Apsidal Motion in The Massive Binary HD 152 248

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Abstract

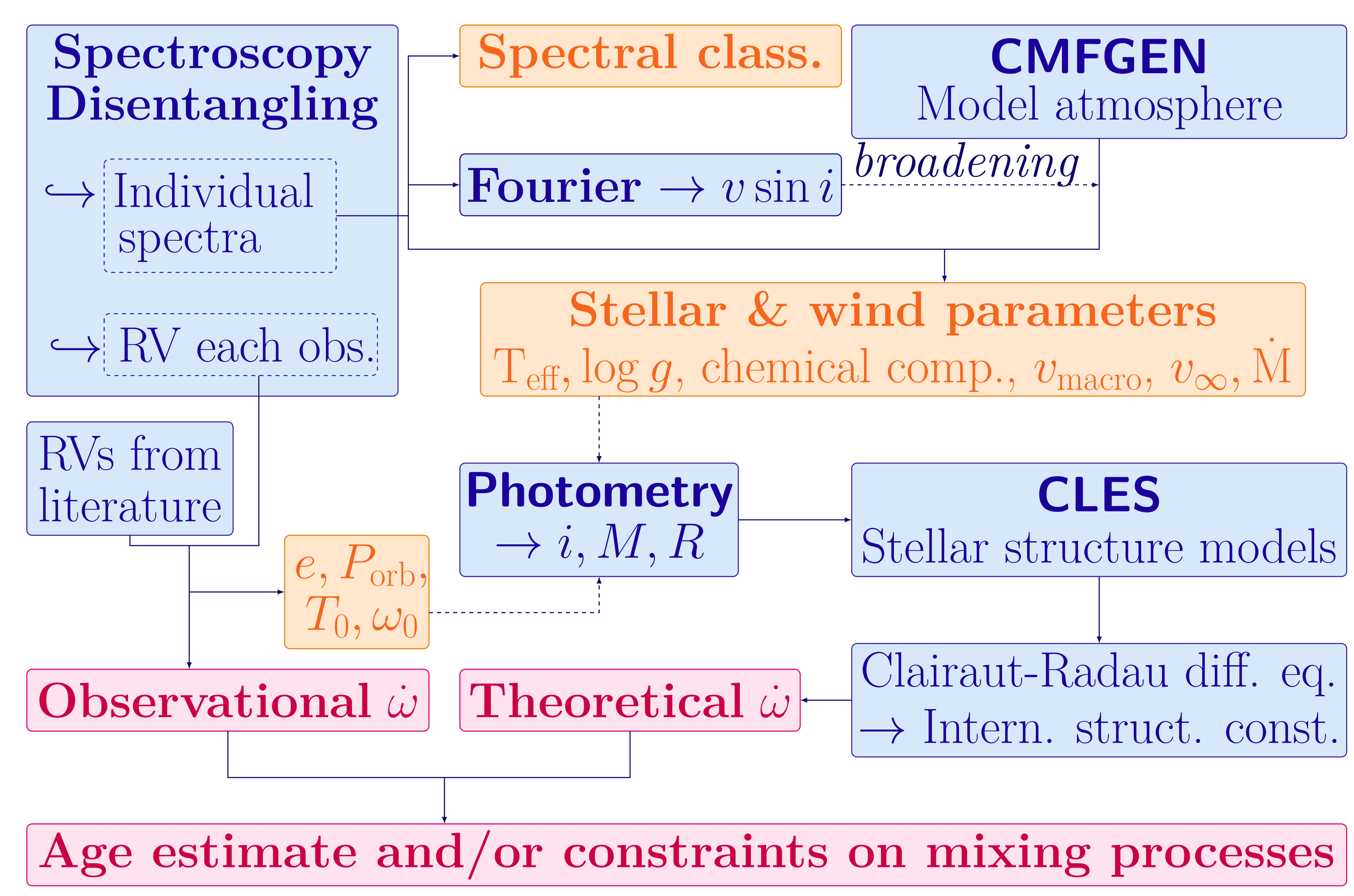
The eccentric massive binary HD 152 248, which hosts two O7.5 III(f) stars, is the most emblematic eclipsing O-star binary in the very young and rich open cluster NGC 6231. Measuring the rate of apsidal motion in such a binary system gives insight into the internal structure and evolutionary state of the stars composing it.

From a set of optical spectra of HD 152 248, we reconstruct the individual spectra of the stars and establish their radial velocities using a disentangling code. Combining radial velocity measurements spanning seven decades, we show that the system displays an apsidal motion at a rate of $(1.750^{+.350}_{-.315})^\circ\,\mathrm{yr}^{-1}$. We further analyse the reconstructed spectra with the `CMFGEN` model atmosphere code to determine stellar and wind properties of the system. The optical light curve of the binary is analysed with the `Nightfall` binary star code to constrain the Roche lobe filling factors of both stars to a value of 0.86 and derive an orbital inclination of $(68.6^{+0.2}_{-0.3})^\circ$. Absolute masses of $28.9^{+0.9}_{-0.8}$ and $29.1^{+0.9}_{-0.5}$ $\mathrm{M}_\odot$ are derived for the primary and secondary star respectively and mean stellar radii of 14.2 ± 0.4 $\mathrm{R}_\odot$ are obtained for both stars.

Motivations

- The **majority** of massive stars belong to **binary** systems:
  - Considerably affects the **evolution** of the stars;
  - Offers possibilities to constrain the **properties** of the stars.
- Interesting systems: **double-line spectroscopic eclipsing binaries**
  - Combine the photometric eclipses and the radial velocities obtained with spectroscopy;
  - Determine the masses and radii of the stars in a **model independent** way.
- Most interesting systems: binaries showing a significant **apsidal motion**
  - Slow precession of the line of apsides in an eccentric binary;
  - Arises from tidal interactions occurring between the stars of a close binary, interactions which are responsible for the non-spherical gravitational field of the stars.
- The **rate of apsidal motion** is **directly related to the internal structure of the stars**. Measuring the rate of apsidal motion hence
  - Provides a diagnostic of the **internal mass-distribution of the stars**, which is otherwise difficult to constrain;
  - Offers a test of our understanding of **stellar structure and evolution**.

Methods



Results

Spectroscopic analysis

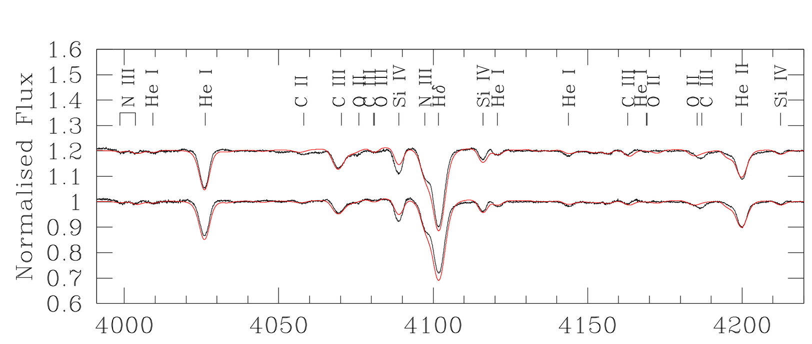


Figure 1: Normalised disentangled spectra (black) of the primary and secondary star of HD 152 248 together with the best-fit `CMFGEN` model atmosphere (red).

↪ $T_{\rm eff} = 34\,000 \pm 1\,000$ K

↪ $\log g = 3.48 \pm 0.10$ (cgs)

Limitations:

- Disentangling introduces artefacts in the wings of broad lines;
- `CMFGEN` does not account for the binarity → $\log g$ is underestimated and $T_{\rm eff}$ is only an average.

Photometric analysis

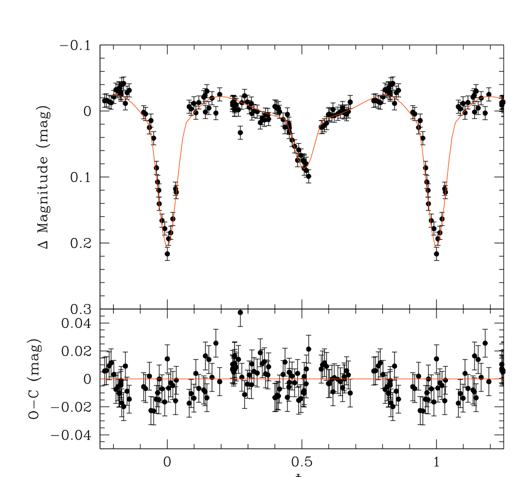


Figure 2: Best-fit `Nightfall` solution of the lightcurve of HD 152 248.

`Nightfall` uses Roche potential to describe the shape of the stars, accounts for reflection effects (mutual irradiation) and adopts a quadratic limb-darkening law.

↪ $i = (68.6^{+0.2}_{-0.3})^\circ$

↪ $f_{\rm P} = f_{\rm S} = 0.86^{+0.03}_{-0.02}$

↪ $\mathrm{M}_1 = 28.9^{+0.9}_{-0.8}$ $\mathrm{M}_\odot$
$\mathrm{M}_2 = 29.1^{+0.9}_{-0.5}$ $\mathrm{M}_\odot$

↪ $R_1 = R_2 = 14.2 \pm 0.2$ $\mathrm{R}_\odot$

Radial velocities and apsidal motion

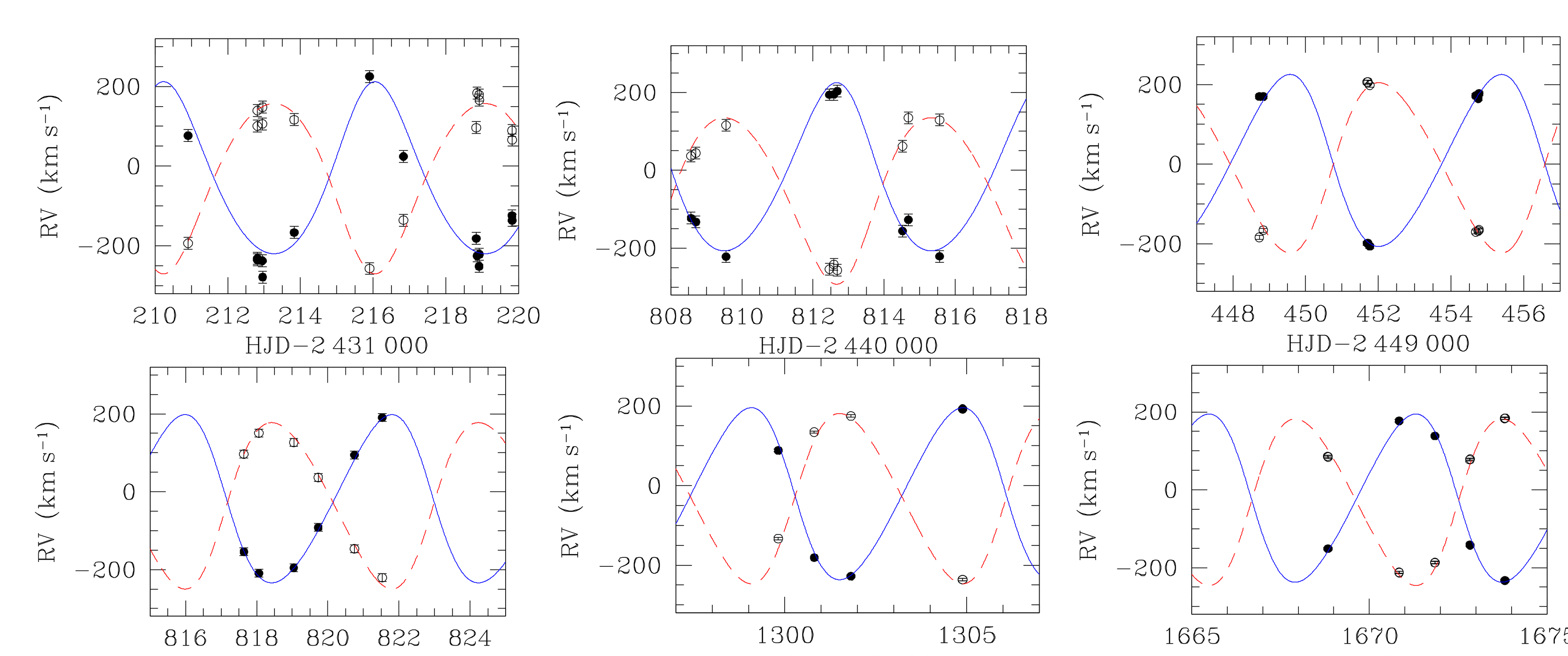


Figure 3: Comparison between the measured RVs of the primary (filled dots) and secondary (open dots) and the RVs computed using the `CMFGEN` best-fit parameters. Top panels correspond to data from Struve (1944, left), Hill et al. (1974, middle) and one epoch of *IUE* data from Penny et al. (1999, right). Bottom left panel yields one epoch of data from Mayer et al. (2008) while bottom middle and right panels correspond to RVs re-derived in this work.

↪ $P_{\rm orb} = 5.816475^{+0.000085}_{-0.000075}$ d

↪ $e = 0.134^{+0.007}_{-0.004}$

↪ $\dot{\omega} = (1.750^{+.350}_{-.315})^\circ\,\mathrm{yr}^{-1}$

Future work

The next steps consist in

- Building `CLES` models;
- Computing the theoretical $\dot{\omega}$;
- Inferring an age estimate of the binary system and constraints on mixing processes inside the stars.

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Further Information

- Email: sophie.rosu@uliege.be
- Rosu S., Rauw G., Gosset, E., Manfroid, J. & Royer, P. 2019, A&A, in preparation

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