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Comparing the asteroseismic properties of pulsating extremely low-mass pre-white dwarf stars and δ Scuti stars

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Abstract. We present the first results of a detailed comparison between the pulsation properties of pulsating Extremely Low-Mass pre-white dwarf stars (the pre-ELMV variable stars) and δ Scuti stars. The instability domains of these very different kinds of stars nearly overlap in the $\log T_{\rm eff}$ vs. $\log g$ diagram, leading to a degeneracy in the classification of the stars. Our aim is to provide asteroseismic tools for their correct classification.

1 Introduction

Main sequence δ Scuti stars, with masses between 1.2 and 2.5 $M_{\odot}$, pulsate in low-order p and g modes in the range 700 – 36300 sec approximately, driven by the κ mechanism operating in the He II ionization zone. They are variables of spectral type between A0 and F5, lying on the extension of the Cepheid instability strip towards low luminosities, at effective temperatures between 6000 K and 9000 K and $3.25 \lesssim \log g \lesssim 4.75$. On the other hand, pulsating pre-Extremely Low-Mass (ELM) white dwarfs (WD), with masses between $\sim 0.15\, M_{\odot}$ and $\sim 0.30\, M_{\odot}$, constitute a class of pulsating stars called pre-ELMV stars which exhibit radial-, p- and possibly g-mode pulsations with periods between 380 and 3500 sec, driven by the κ mechanism operating in the zone of the second ionization of He. The pre-ELMV WDs and the δ Scuti instability domains nearly overlap in the $\log T_{\rm eff}$ vs. $\log g$ diagram (see Fig. 1), and their period ranges also overlaps in the range 700 – 3500 sec approximately, leading to a degeneracy in the classification of the stars, since their spectra could exhibit similar atmosphere parameters. Asteroseismology can be employed to distinguish these very different kinds of stars. Motivated by this fact, we addressed an asteroseismic comparison between these two families of pulsating stars, with the aim of providing tools for their correct classification.

2 Models and results

The pulsation analysis of this work makes use of full stellar evolution models of δ Sct stars and pre-ELM WDs generated with the LPCODE stellar evolution code ([1]) and the LP-PUL pulsation code ([2]). δ Sct and pre-ELM WD stellar models were calculated as in [3] and [4], respectively. We choose two template models with similar surface gravity and effective temperature, one of them representative of δ Scuti stars and the other one representative of pulsating pre-ELM WDs, both with $T_{\rm eff} \approx 7660$ K

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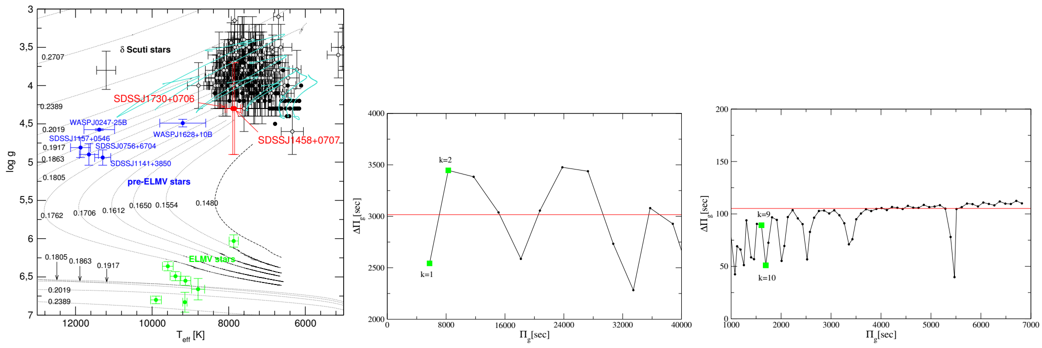

Figure 1. Left: $T_{\rm eff} - \log g$ diagram with the location of ELM WDs and evolutionary tracks of low-mass He-core WDs ([5], black curves), and the location of a δ Sct stars sample (black dots) along with some evolutionary tracks (cyan curves). Also included is the location of the stars reported in [6] (red dots), along with the pre-ELMV WDs ([7, 8]). Centre: period spacing vs. period for g modes corresponding to the δ Sct template model. Right: same as in the centre panel, but for the pre-ELM WD template model. We include the asymptotic period spacing (red line).

and $\log g \approx 4.078$. The δ Sct model is characterized by a H/He core surrounded by an H-dominated envelope. The pre-ELM WD model has a pure He core, with surface layers composed by H and He. The H/He chemical transition leaves notorious signatures in the Brunt Väisälä (B-V) frequency. In the δ Sct model, this frequency becomes null in the convective core and in an outer convective layer. Also, there exists a "bump" in the chemical gradient region at the boundary of the convective core. In the pre-ELM WD model, the B-V frequency becomes null only in a convective outer layer, and the bump is located at more internal layers than in the δ Sct model. These differences lead to notorious differences in p- and g- mode behavior. Among other results, we found that the g-mode period spacing for the δ Sct model is much larger than for the pre-ELM WD model (Fig. 1); in addition, the pre-ELM WD model shows a frequency spacing somewhat larger than the δ Sct model for p modes.

3 Conclusion

The very different g-mode period spacing ($\Delta\Pi_g$) of the two classes of stars indicates that it would be possible to distinguish δ Sct stars from pre-ELMVs using asteroseismology. A typical value of $\Delta\Pi_g$ for a δ Sct is $\approx$ 2500 sec, while for a pre-ELM WD it is $\approx$ 90 sec. Then, the detection of g-modes with consecutive radial orders could shed light on the nature of these stars.

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