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Pulsating White Dwarfs ⋆

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Abstract. Few variable White Dwarfs and nuclei of Planetary Nebulae are known, whose pulsational properties may be used to check the reliability of stellar evolution theory. As an example, we illustrate the potential of variable white dwarfs for the comprehension of the internal composition and the implications for the current theory of core He-burning stars.

Key words. Convection – Nuclear reactions – Stars: horizontal branch – Stars: oscillations – White dwarfs

1. Introduction

White dwarfs (WDs) are the finale fate of the evolution of low and intermediate mass stars (M< 8 $M_\odot$) When nuclear burning definitely dies down, these stars consume their thermal content and cool. A typical white dwarfs have a core ($0.5-1$ $M_\odot$) made of C and O, i.e. the products of the He burning, surrounded by an He-rich mantel ($\sim 10^{-2}$ $M_\odot$). The thin ($< 10^{-4}$ $M_\odot$) most external layer may be both H-rich (DA) or H-poor (DB). As a WD cools, a partially ionized He layer, located at the top of the mantel, and/or a partially ionized H layer provide the driven mechanism that excites pulsations of these stars. Typical periods range between 100 s and 3000 s. There exist three different pulsational instability strips along the cooling sequence (see table 1). In addition to these strips, some central nuclei of planetary nebulae (PNNV) show stable pulsations. Recently it has been discovered a new class of variable stars that are located, in the HR diagram, close to the upper part of the cooling sequence, namely the variable hot subdwarfs (sdBV).

All these objects could be used to constrain the evolution of the progenitors and the physics governing the cooling process. From the power spectrum we may derive information on the internal chemical stratification, the rate of cooling (as, for example, due to neutrinos emission), the equation of state of dense matter, rotation and magnetic fields, mass, intrinsic luminosity,

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Table 1. Known variable White Dwarfs

name	T_e range	surface composition
DBV	24000-29000	He
DAV or ZZ Ceti	11000-13000	H
DOV or GW Vir	80000-180000	He,C,O

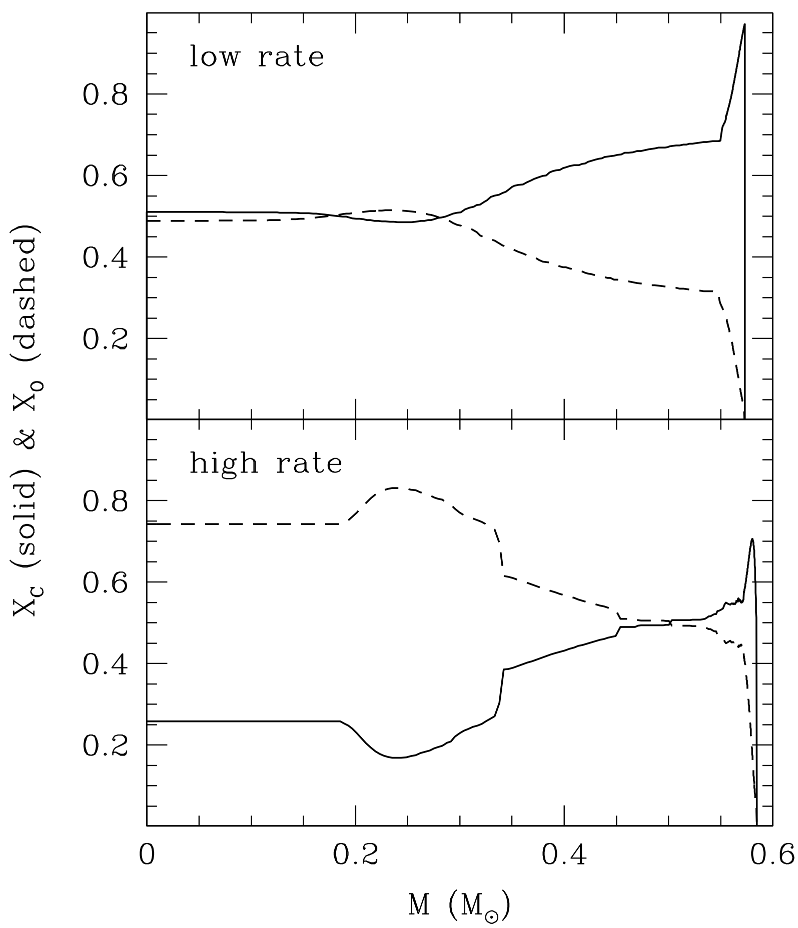

Fig. 1. The predicted internal composition of a 0.6 WD. Upper panel: as obtained by using a low rate of the $^{12}C(\alpha,\gamma)^{16}O$ reaction. Lower panel: as obtained by adopting a high rate. The same mixing scheme has been applied.

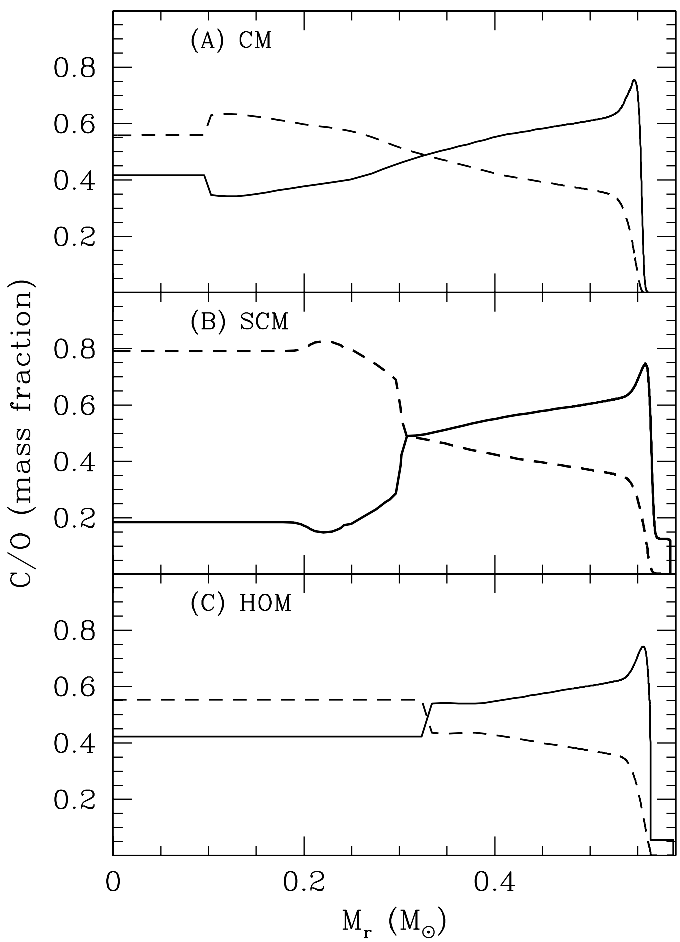

Fig. 2. The predicted internal composition of a 0.6 WD. Upper panel: as obtained in classical models (no overshoot, no semiconvection). Central panel: as obtained by applying a semiconvective algorithm. Lower panel: as obtained by adopting a substantial convective core overshoot. The same nuclear reaction rates have been used.

distance and the like. Unfortunately, only a few number of stars are known to belong to a particular class of WD variables. For example, only 4 DOV and 8 DBV have been clearly identified. An extended survey devoted to the search of short period variables could produce a great improvement of our understanding these very interesting stars. A similar survey may also help the identification of suitable targets for asteroseismology from satellite (ESA Eddington mission or similar). In the following we illustrate an example of the potential of these variable stars in inquiring stellar evolution.

2. Internal composition of WDs and the physics core He-burning stars

The majority of the white dwarfs have a core made of the ashes of the He burning: carbon, which is produced by the 3α reaction, and oxygen, which is synthesized by the $^{12}C(\alpha,\gamma)^{16}O$. At the beginning of the core He burning, the 3α reactions accumulate carbon. Later on, when the residual mass fraction of He fuel drops below 0.1, the $^{12}C(\alpha,\gamma)^{16}O$ reactions partially convert this C into O. The final C/O ratio depends on the efficiency of the $^{12}C(\alpha,\gamma)^{16}O$, but also depends on the extension of the central convection during the late core He burning phase (see e.g. Imbriani et al. 2001 and Straniero et al. 2003). Fig 1 and 2 illustrate the effect of changing the nuclear reaction rate and the convective scheme, respectively. By combining the uncertainty on the $^{12}C(\alpha,\gamma)^{16}O$ reaction and that due to the convective efficiency, the theoretical predictions on the final central oxygen mass fraction vary between 0.3 and 0.9. It is obvious that a direct measurement of the central composition of WDs would be a great help in distinguish between the various theoretical scenarios. Recently Metcalfe et al. (2001), by using a genetic algorithm to analyze the power spectrum of a variable WD with an He-rich atmospheres (GD358), conclude that this stars should have a rather large amount of central oxygen, namely about 80% by mass. This kind of study have a direct impact on our understanding stellar evolution.

3. Conclusions

The uncertainty on the theory of core He - burning convection implies an uncertainty of a factor 2 for the predicted central C (30% for the central O). Similar variations are found by changing the rate of the $^{12}C(\alpha,\gamma)^{16}O$ reaction within the experimental error. Preliminary results from asteroseismology of WDs, support semiconvective models and a moderate rate of the $^{12}C(\alpha,\gamma)^{16}O$ reaction, in good agreement with the observed ratio of AGB and HB stars in Globular Clusters (see Buonanno et al. 1985), as well as in agreement with the recent measurements of the key reaction rate (Kunz et al. 2001).

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