A simulation-based Convective-Boundary Mixing model for AGB star evolution and nucleosynthesis

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Introduction and method

The production of the s-process elements has been directly observed for a large sample of intrinsic or extrinsic AGB stars at different metallicities. Most of the neutrons for the s-process come from the ^{13}C(,n)^{16}O neutron source, activated in the radiative ^{13}C-pocket in the He intershell stellar region (Straniero et al. 1995). The physics mechanisms driving the formation of the ^{13}C-pocket are still matter of debate (see Herwig et al. 2005, and references therein), and will also be discussed in this work. To address this challenge (Denisenkov et al. 2003, hereafter De03) investigated mixing induced by internal gravity waves (IGWs) and found a ^{13}C-pocket with approximately the size of 10^{-4}M (see their Fig. 5). Herwig et al. (2007) (hereafter He07) studied the CBM at the bottom of the pulse-driven convective zone (PDCZ). via 2-dimensional hydrodynamical simulations, showing that their results can be reproduced by a first initial decay of the mixing efficiency, followed by a second shallower decay term.

In this work, using the stellar evolution code MESA (revision number 4219) we apply without any finetuning by hand the CBM model parameters by He07 as well as a CBM model proposed by De03 at the bottom of the convective envelope for the formation of the 13C-pocket representing the Convective-Boundary-Mixing (CBM) at the bottom of the convective thermal pulses (TPs) and IGW mixing respectively (see Figure 1).

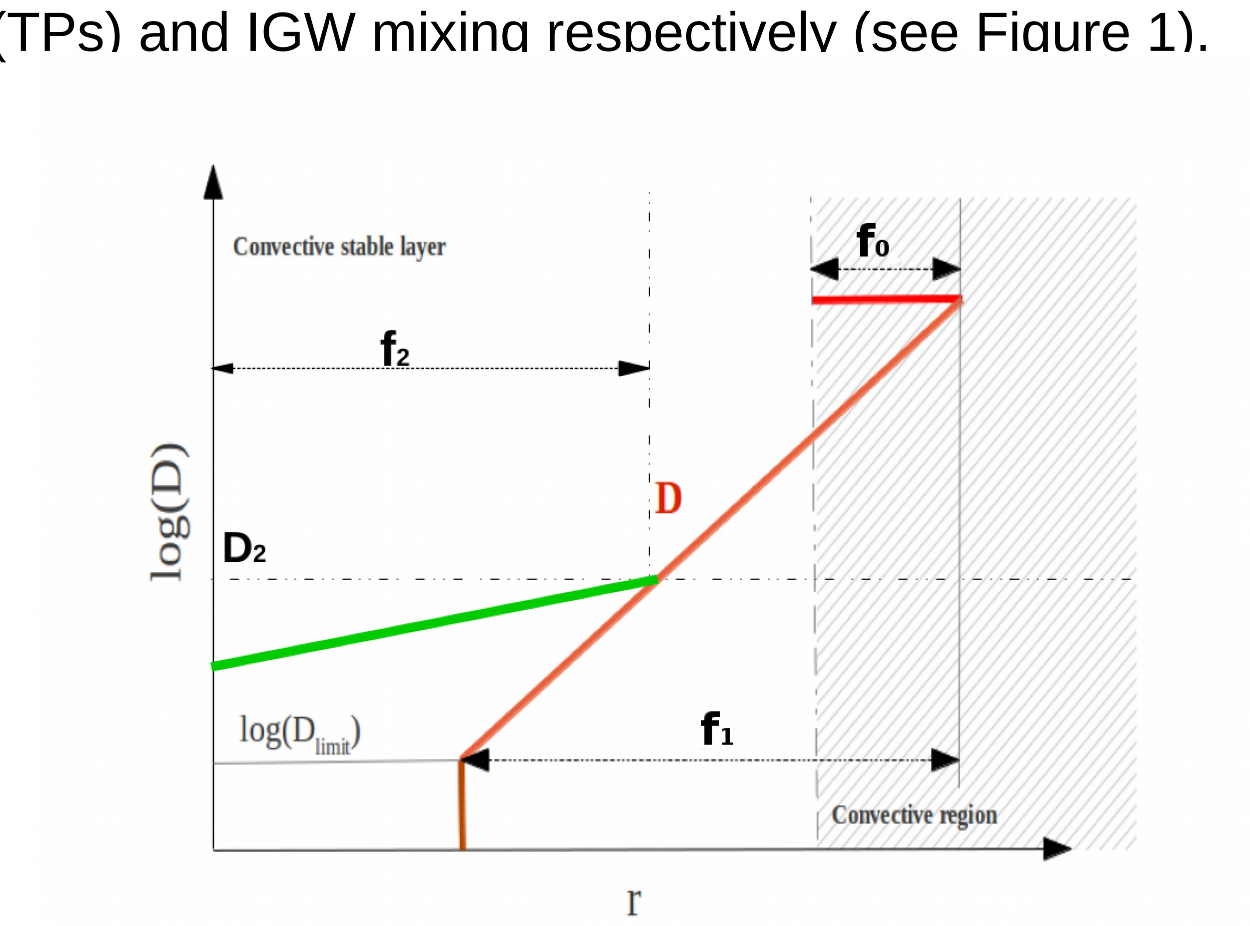

Figure 1: Schematic description of the double-exponential CBM applied in this work. The red line is the standard overshooting mixing coefficient profile following the single-exponential decay. In order to take into account IGW, in this work we apply a second, slower, decreasing profile (green line) that becomes more relevant than the first one as soon as the mixing coefficient is equal or lower that a 'D 2 ' value.

Conclusions

For the first time, our models study the impact of the following physics ingredients on AGB stellar evolution and nucleosynthesis: the Convective-Boundary-Mixing (CBM) at the bottom of the convective TPs according to Herwig et al. (2007) simulations and the CBM below the TDU driven by Internal Gravity-Waves (IGW) according to Denisenkov et al. (2003). At the end of the AGB evolution we obtain an s-process production 0.36 <[s/Fe] <0.78 and -0.23 <[hs/ls] <0.45, which is consistent with spectroscopic observations of C-rich AGB stars. Within the mass range considered we do not produce low enough δ(96 Zr/ 94 Zr) ratios as observed. On the other hand, present AGB models are getting much closer to fit the grain data than previous works where the CBM at the bottom of the PDCZ was used, in particular for the ratio δ(96 Zr/ 94 Zr), Moreover, future models including rotation (and magnetic field) may also have an important impact in this discussion eventually reducing the δ(96 Zr/ 94 Zr).

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Results

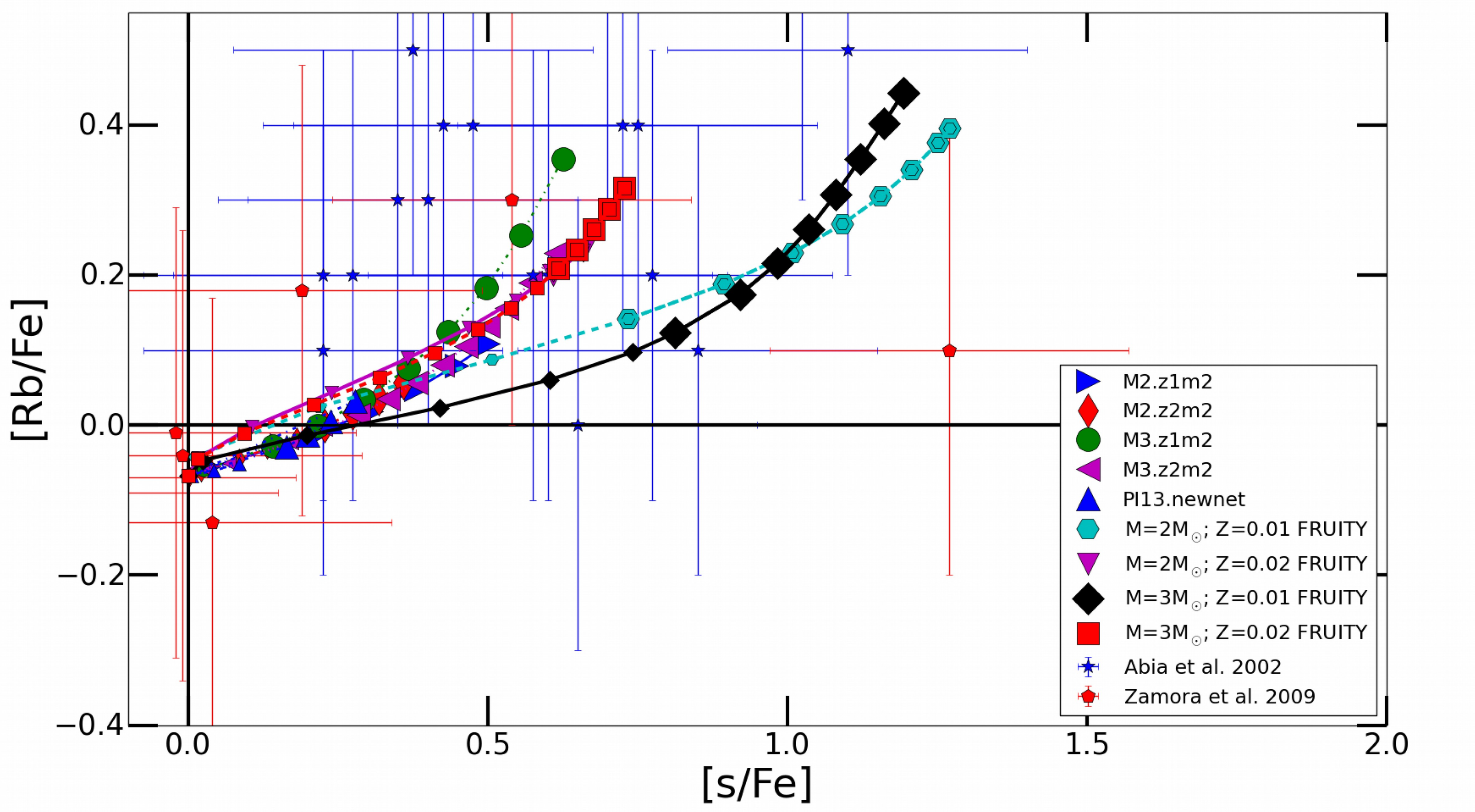

Figure 2: [Rb/Fe] and [s/Fe] ratios obtained from the indicated AGB models, in comparison with a sample of C stars by Abia et al. (2002) and Zamora et al. (2009), and with analogous theoretical AGB models by the FRUITY database (Cristallo et al. 2015). Only stars with [M/H] >-0.3 are considered.

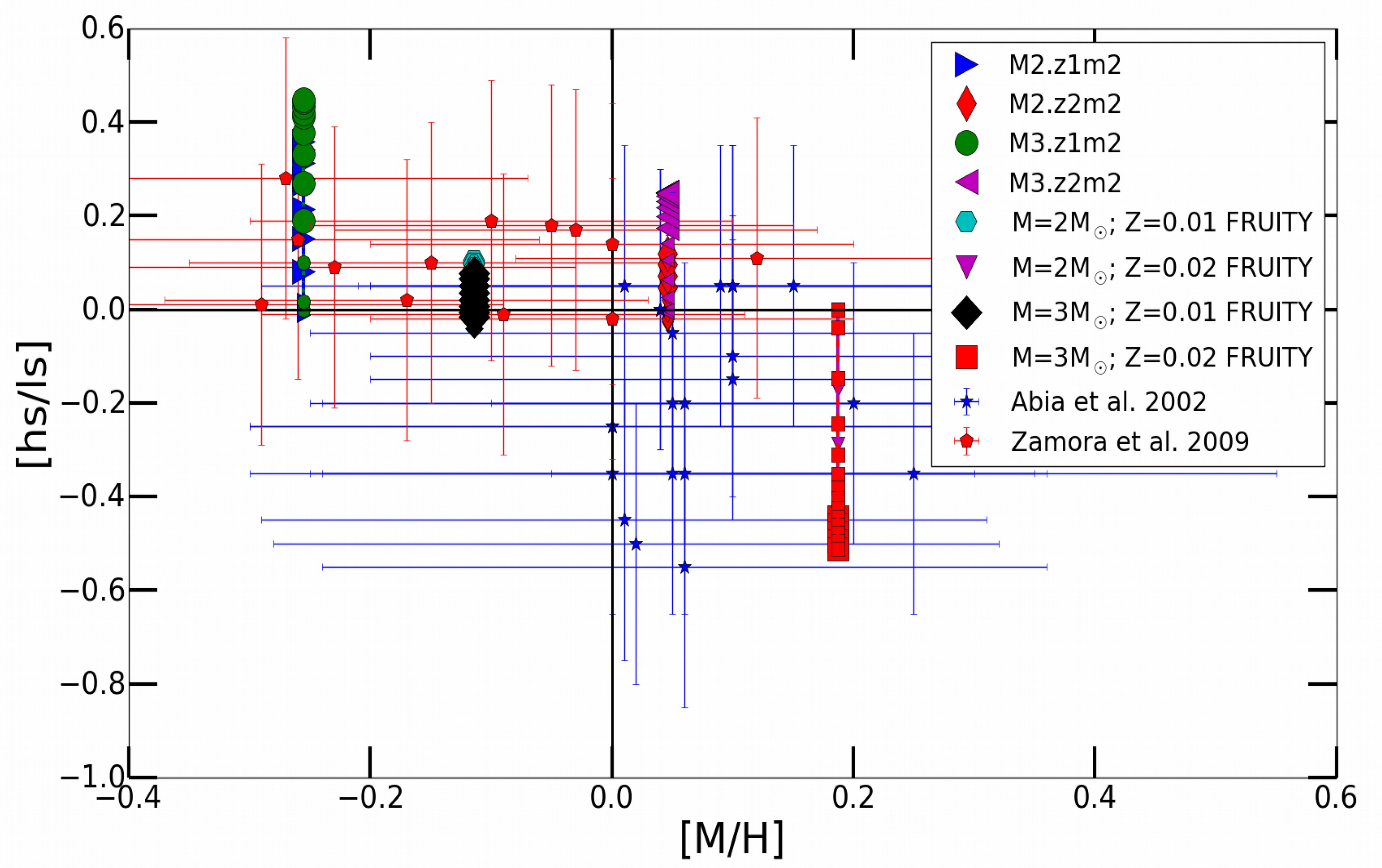

Figure 3:Comparison of the [hs/ls] vs [M/H] obtained from our models with observational data from Abia et al. (2002) and Zamora et al. (2009). We also report the AGB calculations from the FRUITY database (Cristallo et al. 2015).

References

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