Convective-Boundary Mixing instabilities in Asymptotic Giant Branch stars: Impact on nucleosynthesis

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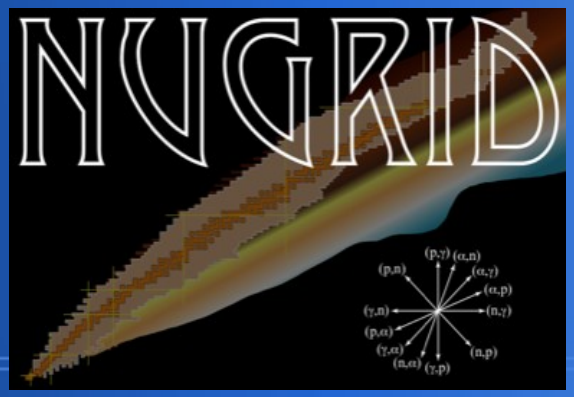
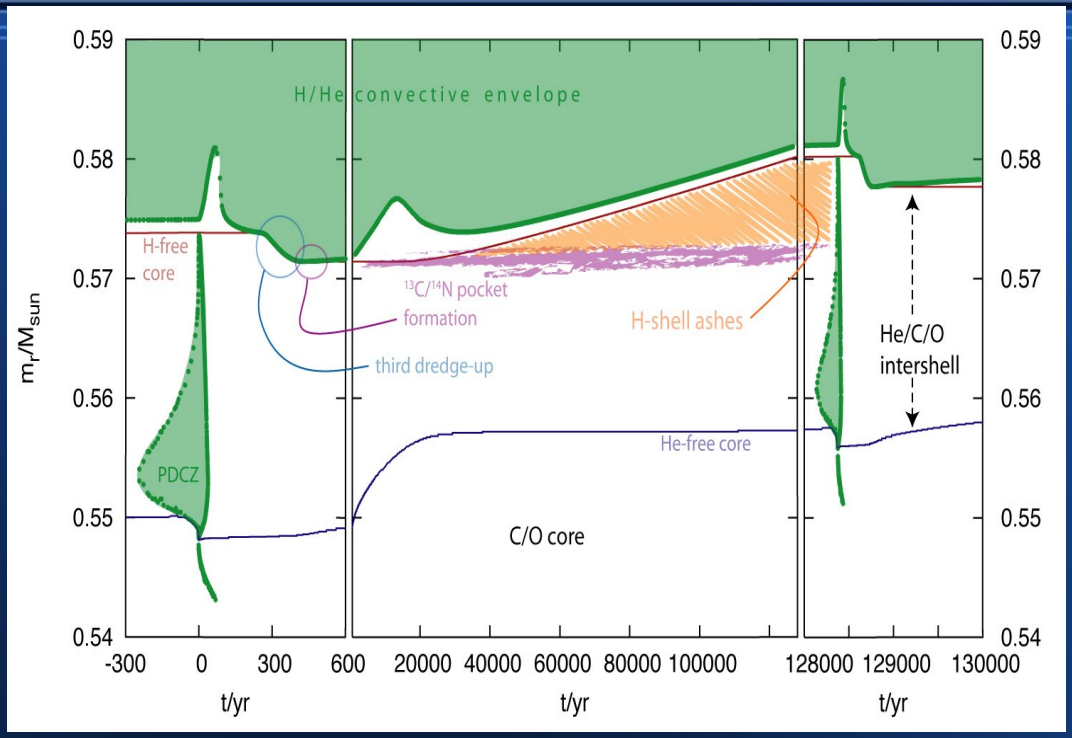
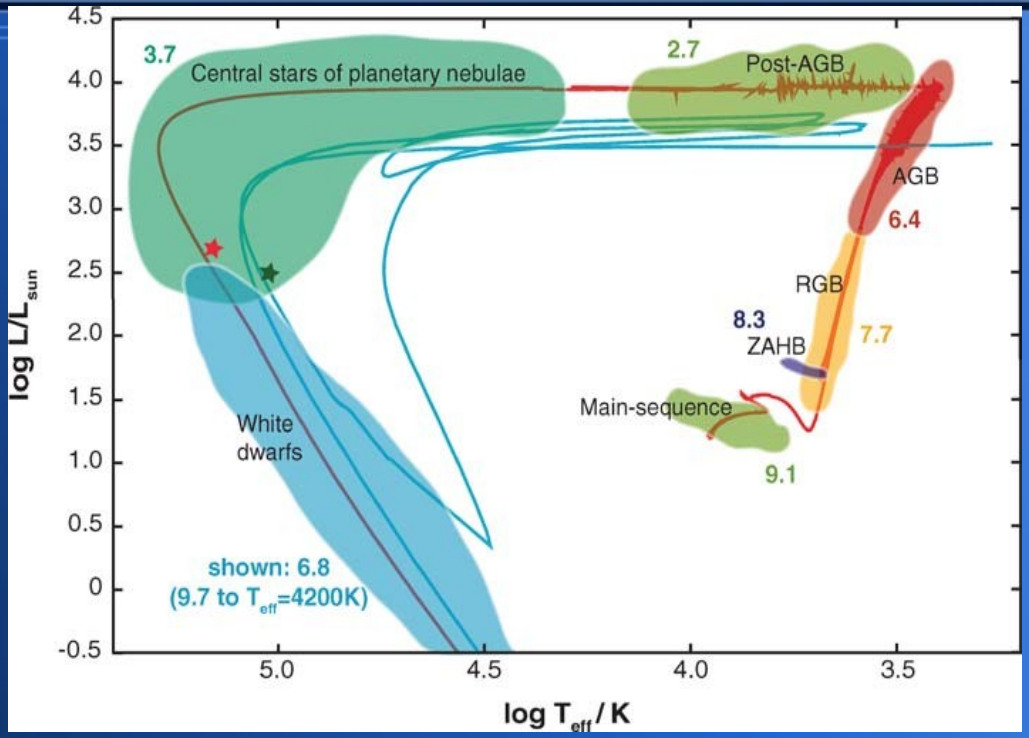


AGB stars: overview

Pictures from Herwig 2005



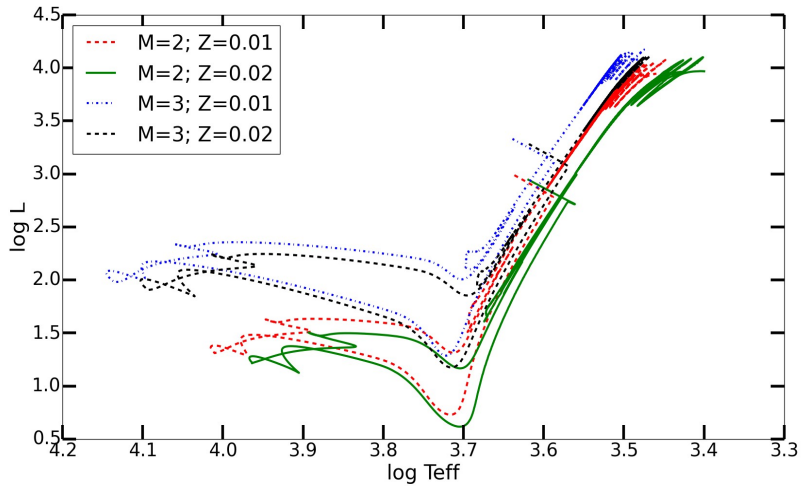


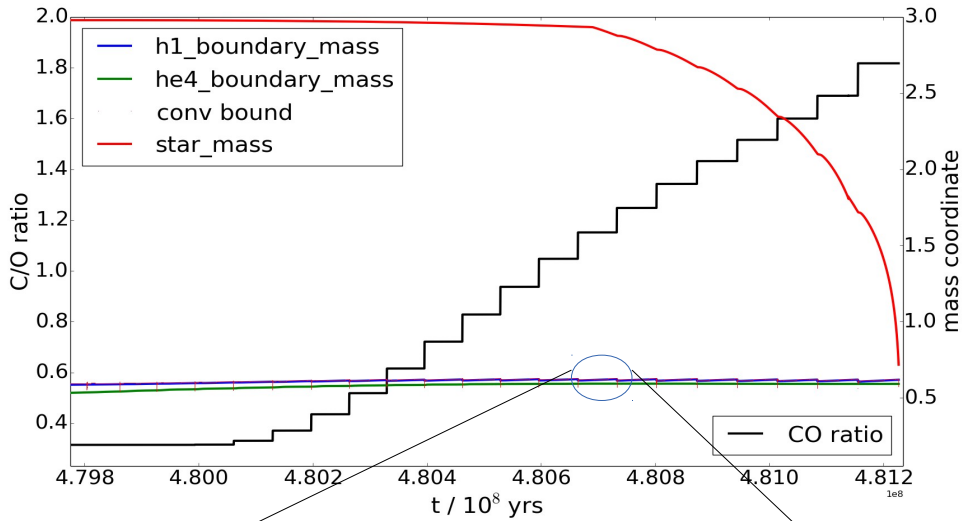
- Evolutionary phase following main-sequence, Red-Giant phase, Horizzontal Branch
- Central degenerate CO core surrounded by Helium-intershell, H-burning shell and a convective envelope.
- Energy output from H-burning shell and triple-α driven thermal-pulses (TP) in the intershell.
- Third dredge-up (TDU) episodes eventually originate a carbon star and form the ^{13}C-pocket.

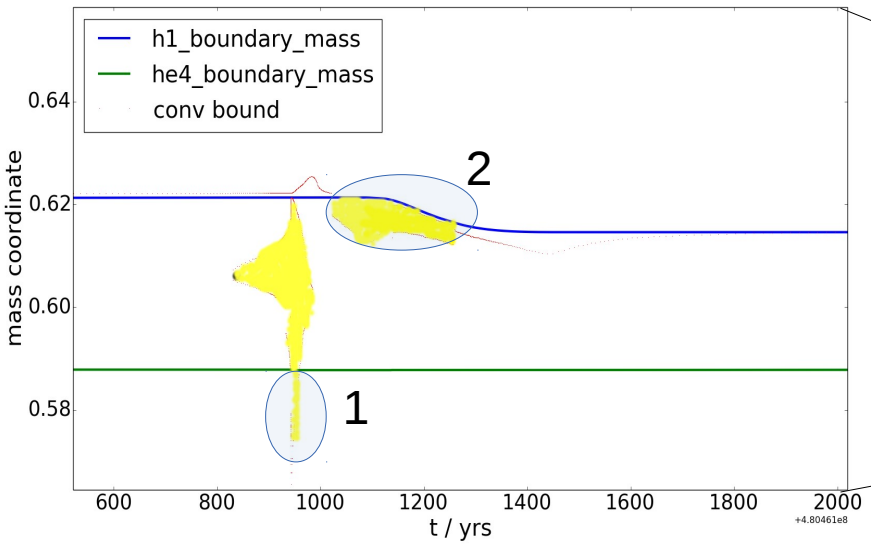
Stellar models

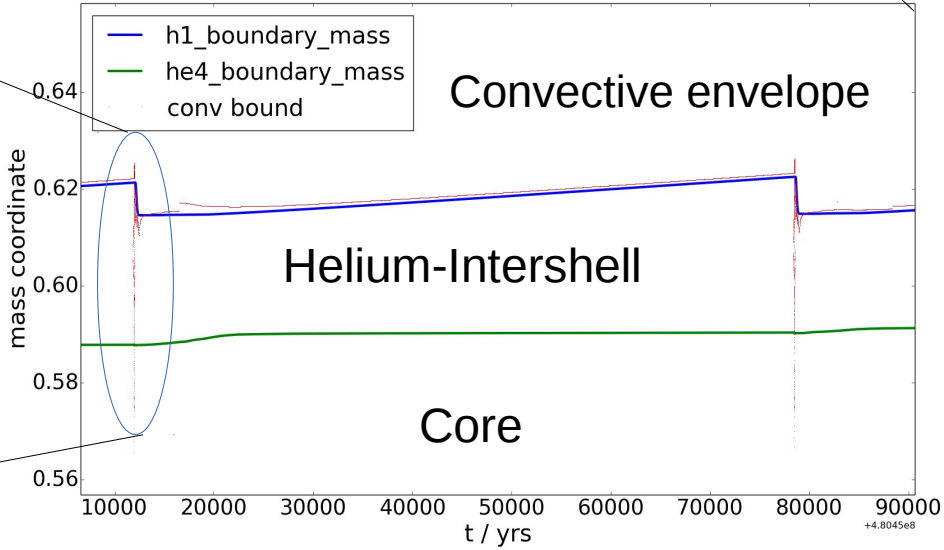
Battino et al. 2014, in prep.:

- Stellar models: 1D stellar evolution code MESA (Paxton et al. 2011), rev 4219.
- Nucleosynthesis simulations: post-processing, MPPNP NuGrid code (e.g., Pignatari et al. 2013)





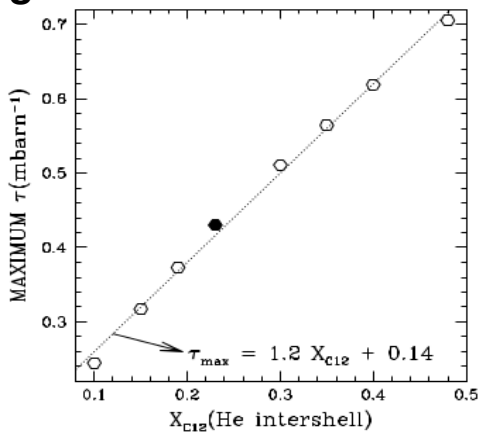




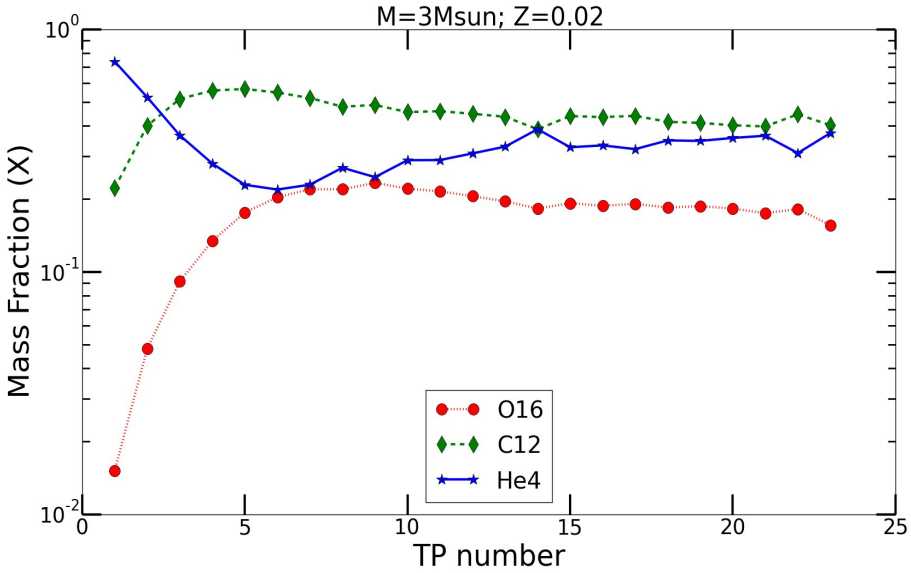
ZONE 1: CBM under the He-Intershell

- CBM recipe for 1D stellar model: Multi-dimensional hydrodynamics simulations of He-shell flash convection by Herwig et al. 2007 (CBM profile below the He-intershell dominated by Kelvin-Helmholtz instabilities and gravity waves);
- Hydrogen deficent post-AGB stars offer direct observational constraints about He-intershell final abundances (Werner et al. 2005).

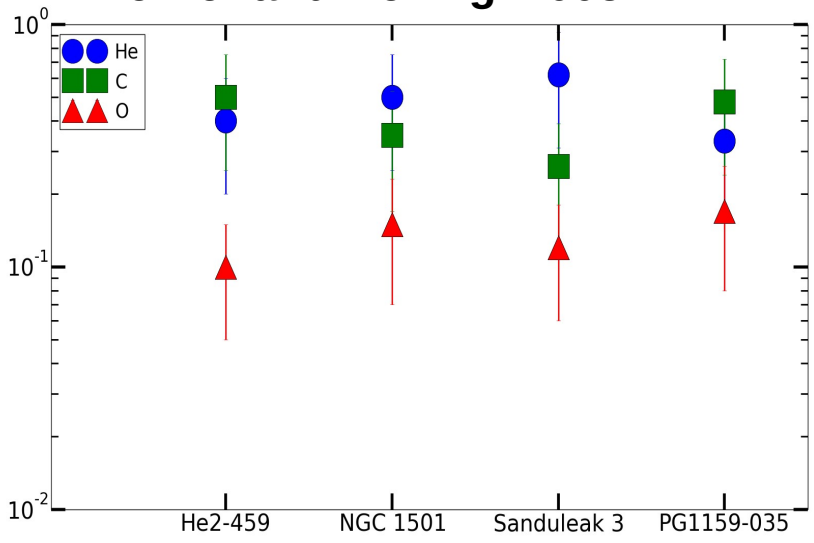
Lugaro et al. 2003



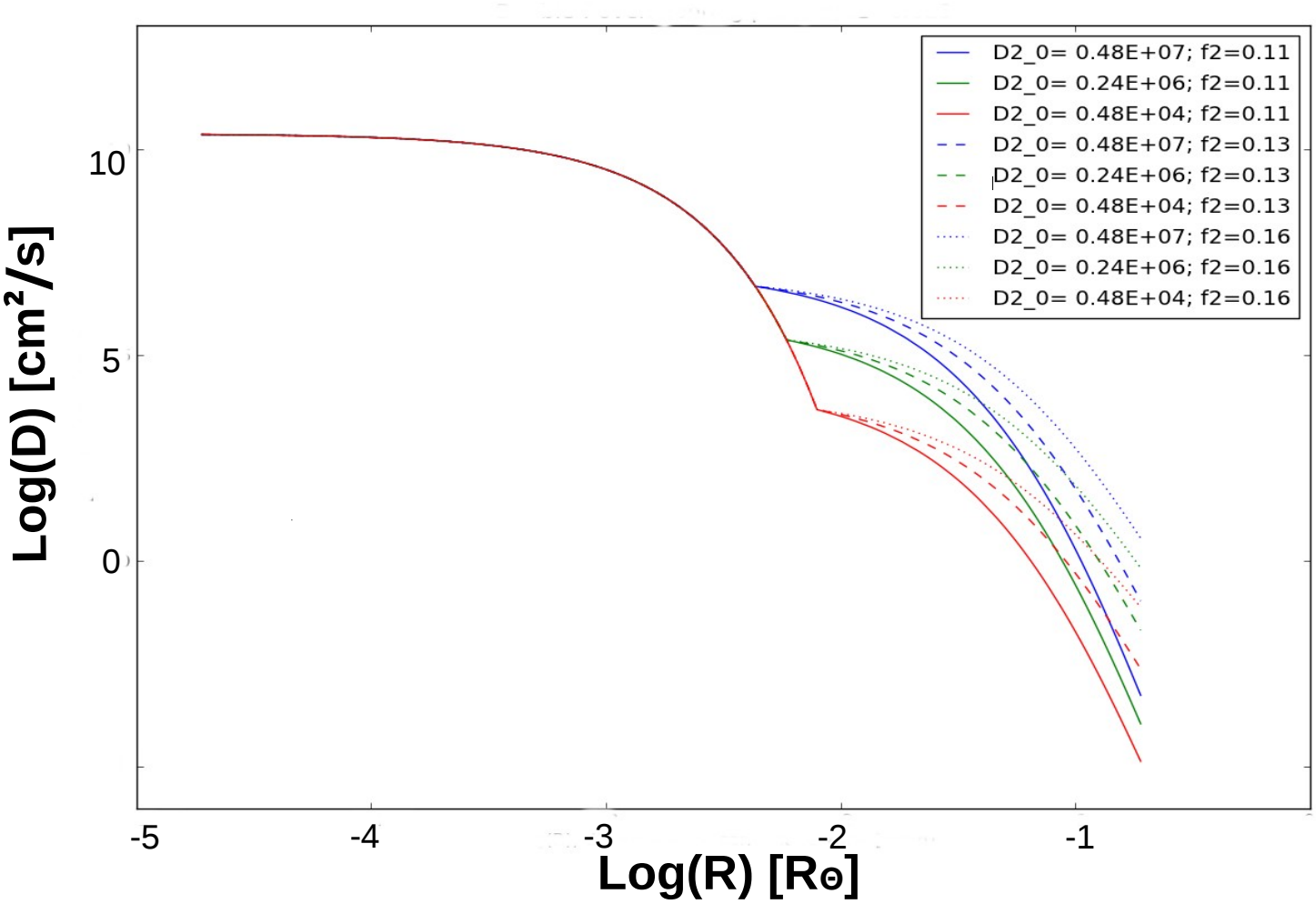
C12(p,γ)N13(β+)C13(α,n)O16



Werner and Herwig. 2005



CBM parameterization



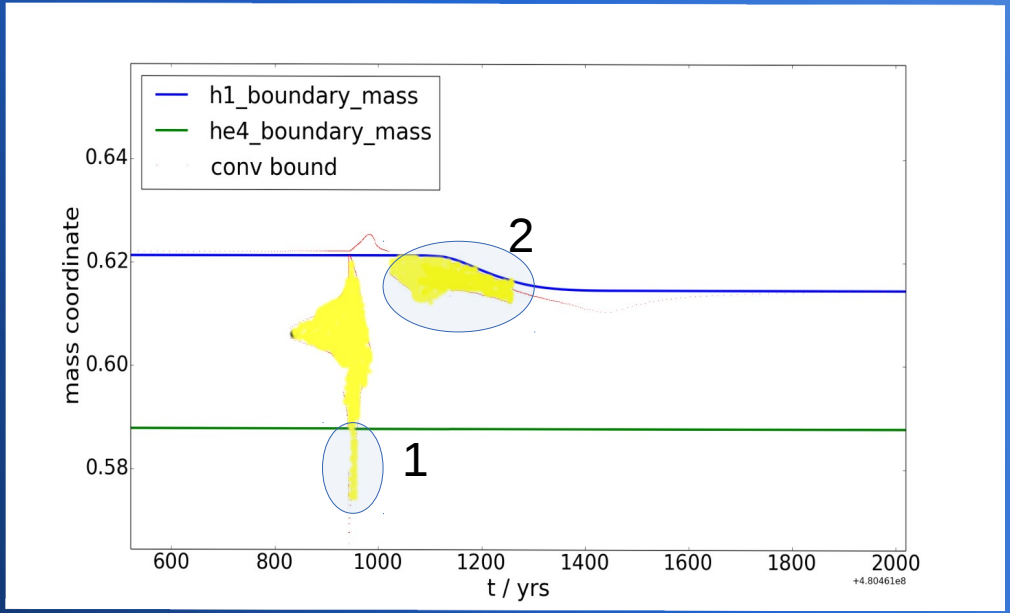
Classic single-exponential overshooting formalism (Herwig et al. 1997):

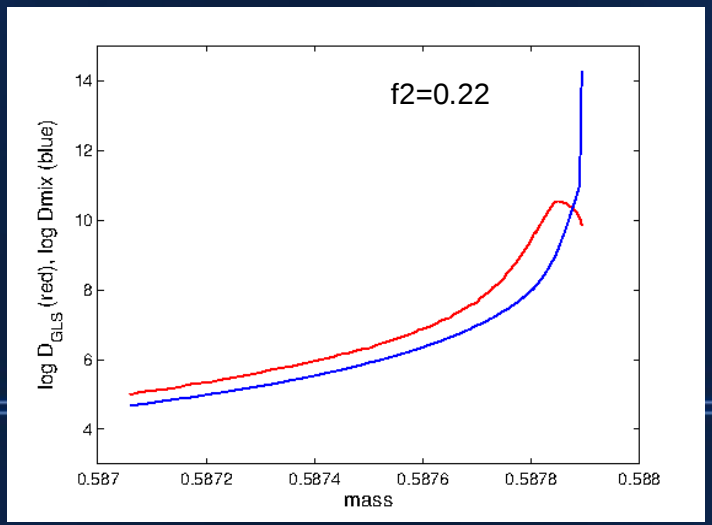
$$D_{ov} = v_0 \cdot H_P(0) \exp\left[\frac{-2z}{f \cdot H_P(0)}\right]$$

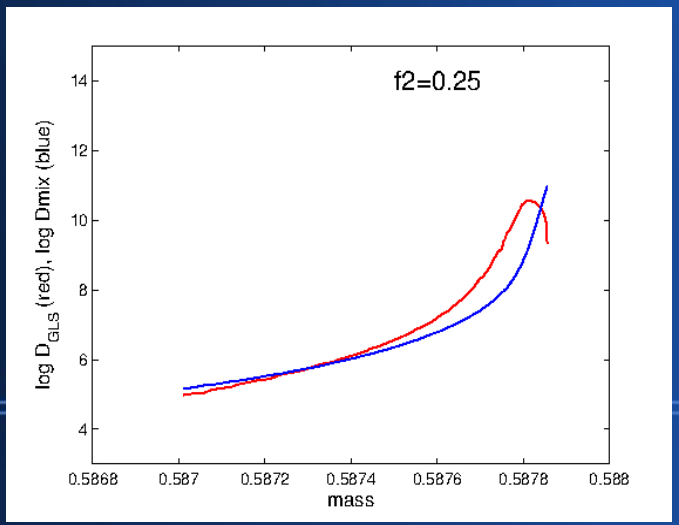
This work: double-exponential mixing coefficent decay, second slope determined by f2.

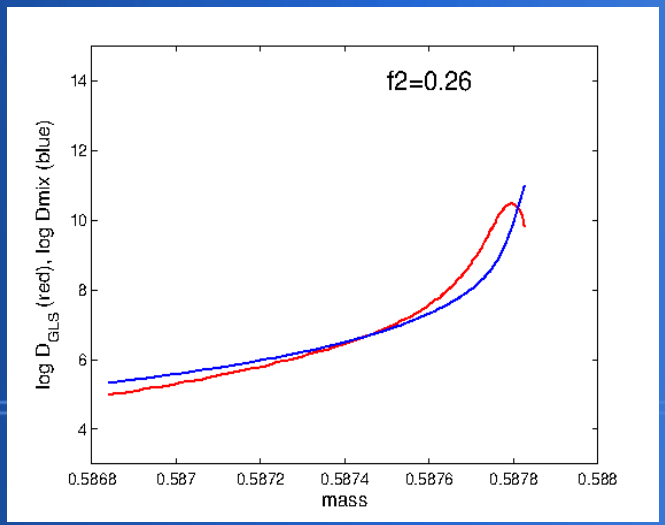
ZONE 2:CBM under the convective envelope

- CBM affecting the formation of the ^{13}C-pocket.
- CBM recipe: fitting of IGW model by Denisenkov and Tout (2003).
- ^{13}C-pocket size obtained: 6.5-8 10^{-5} $M_\odot$



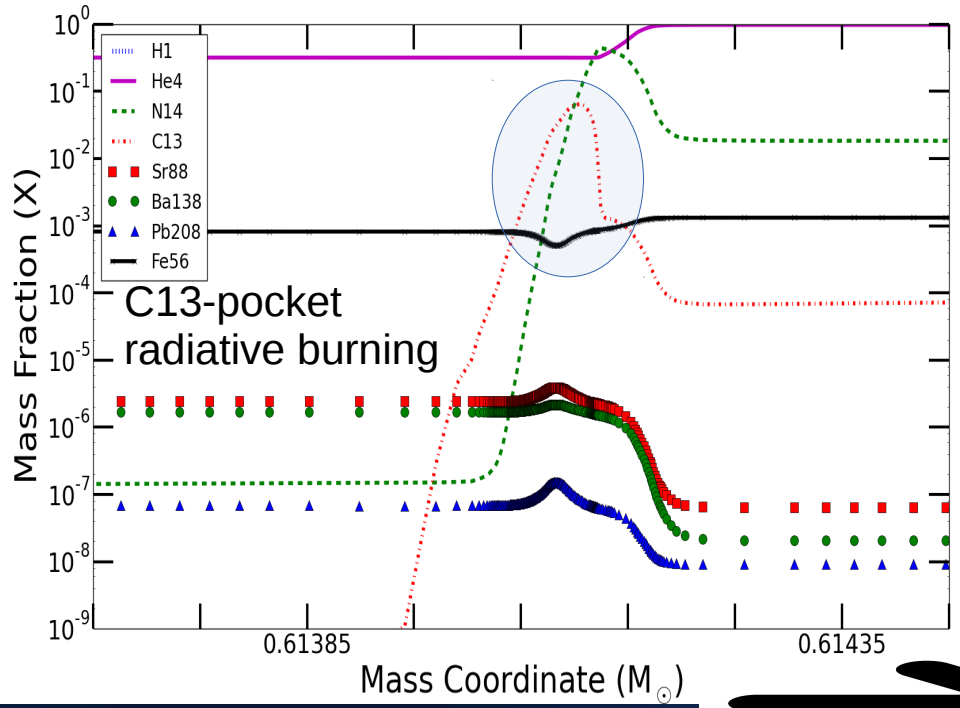


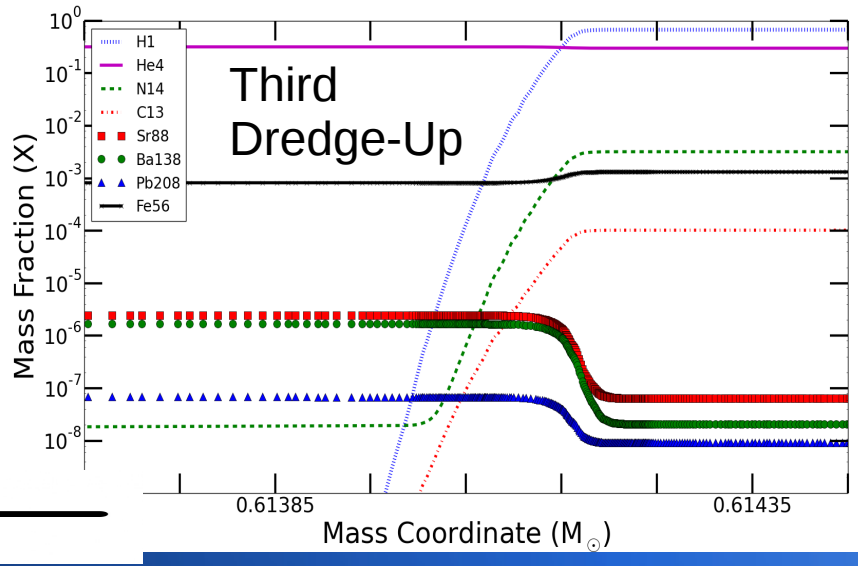


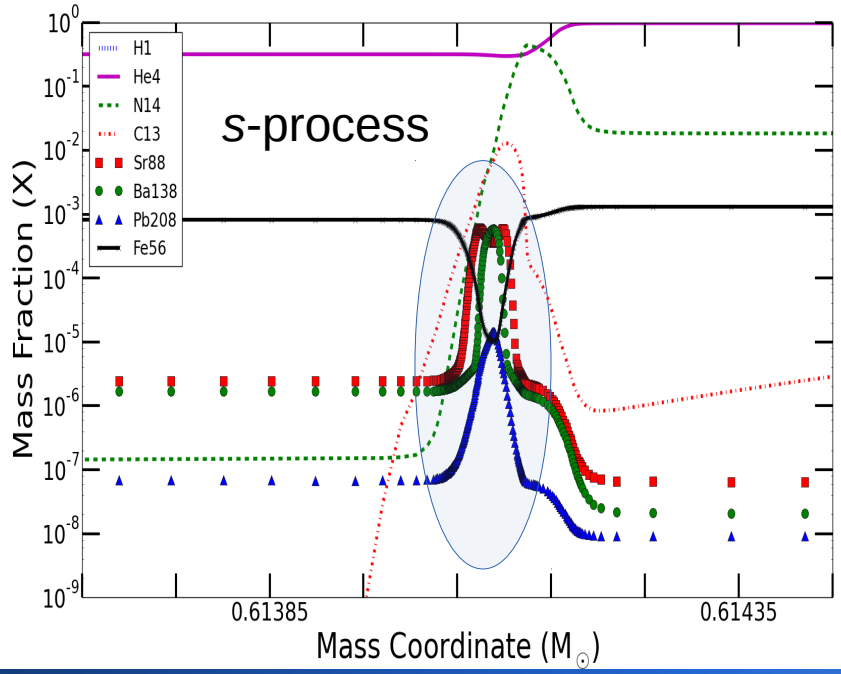


C13-pocket formation

C13-source in the intershell: $^{12}C(p,\gamma)^{13}N(\beta+)^{13}C$

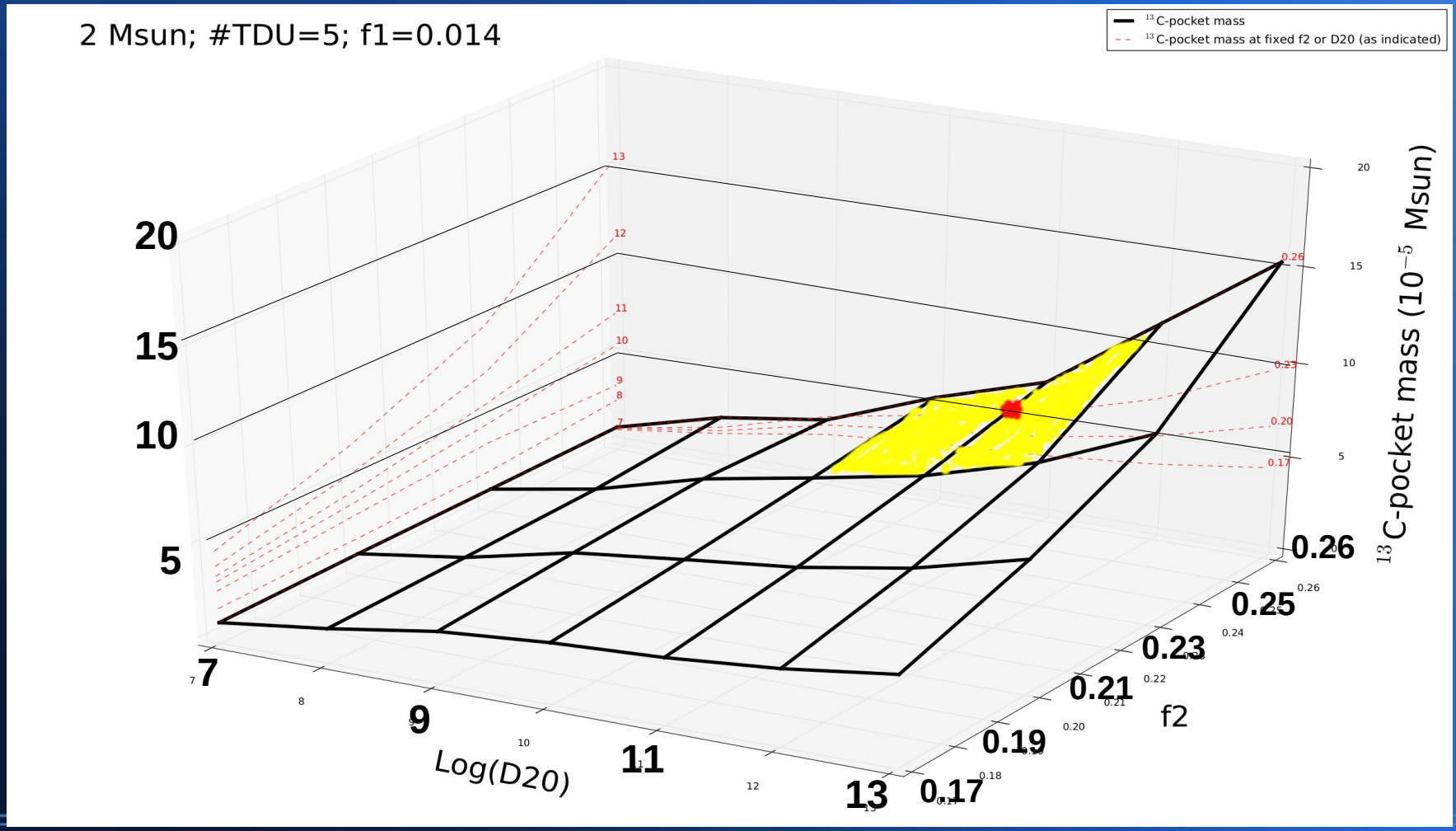






Neutron source reaction:
$^{13}C(\alpha,n)^{16}O$

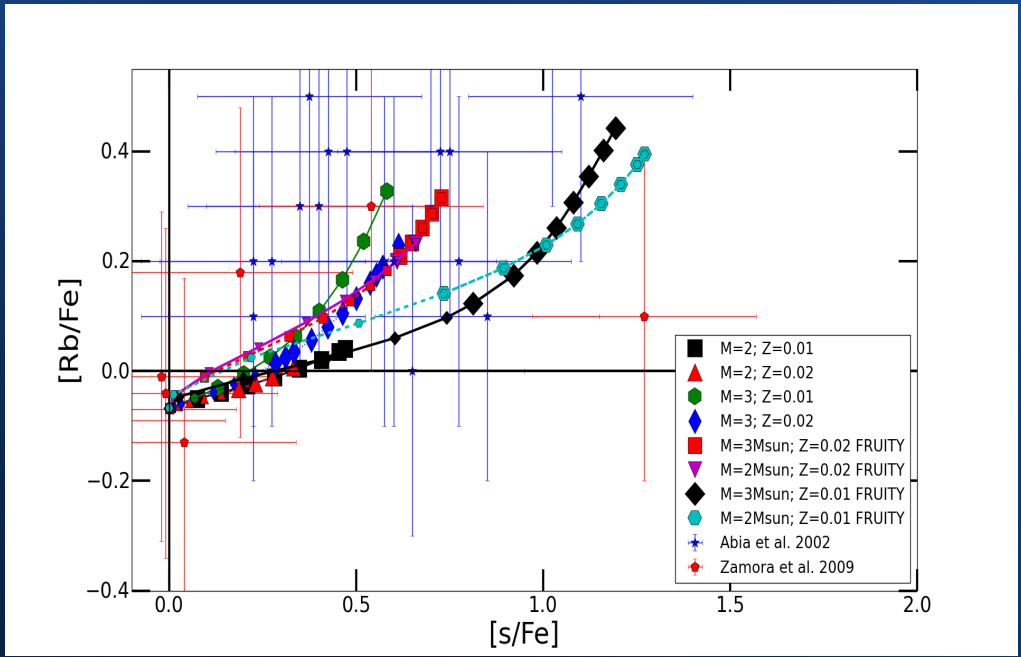
C13-pocket formation: dependence on CBM parameters

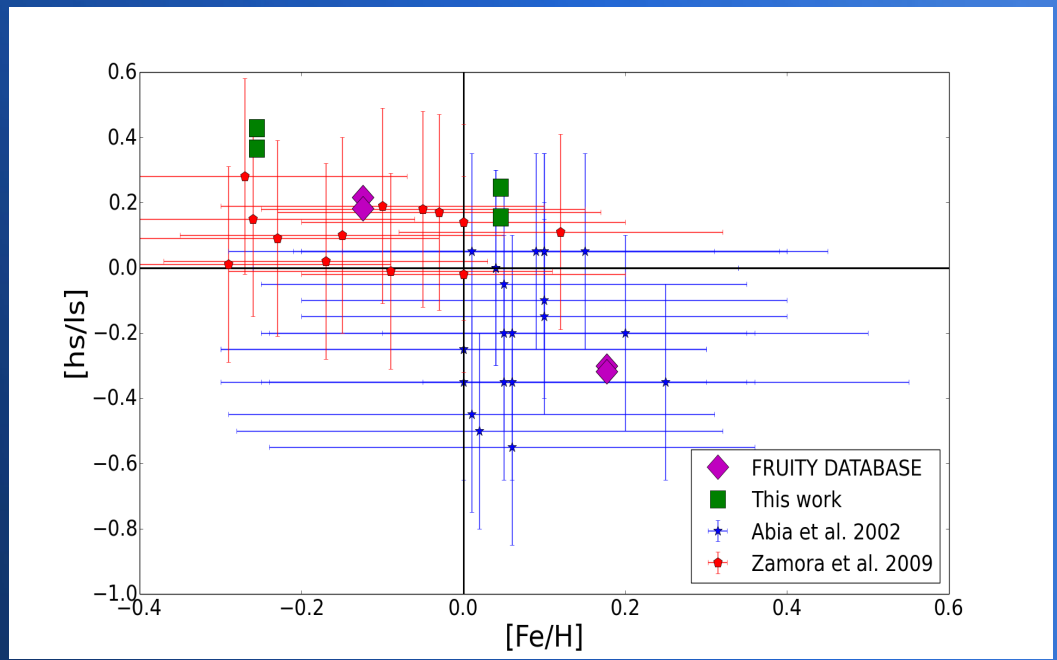


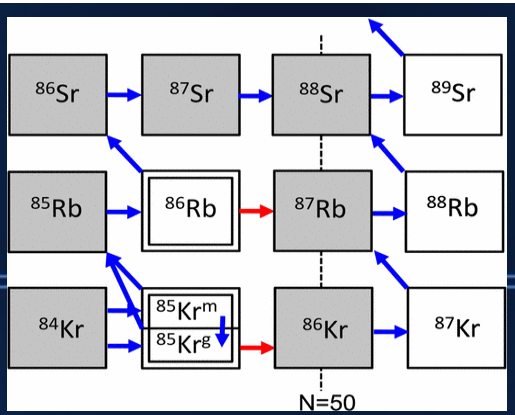
4.5 10^{-5} Msun < C13-pocket size < 1.2 10^{-4} Msun

Comparison of AGB nucleosynthesis results with stellar observations

[s/Fe] = Log10((s/Fe)/(s/Fe)$_\odot$)
[hs/ls] : hs represents the Barium peak production
ls represents the Strontium peak production







- FRUITY: Cristallo et al. 2011, ApJS 197
- Production of Rb in AGB stars: Abia et al. 2001
- Key-reactions: ^{13}C(α,n)^{16}O (after TDU) and ^{22}Ne(α,n)^{25}Mg (during TP)
- Comparison with grains data will be given by Marco Pignatari in his talk.

Raut et al. 2013

Conclusions

- We produced a set of four AGB models (3 and 2 Msun at Z=0.01, 0.02). We tested the role of Kelvin-Helmotz instabilities and gravity waves on AGB stars nucleosynthesis, accounting them with a CBM parametrization (stellar code MESA; post-processing nucleosynthesis code MPPNP);
- Kelvin-Helmotz instabilities have the largest impact on He-intershell abundances of C and O;
- We tested the internal gravity waves as a physics mechanism to form the ^{13}C-pocket. The size of the ^{13}C-pocket obtained from gravity waves seems to be compatible with observations. Compared to the stars with the highest observed s-process enrichment, present models produce [s/Fe] lower by about a factor of two. This is still ok within the uncertainties;
- Our first results show the [hs/ls] index and the slope of the [Rb/Fe] vs [*s*/Fe] in accordance with observations on the surface of carbon stars.
- The complete results will be published this year (Battino et al. 2014, in prep.).