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The sdBV+dM close-to-synchronization binary TIC 137608661: inclination and thin disk population

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Abstract

TIC 137608661 is a new sdBV+dM reflection-effect binary discovered by the *TESS* space mission with an orbital period of 7.21 hours. In addition to the detailed study of this system that was recently published (Silvotti et al., 2022), this article contains a further discussion on its inclination. Moreover, from the 3D space velocities of the binary obtained from the system's radial velocity and from the Gaia DR3 proper motion, it is shown that TIC 137608661 belongs to the galactic thin disk population.

Keywords: stars: horizontal branch; stars: binaries; stars: oscillations (including pulsations); asteroseismology; stars: individual: TIC 137608661

1. Introduction

In this section I summarize the main results obtained by Silvotti et al. (2022), which were presented at the sdOB10 meeting, and I refer to that paper for further details. Moreover, following some discussions occurred during the meeting, in the next sections some new information is given. Section 2 contains a short discussion on system's inclination. In section 3 it is shown that TIC 137608661 belongs to the galactic thin disk population.

TIC 137608661 is a new sdBV+dM reflection-effect binary discovered by the *TESS* space mission with an orbital period of 7.21 hours. At low frequencies the Fourier spectrum of the system is dominated by the orbital modulation and its first harmonics, but from 90 μHz up to $\sim$690 μHz many peaks correspond to the spectrum of a typical sdB g-mode pulsator. From a preliminary analysis of the light curve, we were able to immediately notice a well-defined rotational splitting of the pulsation frequencies, leading to a robust measurement of the rotation period in the sdB star's deep layers, equal to $\sim$4.6 days. This is the reason why we started a spectroscopic follow-up programme with two objectives: i) determine the atmospheric parameters of the sdB star from low-resolution spectra and ii) measure the sdB rotation rate in the outer layers of the star through rotational line-broadening from high-resolution spectroscopy. From low-resolution spectroscopy we obtained $T_{\rm eff} \simeq 27500$ K, $\log g \simeq 5.40$, $\log(\rm N_{He}/N_H) \simeq$ –2.90. The second goal was only partially achieved: we managed to rule out an sdB rotation synchronized with the orbital period also in the outermost layers of the star, but we could not totally exclude a rigid rotation. However, our analysis suggests a differential rotation for TIC 137608661, with the envelope rotating faster than the core at a projected rotation velocity not higher than 7.5 km/s. This velocity would correspond to an orbital period of 1.3 days when we assume an inclination of 65° for the rotation axis of the sdB star. A differential rotation with the envelope rotating faster than the core has been seen also in a few other systems similar to TIC 137608661 (Silvotti et al., 2022, Table 4 and refs therein). The results obtained for TIC 137608661 are important because this binary falls in a critical and poorly populated region of the P_{orb}-P_{rot} plane, in which the sdB star is gaining angular momentum without having already achieved full synchronization with the orbital period. In Figure 1 the position of TIC 137608661 in the P_{orb}-P_{rot} plane is compared with all the others sdB/O+dM and sdB/O+WD short-period binaries for which the sdB/O rotation period was measured. More details are given in the caption.

2. Inclination

In Silvotti et al. (2022, section 6.2) an inclination of $(65^{+10}_{-20})^{\circ}$ was obtained for the angle between sdB rotation axis and line of sight by measuring the relative amplitudes of the components of five l=1 pulsation frequency triplets. To test the reliability of this measurement, we compare this result with the inclination that we obtain from a new method presented in this meeting by Brad Barlow. Following the method, the inclination of a "reflection system" similar to TIC 137608661 can be determined from the amplitude ratio between orbital frequency and 1st-harmonic. In our case an amplitude ratio of 0.165 would correspond to an inclination of about 54°, compatible with our asteroseismic measurement. Note that the angle measured by Silvotti et al. (2022) is the inclination between sdB rotation axis and line of sight, while the angle obtained from Barlow's method is the inclination between perpendicular to the orbital plane and line of sight. In general the two angles can be different and are exactly the same only if the sdB rotation axis is perpendicular to the orbital plane.

Finally, we note that a lower inclination would be obtained using the relations proposed by Schaffenroth et al. (2018, Fig. A.2). Considering both the amplitude of the reflection effect and the RV amplitude and interpolating the two curves for a companion mass of $\approx$100 M_{Jup} (as obtained by Silvotti et al. 2022), we get an inclination between $\sim$26° and $\sim$40°. But this estimate of the inclination can have quite large errors since it is based on only two HW Vir systems.

3. Galactic population

From TIC 137608661's system radial velocity of –28.6 km/s (Silvotti et al., 2022) and the Gaia DR3 proper motion (PMRA=13.45 mas/yr, PMDEC=26.63 mas/yr), we compute the 3D space velocities of the system which are shown in Figure 2. These velocities are compatible with TIC 13760866 beeing part of the thin disk galactic population.

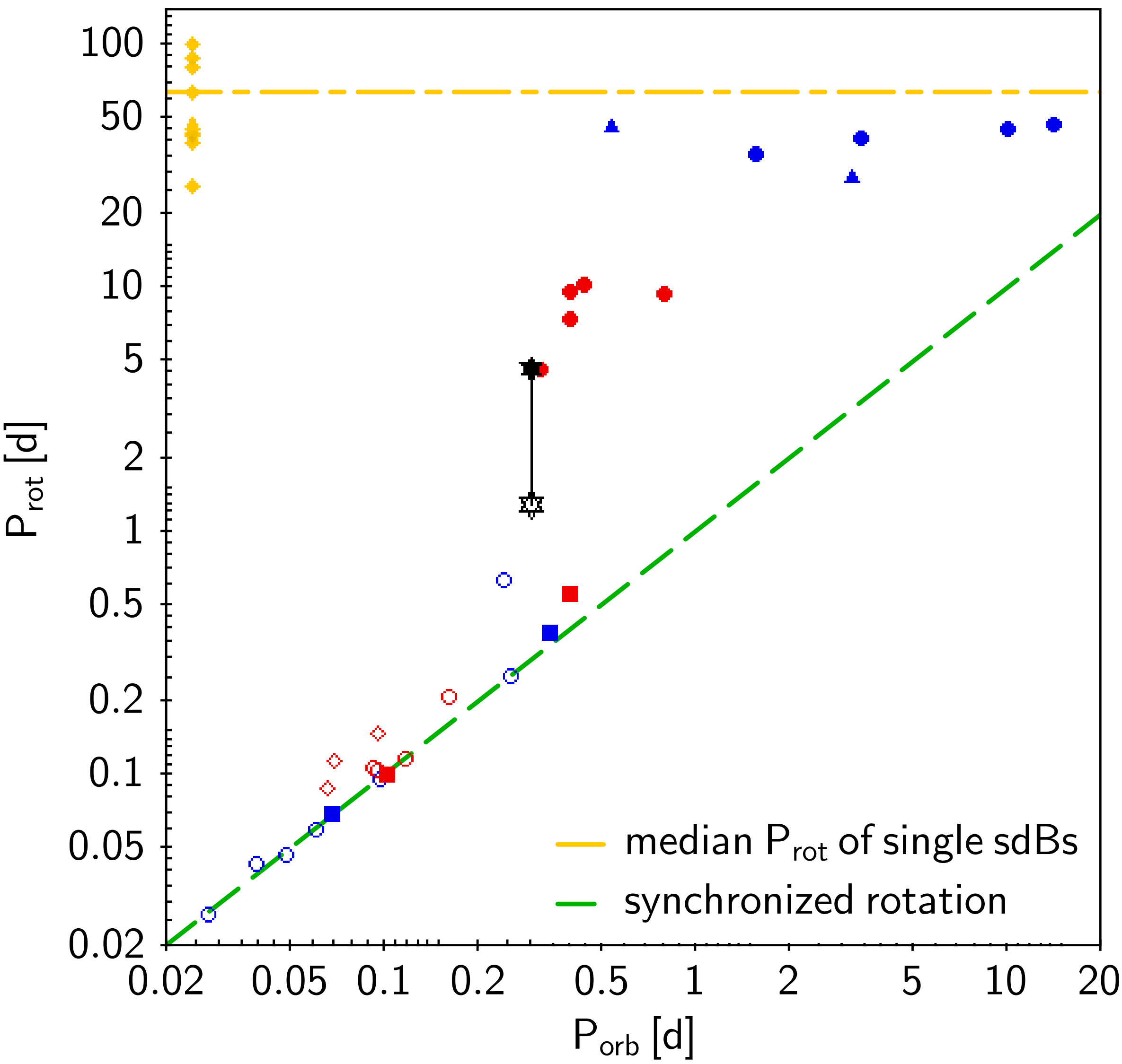

Figure 1: SdB/O rotation period vs orbital period. Black symbols: TIC 033834484, deep-layers rotation period from g-modes frequency splitting (filled star), and lower limit to the surface rotation period from spectral line broadening (empty star). Red symbols: sdB/O+dM systems with sdB/O rotation period obtained from g-mode or p-mode frequency splitting (filled circles and filled square respectively) or from spectral line broadening (empty circles or empty diamonds, the latter indicating a brown dwarf companion). Blue symbols: sdB/O+WD systems with sdB/O rotation period obtained from g-mode frequency splitting (filled circles or filled triangles that indicate a lower limit) or p-mode frequency splitting (filled squares) or from spectral line broadening (empty circles). Yellow symbols: as a reference, the rotation periods of single sdB stars, obtained from g-mode frequency splitting, are also shown (triangle indicating a lower limit). A list of references for each star shown in this plot is given in Silvotti et al. (2022, Table 4 and caption of Figure 16). In that figure the sdB+dM binary V1405 Ori (Reed et al., 2020), corresponding to the red square at $P_{orb} = 0.398$ d and $P_{rot} = 0.555$ d, was missing.

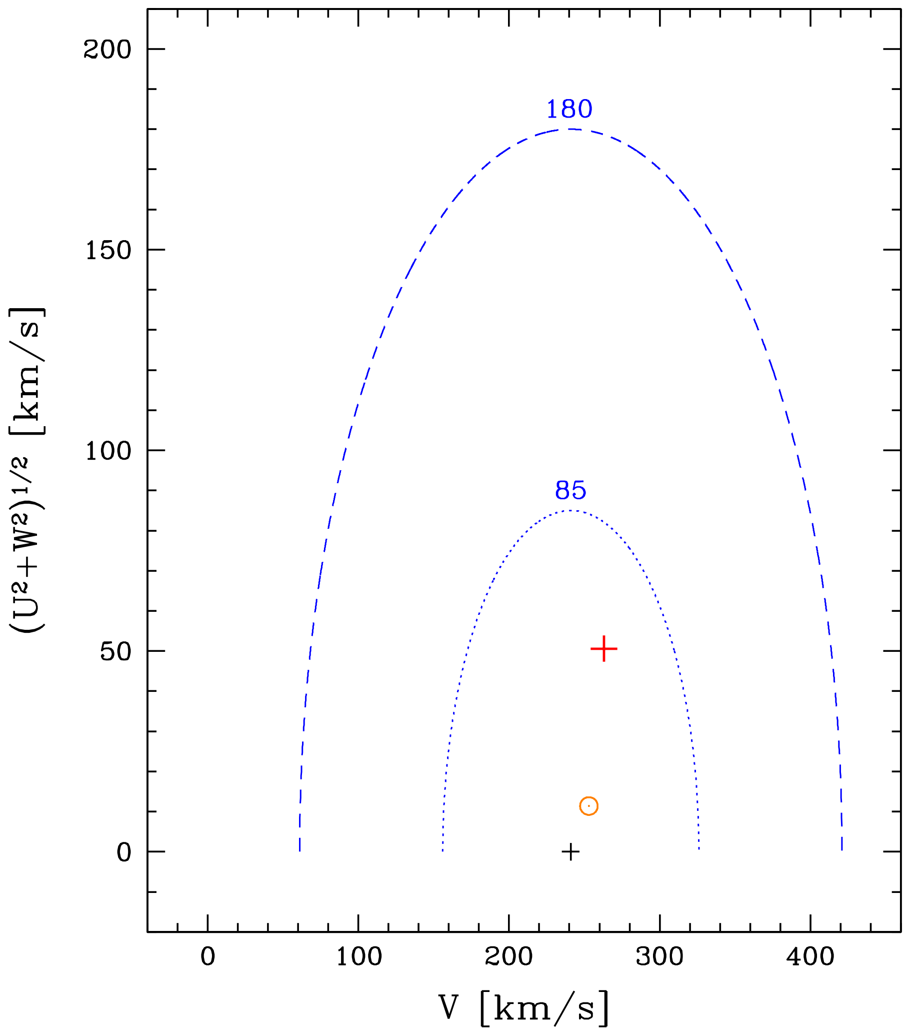

Figure 2: The position of TIC 137608661 in the Toomre diagram (red cross, errors are smaller than the cross). The velocity component V is measured in the direction of the rotation of the Galaxy, U towards the Galactic centre, and W perpendicular to the plane. The black cross and the yellow circled dot mark the local standard of rest (LSR) and the position of the Sun, respectively. According to Fuhrmann (2004), the boundaries for thin and thick disk are located at 85 and 180 km/s (dashed blue lines centered around the LSR).

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Further Information

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Conflicts of interest

The author declares no conflict of interest.

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