Models of red giants in the CoRoT asteroseismology fields combining asteroseismic and spectroscopic constraints

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Context and objectives: The availability of asteroseismic constraints for a large sample of red giant stars from the CoRoT and Kepler missions paves the way for various statistical studies of the seismic properties of stellar populations. We use the first detailed spectroscopic study of 19 CoRoT red-giant stars (Morel et al 2014) to compare theoretical stellar evolution models to observations of the open cluster NGC 6633 and field stars.

Sample: 19 red-giant targets of which 15 were observed by CoRoT including three members of the young open cluster NGC 6633. Morel et al (2014) (M14) derived the lithium abundances for all the stars in the sample and $^{12}C/^{13}C$ for four of them. The asteroseismic parameters large separation, $\Delta\nu$, and frequency of maximum oscillation power, ν_{max}, are also taken from M14. Three different methods were used to obtain these global asteroseismic properties (Mosser & Appourchaux 2009; Hekker et al. 2010; Kallinger et al. 2010a).

Models: Stellar evolution models were computed with the code STAREVOL (e.g., Lagarde et al. 12). They take into account

(1) rotation-induced processes following the formalism by Zahn (92) and Maeder & Zahn (98), known to change chemical properties of main sequence and sub-giant stars (e.g. Palacios 06)

(2) thermohaline mixing as described by Charbonnel & Zahn (07), which governs the surface chemical properties of low-mass RGB stars (e.g. Charbonnel & Lagarde 2010).

Stellar properties

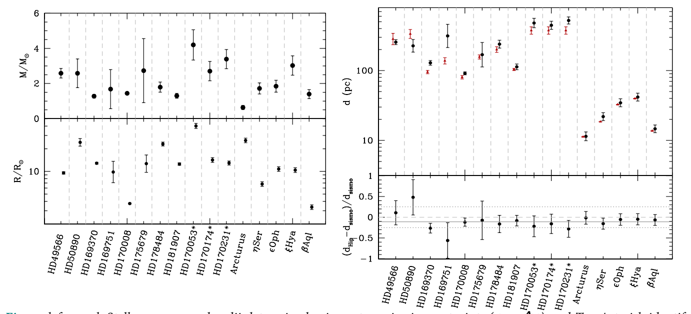

Fig 1- Left panel: Stellar masses and radii determined using asteroseismic constraints (ν_{max},$\Delta\nu$) and T_{eff}. Asterisk identify the cluster members. Right panel: Comparison between the distances determined from asteroseismic constraints (ν_{max},$\Delta\nu$) and T_{eff} (black open circle), and the Hipparcos distance (red triangle). In the lower panel, the grey solid line represent the weighted average difference, while the grey dashed lines represent a difference of 25%.

NGC 6633

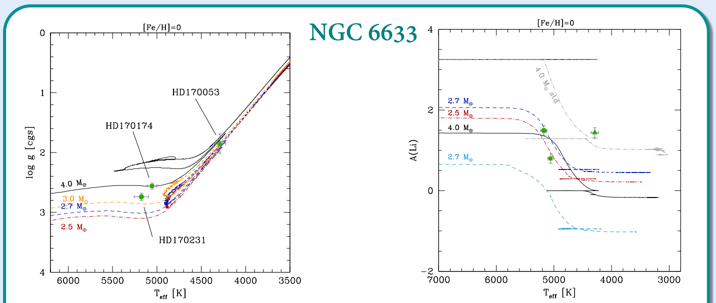

Fig 4- Theoretical evolutionary tracks plotted in logg-Teff diagram (left panel) and theoretical evolution of Li (right panel) as a function of T_{eff} (from the main sequence up to the early-AGB) computed with thermohaline instability and rotation-induced mixing at solar metallicity for 4.0 $M_{\odot}$ (V_{ZAMS}=144 km/s, solid black line), 3.0$M_{\odot}$ (V_{ZAMS}= 136 km/s, orange long dashed line), 2.7 $M_{\odot}$ (V_{ZAMS}=110 km/s, blue dashed line), and 2.5 $M_{\odot}$ (V_{ZAMS}=110 km/s, red dashed line).

Chemical properties

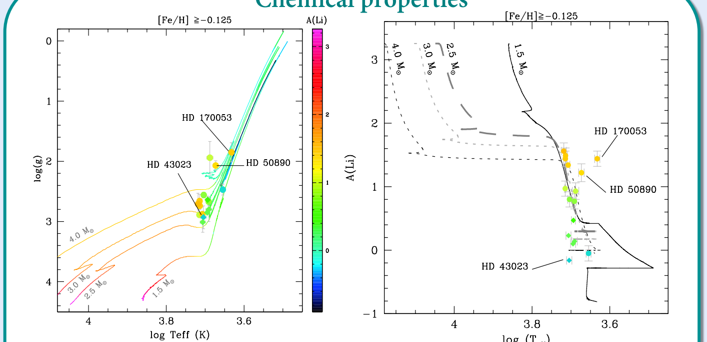

*Fig 2- Left panel: Color-coded HR diagram for different stellar masses. The color code represents the values of A(Li) at the stellar surface. Right panels: The evolution of surface lithium abundance (from the ZAMS to the end of the He-burning phase) as a function of effective temperature. Circles and diamonds denote, respectively, Li detections and upper limits for stars with **[Fe/H]≥-0.125**. Error bars are shown for all stars.*

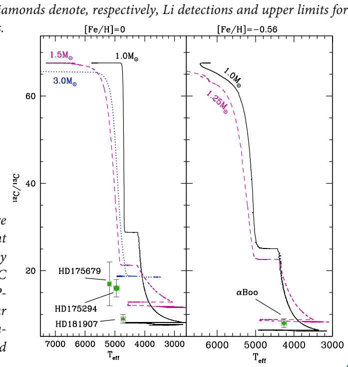

Fig 3- $^{12}C/^{13}C$ data in our red-giant stars that are segregated according to their metallicity (left and right panels include respectively sample stars with metallicity close to solar and [Fe/H]=-0.56). Theoretical $^{12}C/^{13}C$ surface abundance is shown from the ZAMS up to the TP-AGB. Various lines correspond to predictions of stellar models of different masses including effects of rotation-induced mixing (with an initial V/V_{crit}=0.30) and thermohaline instability.

Some results

- The weighted average of the relative difference between Hipparcos and seismic distances (**-0.12±0.03**) indicates a possible disagreement (Fig 1).
- For low-mass stars as αBoo and HD181907, **the low carbon isotopic ratio is well explained by thermohaline instability** (Fig. 3).
- For more massive stars it is rotation that is the most efficient transport process for chemical species. Our models at different initial velocities can explain the surface abundances of lithium and $^{12}C/^{13}C$ (Fig.2 & 4)
- **NGC 6633 (Fig. 4)** is a first and last example of a cluster observed by CoRoT including RG stars, for which chemical properties are also available.
  The distances for the cluster members deduced from asteroseismic properties are self consistent, but slightly large compared to Hipparcos distances.
  The age of the cluster determined by isochrone fitting in Smiljanic et al. (2009) (t= 4.5.108 yrs) implies that stars in the He-core-burning stage have **2.8<M/M$_{\odot}$< 3.0, which is compatible with the stellar mass determined with asteroseismology.**

Tighter constraints on the physics of the models would require the measurement of the core and surface rotation rates, and of the period spacing of gravity-dominated mixed modes. A larger number of stars with longer times series, as provided by *Kepler* or expected with Plato, would help for ensemble asteroseismology. In the future, Gaia-ESO survey, and APOGEE would be extremely helpful to gain the maximum from the asteroseismic properties matched by knowledges surface chemical abundances.

SEVENTH FRAMEWORK PROGRAMME
MARIE CURIE ACTIONS

UNIVERSITY OF BIRMINGHAM