Abstract

The eccentric massive binary HD 152248, 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 152248, 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 \((1.750 \pm 0.250) \times 10^{-3} \text{yr}^{-1}\). 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 \((68.6^{+0.3}_{-0.3})^\circ\). Absolute masses of \(28.9^{+0.9}_{-0.8}\) and \(20.1^{+0.9}_{-0.5}\) \(M_\odot\) are derived for the primary and secondary star respectively and mean stellar radii of 14.2 \pm 0.4 \(R_\odot\) 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.

Limitations:

- Disentangling introduces artefacts in the wings of broad lines;
- CMFGEN does not account for the binarity to \(\log g\) is underestimated and \(T_{\text{eff}}\) is only an average.

Methods

- Spectral Disentangling
- Fourier \(\rightarrow v \sin i\)
- Individual spectra
- RV each obs.
- RVs from literature
- Stellar & wind parameters
- CMFGEN Model atmosphere
- Stellar structure models
- CLes
- Nightfall binary star code
- \(T_{\text{eff}}, g, \log g, \text{chemical comp.}, v_{\text{micro}}, v_{\infty}, M\)
- \(\epsilon, P_{\text{orb}}, T_{\text{orb}}, \omega\)
- Photometry
- \(\rightarrow i, M, R\)
- Observational \(\omega\)
- Theoretical \(\omega\)
- Clairaut-Radau diff. eq.
- Intern. struct. const.
- Age estimate and/or constraints on mixing processes

Results

Spectroscopic analysis

Figure 1: Normalised disentangled spectra (black) of the primary and secondary star of HD 152248 together with the best-fit CMFGEN model atmosphere (red).

\(T_{\text{eff}} = 34,000 \pm 1,000\) 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 to \(\log g\) is underestimated and \(T_{\text{eff}}\) is only an average.

Photometric analysis

Figure 2: Best-fit Nightfall solution of the lightcurve of HD 152248.

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

\(i = (68.6^{+0.3}_{-0.3})^\circ\)

\(f_B = f_S = 0.86^{+0.01}_{-0.02}\)

\(M_1 = 28.9^{+0.9}_{-0.8} M_\odot\)

\(M_2 = 20.1^{+0.9}_{-0.5} M_\odot\)

\(R_1 = R_2 = 14.2 \pm 0.2 R_\odot\)

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.

\(P_{\text{orb}} = 5.816475^{+0.00095}_{-0.00097} \text{d}\)

\(c = 0.134^{+0.007}_{-0.004}\)

\(\omega = (1.750^{+0.250}_{-0.250}) \times 10^{-3} \text{yr}^{-1}\)

Future work

The next steps consist in

- Building CLes models;
- Computing the theoretical \(\omega\);
- Inferring an age estimate of the binary system and constraints on mixing processes inside the stars.

References


Further Information

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