Which constraints can we set on the convective core of HD49933?

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ABSTRACT

The first asteroseismological results from CoRoT have been published on the data obtained for HD49933, a F5 V star presenting solar-like oscillations (Appourchaux et. al 2008). By analyzing the power spectrum obtained during the initial run (60 days), the frequencies of more than 40 acoustic modes have been measured. However, some difficulties in unambiguously identifying the degrees of these modes have appeared, leading to two different plausible scenarios for the identification. The authors have discriminated between the two interpretations by means of statistical tests.

In this poster, we will first show whether we can use a priori knowledge from stellar models to help in the mode identification. Next, we will discuss the constraints we can impose on the structure of this star by taking into account the seismic information. We will especially focus on the convective core properties, addressing the question of overshooting. For this purpose we have computed a grid of specific models, with the Garching Stellar Evolution Code (GARSTEC) coupled with an adiabatic pulsation package (ADIPLS), for the computation of mode frequencies.

The Star HD 49933

HD 49933 is a main sequence F star with an absolute visual magnitude of Mv=3.408±0.026 derived from Hipparcos parallax measurements (van Leeuwen 2007). It has an iron abundance of [Fe/H]=-0.37 (Solano et al. 2005). Using Hipparcos and 2MASS photometry, combined with an infrared flux method (Casagrande et al. 2006), we derived observational parameters accounting for random errors in photometry, and uncertainties in parallax and metallicity. The obtained observable values are presented in Table 1. The temperature obtained with this method is consistent with the one given by Brunt et al. 2008.

HD 49933 physical parameters	
[Fe/H]	-0.37
T_{eff}	6750±140 K
$Log(L/L_{\odot})$	0.549±0.02

Table 1 Physical parameters used for the models, as obtained from literature and using the infrared flux method

HD 49933 has been analyzed from ground based observations (Mosser et al. 2005) and from data obtained during the initial run of CoRoT (Appourchaux et al. 2008). It has been possible to observe mode frequencies and estimate an average value for the large frequency separation, without a priori constraints from stellar evolution models. However, the degrees of the modes have not yet been unambiguously identified.

In this poster we present our first results on the modeling of HD 49933, aiming to help on the identification of the angular degree of the modes, and put constrains in the convective core of the star.

Stellar Models

A set of models has been computed using the Garching Stellar Evolution Code (GARSTEC). GARSTEC is a one-dimensional hydrostatic code which does not include the effects of rotation. A detailed description of the numerics and input physics of the code is given in Weiss & Schlattl 2008. We constructed two grids of models in the mass range between 1.0 and 1.3 $M_{\odot}$, in steps of 0.01 $M_{\odot}$, where one of the grids includes the effects of overshooting.

For the models, an initial helium abundance of Y=0.255 was considered and a metal content of (Z/X)=0.007 deduced from the [Fe/H] value. Convection was treated with the mixing length theory using α_{MLT}=1.741, which is the value calibrated for the sun. The models where evolved from the pre-ms up to 4 Gyr, ignoring the effects of diffusion.

The treatment of overshooting used in GARSTEC is the diffusive approach, which is an exponential decay of the convective velocities within the radiative zone. The diffusion coefficient is computed as:

$$D = D_0 e^{\frac{-r}{A \cdot H_P}}$$

Where the efficiency parameter A has been calibrated for main sequence stars.

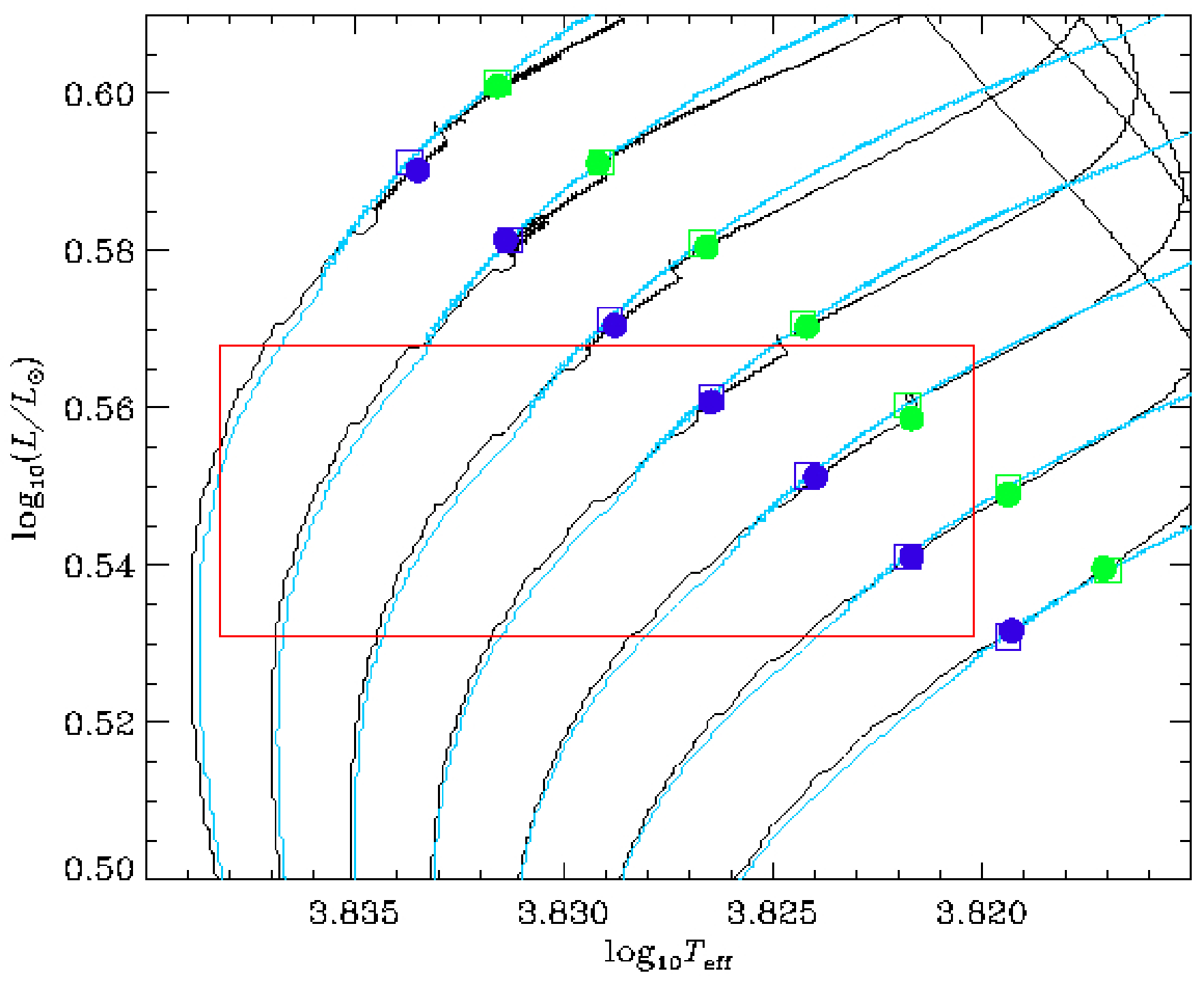

Fig. 1 HR diagram presenting the tracks between 1.17 $M_{\odot}$ and 1.23 $M_{\odot}$ (solid black lines). Also plotted are the tracks including overshooting for the same mass range (light blue lines). Marked in green are the models presenting the first case identification, and in blue the second case (squares for models with overshooting, circles for models without overshooting). The red lines depict the observational error box.

The Computed Frequencies

Frequencies for several models in various of the evolutionary tracks where computed using the Aarhus Adiabatic Oscillation Package (ADIPLS, Christensen-Dalsgaard 2008). These frequency computations allowed us to calculate the average large frequency separation for the models, and compare our simulations with the CoRoT data.

Data Comparison

The first task we address here is the identification of the degree for the modes observed in the initial run of CoRoT. One possible scenario has been proposed in Appourchaux et al. 2008, using a maximum likelihood estimation of the power spectrum, which also allowed them to derive an average large frequency separation value of 85.9±0.15 μHz.

In Fig. 2 we present 4 echelle diagrams, for four different models of 1.20 $M_{\odot}$, two of them including overshooting. The folding frequency $\Delta\nu_0$=85.06 μHz has been used to plot all of them. As can be seen from the figure, both identification scenarios are certainly possible, since for the same evolutionary track a more evolved model swaps the position of the ridges for l=1 with the location of the l=0 and l=2 lines.

In the first place, we consider the models which have the l=1 ridge on the left side of the plot, which is the identification proposed by Appourchaux et al. 2008. In Fig. 2, this corresponds to the second panel on the left and the right hand side. As it can be seen, this identification is possible for models considering overshooting and models without it. However, it must be noticed that the theoretical ridges do not reproduce very precisely the shape of the data. Also, the position of these models, as presented in green color over the 1.20 $M_{\odot}$ tracks in the HR diagram of Fig. 1, is slightly above the edge of the observational error box. Nevertheless, it must be considered that models for lower mass values with and without overshooting are capable of reproducing this identification inside of the error box, as also shown in Fig. 1.

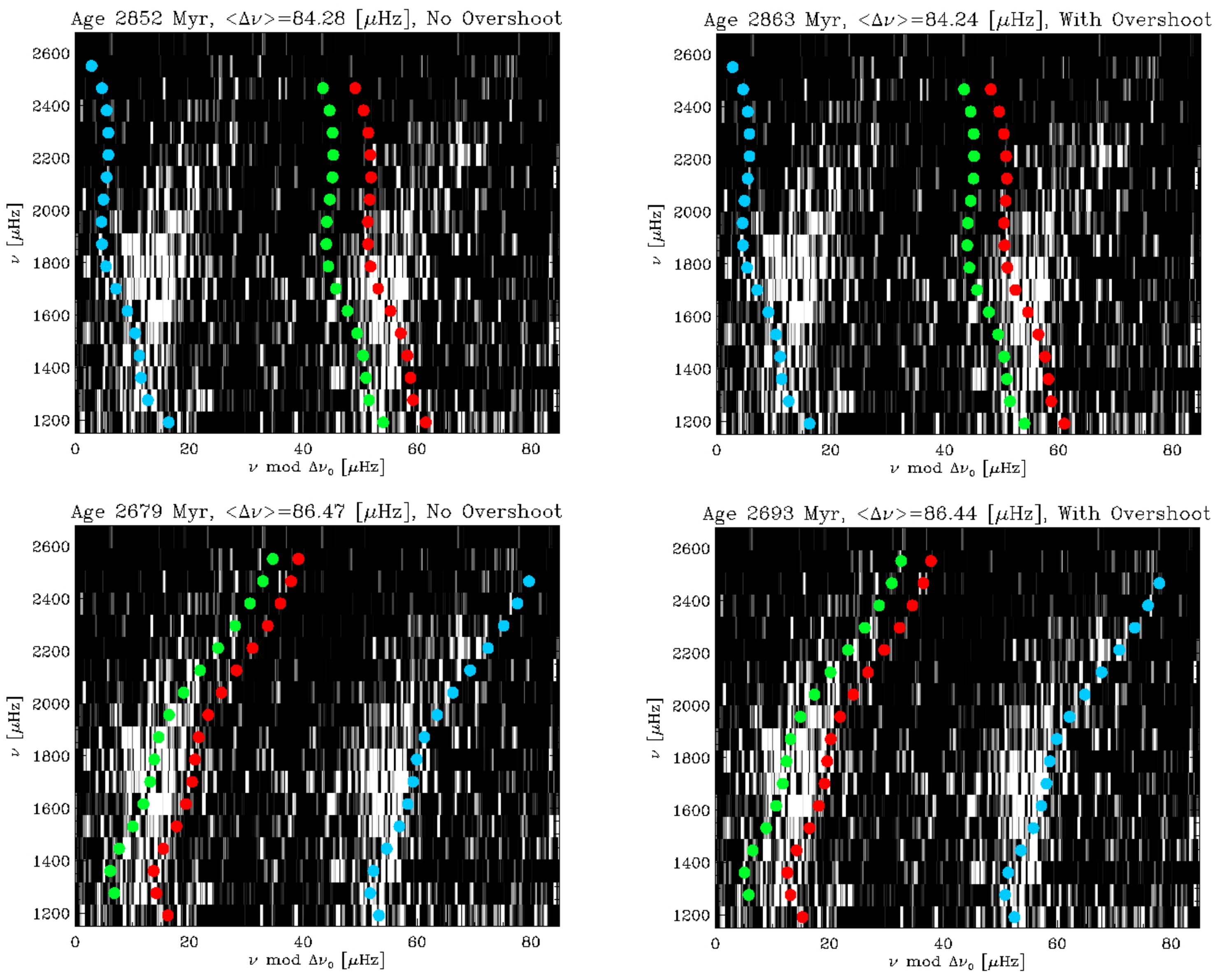

Fig. 2 *Upper panels:* echelle diagrams for the models presenting the first identification scenario, with and without overshooting. The title of each diagram gives the age of the model and the average value of the computed large frequency separation. Colors: l=1 (light blue), l=0 (red), l=2 (green). *Lower panels:* same for the models presenting the second identification possibility. See text for details.

As a second case, we consider the opposite possibility, which is when the l=1 ridge is on the right hand side of the plot. Again, models with and without overshooting are able to reproduce the position of the ridges. However, the shape of the theoretical ridges and the data is in much better agreement than in the previous case, seeming to favor this identification over the one made by Appourchaux et al. 2008. In this case, more models inside the observational error box can be found to fit the observational echelle diagram than for the previous identification (see Fig. 1).

The Effects of Convective Overshooting

It can be seen from the HR diagram presented in Fig. 1 that there is an overlap in the position of the models with and without overshooting, in both possible degree identification scenarios. This is the case for all the tracks presented in Fig. 1, where the extension of the convective core is almost equal regardless of the inclusion of the overshooting treatment. Up to this point, the effects of overshooting in the models are almost negligible. However, the behavior will be certainly different in the case of a higher mass value, a more evolved model, or an increase on the overshooting efficiency parameter A.

In Fig. 3 we present a plot of the small frequency separation for the 4 models considered in the 1.20 $M_{\odot}$ tracks, with and without overshooting. The small separation is known to be an efficient tracker for physical processes in the stellar core. Especially, Soriano & Vauclair 2008 found that the small separations become negative for a certain range of frequencies, as a consequence of the rapid variation in the sound speed near helium-rich cores. As can be seen from Fig. 3, in the first identification case there is a constant offset in the small frequency separation between the model with overshooting and the model without it. However, for the second identification case, the values are equal up to 2000 μHz where they diverge.

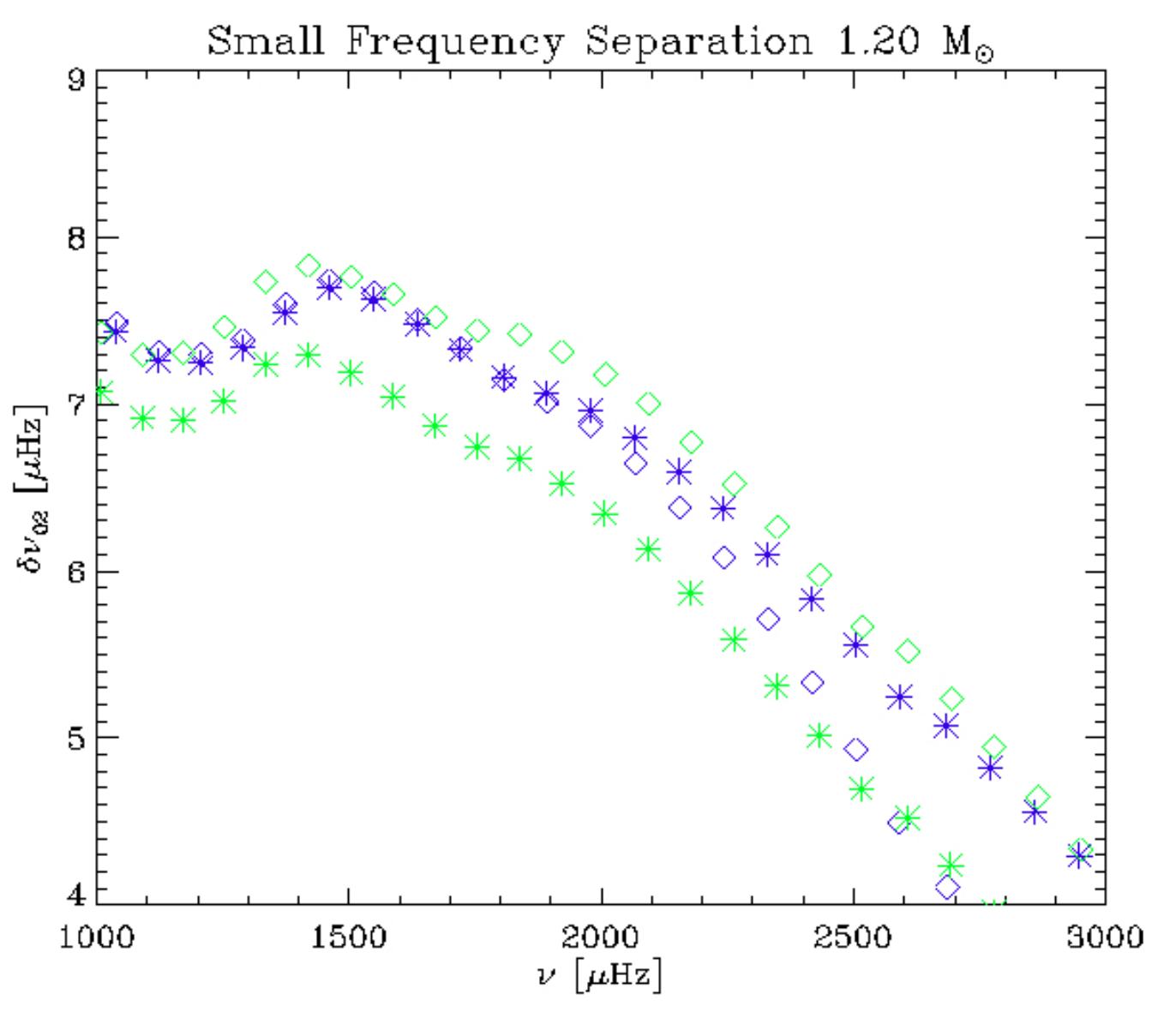

Fig. 3 Small frequency separation for the 1.20 $M_{\odot}$ models. As in Fig. 1, first case identification models are plotted in green, and second case identification models are plotted in blue. Diamonds correspond to models without overshooting, asterisks to models with overshooting.

Such a behavior is not observed in our models since the abundance of helium in the center of the star has not yet reached high enough values to produce such a signature. Models with a long enough evolutionary time to present such a characteristic are evolved away from the observational error box.

In this poster we have discussed the case for the 1.2 $M_{\odot}$, the are results are general and apply for the other masses considered.

Future Perspectives

So far, our work has been devoted mainly to aiding the identification of the degree of the modes using a priori knowledge from theoretical models, and studying the possible effects of overshooting in models which fit the observational data. The next steps we wish to follow in the current study are to include a treatment of diffusion and use different initial helium abundance on the models. We further hope to quantify these effects by comparison with observational data.

References: Appourchaux, T., et al. 2008, A&A, 488, 705; Bruntt, H., De Cat, P., & Aerts, C. 2008, A&A, 478, 487; Casagrande, L., Portinari, L., Flynn, C. 2006, MNRAS, 373, 13; Christensen-Dalsgaard, J. 2008, Ap&SS, 316, 113; Mosser, B., et al. 2005, A&A, 431, L13; Solano, E., Catala, C. & Garrido, R., et al. 2005, AJ, 129, 547; Soriano, M., & Vauclair, S. 2008, A&A, 488, 975; van Leeuwen, F. 2007, Ap&SSL, 350, 20; Weiss, A. & Schlattl, H. 2008, Ap&SS, 316, 99