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The driving mechanism of roAp stars : effects of local metallicity enhancement

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Abstract

We have investigated the influence of a local metallicity enhancement on the excitation mechanism of roAp star pulsations. Our computations show that such accumulations poorly affect the position of the theoretical roAp star instability strip although the opacity in the driving region of roAp modes is affected by metal accumulation.

Context

In the past, several studies investigated the excitation of pulsations in roAp stars (e.g. Dolez & Gough 1982, Dziembowski & Goode 1996, Gautchy & Saio 1998, Balmforth et al. 2001, Cunha 2002). Chemically homogeneous models and models with stratified helium and hydrogen compositions have been proposed to account for the roAp star properties but they failed to account for the extent of the roAp star instability strip.

Up to now the effects of a metal stratification (probably induced by microscopic diffusion) have not been considered in roAp star models. However abundance determinations suggest a relation between the excitation mechanism of pulsations in roAp stars and their heavy element distribution (Gelbmann 1998, Kochukhov 2003, Ryabchikova et al. 2004) and numerous cool magnetic Ap stars show vertical stratification and evidences for accumulations of some heavy elements in the deeper atmosphere (Bagnulo et al. 2001, Ryabchikova et al. 2002, 2005, Kochukhov 2003, Kochukhov et al. 2004).

Computations and results

With this in mind, we have computed with the code Clés (Scuflaire et al. 2008) grids of stellar evolutionary models adequate for A stars, including a local metal accumulation profile in their external layers, to test if such an accumulation could explain the location and the extent of the roAp instability strip. Following Balmforth et al. (2001), we assumed that the convective motions which take place in the envelope of A stars, are suppressed by the magnetic field: our models have then a fully radiative envelope. They include the solar metal mixture (Asplund, Grevesse and Sauval 2005, thereafter AGS05) with $X=0.71$. The opacity tables (computed with the AGS05 mixture) are those of OPAL96 (Iglesias & Rogers 1996) completed at low temperature with tables based upon calculations from Ferguson et al. (2005). As outer boundary conditions, Kurucz atmospheres (Kurucz 1998) are joined to the interior at an optical depth equal to 1. Each grid of models (labelled pZ1 to pZ5) includes a Z-accumulation profile centered on a given temperature (as shown in fig. 1a). The stability of these models has been computed using the nonadiabatic pulsation code MAD (Dupret 2002).

Fig. 1b shows that the position of the roAp theoretical instability strip is poorly sensitive to metal accumulations whatever their location in the stellar envelope, although these accumulations strongly affect the opacity profile. Our models account for the blue edge of the instability strip but they lead to too hot red edges. These results, which are discussed in details in Théado et al. (2009), fail to explain the correlation observed between the excitation mechanism and the metal distribution in roAp stars and cannot account for the roAp modes excitation in cool roAp stars.

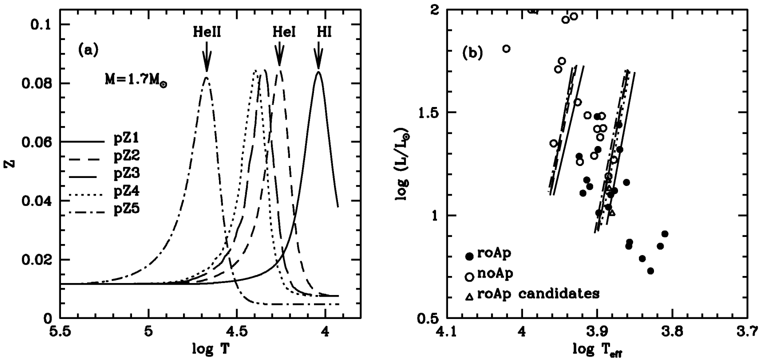

Figure 1: a) Z-accumulation profiles introduced in our models, each grid of models includes a different profile labelled pZ1 to pZ5. The vertical arrows show the position of the H and He ionization regions. b) Theoretical instability strips for the five grids of models, the line convention are the same for the 2 figures. Observational points are from Kochukhov & Bagnulo (2006) and North et al. (1997)

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