Exploration of parameter space for modeling CoRoT targets with CESAM/CLES codes

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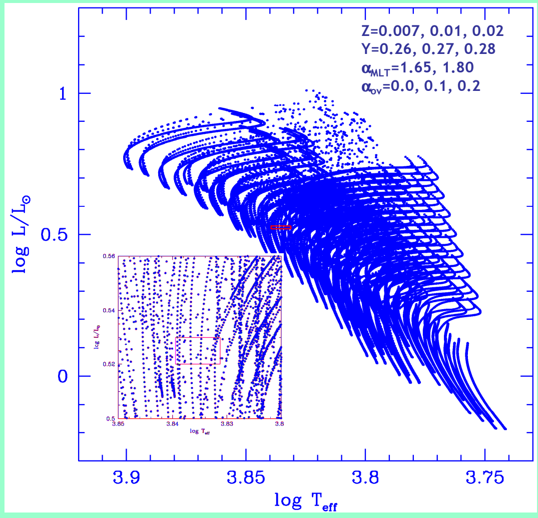
ABSTRACT: In order to determine the unknown parameters of stellar models that allow to fit the observational constraints of a given star χ^2 minimization methods such as the Levenberg-Marquardt method are currently used. However the direct application of a minimization method may be dangerous if not enough observational constraints are available. In that case, several local minima could exist, and the space of solutions might be degenerate. To be prepared to this eventuality we have computed a wide grid of stellar models and their associated oscillation frequencies and we have designed a tool to evaluate the value of χ^2 on that grid for different possible sets of observational data. The χ^2 function of a set of theoretical stellar parameters provides the starting point for the application of the Levenberg-Marquardt algorithm and is therefore the basis of deep analysis and interpretation of the seismic and classical observables. Stellar models have been calculated either with the CESAM or the CLES stellar evolution code for values of the mass in the range 0.80-2.00 solar masses, initial metallicity Z in mass fraction in the range 0.0040-0.0275 and initial helium abundance in the range 0.26-0.28, and we considered different values or options for the input physics of the models (microscopic diffusion, mixing-length parameter of convection, overshooting). The oscillation frequencies have been computed with the LOSC adiabatic code for p-modes of degree ℓ=0, 1 and 2.

STELLAR MODELS CALCULATION - INPUT PHYSICS

Stellar models have been calculated with the CESAM (Morel & Lebreton, 2008) and CLES (Scuflaire et al., 2008a) evolution codes. Those codes have both been validated and thoroughly compared during the ESTA stellar model comparison activity (Lebreton et al., 2008a; Montalban et al. 2008). We adopted the ESTA input physics described in Lebreton et al. (2008b)

- *Opacity tables:* OPAL96 tables (Iglesias & Rogers, 1996) complemented at low temperatures by Alexander & Ferguson (1994) tables
- *Equation of state:* OPAL 01 tables (Rogers & Nayfonov 2002).
- *Nuclear reactions rates:* NACRE rates (Angulo et al. 1999)
- *MLT theory for convection* (Bohm-Vitense 1958; Heyney et al 1965)
- *Convective core overshooting*: temperature gradient equal to adiabatic gradient in the overshooting region (Zahn 1991)
- *Microscopic Diffusion* (Burgers 1969, Thoul et al. 1994)
- *Atmosphere*: Eddington grey law



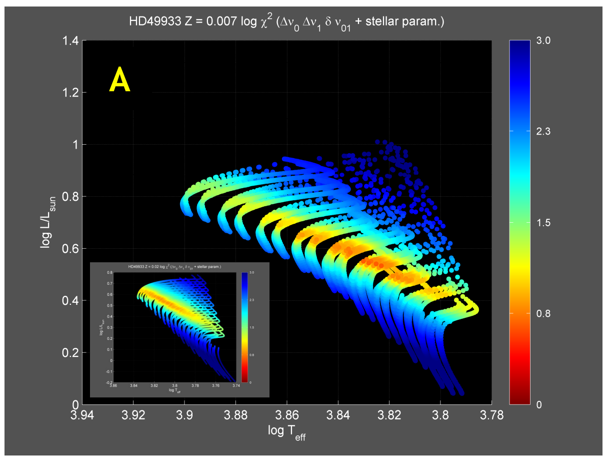
Subsample of evolutionary tracks with in inset a zoom illustrating the resolution of the model grid.

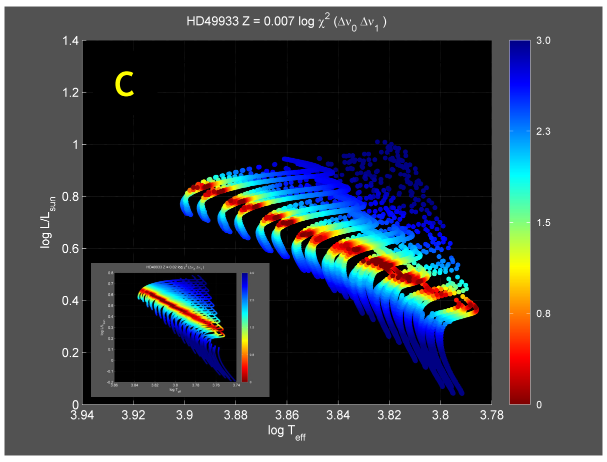
OSCILLATIONS CALCULATION

We calculated the oscillation frequencies of p modes of degree ℓ=0, 1 and 2 and the frequency differences of a large number of models along the evolutionary tracks using the LOSC adiabatic oscillation code (Scuflaire et al. 2008b)

GRIDS SPECIFICATIONS - INPUT PARAMETERS

- *mass* $M/M_\odot \in [0.8,2.0]$, by steps of $\Delta M = 0.05\ M_\odot$
- *initial metallicity* $Z \in [0.0040, 0.0275]$ by steps of ΔZ=0.0015-0.0025
- *initial helium content* Y=0.26, 0.27, 0.28
- *mixing-length parameter* $\alpha_{MLT} = \ell_{MLT}/H_p$ = 1.65, 1.80
- *core overshooting parameter* $\alpha_{ov} = \ell_{MLT}/H_p$ = 0.0, 0.1, 0.2
- *with and without microscopic diffusion*





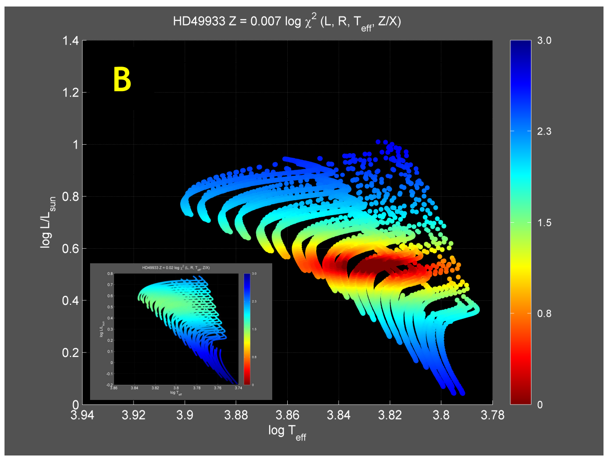
ILLUSTRATION

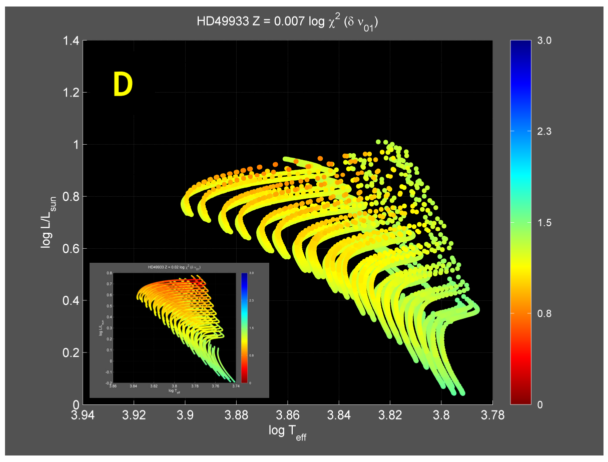
CALIBRATION OF THE COROT TARGET HD 49933

OBSERVATIONAL CONSTRAINTS: frequencies and stellar global parameters from Appourchaux et al. 2008.

For each model on the grid the log χ^2 value is indicated according to the colour code given on the right. We considered here masses in the range 1.00-1.40 $M_\odot$. Large figures are for Z=0.007 while insets are for Z=0.020.

Depending on the subset of observational parameters kept as model constraints regions with low χ^2 emerge or not. When all available constraints are considered (panel A) χ^2 values remain high in the whole region covered by the grids making the star calibration difficult. If only global parameters are considered (panel B) low χ^2 can be reached for Z=0.007 but high Z values are excluded. The large frequency separations (panel C) are easily fitted by models which have a similar mean density and are sitting on the middle of the main sequence (MS) while the small frequency separation (panel D) is not well reproduced by any of the standard models considered here, except by very evolved models of high Z. Note that there is no overlap between best cases for the small frequency separation (evolved models) and best cases for the large frequency separation (MS models).





REFERENCES

Alexander & Ferguson 1994, ApJ 437, 879
Angulo et al. 1999, Nucl. Phys. A, 856, 33
Appourchaux et al. 2008 A&A, 488, 705
Bohm-Vitense 1958, Z. Astrophys., 46, 108
Burgers 1969, Flow equations for composite gases, New York Academic Press
Heyney et al 1965, ApJ, 142, 841
Iglesias & Rogers, 1996 ApJ, 464, 943
Lebreton et al., 2008a Ap&SS, 316, 187
Lebreton et al., 2008b Ap&SS, 316, 1
Montalban et al. 2008 Ap&SS, 316, 219
Morel & Lebreton, 2008 Ap&SS, 316, 61
Scuflaire et al., 2008a Ap&SS, 316, 149
Scuflaire et al., 2008b Ap&SS, 316, 83
Rogers & Nayfonov 2002 ApJ 576, 1064
Thoul et al. 1994 ApJ 421, 828
Zahn 1991 A&A 252, 179