Probing the Internal Mixing Processes and Angular Momentum Transport in B-type Hybrid Pulsators on the Main Sequence

PI.: ***Dr. Péter I. Pápics****. Co-Is.: Prof. Dr. Conny Aerts, Dr. Ehsan Moravveji*
University of Leuven, Belgium

Towards more **massive stars** (stars having a convective core and a radiative envelope) along the main sequence, stellar lifetime becomes strongly influenced by **internal mixing processes** such as core overshooting, diffusion, and rotation. Our knowledge of these processes is very limited, and this lack of understanding results in large uncertainties on current stellar structure and evolution models of massive stars. As these models are important cornerstones for several fields of modern astrophysics (e.g., chemical enrichment of galaxies, stellar life cycles and their effects on star and planetary system formation, dynamics of stellar clusters, etc.), these shortcomings need to be resolved.

Asteroseismology is one of the few tools that allow us to study the interiors of stars by the interpretation of their pulsation signal. The last decade brought an immense revolution to the field thanks to the succes of space telescopes such as CoRoT and *Kepler*, and thanks to vast improvements of asteroseismological techniques. While the nominal *Kepler* mission already delivered the long-sought-after revolution in stellar physics for solar-like stars and red giants, similar achievements were not possible for massive stars as most of these targets were avoided in the FoV. The scanning nature of the K2 mission provides a few selected fields in or very near the galactic plane that are rich in OB stars, and with this proposal **our goal is to exploit the special opportunity given by the position of Field 9 on the Galactic plane to extend K2's legacy towards the calibration of stellar structure and evolution models of massive stars using hybrid pulsator B dwarves**.

There are two large groups of heat-driven OB pulsators (Aerts et al. 2010, Asteroseismology, Springer). The more massive ($\mathcal{M} > 8\mathcal{M}_\odot$) and hot ($18\,000 - 32\,000$ K) β Cep stars oscillate in low-order p and g modes with typical periods of $2 - 8$ h. Their oscillation spectra shows a quasi-equidistant spacing in frequency space. The less massive and cooler ($11\,000 - 22\,000$ K) slowly pulsating B (SPB) stars pulsate in high-order g modes with periods of $0.8 - 3$ days. Their dominant modes show spacings in period. The two instability regions overlap around spectral type B2 – B3, where hybrid pulsators have been found (see Fig. 1). The pulsation properties of these stars are strongly influenced by the mentioned mixing processes (e.g., Miglio et al. 2008, MNRAS, 386, 1487), which makes them ideal asteroseismic probes of internal angular momentum distribution and chemical mixing.

Even in the era of space-based telescopes, observations of OB stars are a rarity. They are handicapped not only because of their relatively low number compared to Solar-like and KM dwarves, but also because most missions are driven by exoplanet detections, where these starts are preferably avoided. As a consequence, we have less than two dozens of OB dwarves at the moment where in-depth studies managed to put at least some constraints on the extent of the overshoot region around the core and a small subsample on the internal rotation profile (Aerts 2015, IAUS, 307, 154A). Even more striking is that there is only one star where a full actual seismic modelling was carried out based on gravity modes, resulting in stringent constraints on – besides other fundamental parameters – the core overshoot (Pápics et al. 2014, A&A, 570, A8), the diffusive mixing (Moravveji et al. 2015, A&A, 580, A27), and even an inversion of the internal rotation profile (Triana et al. 2015, ApJ, 810, 16). The available observational studies (e.g., Degroote et al. 2010, Nature, 464, 259; Pápics et al. 2011, A&A, 528, A123; Degroote et al. 2011, A&A, 536, A82; Balona et al. 2011, MNRAS,

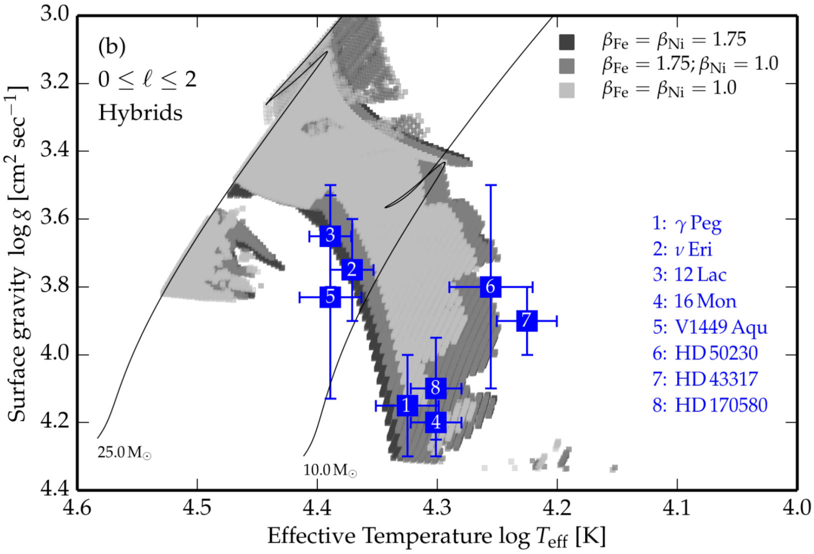

Figure 1: *The extension of the hybrid instability strip on the Kiel diagram. The blue squares show the position of confirmed hybrid pulsators. (Moravveji 2016, MNRAS, 455, L67)*

413, 2403; Pápics et al. 2012, A&A, 542, A55; Pápics et al. 2013, A&A, 553, A127; Pápics et al. 2015, ApJL, 803, L25) have demonstrated that the richness of variable behaviour among these stars is so large that the details in the internal physics among these objects must be different. The real progress in statistically meaningful modelling efforts is held back not only by the low number of available targets, but also by the lack of targets that are most suitable for modelling: the **hybrid pulsators**. The fact that they harbour both p and g modes mean that their pulsations have **probing power both near the surface and near the core regions**. Unluckily we have no *Kepler*/K2 photometry of hybrid pulsators so far.

We propose the observation of 27 potential hybrid pulsators, which have been selected based on their spectral type and brightness. We propose the relatively brighter stars to avoid serious crowding issues and because for these stars we can conduct **simultaneous and follow-up observations** with the high-resolution HERMES spectrograph and the 3-channel MAIA CCD camera installed on the 1.2 meter Mercator Telescope on La Palma (operated by the host institute of the PI and the Co-Is, the Institute of Astronomy, KU Leuven).

Our **methodology** is as follows: we do frequency analysis on the detrended K2 data, then we attempt mode identification using period- and frequency-spacing patterns, or – if this is not possible – using multicolour photometry or time-resolved high-resolution high signal-to-noise spectroscopy. This is followed by forward modelling of the zonal modes. We iterate over theoretical frequency sets calculated using different input physics to fine-tune the equilibrium models until we reach the best fit. **This will result in a new generation of stellar structure models**. There might be stars that are found to be non pulsating, but these non-detections coupled with precise spectroscopy will be also very useful to validate the current excitation calculations, especially since at the moment the predicted region of hybrid pulsators on the HRD (see Fig. 1) is severely undersampled in terms of observational data.