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Wide-Field Variability Surveys: A 21st Century Perspective

Pulsational instabilities in hot pre-horizontal branch stars

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Abstract. The ϵ-mechanism is a self-excitation mechanism of pulsations which acts on the regions where nuclear burning takes place. It has been shown that the ϵ-mechanism can excite pulsations in models of hot helium-core flash, and that the pulsations of LS IV-14°116, a He-enriched hot subdwarf star, could be explained that way. We aim to study the ϵ-mechanism effects on models of hot pre-horizontal branch stars and determine, if possible, a domain of instability in the $\log g - \log T_{\rm eff}$ plane. We compute non-adiabatic non-radial pulsations on such stellar models, adopting different values of initial chemical abundances and mass of the hydrogen envelope at the time of the main helium flash. We find an instability domain of long-period ($400\,{\rm s} \lesssim P \lesssim 2500\,{\rm s}$) g-modes for models with $22000\,{\rm K} \lesssim T_{\rm eff} \lesssim 50000\,{\rm K}$ and $4.67 \lesssim \log g \lesssim 6.15$.

1 Introduction

Hot horizontal branch (HB) stars are core helium-burning low-mass stars ($\sim 0.5\,M_{\odot}$). Before settling in this phase, low-mass stars undergo a helium-core flash and subsequent subflashes. The blue horizontal branch (BHB; $7000\,{\rm K} \lesssim T_{\rm eff} \lesssim 21000\,{\rm K}$) is the hot part of the HB to the left of the RR Lyrae gap in the Hertzsprung-Russell diagram. The extreme horizontal branch (EHB) forms an extension of the HB at higher temperatures. The position of stars in the BHB or the EHB depends mainly on their hydrogen-rich envelope mass. EHB stars have hydrogen envelopes too thin to sustain hydrogen burning ([1]). The pre-EHB and pre-BHB stars are going through He-subflashes. EHB stars are identified with the hot subdwarf B stars in the field (sdB). The atmospheres of sdB stars are mostly hydrogen pure due to the action of diffusion. But there are some sdBs with mild helium enrichment. These stars could be at the pre-EHB phase where the ongoing diffusion has had no time to turn the envelope hydrogen pure ([2]). It has been shown that the ϵ-mechanism can excite pulsations in models of hot helium-core flash, and in the subsequent subflashes ([2]). However, a complete exploration of the properties of ϵ-driven pulsations in pre-EHB and pre-BHB stars is lacking. Here, we aim to extend the study of the ϵ-mechanism effects on stellar models appropriate for pre-BHB and pre-EHB stars.

2 Metodology and results

We constructed pre-EHB and pre-BHB models in the hot-flasher scenario, i.e., removing different amounts of the hydrogen-rich envelope by an artificially enhanced mass loss at the red giant branch

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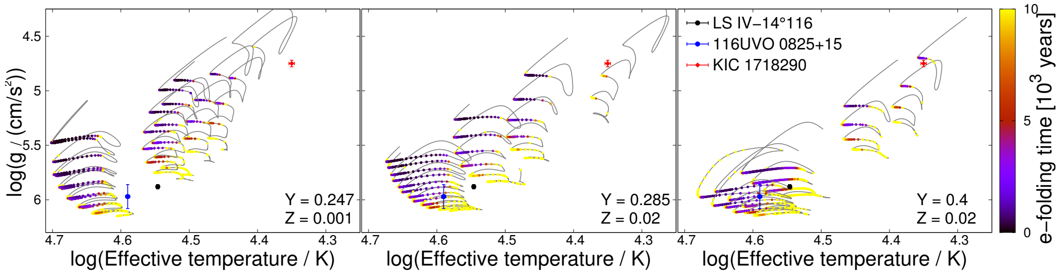

Figure 1. He-subflashes phase (grey lines) along with the location of the known He-rich hot subdwarf pulsators ([5–7]). Colored points are models with excited modes and the color coding shows the minimum e-folding time.

tip. We computed adiabatic and non-adiabatic non-radial pulsations in stellar models going through He-subflashes. The calculations were carried out with LPCODE and LP-PUL codes ([3, 4]). We found in all cases that the periods excited are in the range $400\,\mathrm{s} \lesssim P \lesssim 2500\,\mathrm{s}$. The longest and most unstable periods correspond to the first subflashes due to the larger nuclear energy release. We found an instability region at about $4.67 \lesssim \log g \lesssim 6.15$ and $4.3 \lesssim \log T_{\rm eff} \lesssim 4.7$ (Fig. 1). In models with lower surface gravities the modes are stabilized by radiative damping in the outer layers. Within the hot-flasher scenario there are no stellar models with greater temperatures and gravities. The characteristic times in which modes are excited are shorter than the typical timescales of subflashes. Therefore, they could grow to observable amplitudes. We found that ∼3 out of 100 pre-EHB stars should be pulsating.

3 Conclusion

We found an instability domain of long-period g-modes driven by the ϵ-mechanism associated to pre-EHB stellar models, but on the other hand, we did not obtain pulsational instability in pre-BHB stellar models. The location of known He-rich hot subdwarf pulsators (Fig. 1) is well reproduced by our theoretical predictions, although the observed periods in these stars are systematically longer than the predicted ones. Our results could constitute a theoretical basis for future searches of pulsators in the Galactic field and stellar clusters.

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