The extended NuGrid stellar evolution, nucleosynthesis and yield data set

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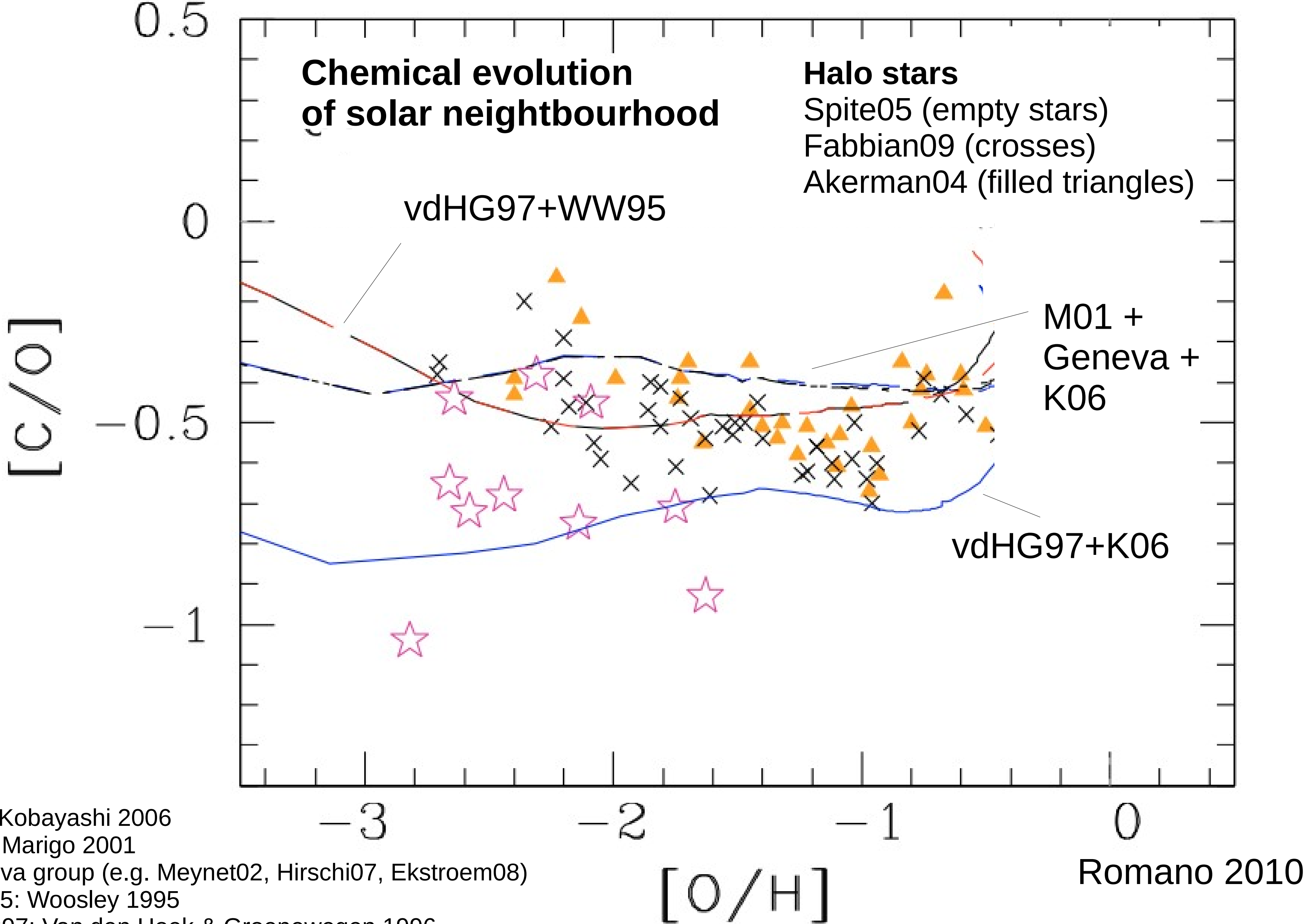
Outline

- Stellar yield modeling: 1-25Msun, Z=0.0001 … 0.02
- Properties of the NuGrid yield sets
  - C13-pocket s process
  - Hot-bottom burning & hot-dredge up
  - Fallback in massive stars
- Simple stellar populations with **S**tellar **Y**ields for **G**alactic **M**odeling **A**pplications (SYGMA)

P. A. Denissenkov, J. Navarro, NuGrid collaboration, F. Herwig, C. Fryer, S. Jones, M. Pignatari, E. Starkenburg, R. Hirschi, N. Nishimura,

Puzzling yield sets for chemical evolution



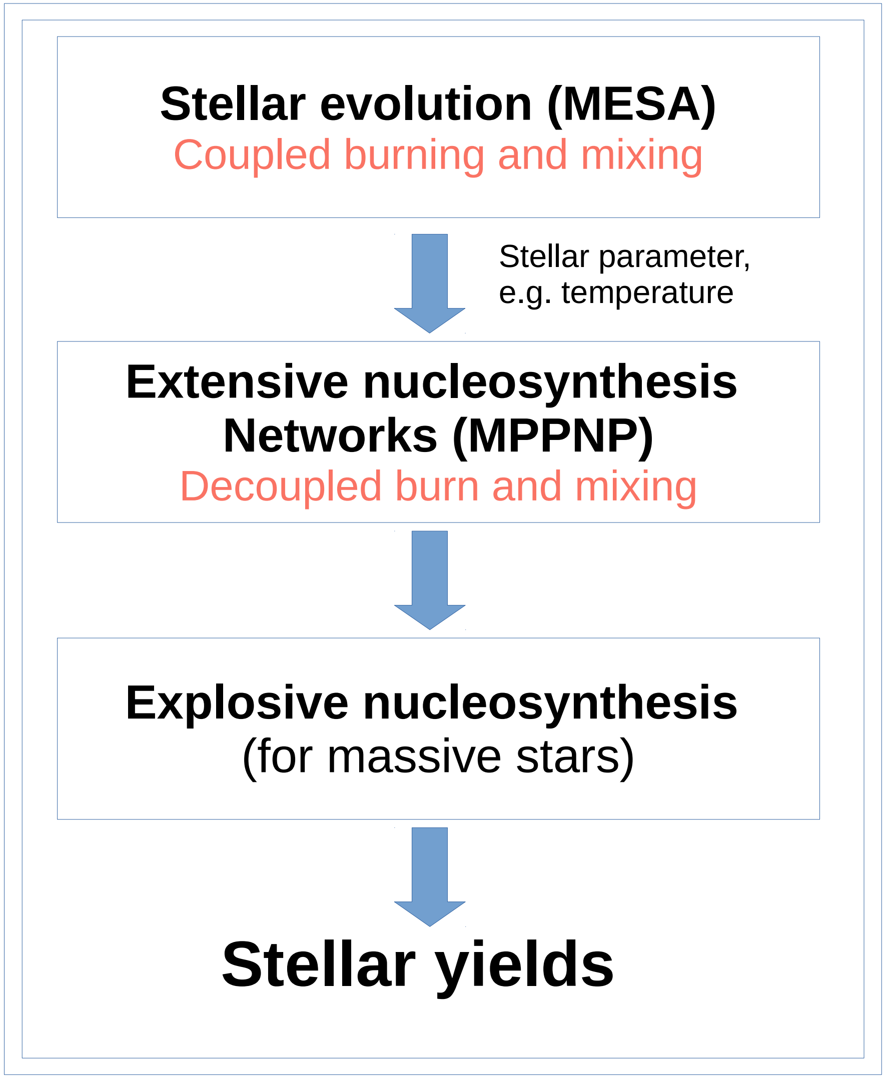
Romano 2010

K06: Kobayashi 2006
M01: Marigo 2001
Geneva group (e.g. Meynet02, Hirschi07, Ekstroem08)
WW95: Woosley 1995
VdHg97: Van den Hoek & Groenewegen 1996

Yield data sets for galactic modeling applications

The NuGrid approach:

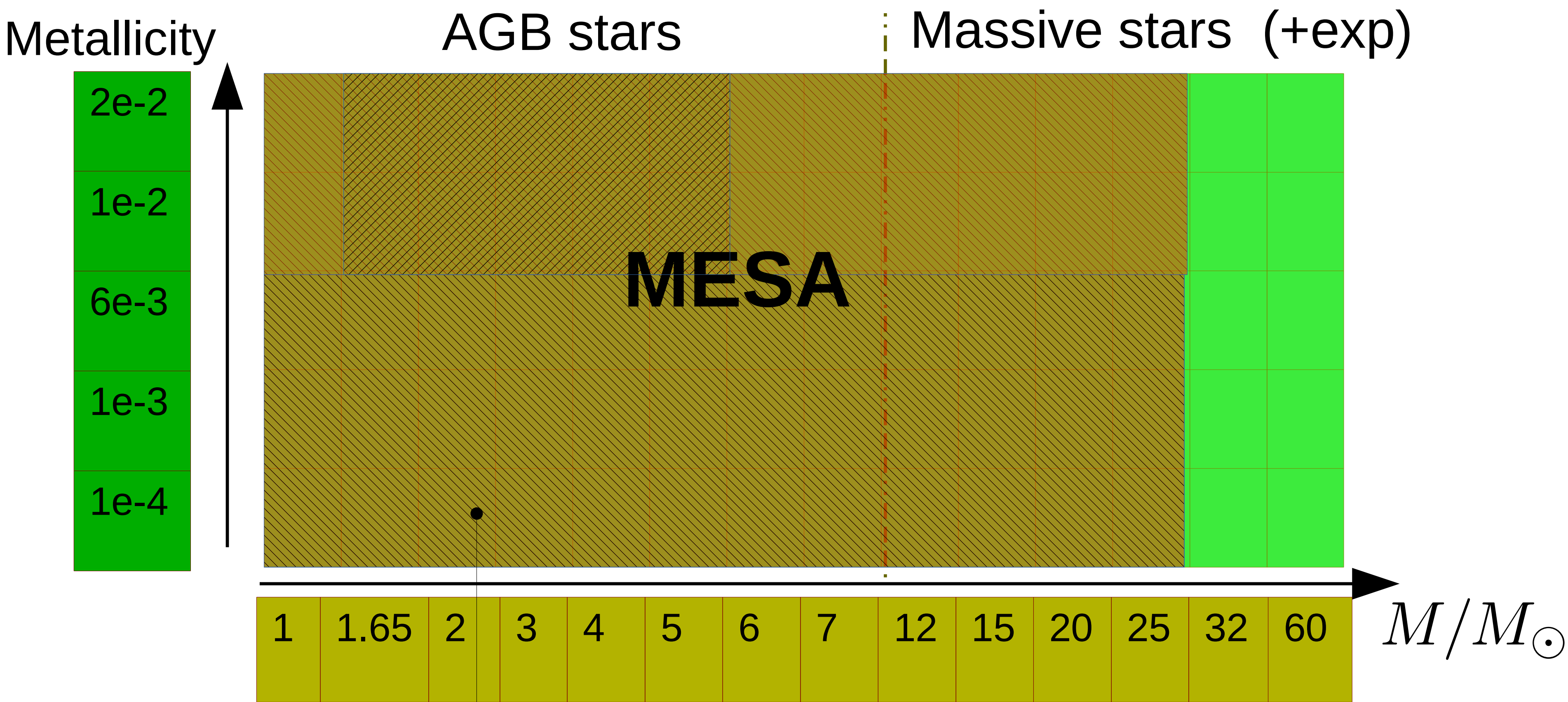
- Complete dataset including full mass range of AGB and massive stars
- Same rate input in stellar simulations and post-processing
- All stable elements + isotopes in complete network
- Mass- and metallicity coverage
- Semi-analytical model for SNII
- No rotation, no B fields



Set 1: astro-ph Pignatari13+, arxiv:

Set 1 extension

C. Ritter, S. Jones, M. Pignatari, F. Herwig, R. Hirschi, C. Fryer, N. Nishimura, P. A. Denissenkov & the NuGrid collaboration



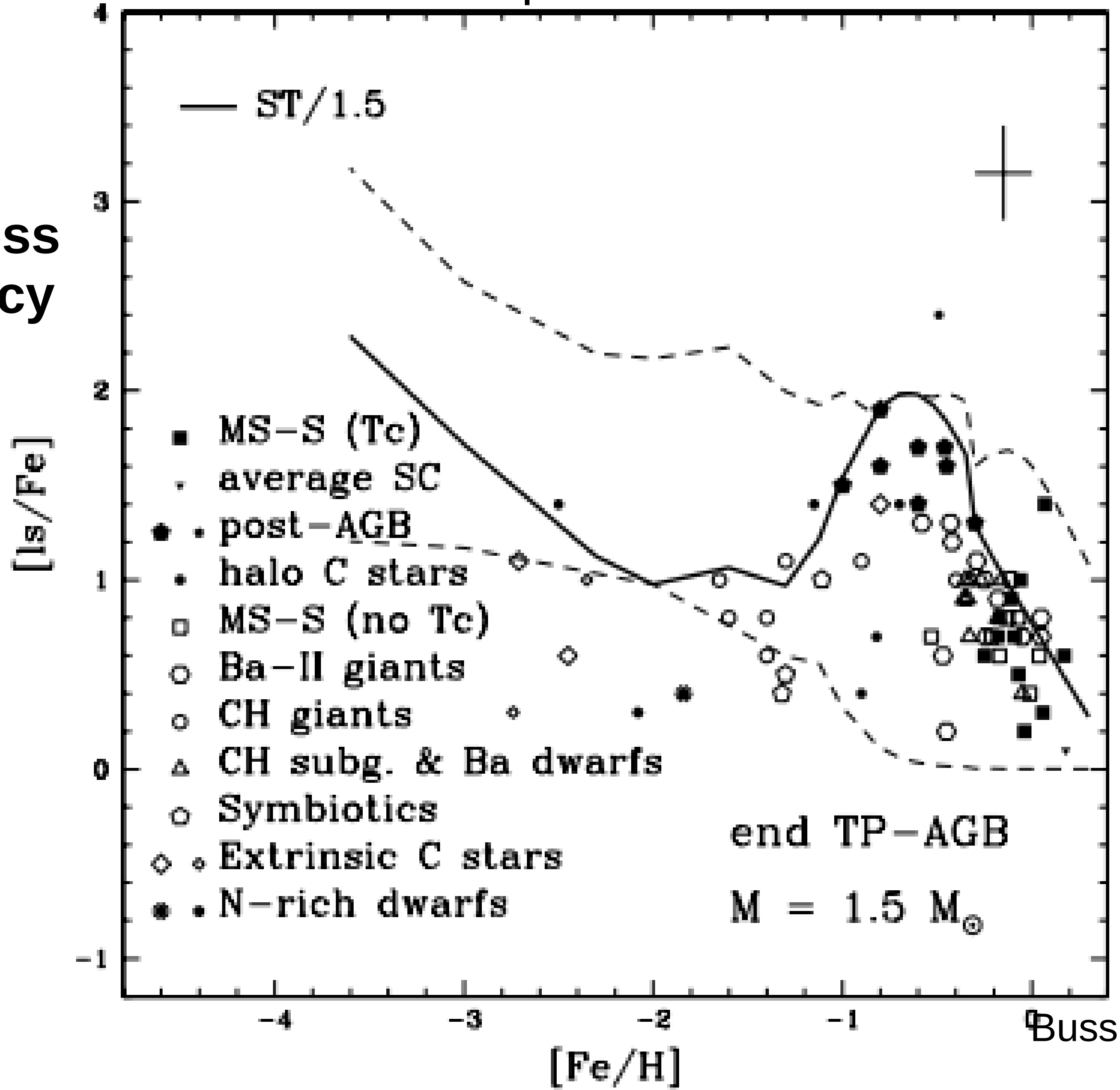
Reference data available at http://data.nugridstars.org w/ Python tools to analyse and explore data.

- <1000 isotope
- 2000 grid zones
- 10^5 models

+ Stellar evolution data for each time step and mass zone

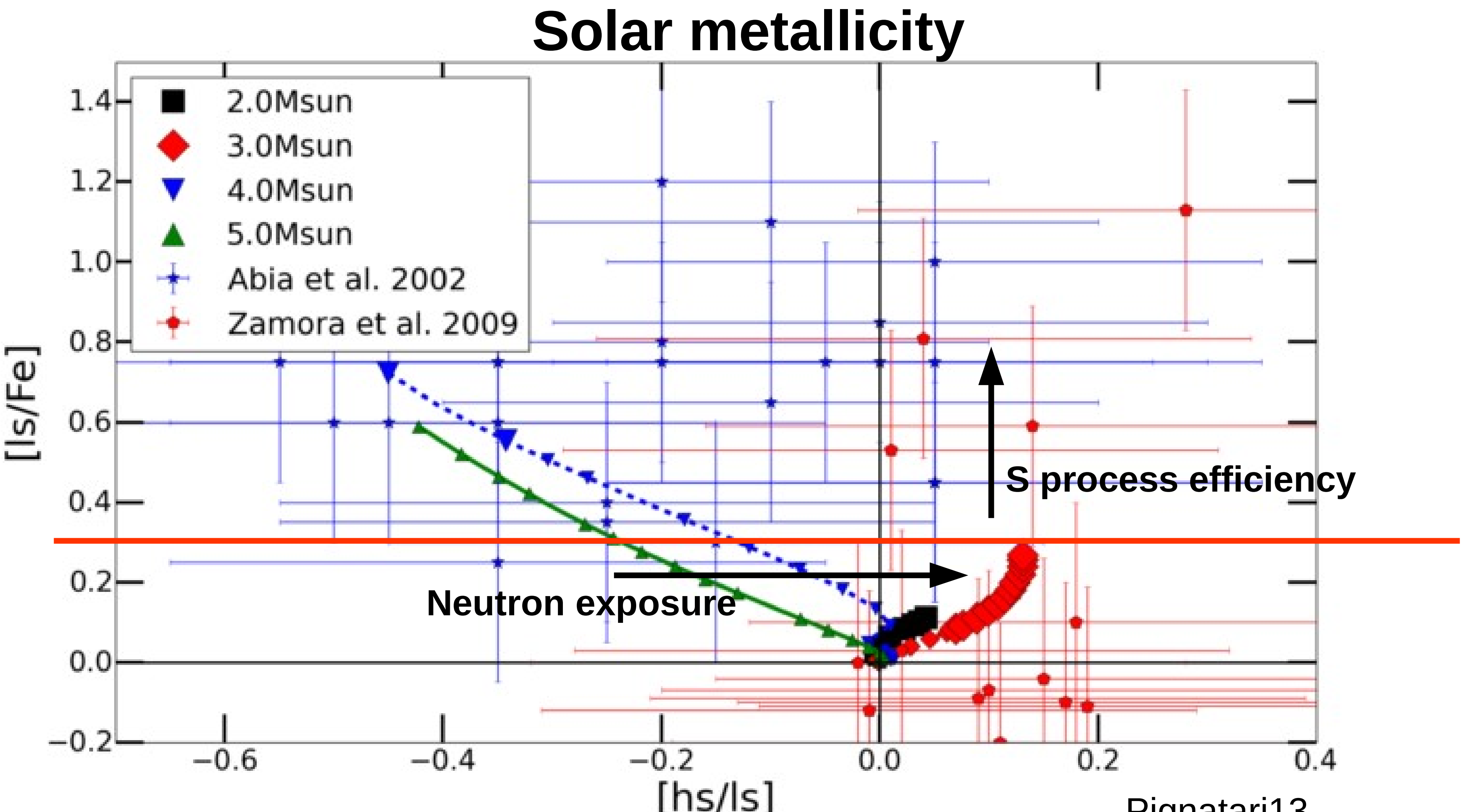
Observed s process in AGB stars

s-process efficiency



Busso01

S process in NuGrid models

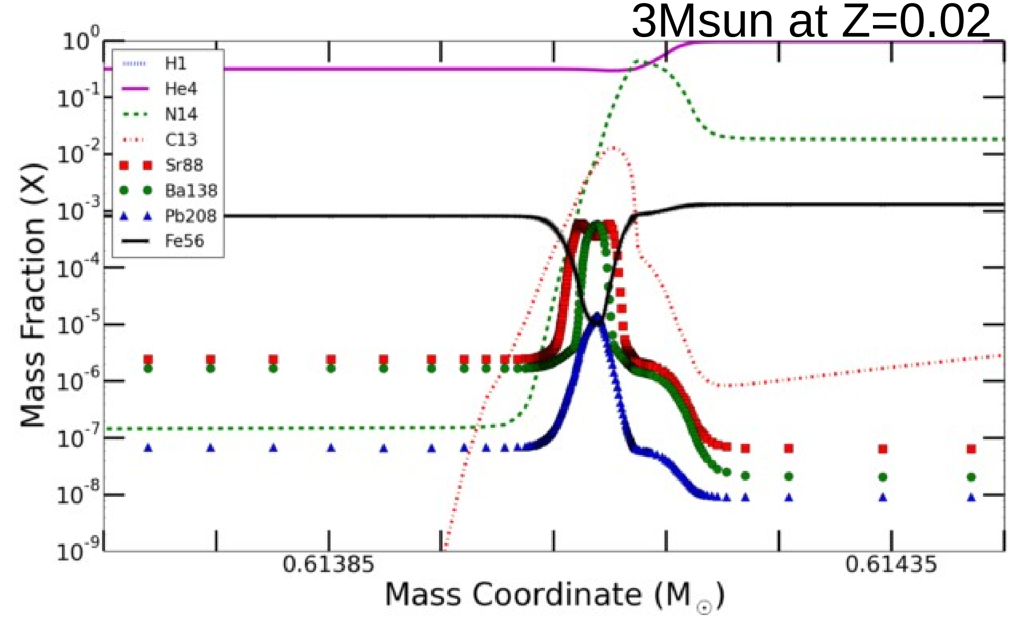


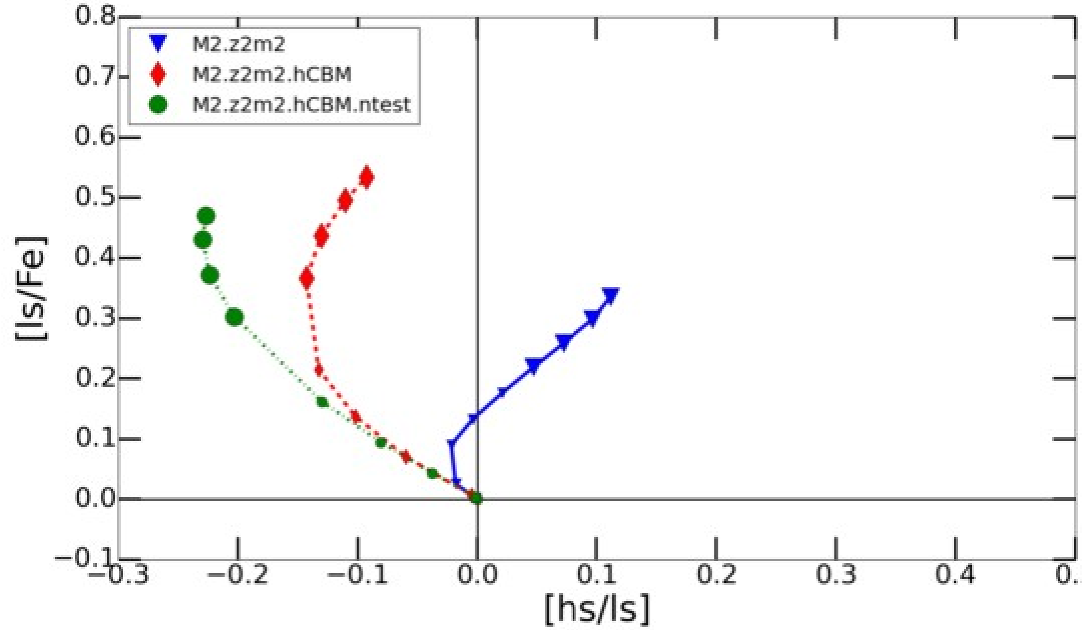
Pignatari13

S process in NuGrid models

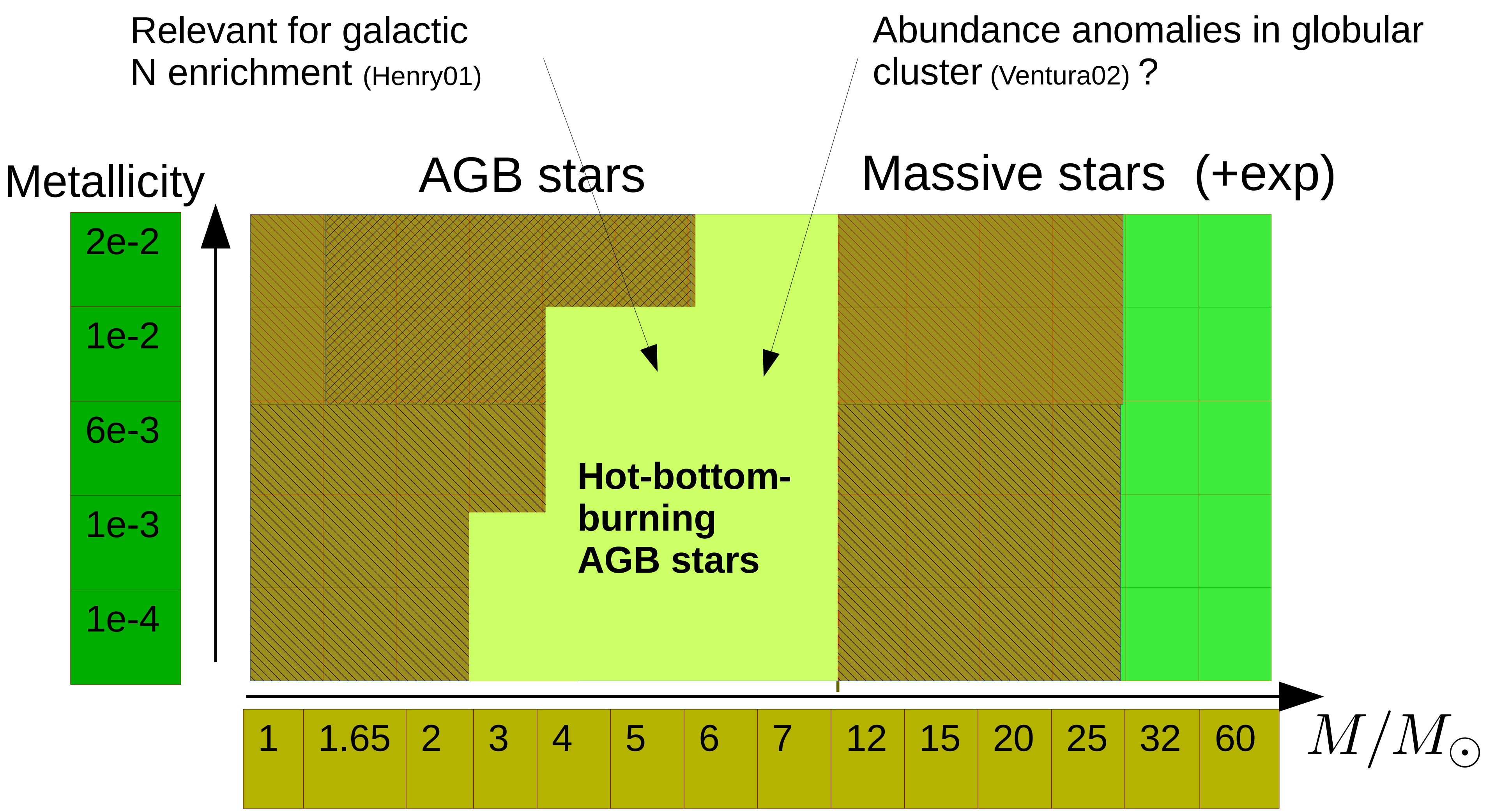
- Gravity-wave induced mixing (Battino15, in prep)
- Better agreement with observations
- He, C, O in agreement with post-AGB stars

3Msun at Z=0.02

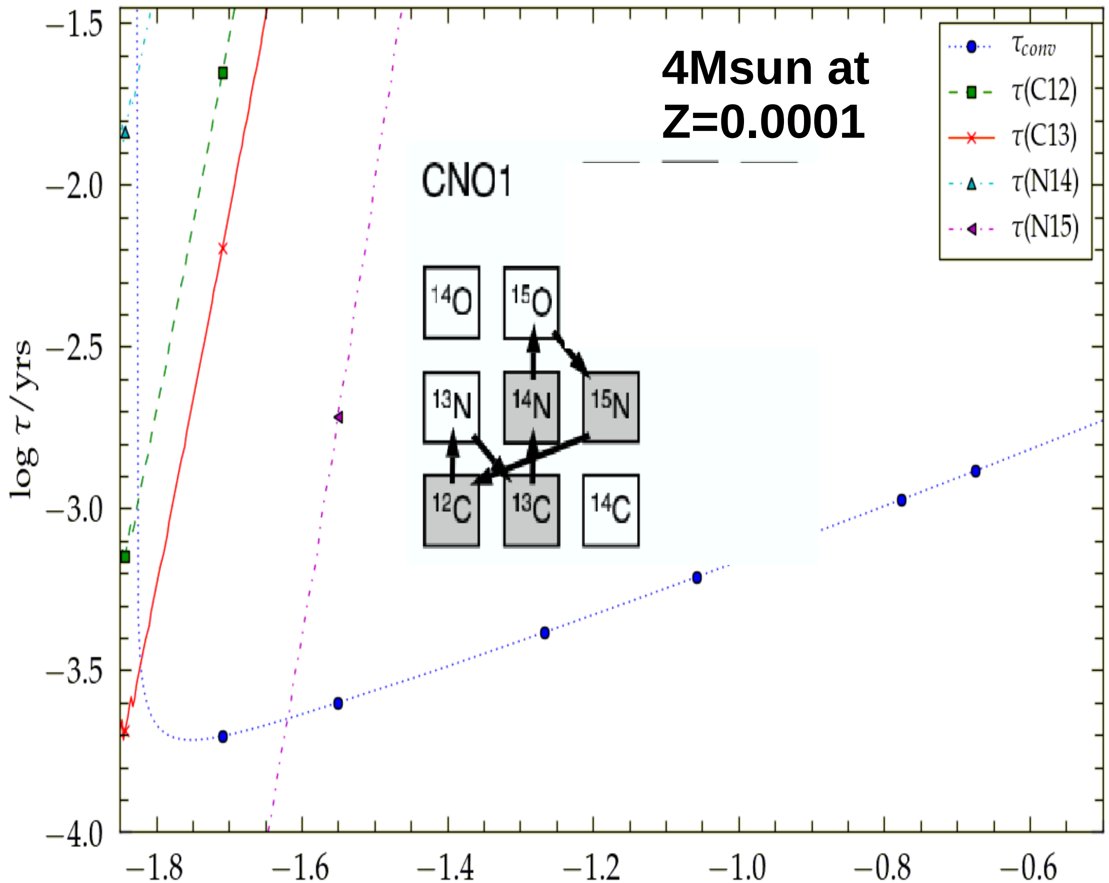




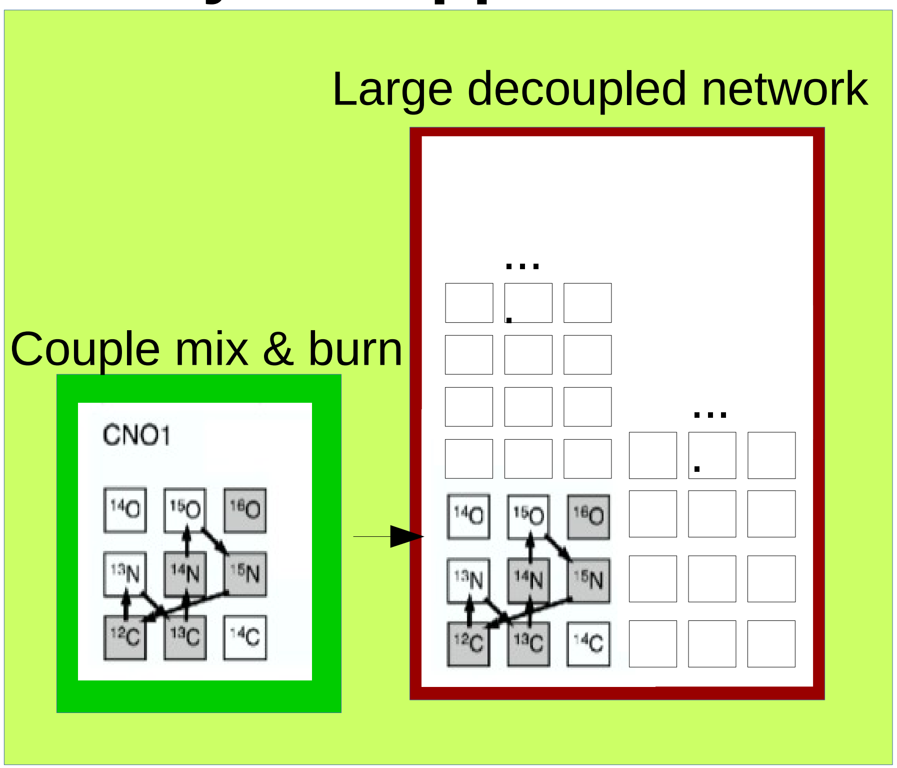
Hot-bottom burning AGB stars



Hot-bottom burning in massive AGB stars

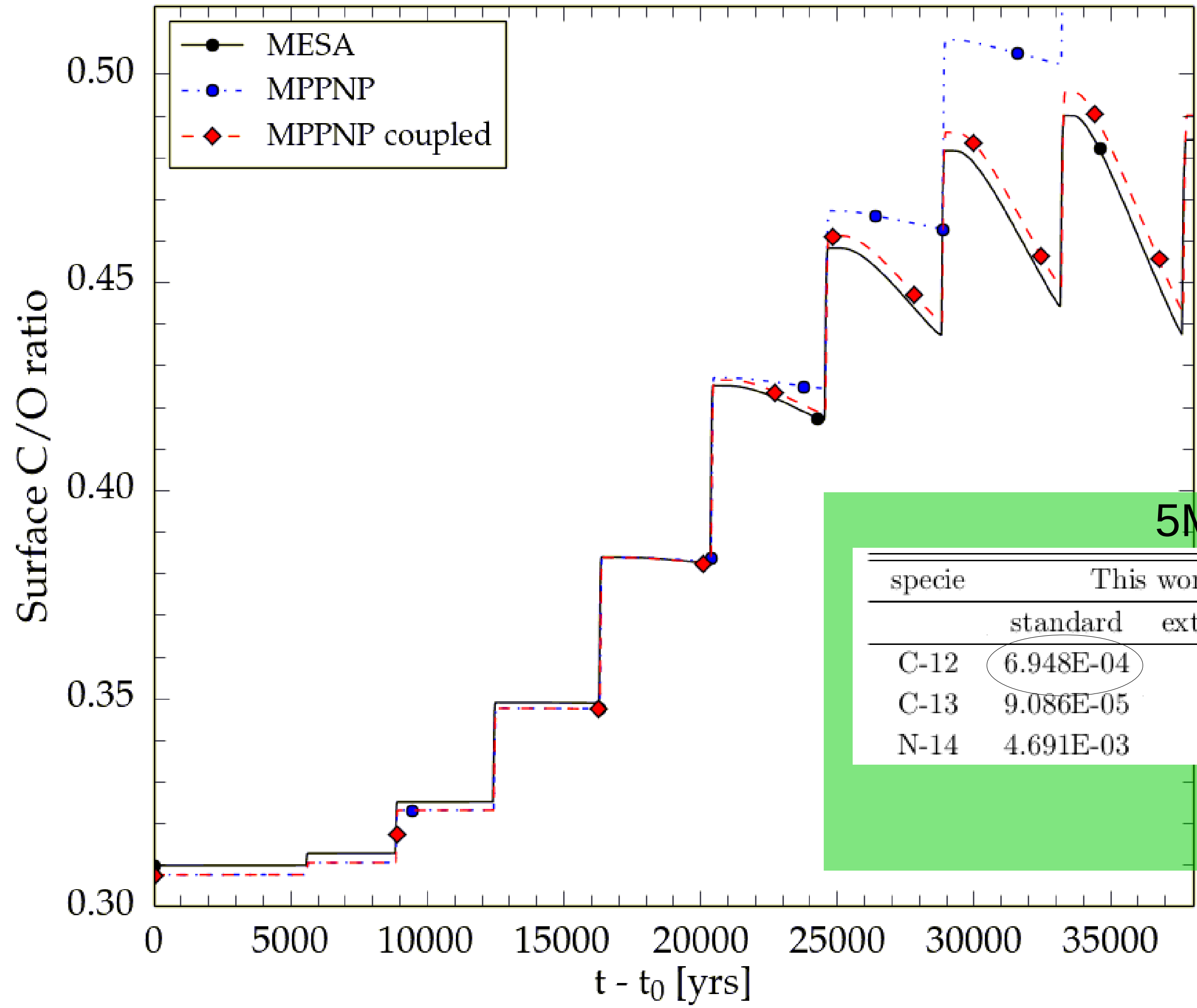


Hybrid approach



- Mixing and burning on same time scale
- Need coupling of mixing and burning
- BUT: with large networks to model s-process synthesis too expensive

Hybrid approach



5Msun at Z=0.0001

specie	This work		H04	K10	C15
	standard	extra CBM			
C-12	6.948E-04		4.587E-04	2.787E-03	1.274E-02
C-13	9.086E-05		4.372E-05	4.059E-04	1.856E-04
N-14	4.691E-03		1.680E-03	2.405E-02	3.405E-04

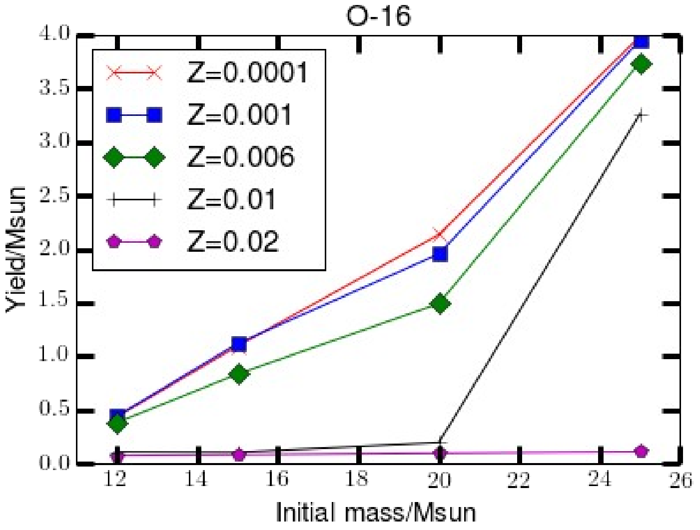
Yield/Msun

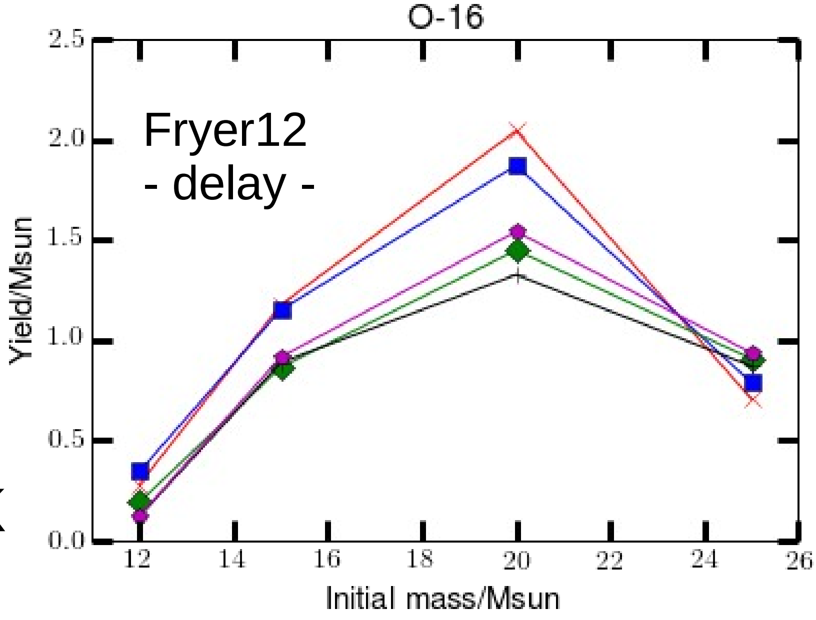
K10: Karakas10
C15: Cristallo15

Prediction of light & heavy elements!

How much fallback in core-collapse SN?

- Classical approach: Set Fallback to prevent ejection of neutron-rich material (e.g. Colgate71)
- We adopt mass-and metallicity dependent fallback from Fryer12
- NuGrid provides yields with mass cut deduced from ye jump, Fryer12 with delay, rapid fallback



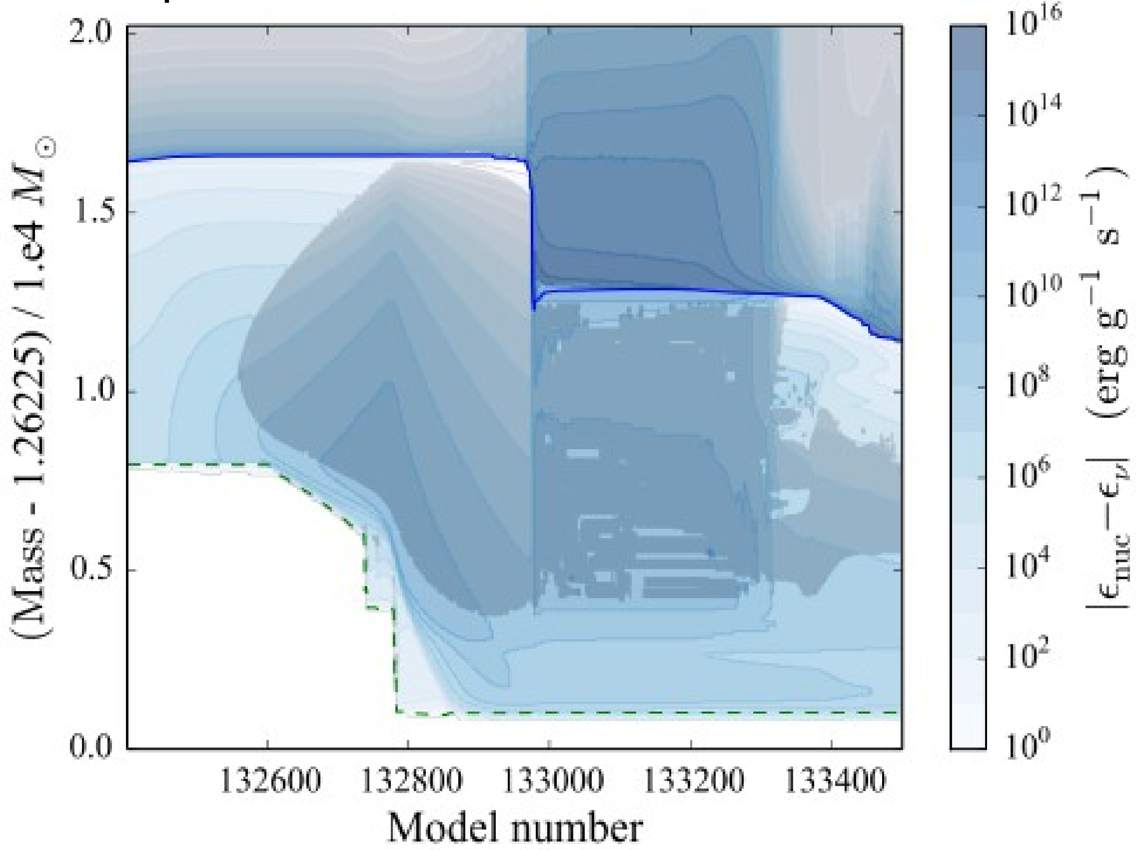


Challenge below [Fe/H] ~ -2.3

Below this metallicity:

- He-core flashes (e.g. Campbell10)
- He-shell flashes (e.g Sudao10)
- VLTP pulses (Herwig11)
- SAGB stars (Jones+ 15, submitted)
- Massive stars

Super AGB star of 7Msun at Z=0.0001



Jones 2015

Dark Matter, Gas and Stars in the Local Group

A cosmological hydrodynamical simulation of the Local-Group environment, where the formation of stars and the enrichment of the interstellar medium is followed self-consistently.

VIRGO consortium
Julio Navarro
Fattahi+ ’15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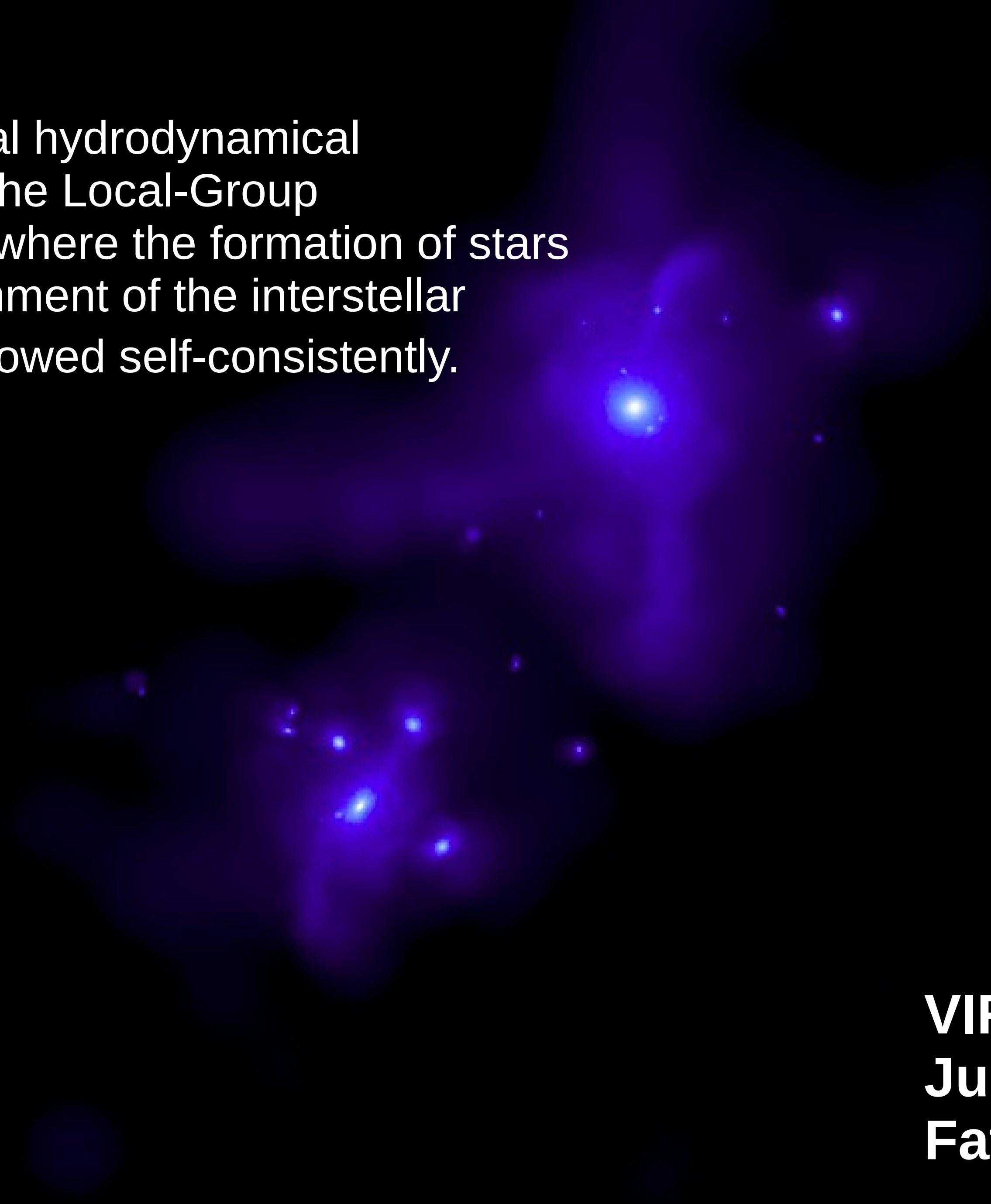
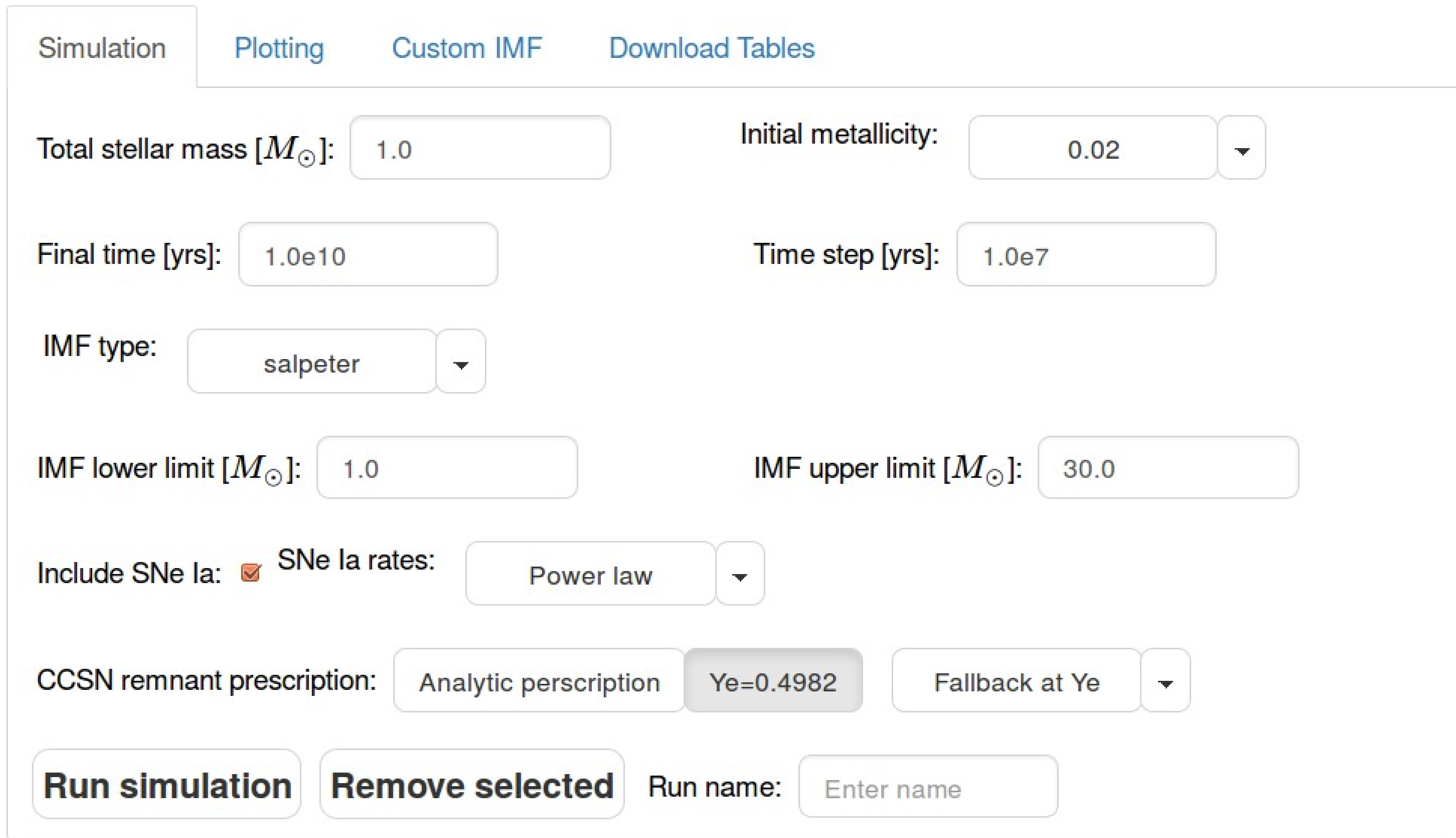


VIRGO consortium
Julio Navarro
Fattahi+ ’15

SYGMA

- Stellar yields for galactic modeling applications
- Fold yields into simple stellar populations
- Simple and easy accessible web interface

SYGMA interface



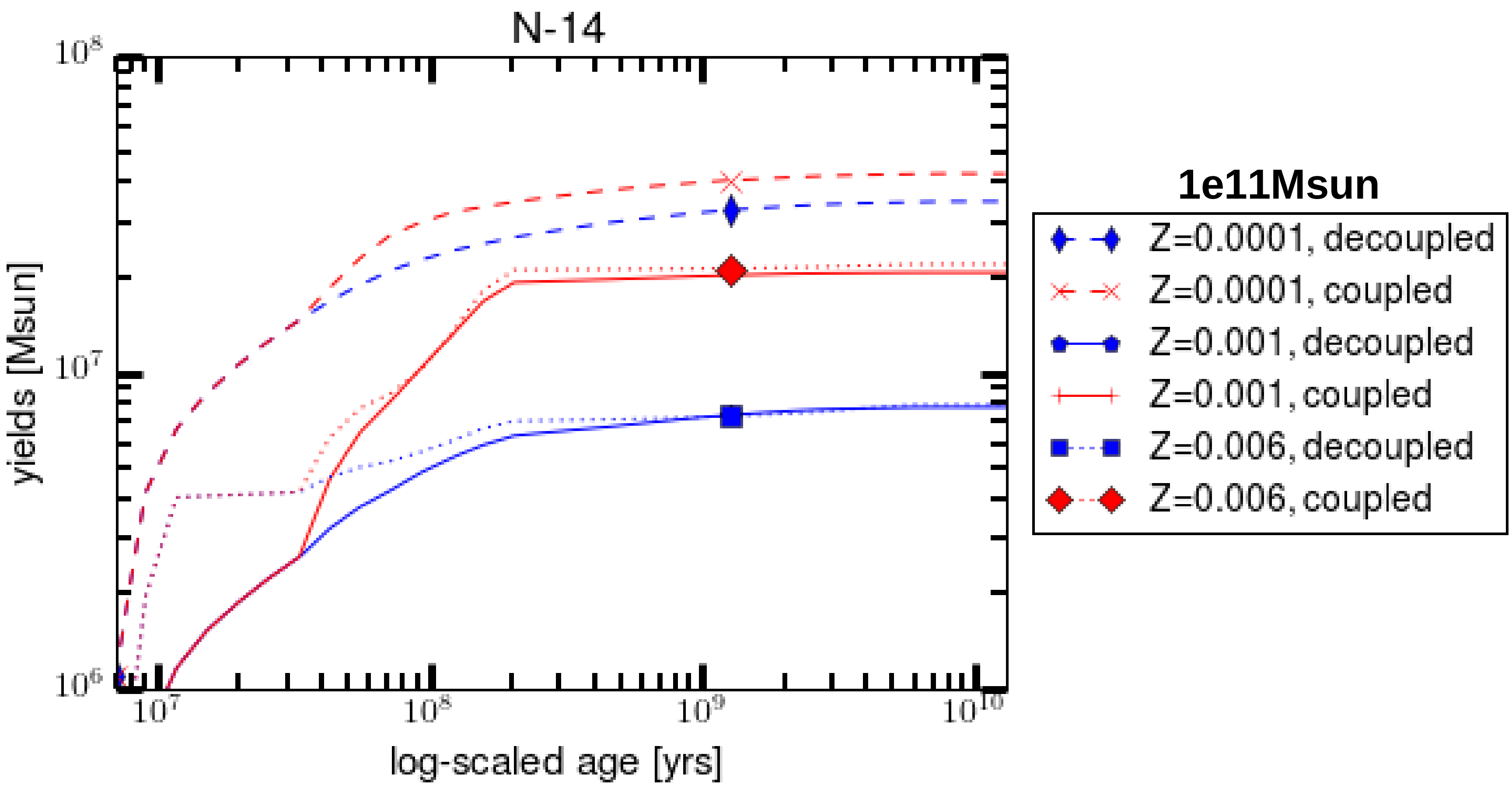
Available at http://nupycee.bitbucket.org/

SYGMA

- Second goal: Probe the impact of nuclear physics and model assumptions on chemical evolution
  - Test impact by varying reaction rates
  - Test impact of CCSN prescription
  - Test of impact of resolving hot-bottom burning
  - Test of physics assumption: Convective boundary mixing assumption

Impact of resolving HBB

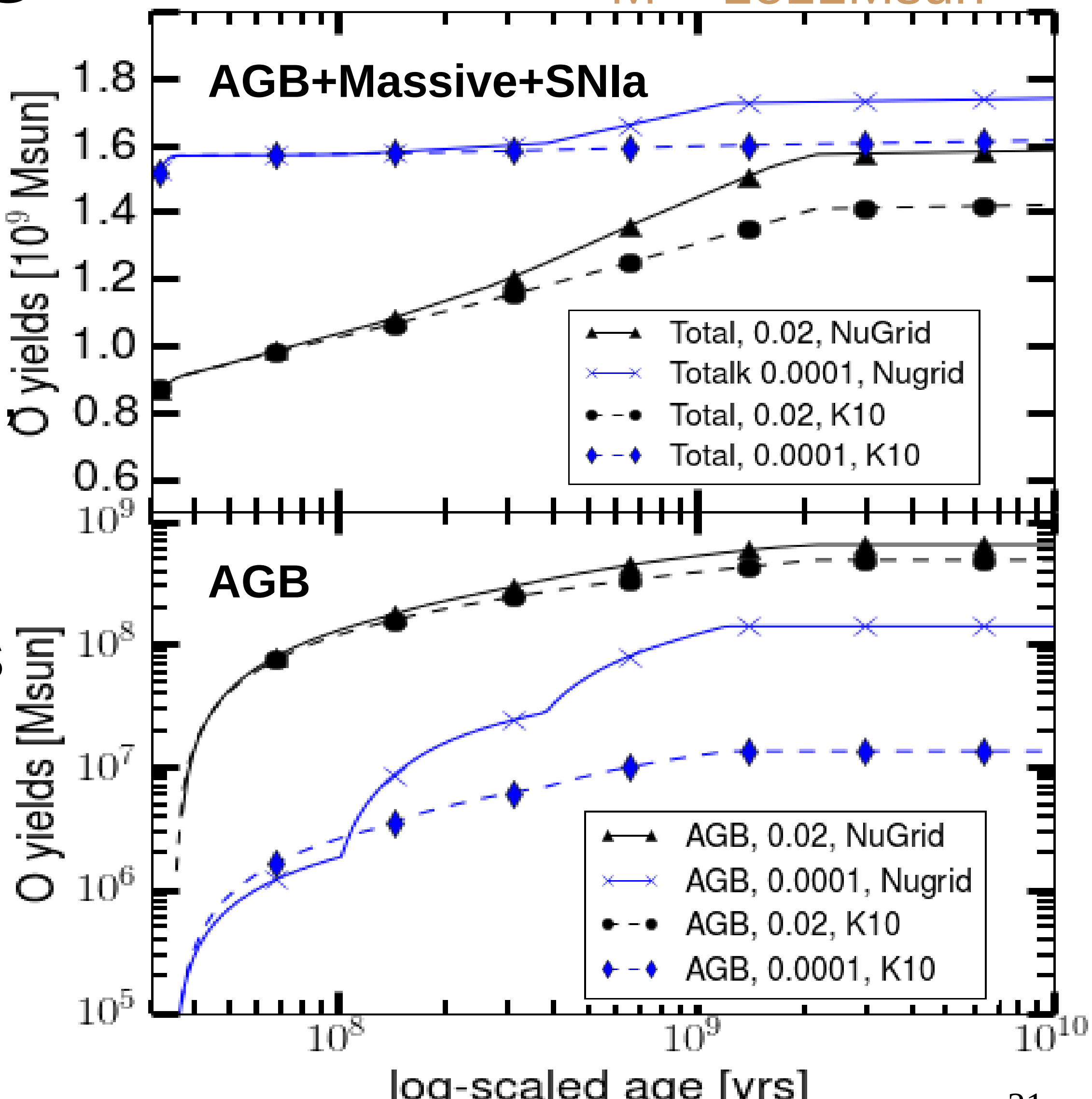
- Relevant especially low Z



Impact of convective boundary mixing on SSP's

- At all conv. boundaries in AGB models motivated by multi-dimensional simulations (e.g. Miller-Bertolami06, Weiss09; Herwig14, Woodward15)
- Intershell O in low-mass AGB stars:
  - CBM: 15%
  - no CBM/K10: 2%
- Conflict with O in GCE?

M = 1e11Msun



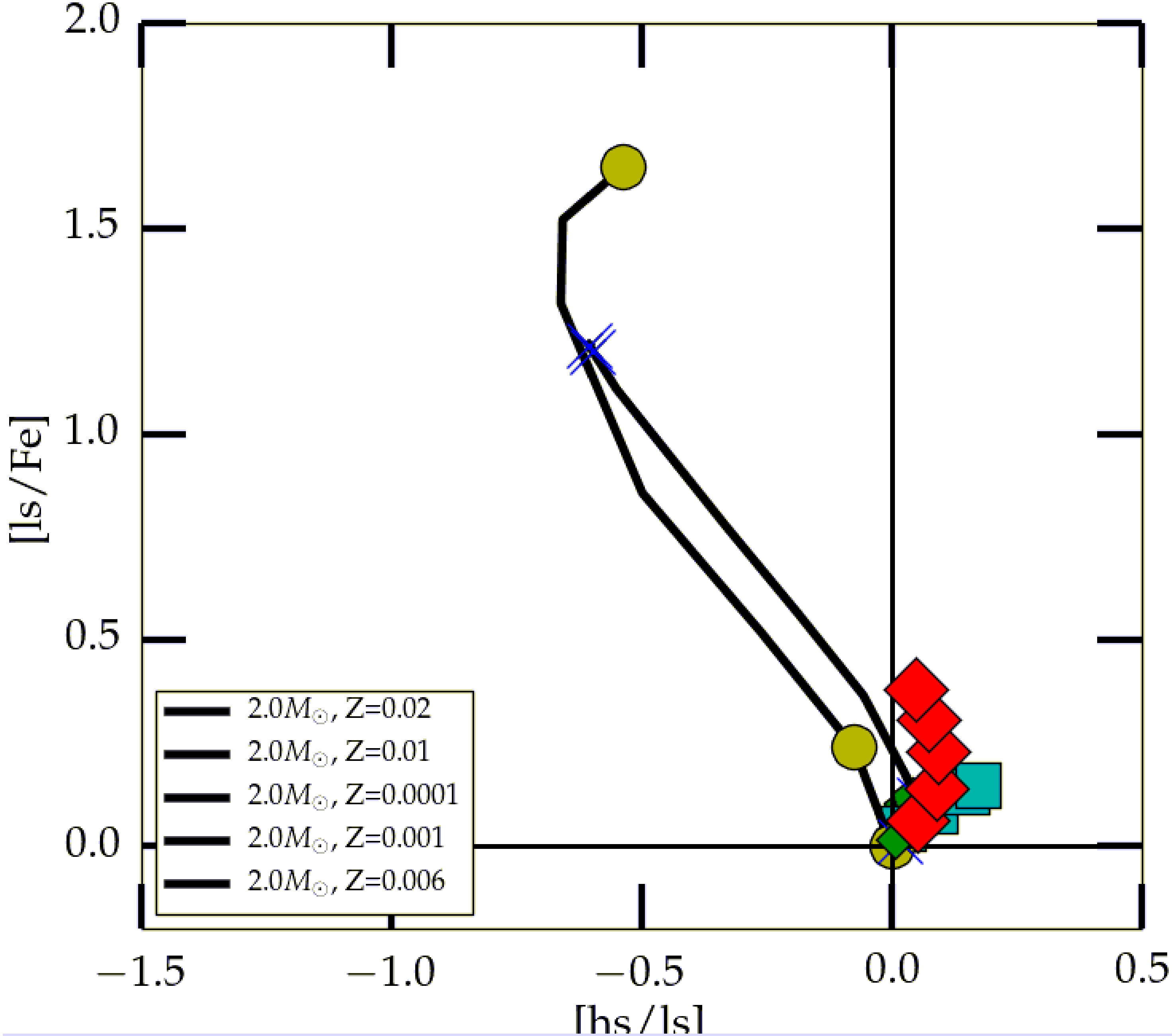
K10: Karakas10

Next plans

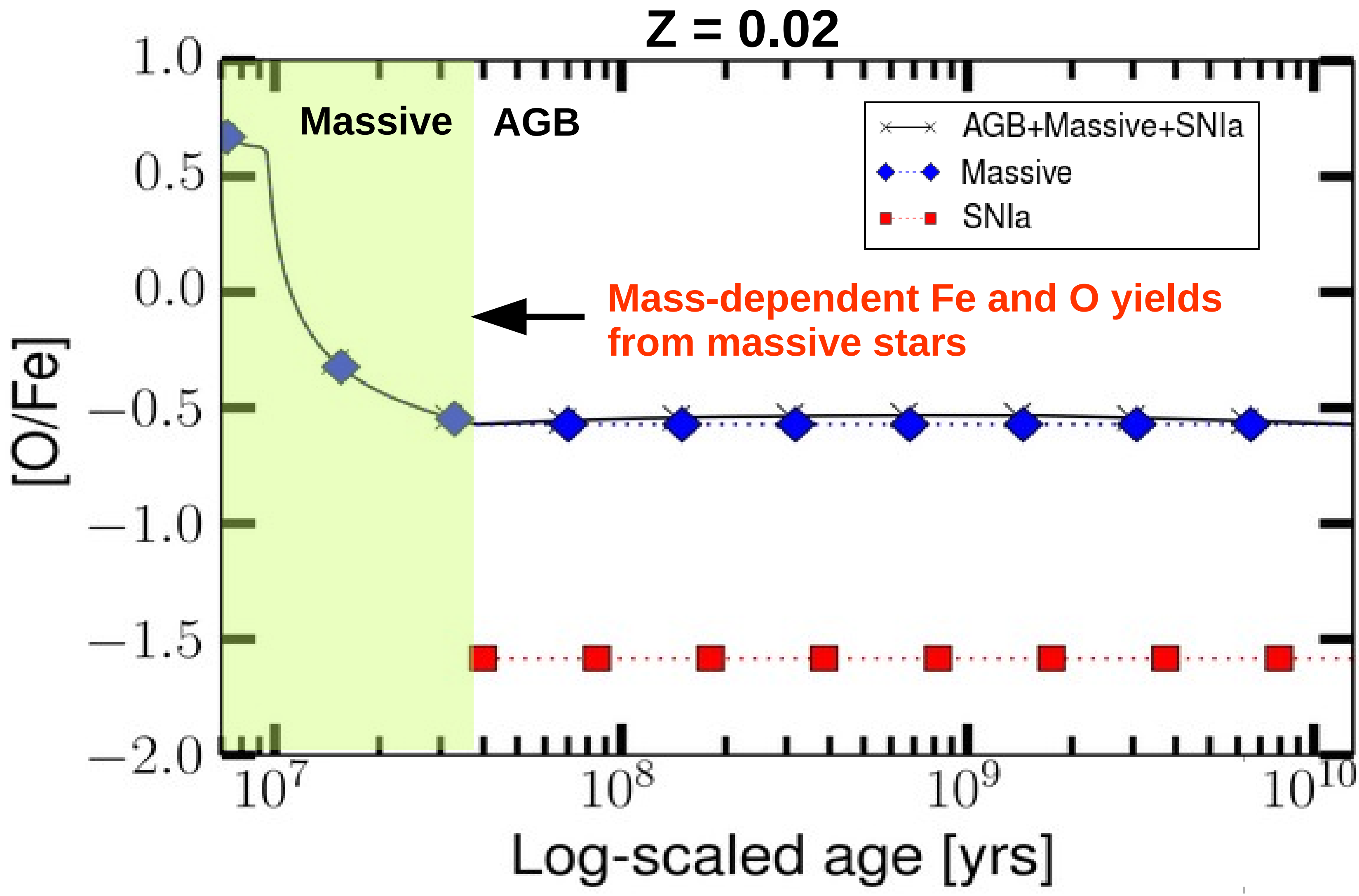
- Test impact of rates on whole mass-metallicity yield grid and chemical evolution
- Update physics:
  - Improved 1D explosion (Chris Fryer)
  - Yields from SNIa (Kathrin, Claudia, Dean)
  - Gravity wave mixing (Umberto)
- Increase sparsity of grid

Thank you very much!

Backup slides


2.0
1.5
1.0
0.5
0.0
[ls/Fe]
−1.5
−1.0
−0.5
0.0
0.5
[hs/ls]
$2.0M_\odot$, Z=0.02
$2.0M_\odot$, Z=0.01
$2.0M_\odot$, Z=0.0001
$2.0M_\odot$, Z=0.001
$2.0M_\odot$, Z=0.006

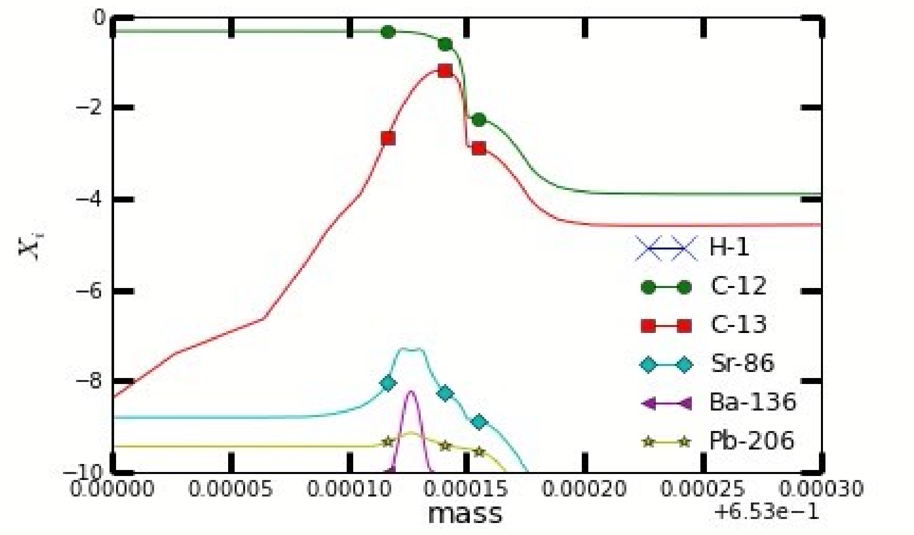
Evolution of [O/Fe] at solar Z



AGB stars: convective boundaries

This is the ^{13}C pocket for low-mass AGB Stars, with exponential CBM with f_ce = 0.126.

M=2Msun, Z=0.0001



If we use such a large f in low-Z high-M models:

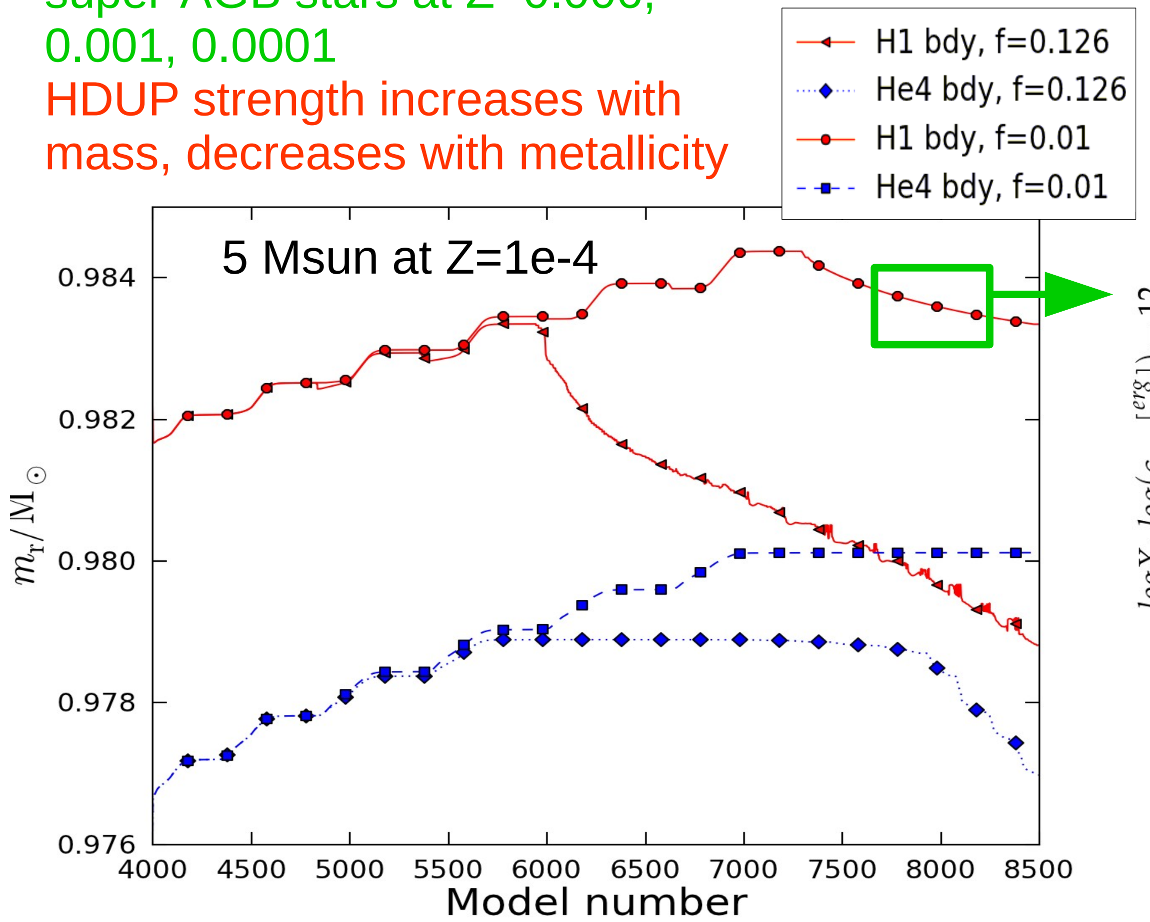
Extreme hot dredge-up

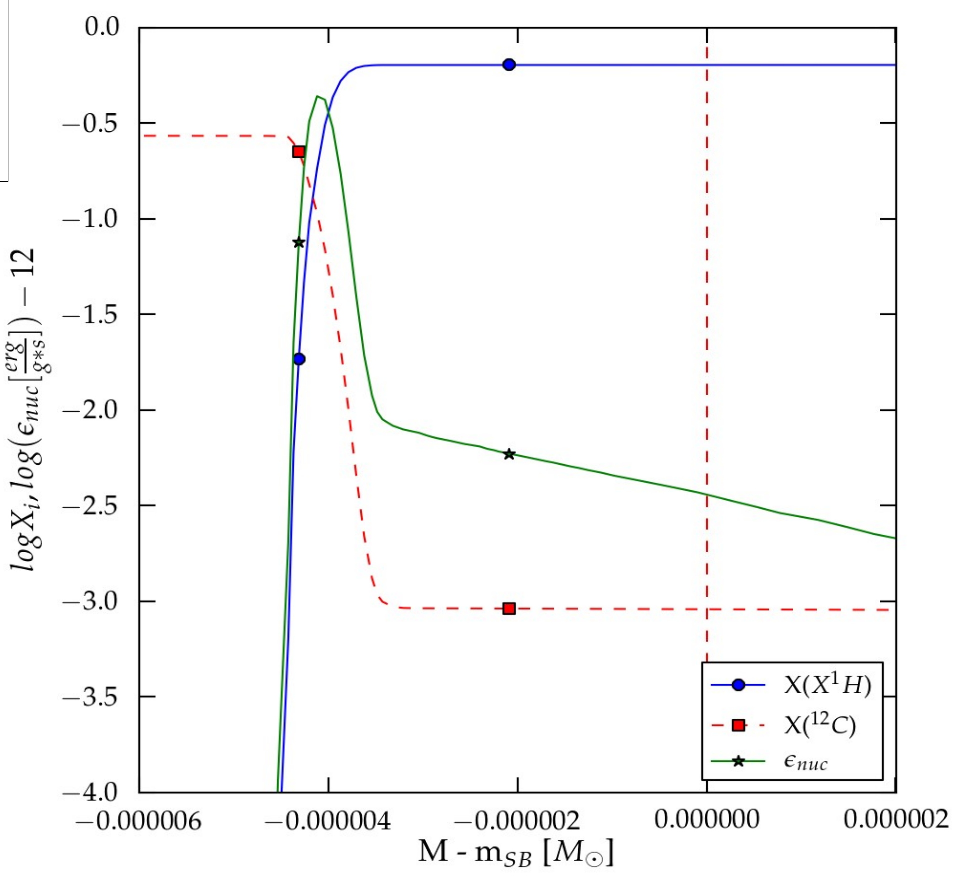
(Herwig 2004, Goriely & Siess 2004)

AGB stars at low-Z

- Hot dredge-up in massive and super-AGB stars

HDUP occurs in massive and super-AGB stars at Z=0.006, 0.001, 0.0001
HDUP strength increases with mass, decreases with metallicity





AGB stars at low-Z

- What is the right f_ce for low-Z?
  - Convective-reactive feedback reduces f_ce
  - f_ce cannot be zero but could be very small

Reduce by a factor of at high mass & low Z to f_ce = 0.002

Still HDUP luminosity is higher than He peak luminosity!

Scheme of H ingestion