β Lup, δ Lup, and τ^1 Lup observed by BRITE-Constellation

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Time-series analysis of BRITE-Constellation photometry of β Lup, δ Lup and τ^1 Lup revealed 16, 22 and four pulsation modes, respectively. An attempt to constrain internal structure of these stars via seismic modelling was also made.

The BRITE-Constellation (B-C) satellites observed many bright stars in the Scorpius-Centaurus (Sco-Cen) OB association. In this paper, we report preliminary results of the study of three early B-type stars (β Lup, δ Lup, and τ^1 Lup), members of the Upper Centaurus-Lupus subgroup of Sco-Cen. Their membership was established by Hipparcos proper motions and distances (de Zeeuw et al., 1999).

The combined blue and red-filter B-C photometry of the three program stars revealed their rich frequency spectra which are shown in Fig. 1. In β Lup (B2 IV, $m_V = 2.7$ mag), 16 frequencies were detected, all in the gravity mode domain. This makes this star an interesting case of early B-type SPB star (see also Daszyńska-Daszkiewicz et al., these proceedings). δ Lup (B1.5 IV, $m_V = 3.2$ mag) and τ^1 Lup (B2 IV, $m_V = 4.5$ mag) are both hybrid β Cep/SPB stars: we detected 19 gravity (g) and three pressure (p) modes plus one combination term in δ Lup, and two g- and two p-modes in τ^1 Lup. Since by now only a single p-mode was known in δ Lup and a single p-mode in τ^1 Lup, the discovery of over 40 modes in these three stars shows clearly the potential of BRITE photometry in the studies of bright massive pulsators.

Both β Lup and δ Lup are relatively fast rotators ($V \sin i$ equals to about 100 and 210 km s^{-1}, respectively) and show frequency groupings, similar to those seen in Kepler observations of some B-type stars (Balona et al., 2011). With 16 intrinsic g-modes of which twelve form two frequency groupings, β Lup seems to be particularly suitable for seismic modeling. For this star, we tried to obtain models, which comply with the following requirements: (i) unstable modes form two separate groups consistent with the observed frequency groupings, (ii) they are either dipole ($l = 1$) or quadrupole ($l = 2$) g-modes, (iii) no other broad groups of unstable dipole and/or quadrupole g-modes are present in the frequency region of 0.2 – 0.6 d^{-1}. Figure 2 shows an example of a model with empirically modified rotation rate $\Omega(r)$ which fulfills the three requirements. In this case, two frequency groups at 0.27 and 0.53 d^{-1} can be interpreted as unstable quadrupole modes with $m = -1$ and 0. Only two more groups of unstable $l = 1$ or 2 modes are located at the frequency region shown in Fig. 1, but their frequencies are below 0.2 d^{-1} where observations do not show any variability exceeding detection threshold.

For δ Lup, which also shows frequency groupings, the frequency spectrum is more complicated, more groups of dipole and quadrupole modes are unstable and some groups of modes overlap. This leads to a large ambiguity in interpreting the observed spectrum.

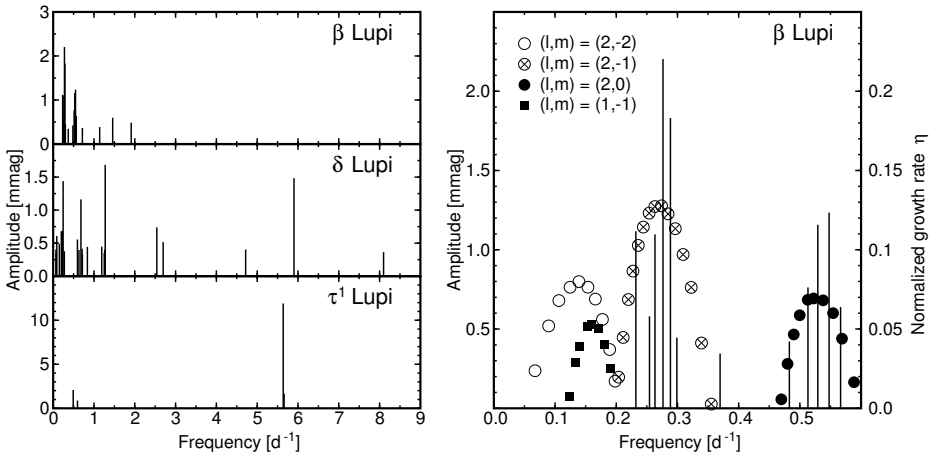

Fig. 1: Left: BRITE frequency spectra for β Lup, δ Lup, and τ^1 Lup. Right: Observed low-frequency region of frequency spectrum of β Lup showing two frequency groupings, centred at 0.27 and 0.53 d^{-1}, and normalized growth rates, η, for several sequences of unstable ($\eta > 0$) dipole ($l = 1$) and quadrupole ($l = 2$) modes.

As it is well known, non-rotating models have problems in explaining in full detail the β Cep/SPB hybridity and, in particular, instability of g-modes. As was already shown for β Cen (Pigulski et al., 2016), taking effects of rotation into account widens considerably the range of frequencies of unstable modes. This is also the case of the three stars studied here, of which two, β Lup and δ Lup, are fast rotators: their frequency spectra can be explained in rotating models. There are at least several other rapidly rotating β Cep stars (ϵ Per, ϵ Cen, β Cru, λ Sco, κ Sco) that have already been observed by the B-C, so that the prospects for detailed seismic studies of rapidly rotating B-type stars with B-C observations are promising.

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