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 (AD2PLS), 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=3.40±0.026 derived from Hipparcos parallaxes (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 this way is consistent with the one given by Brunt et al. 2008.

HD 49933 has been analyzed from ground based observations (Masser 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☉, in steps of 0.01 M☉, where one of the grids includes the effects of overshooting. For the initial helium abundance of Y0=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 (MLT), which was calibrated for these models.

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:

\[ D = \frac{\nu c_s}{\alpha \eta} \]

Where the efficiency parameter \( \alpha \) has been calibrated for main sequence stars.

The Computed Frequencies

Frequencies for several models in various of the evolutionary tracks where computed using the Aarhus Adiabatic Oscillation Package (AD2PLS, 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 on 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☉, two of them including overshooting. The folding frequency \( \nu_s = 85.06 \) µHz has been used to plot all of them. As can be seen from the figure, both degenerate scenarios are certainly possible, since for the same evolutionary track a more evolved model swap 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 diagram, i.e., 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☉ evolutionary track 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 can be reproduced by comparing this identification inside of the error box, as also shown in 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 \( \alpha \).

In Fig. 3 we present a plot of the small frequency separation for the 4 models considered in the 1.20 M☉ tracks, with and without overshooting. The small separation is known to be an efficient tracker for physical processes in the stellar core. Especially, Soriano & Vausour 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.

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 evolving away from the observational error box.

In this poster we have discussed the case for the 1.2 M☉, the one 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: