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Pulsations of Post-AGB Pre-White Dwarfs with Hydrogen-dominated Atmospheres ⋆

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Abstract. It is shown by a fully non adiabatic analysis that pre-white dwarfs with hydrogen-dominated atmospheres in the range of $T_{\rm eff}$ = 40 000 K - 300 000 K are pulsationally unstable due to nuclear reactions in the hydrogen burning-shell against low-degree g-modes in the period range of about 40-200 s. It is also shown that the amount of hydrogen has a significant influence on the instability domain of such pre-white dwarfs in the Hertzsprung-Russel (H-R) diagram. Hence, the thickness of hydrogen-dominated envelopes may be well constrained by observing the presence of the g-mode oscillations.

Introduction and Summary

It is thought about three quarters of post-AGB (Asymptotic Giant Branch) stars entering the white dwarf domain, through the violent mass loss and planetary nebula phase, are the main source of white dwarfs revealing absorption lines of only hydrogen, classified as DA white dwarfs, which are about 85% of white dwarfs. Before using up their nuclear energy generation sources, those stars still have double burning shells; a hydrogen-burning shell and a helium-burning shell. It is well known that interactions between these burning shells induce thermal flashes and consequent structural changes of the star. Shell burning can also be pulsationally unstable. Indeed, nonradial g-modes driven by the ε-mechanism were found for models of hydrogen-deficient post-planetary nebulae nuclei [2]. Stability analyses of such hydrogen deficient pre-white dwarfs were extensively carried out recently by [3] and the presence of g-modes destabilized by the helium-burning shell through the ε-mechanism was confirmed.

However, the majority of white dwarfs are DA stars with pure hydrogen atmospheres rather than the helium-rich, hydrogen-deficient atmospheres. [4] carried out a stability analysis of models of hydrogen shell-burning planetary nebula nuclei, and later, the instability due to hydrogen burning was found in post-EHB (Extreme Horizontal Branch) stars [5]. Periodic light variations of such stars were then searched for, but no pulsations with amplitude larger than ~ 1 mmag were detected. More systematic theoretical investigation of pulsational stability of post-AGB pre-white dwarfs with hydrogen-rich atmospheres should be carried out to get a definitive conclusion.

This is our motivation to investigate the ε-mechanism in post-AGB pre-DA white dwarfs that have substantial nuclear burning in their hydrogen shells. In order to focus on the relation between the envelope thickness and the instability strip, we construct a series of pre-white dwarf models with different amounts of hydrogen by using the MESA (Modules for Experiments in Stellar Astrophysics) stellar evolution code and tuning parameters (the initial mass and the mass loss parameter), It is shown by a fully non-adiabatic analysis that nuclear reactions in the hydrogen burning-shell excite low-degree g-modes in the period range of about 40-200 s for the pre-DA white dwarf models with

⋆ The present paper is a modified extract of a more extensive refereed paper published in [1]. Readers should see the full paper for more details.

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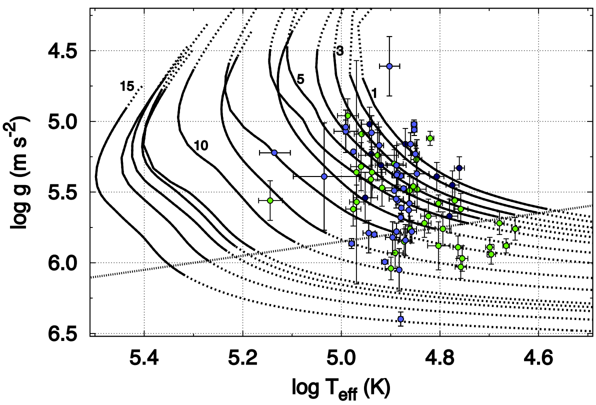

Fig. 1. Evolutionary tracks (log $T_{\rm eff}$-log g diagram) of the model sequences, which are labelled in the order of the thickness of hydrogen envelopes. The dotted lines correspond to models analyzed and the numbers shown in the figure correspond to the label sequence. The bold lines correspond to models having at least one unstable mode. The straight dotted line may be a good indicator for the cool edge of the instability strip. The location of some DA and DAO stars (DA stars exhibiting helium in their optical spectra) are also shown [6], [7], [8].

$T_{\rm eff}$ = 40 000 K - 300 000 K (see Fig. 1). Most of the unstable modes grow fast compared with the evolutionary timescale, hence they must become finite amplitude oscillations.

The amount of hydrogen is crucial in discussing the instabilities due to the ε-mechanism. Hence, the thickness of hydrogen-dominated envelopes may be well constrained by observing the presence of the g-mode oscillations. All the known pulsations of white dwarfs are excited in the ionization zone of a certain chemical element (hydrogen, helium, and other ions), which is located near the photosphere. In contrast, the pulsations treated in this paper are excited at the bottom of the hydrogen envelope of pre-white dwarfs. This opens a new window for asteroseismology to unveil the invisible interior of pre-white dwarfs and test the relevant unsolved physics.

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