*Massive Stars Near and Far*
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# Apsidal Motion in Massive Binaries: CPD-41° 7742, an Extreme Case?

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**Abstract.** We study the apsidal motion in close eccentric massive binaries. Measuring the rate of apsidal motion in such a system gives insight into the internal structure and evolutionary state of the stars. We focus on CPD-41° 7742, for which independent studies in the past showed large discrepancies in the longitude of periastron of the orbit, hinting at the presence of apsidal motion. We perform a consistent analysis of all observational data to solve this apparent discrepancy and report the first determination of apsidal motion in this system. This study confirms the need for enhanced mixing in the stellar evolution models of the primary star to reproduce the observational properties. This points towards larger convective cores than usually considered.

**Keywords.** Stars: early-type, evolution, massive, Binaries: spectroscopic, eclipsing

## 1. Introduction and motivations

The majority of massive stars belong to binary systems: This considerably affects the evolution of the stars and offers tremendous possibilities to constrain their properties in a model independent way. The most interesting systems in this respect are double-line spectroscopic (SB2) eclipsing binaries showing a significant apsidal motion. The apsidal motion is the slow precession of the line of apsides with time. It arises because of the tidal interactions occurring between the stars of a close eccentric binary, interactions which are responsible for the non-spherical gravitational fields 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, and also offers a test of our understanding of stellar structure and evolution. We here focus on the massive SB2 eclipsing binary CPD-41° 7742, located in the young open cluster NGC 6231. Large discrepancies in the longitude of periastron ($\omega$) derived for this binary were reported in the past by independent studies (Sana et al. 2003, Sana et al. 2005, Bouzid et al. 2005). These discrepancies hint at the presence of apsidal motion in the system. We carry out the first consistent analysis of all the observational data of CPD-41° 7742 available at the time of this study to enforce a rate of apsidal motion ($\dot{\omega}$) of the system; further details are given by Rosu *et al.* (2022).

## 2. Methods and results

We used our disentangling code based on the method described by González & Levato (2006) to reconstruct, from a set of optical spectra of CPD-41° 7742, the individual spectra of the stars as well as their radial velocities (RVs) at each time of observation. The reconstructed spectra were analysed with `CMFGEN` (Hillier & Miller 1998) to determine the



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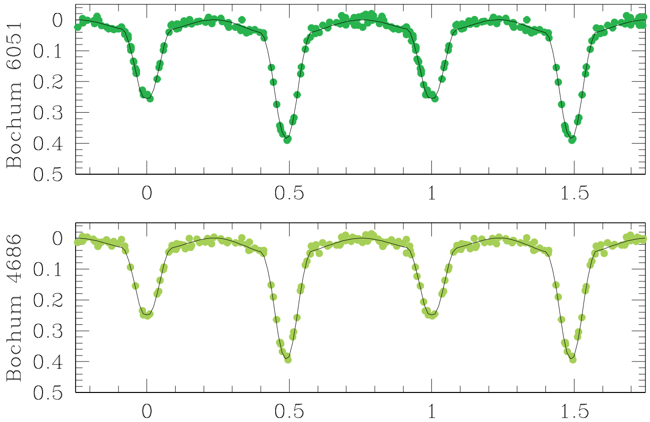


**Figure 1.** Best-fit to the Bochum light curves.

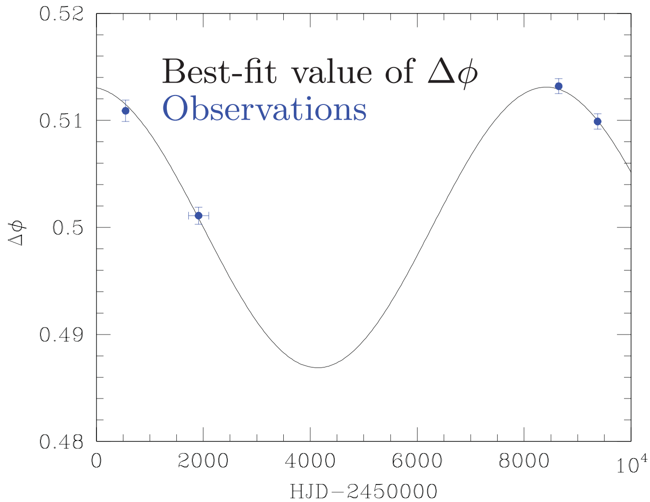


**Figure 2.** $\Delta\phi$ between primary and secondary minima as a function of time.

primary star's effective temperature. We combined our re-derived RVs to those coming from the literature to infer values for the orbital period. We analysed our set of light curves taken with the 0.6 m Bochum telescope at La Silla observatory (Royer et al. 1998) with `Nightfall` (Wichmann 2011) to determine the orbital inclination ($i$), stellar radii and masses, and effective temperature of the secondary star (see Fig. 1). We used the times of minima of the photometric observations (Bochum, *uvby* of Bouzid et al. (2005), and TESS taken during sectors 12 and 39, see Ricker et al. 2015) for the determination of $\dot{\omega}$. We used the relations from Giménez & Bastero (1995) that provide the phase difference as a function of $\omega$, $i$, and the eccentricity $e$ to adjust the curve to the observations, explicitly accounting for the apsidal motion (see Fig. 2). In this way, we derived $\dot{\omega} = 15.^{\circ}38^{+0.42}_{-0.51}\,\mathrm{yr}^{-1}$ and $e = 0.0204 \pm 0.0016$. We computed stellar evolution models for the binary system with the `Clés` code (Scuflaire et al. 2008) adopting different prescriptions for the internal mixing (overshooting and turbulent diffusion). We used the `min-Clés` routine to search for best-fit models of the stars. To reproduce $\dot{\omega}$, a large amount of turbulent diffusion needs to be included in the models of the primary star. The stellar models have thus larger convective cores than standard models.

## 3. Conclusion

We solved the apparent discrepancies in the longitude of periastron through the coherent analysis of all observational data of the system, explicitly accounting for the apsidal motion, which is determined for the first time. This study suggests that massive stars have larger convective cores than usually considered in stellar evolution codes.

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