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The resonant B1II + B1II binary BI 108†

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Abstract. BI 108 is a luminous variable star in the Large Magellanic Cloud classified B1 II. The variability consists of two resonant periods (3:2), of which only one is orbital, however. We discuss possible mechanisms responsible for the second period and its resonant locking.

Keywords. stars: binaries, stars: early-type

1. Introduction

The observed period of BI 108 (OGLE-ID: LMC SC9-125719, MACHO-ID 79.5378.25) of 10.73 d has six equidistant but distinct minima and some symmetry around the deepest minimum. At close inspection, it became clear that the lightcurve can actually be disentangled into two periods with a resonant ratio of 3:2 (see figures in Kołaczkowski *et al.* in press). From October 2008 to January 2009 20 spectra were taken at ten epochs with the echelle spectrograph UVES, mounted at the 8.2 m telescope UT2 on Cerro Paranal.

2. Orbital parameters and spectral disentangling

The obtained spectra are of an SB2 composite nature, however, only one single period is present in the radial velocities, namely $P_{\rm orb.} = 5.37$ d. Star A and B have an almost circular orbit, similar mass, and are in a similar evolutionary stage, being both very early B supergiants, B0 II+B0 II. No circumstellar gas, i.e. no mass transfer, was detected. The spectral disentangling was done with VO-KOREL based on KOREL, Hadrava (1995):

$P_{\rm sup.}$	10.73309 d	Periastron long.	93°
$P_{\rm res.}$	3.57793 d	K_1	170 km/s
$P_{\rm orb.}$	5.36654 d	K_2	225 km/s
Epoch (min. light)	MJD=51 163.3915	q	0.76
Periastron date	MJD=54 742.8345	$a \sin i$	41.5 $R_\odot$
Eccentricity	0.08	$M \sin^3 i$	33.6 $M_\odot$

The resonant period is not completely absent in the spectra, however, but modulates the line strengths. In particular, the total equivalent width (EW) over both components is about constant, while each component varies strongly, i.e. it seems as if a certain fraction of equivalent width is exchanged between the stars with a period of $P_{\rm res.} = 3.58$ d, although admittedly our data is too scarce to claim so with much certainty. For brevity, we call this behavior "EW-shuffling" (see Fig. 1, right) in the following.

3. Discussion

A good hypothesis for the explanation of the system has to fulfill a number of criteria: **1.)** Explain why the superperiod is disentangled into two resonant periods. **2.)** Provide a strong and stable locking mechanism between the two periods. **3.)** Explain the phase

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† Based on observations under ESO program 382.D-0311.

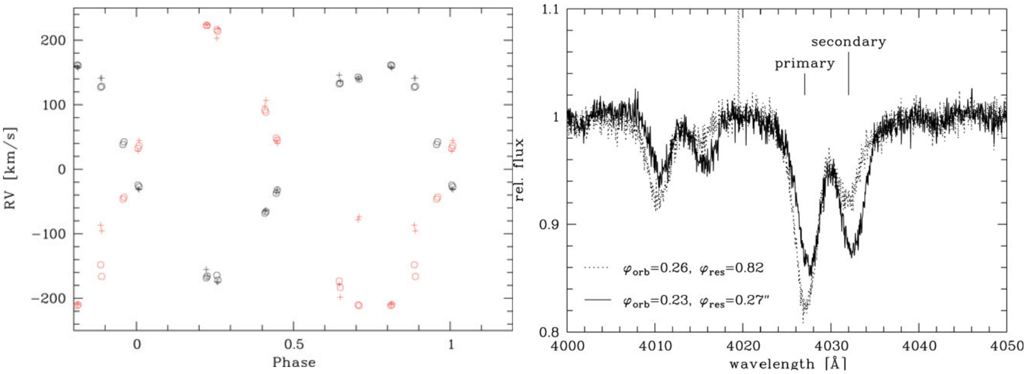

Figure 1. Left panel: Orbital velocities determined by VO-KOREL disentangling. Crosses are values derived from Si III 4553, circles from Hβ. Sort with $P_{\mathrm{orb.}}$=5.36654 d.
Right panel: UVES spectra taken at similar orbital, but opposite resonant quadrature phase. The “EW shuffling” between both lines is obvious.

relation, i.e. **a.)** $T_{\mathrm{min,res.}} = T_{\mathrm{min,orb.}}$, and **b.)** the RV vs. light curve relations, not as a line-of-sight coincidence, but for all aspects. **4.)** Provide an evolution scenario, in which the current system, hosting (at least) two B0 II stars, could have evolved from a plausible off-the-shelf system. **5.)** Provide at least a toy model for the EW shuffling.

In the following we discuss several hypothesis: **Lagrangian triple:** A Lagrangian triple is a system with three stars A+B+C on a common orbit, trailing each other with $\Delta\phi = 120°$. In a more general scheme, concentric orbits for stars with unequal masses are possible as well. EW shuffling might be due to the unrecognized component switching between A and B. However, such a system quite strongly violates criteria 2, 3b, and 4. **Hierarchical system:** A system of type (Aa+Ab)+(Ba+Bb) was the original suggestion when the system was first published Ofir, 2008. However, this suggestion falls short in criteria 1, 2, 3a, and 3b. **Two-star magnetic resonance:** This hypothesis assumes only two stars A+B, with the spin-orbit relation locked by magnetic fields. Criteria 1 and 3 are naturally fulfilled and 4 is not a major problem a priori, but the 3:2 locking ratio might be an issue for criterion 2 (at least for dipoles). Yet neither the EW shuffling nor the photometric curve look like anything a magnetic star usually has to offer. **Two-star tidal resonance:** Also only two stars A+B, but their spin-orbit relation are locked due to tidal interaction. Again criteria 1 and 3 are naturally fulfilled, while according to Witte & Savonije (2001) 2 and 4 are plausible. Geometrical distortion and light modulation by a strong tidal wave is at least a toy model for the EW behaviour.

As Witte & Savonije (2001) point out in a study of a $10\,\mathrm{M}_\odot+10\,\mathrm{M}_\odot$ main sequence binary, such a tidal resonant locking might actually be quite common and stable during extended phases of the orbital circularization. Since we deal with massive stars, it is as well plausible that the stars have evolved away from the main sequence before being fully circularized. Although the tidally locked scenario leaves uncomfortably many open questions, it is the one requiring the least extreme assumptions, satisfying Occam’s razor.

References

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