seem to be a good candidate

- Cases of HD 17505 and HD 206267 : Difficulties inherent to the techniques to be further studied and overcome

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Thank you

Appendix

	Prim.	Sec.
R ($R_\odot$)	13.4	13.6
M ($M_\odot$)	38.1	39.4
$T_{\rm eff}$ (10^4 K)	3.70 ± 0.15	3.67 ± 0.15
$\log(\frac{L}{L_\odot})$	5.50	5.50
$\log g$ (cgs)	3.75 ± 0.20	3.05 ± 0.20
β	1.07	1.07
v_∞ (km s^{-1})	2200	2500
$\dot{M}$ ($M_\odot$ yr^{-1})	2.3×10^{-7}	3.7×10^{-7}

Table 1 : The best-fit CMFGEN model parameters. The quoted errors correspond to $1\,\sigma$ uncertainties.