AGB stars at low metallicity and implications for simple stellar populations

Christian Ritter
critter@uvic.ca

F. Herwig, M. Pignatari, C. Fryer, S. Jones, J.F. Navarro,
R. Hirschi, P. A. Denissenkov & the NuGrid collaboration

Outline

- Stellar yield modeling: 1-25Msun, Z=0.0001 … 0.02
- AGB stars at low Z
- **S**tellar **Y**ields for **G**alactic **M**odeling **A**pplications (SYGMA)

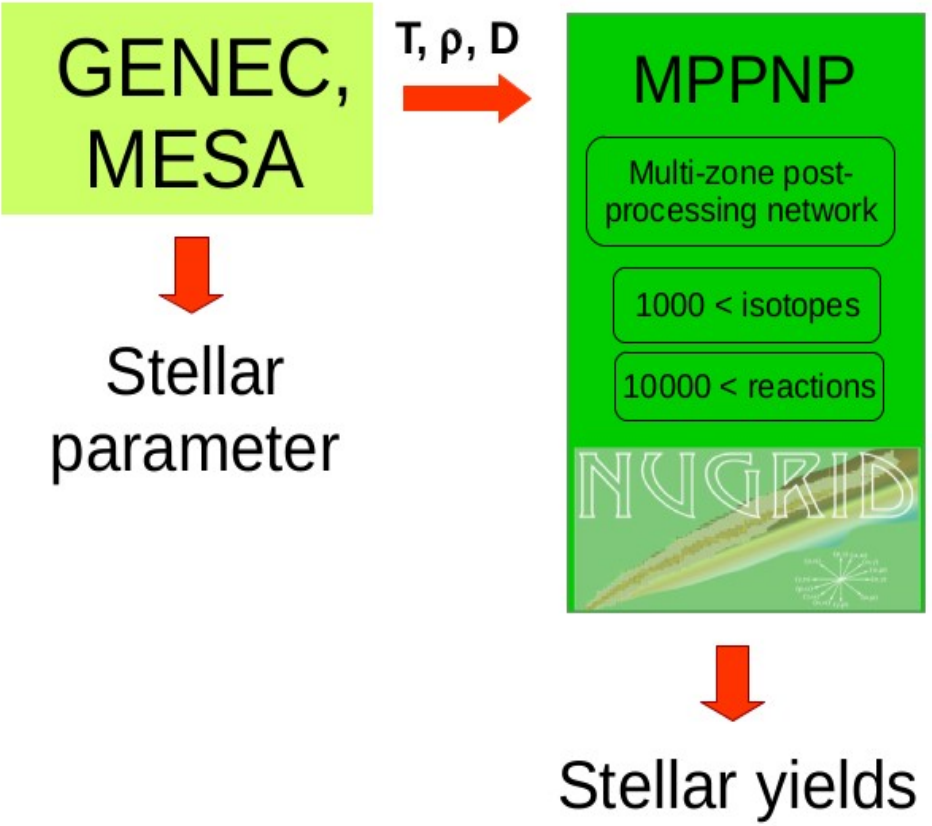
Yield data sets for galactic modeling applications

Ideally combine these features:

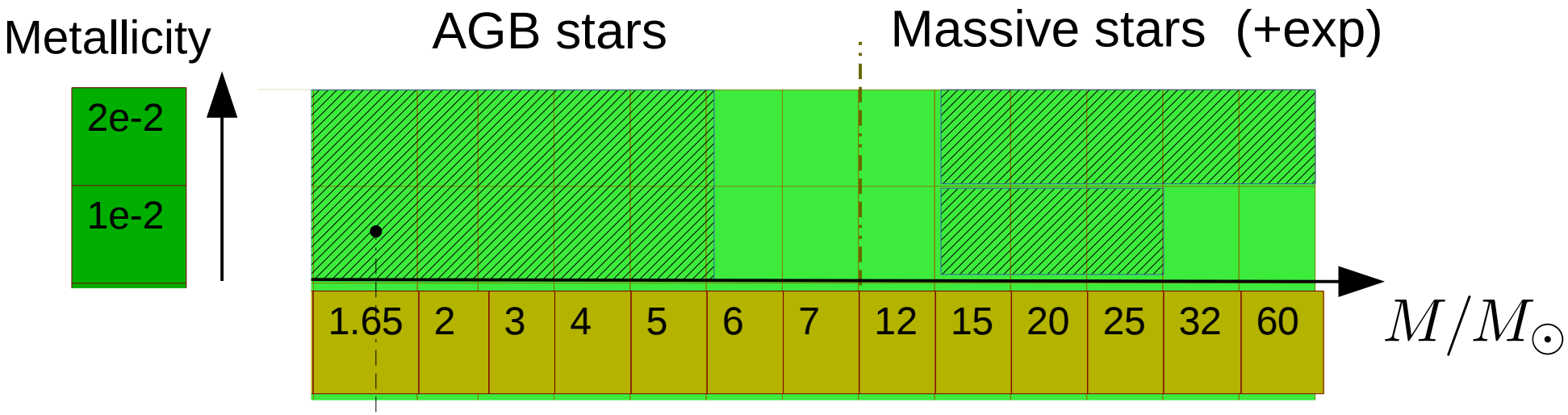
- Complete dataset including full mass range of AGB and massive stars
- Internal consistency: Rates and other physics assumptions
- Complete coverage of all isotopes

We adopt this in the NuGrid approach:

- AGB + massive stars modeling
- Same rate input in stellar simulations and post-processing
- All stable elements + isotopes in complete network
- Semi-analytical model for SNII
- Non-rotating, no B fields



NuGrid data set, incl. yields



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

+

Stellar evolution data for each time step and mass zone

First data set available for solar+ half-solar Z (**Pignatari et al. 13**)

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

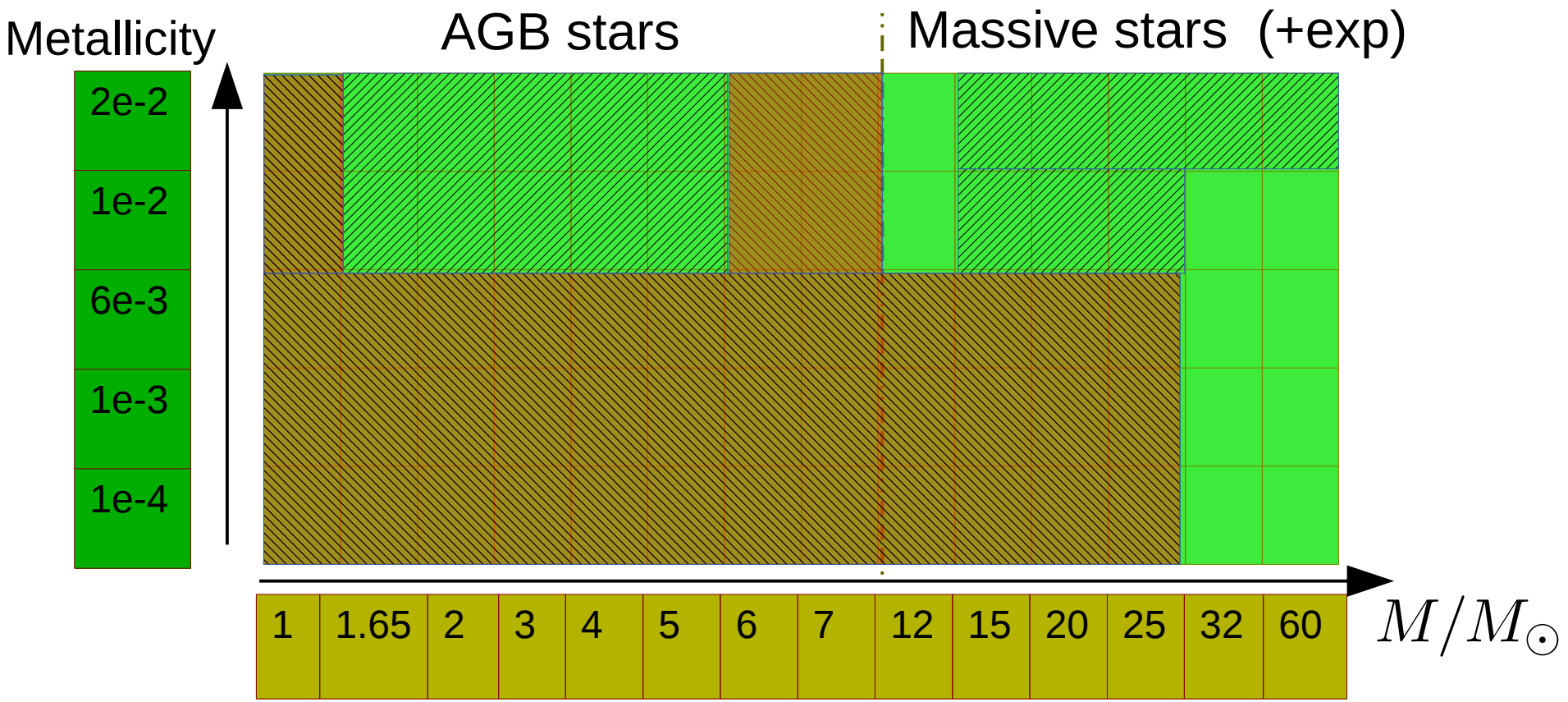
M. Pignatari, F. Herwig, R. Hirschi, M. Bennett, G. Rockefeller, C. Fryer, F. X. Timmes, A. Heger, S. Jones, U. Battino, C. Ritter, A. Dotter, R. Trappitsch, S. Diehl, U. Frischknecht, A. Hungerford, G. Magkotsios, C. Travaglio, P. Young

NuGrid data set, incl. yields

Submitted: Set 1

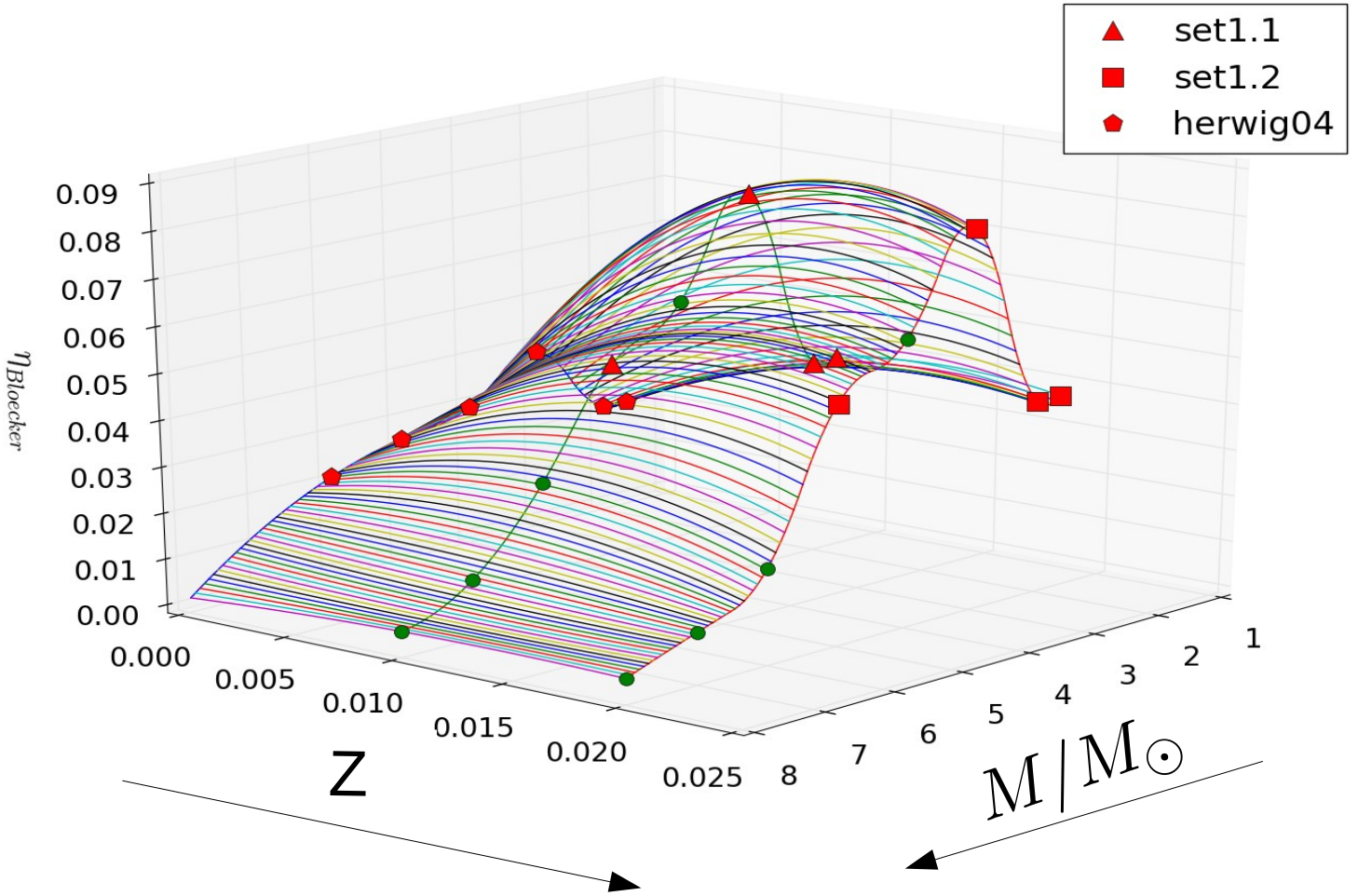
Available: Set 1 extension

C. Ritter, F. Herwig, M. Pignatari, R. Hirschi, C. Fryer, S. Jones, N. Nishimura,P. A. Denissenkov & the NuGrid collaboration[7]



AGB stars: mass loss

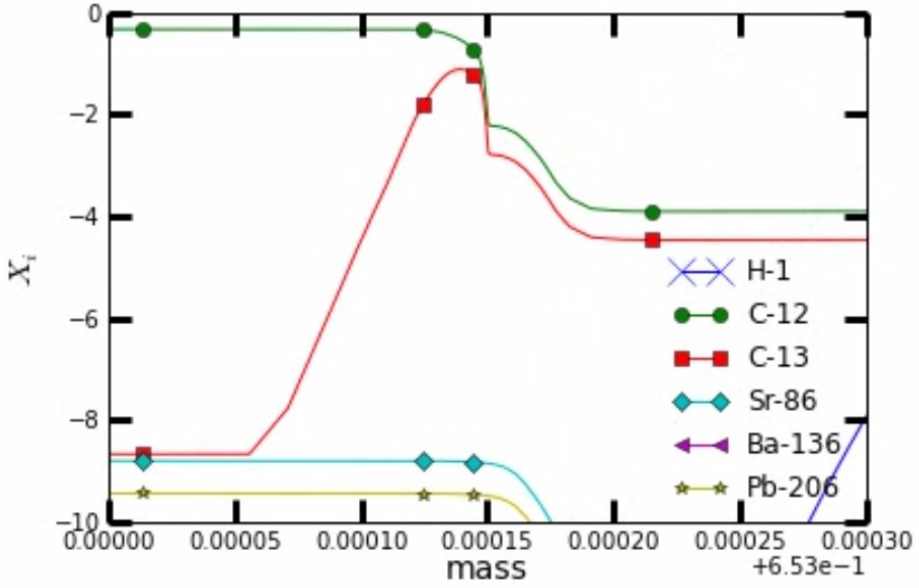
- Mass-metallicity fit for mass loss
- Consistent with Herwig (2004) for low Z and NuGrid Set1 (Pignatari et al. 2013)



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)

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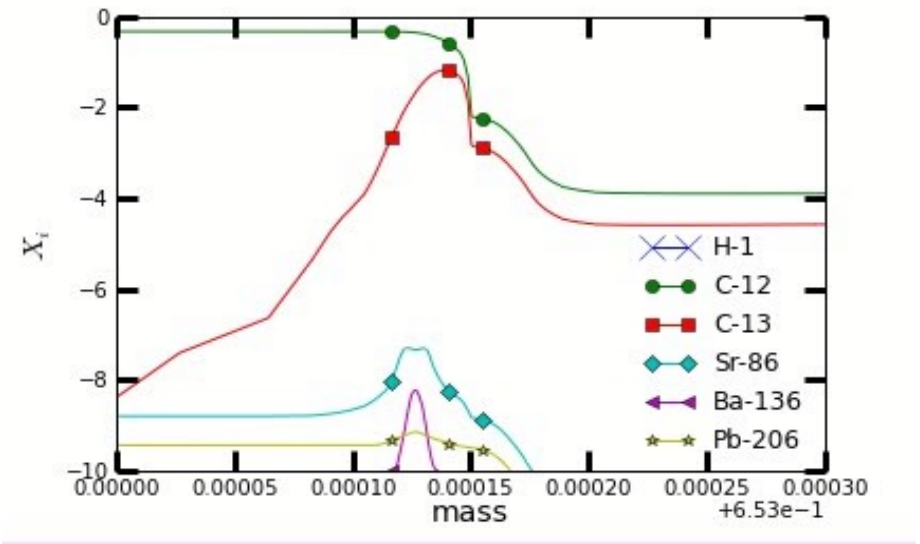

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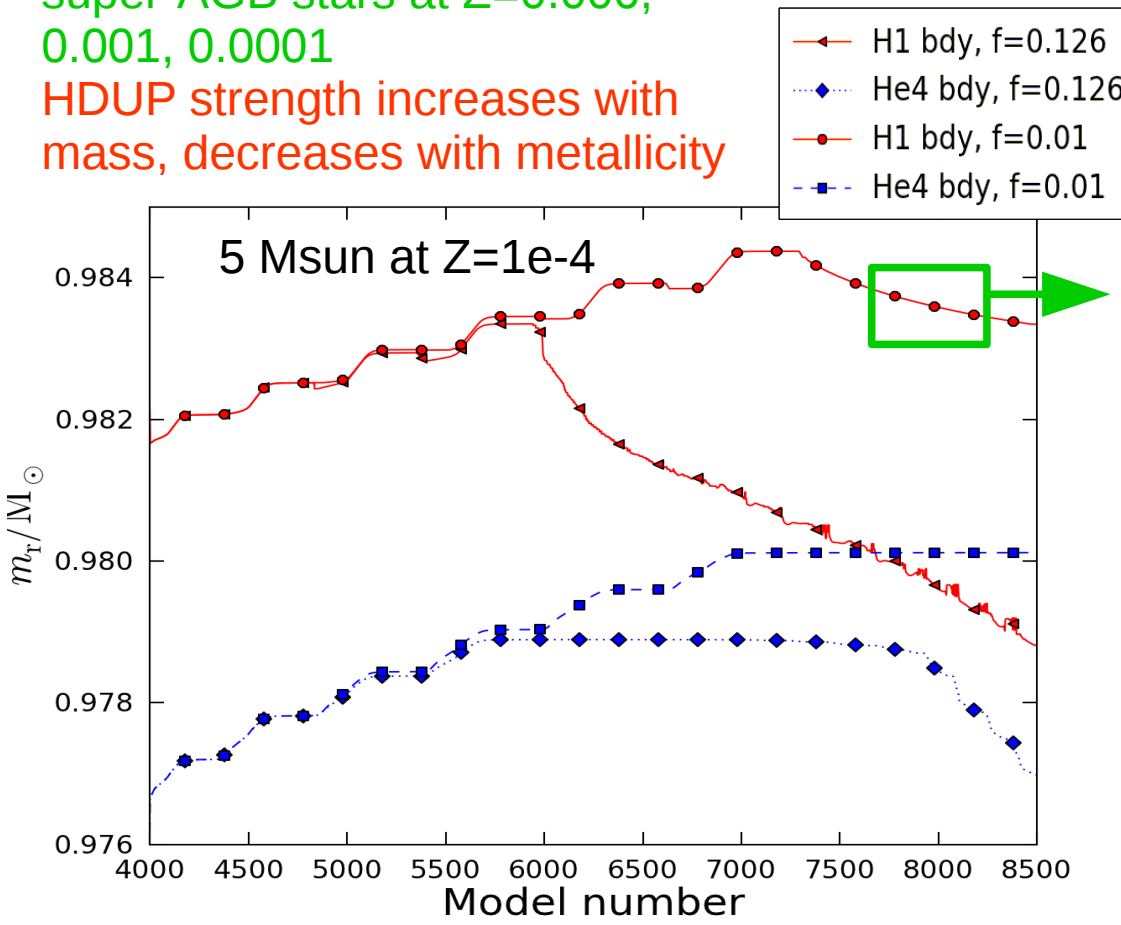
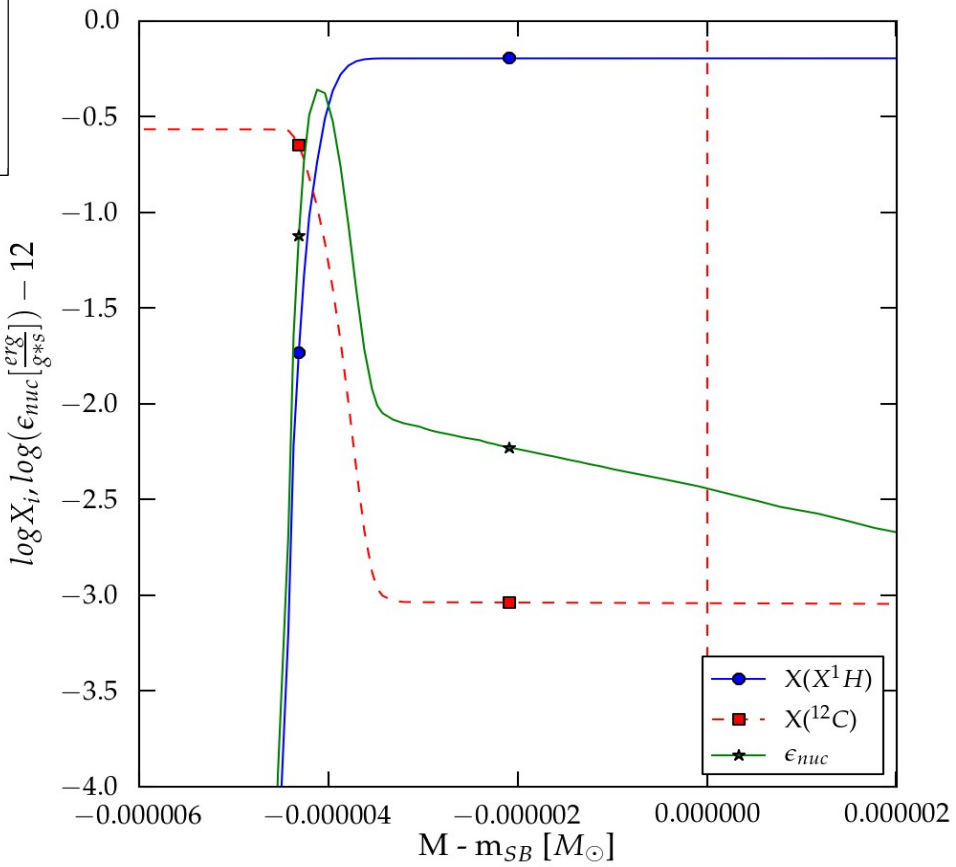
AGB stars at low-Z

- 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

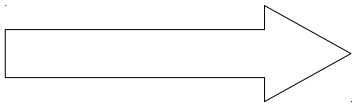
HDUP strength increases with mass, decreases with metallicity





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

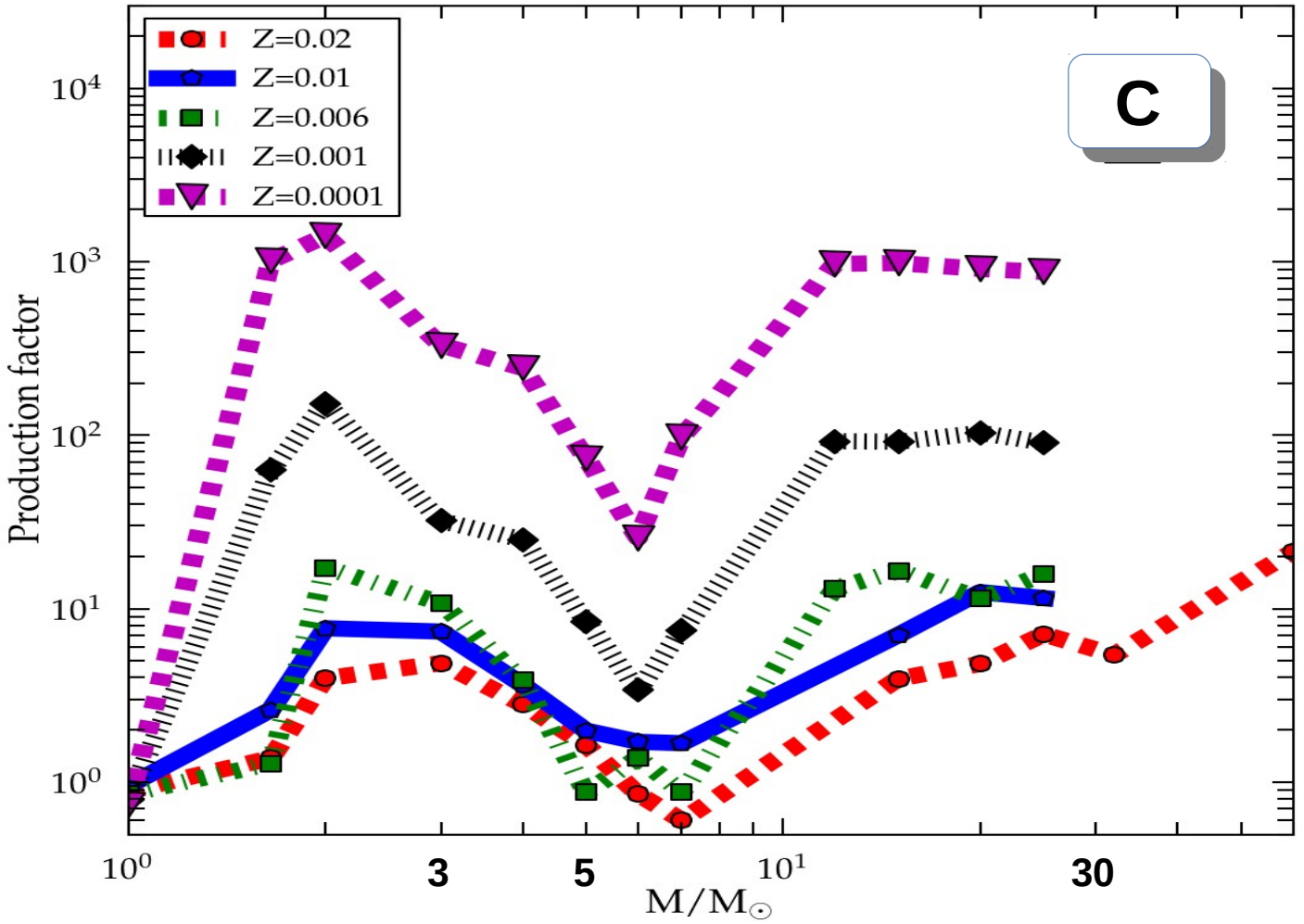


Reduce by a factor of at high mass & low Z to f_ce = 0.002

Still HDUP luminosity is higher than He peak luminosity!

AGB stars

- Competition in C production

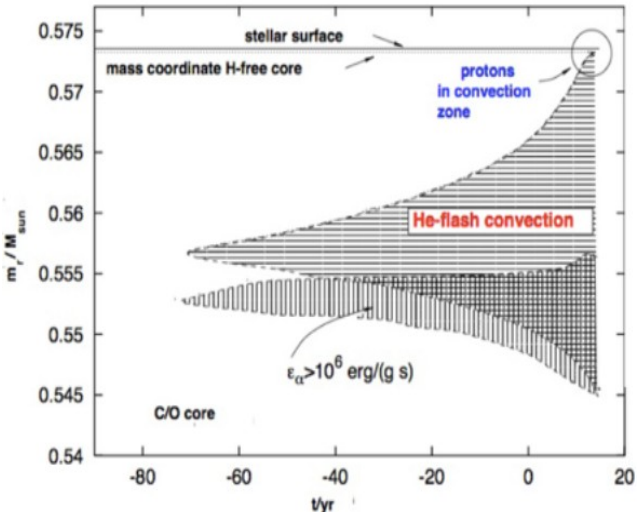


Why not (yet?) lower than [Fe/H] ~ -2.3?

Below this metallicity:

- H-ingestion in He core flashes, He shell flashes
- 1D stellar evolution ab initio can not reproduce observed properties of H-ingestion object Sakurai's object (Herwig etal. 2011)
- Recent 3D simulations confirm the non-radial nature of H-ingestion flash

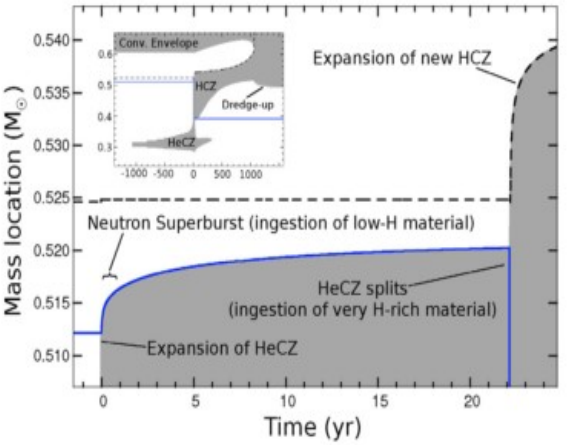
VLTP in Sakurai's object



Herwig 2001

He core flashes:

[Fe/H] = -6.5



Campbell et al. 2010

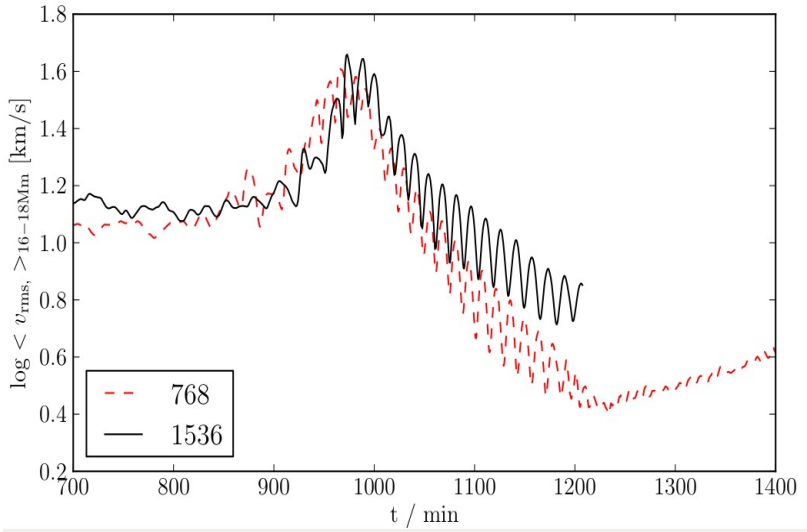
He shell flashes:

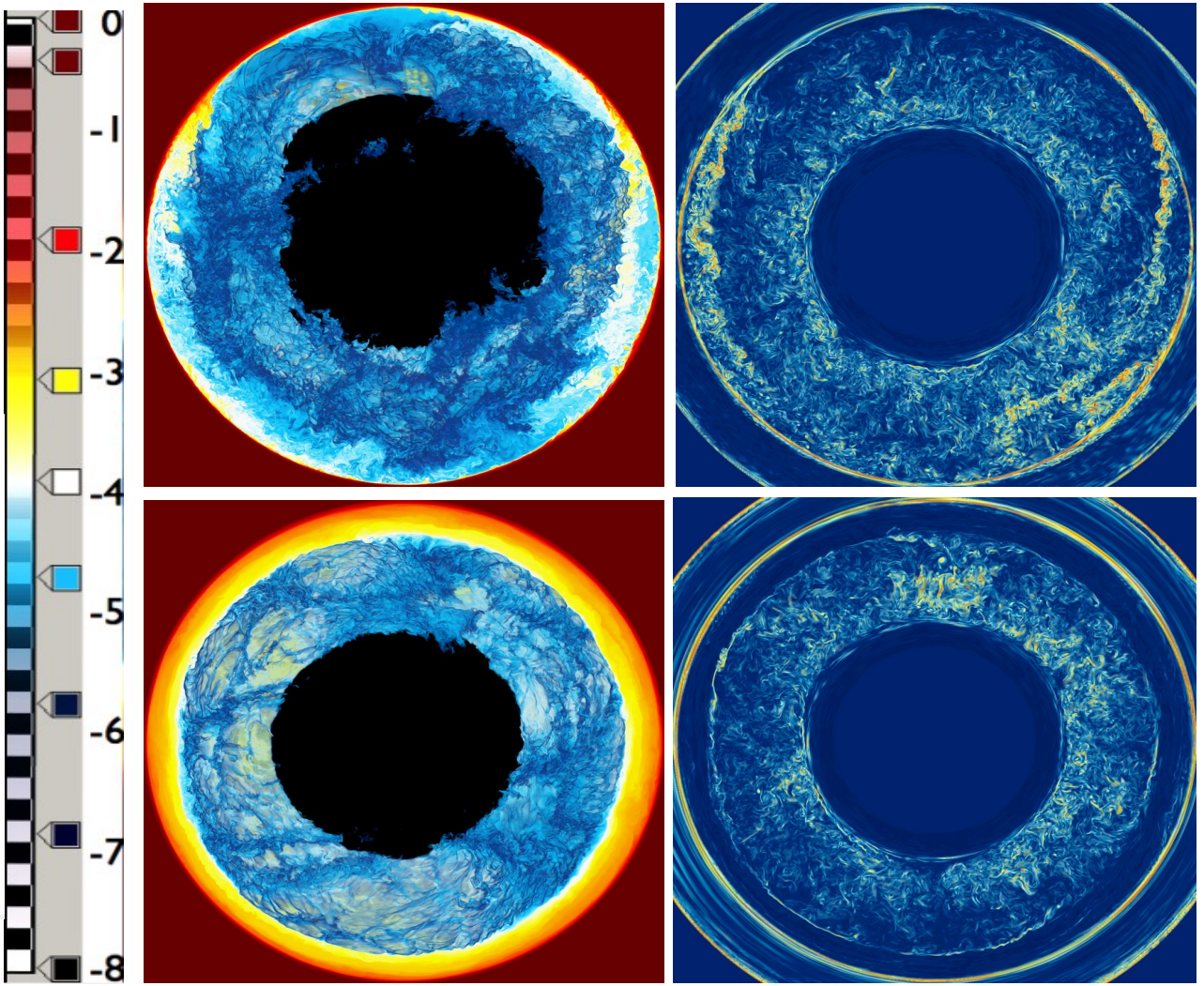
Suda et al. 2010

and many more!

Global Oscillation in Shell H-ingestion

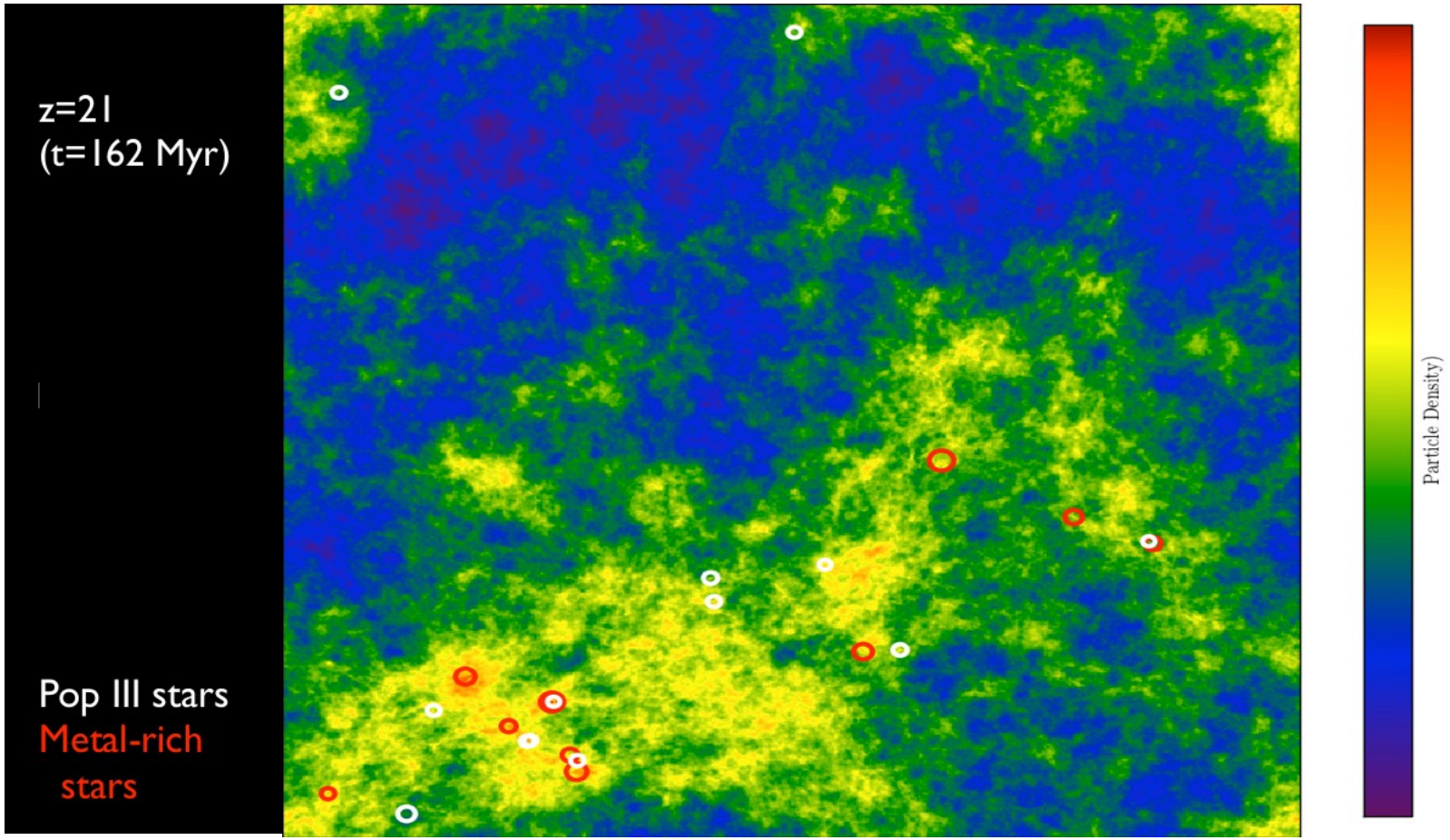
- Global non-radial oscillation
- Transition to H-driven convection zone
- Not yet known if/how to model in 1D





Herwig, Woodward and Lin, astro-ph/1310/4584

SYGMA



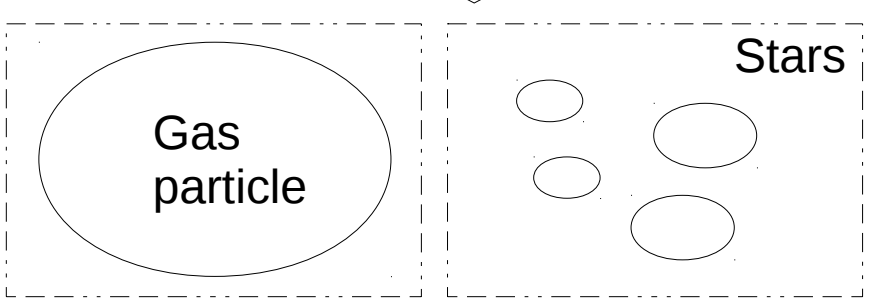
Brian O'Shea, MSU

SYGMA

- Simple stellar population for DM+gas sims
- 1-zone box model
- NuGrid yield input w/ AGB and massive stars
- Supernova ejecta from type Ia, II
- Keep track of all stable elements, many isotopes

SYGMA

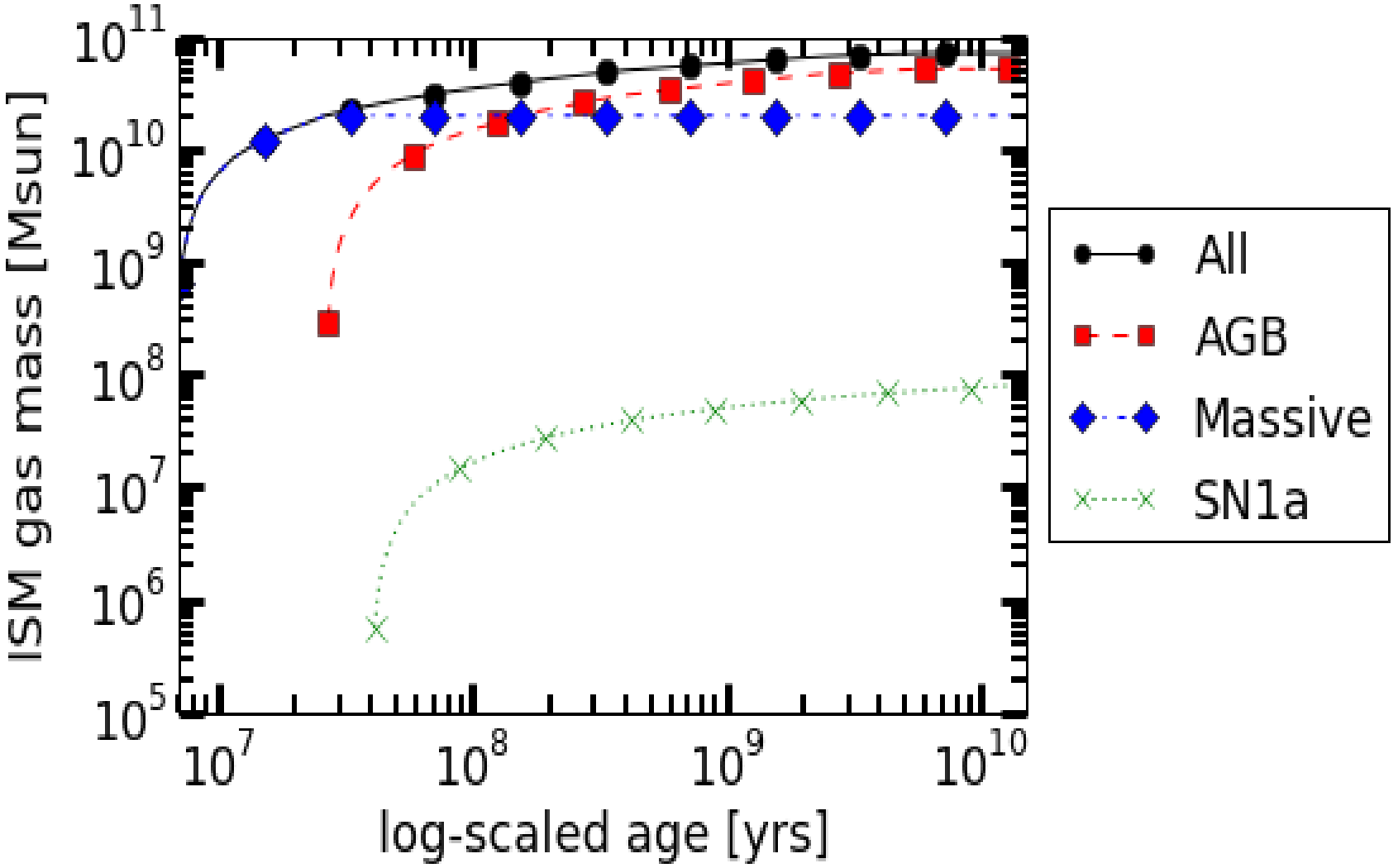
SSP assumptions:
- Initial metallicity
- Total mass
- IMF type, range
- SNIa implementations
- and more



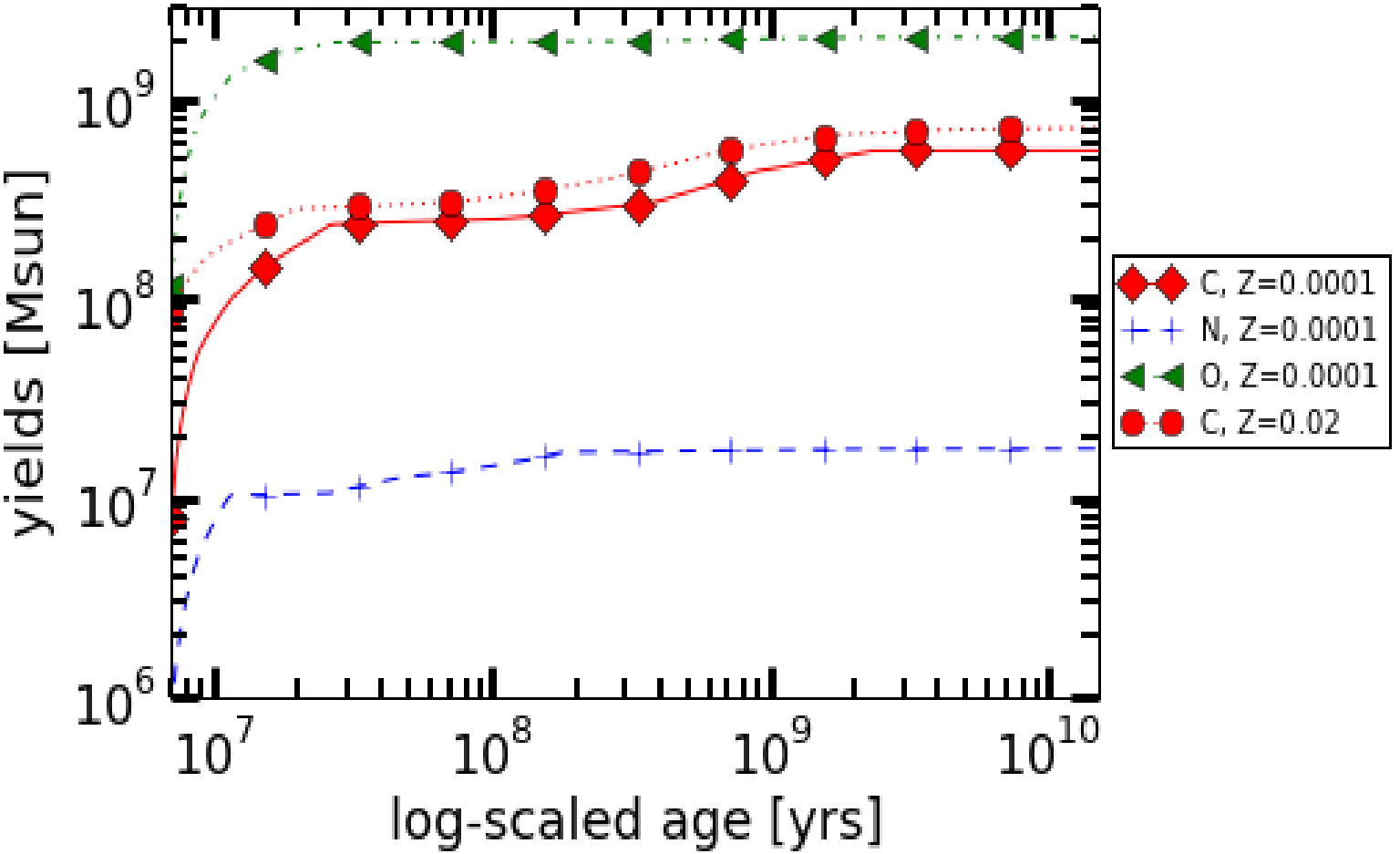
Online user interface

Online Intro

SYGMA


ISM gas mass [Msun]
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{7}
10^{8}
10^{9}
10^{10}
log-scaled age [yrs]
All
AGB
Massive
SN1a

SYGMA


yields [Msun]
10^9
10^8
10^7
10^6
10^7
10^8
10^9
10^{10}
log-scaled age [yrs]
C, Z=0.0001
N, Z=0.0001
O, Z=0.0001
C, Z=0.02

Thank you for your attention!