Super-AGB Supernova Progenitors

Falk Herwig

Theoretical Astrophysics Group, LANL

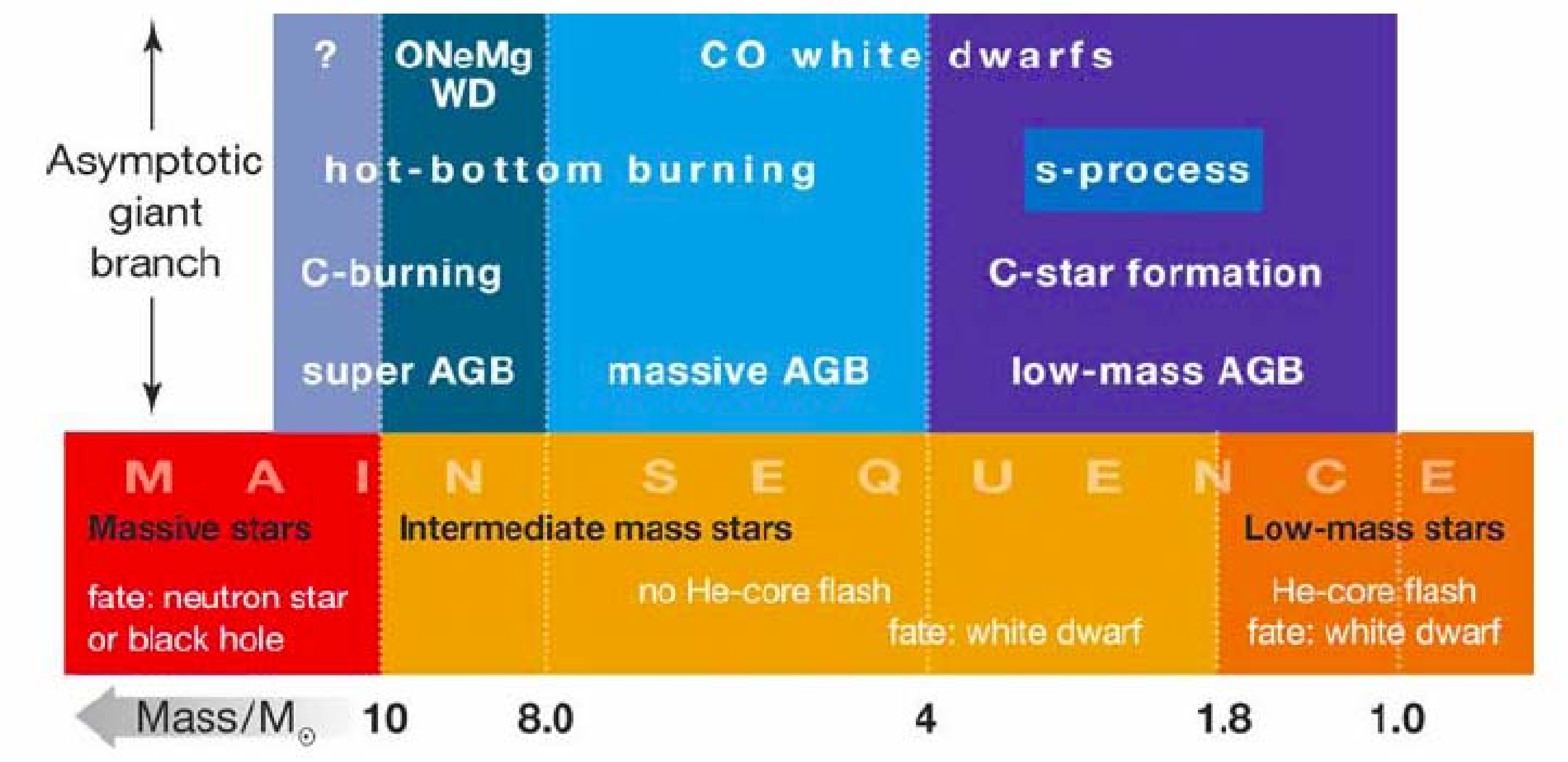
In collaboration with Arend Jan Poelarends, Norbert Langer and Alexander Heger.

Los Alamos NATIONAL LABORATORY

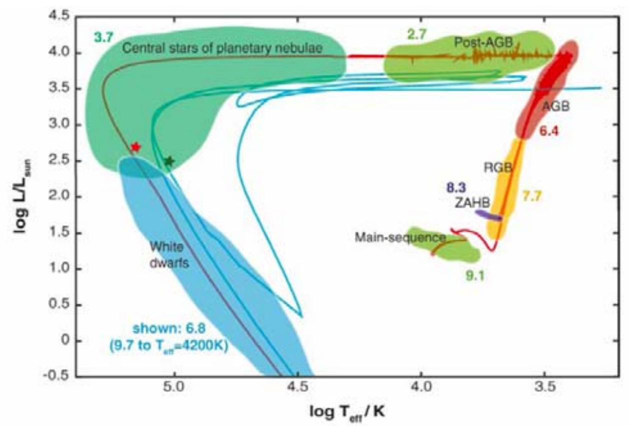
What do we want to know about SAGB SN progenitors

- What is the initial mass range?
- How do SAGB SN progenitors evolve?
- What is the internal composition of SN-CC initial models?

Initial mass and evolution fate

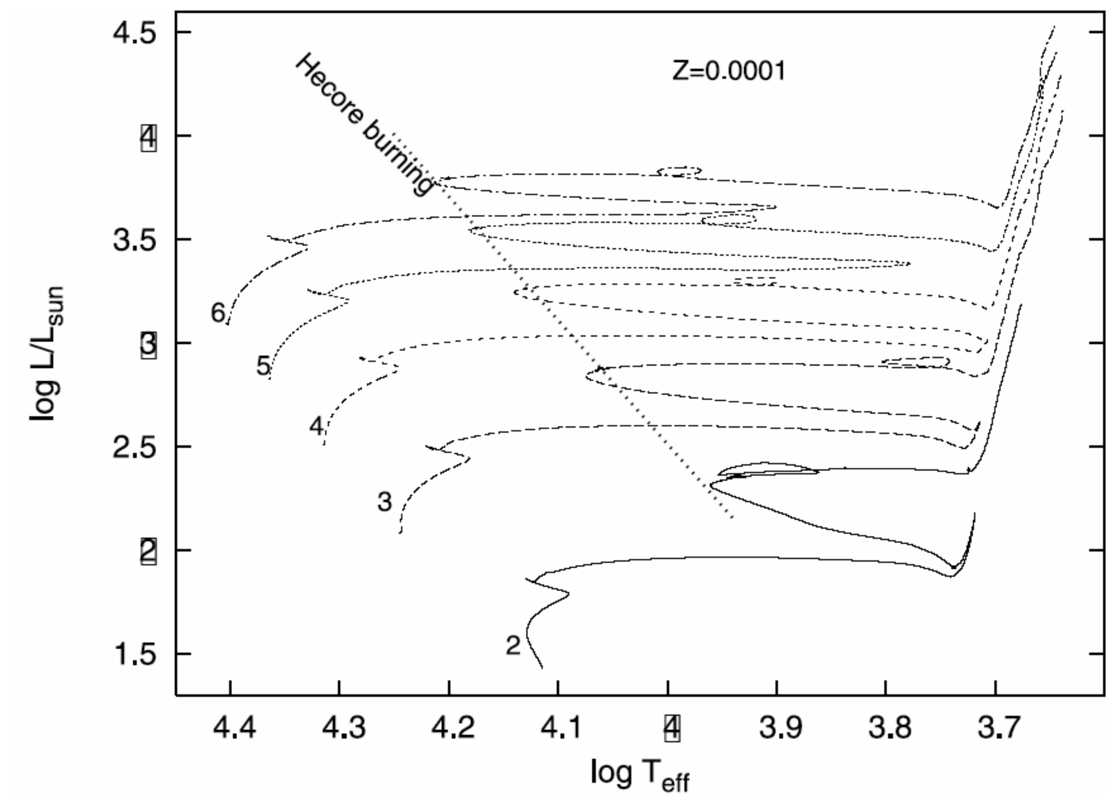


Herwig (2005)



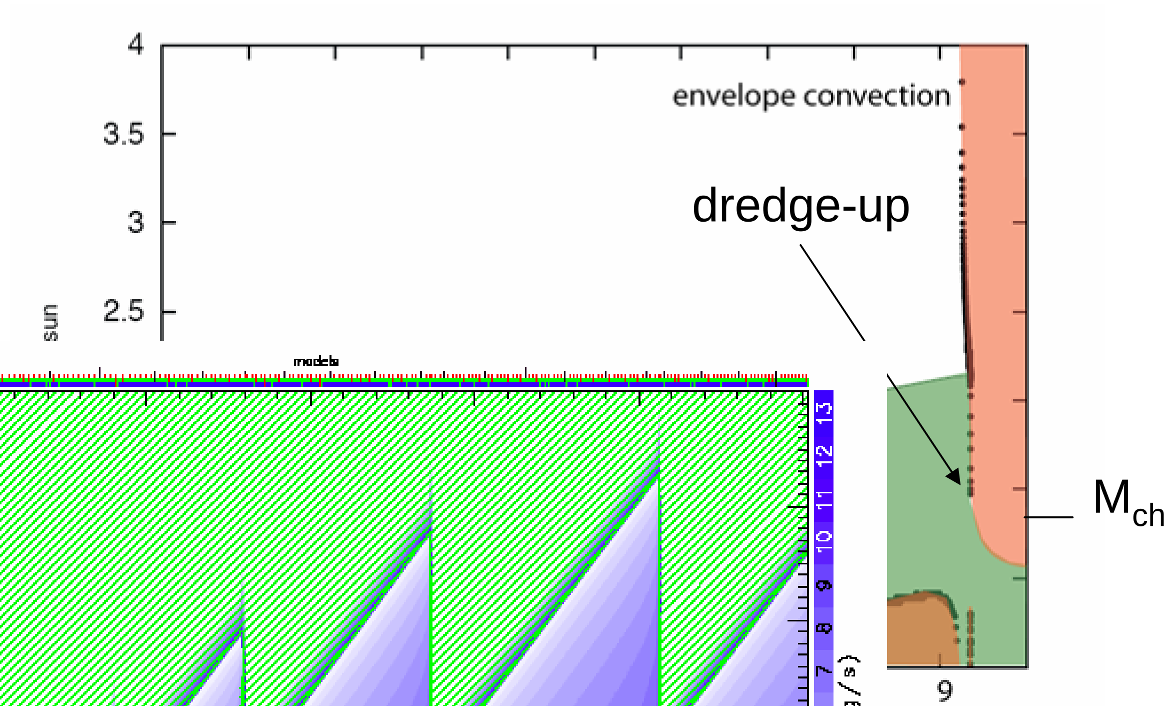
"Standard" evolution of metal-poor stars

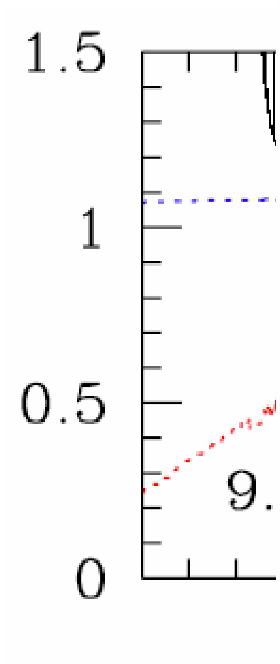
- A grid of intermediate mass AGB stars (2-6$M_\odot$)
- $Z=10^{-4}$, [Fe/H] = -2.3
- 1D spherically symmetric stellar structure and evolution simulation
- Simplified mixing assumptions
- Extensive nuclear network with two neutron sinks
- Herwig 2004, ApJS 155, 651.

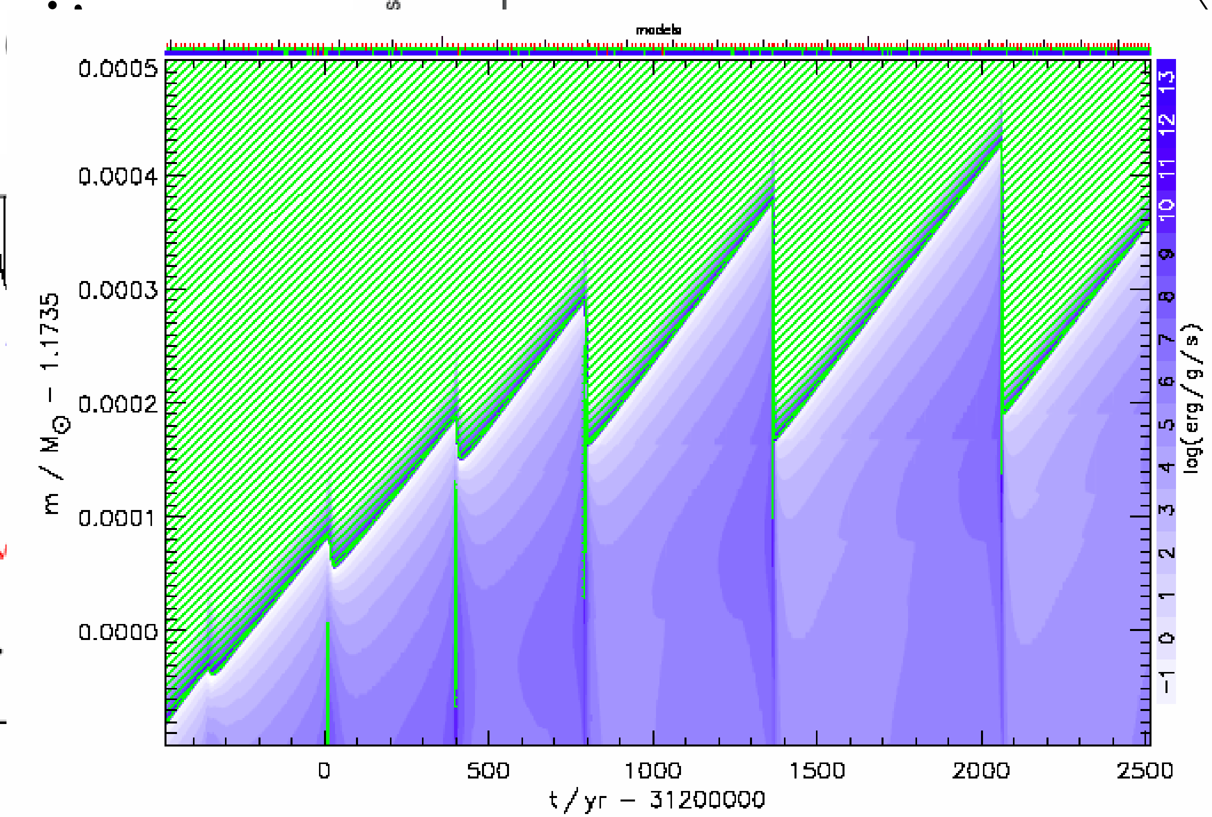


Mixing and burning evolution in SAGB proge...

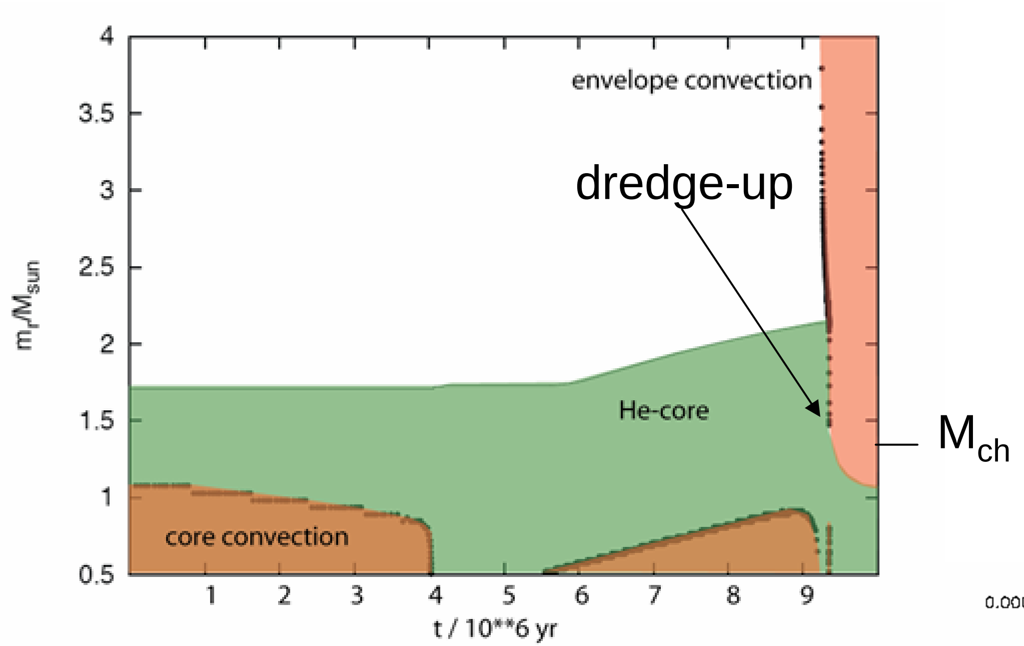
$7M_{sun}$, $Z=10^{-4}$: evolution to AGB

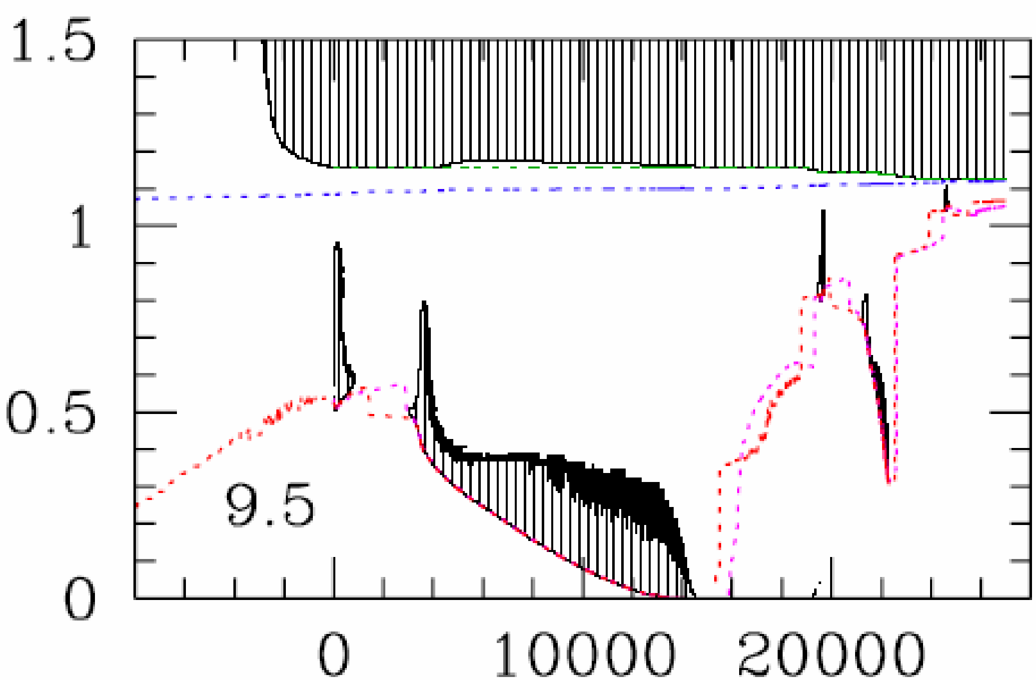


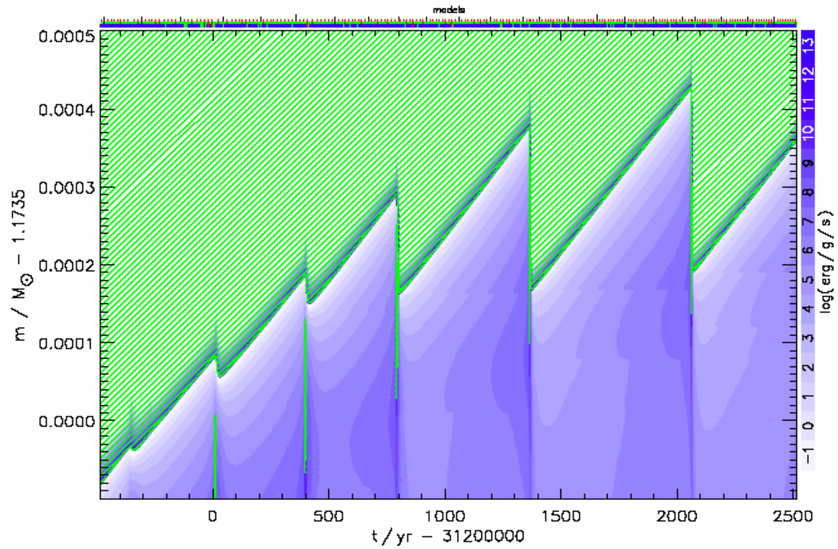




TP-SAGB
$9. M_{\odot}$
$Z=Z_{\odot}$


envelope convection
dredge-up
He-core
core convection
M_ch
m_r/M_{sun}
t / 10**6 yr


9.5


models
$m / M_\odot - 1.1735$
t / yr − 31200000
log(erg/g/s)

Evolution of internal abundance distribution

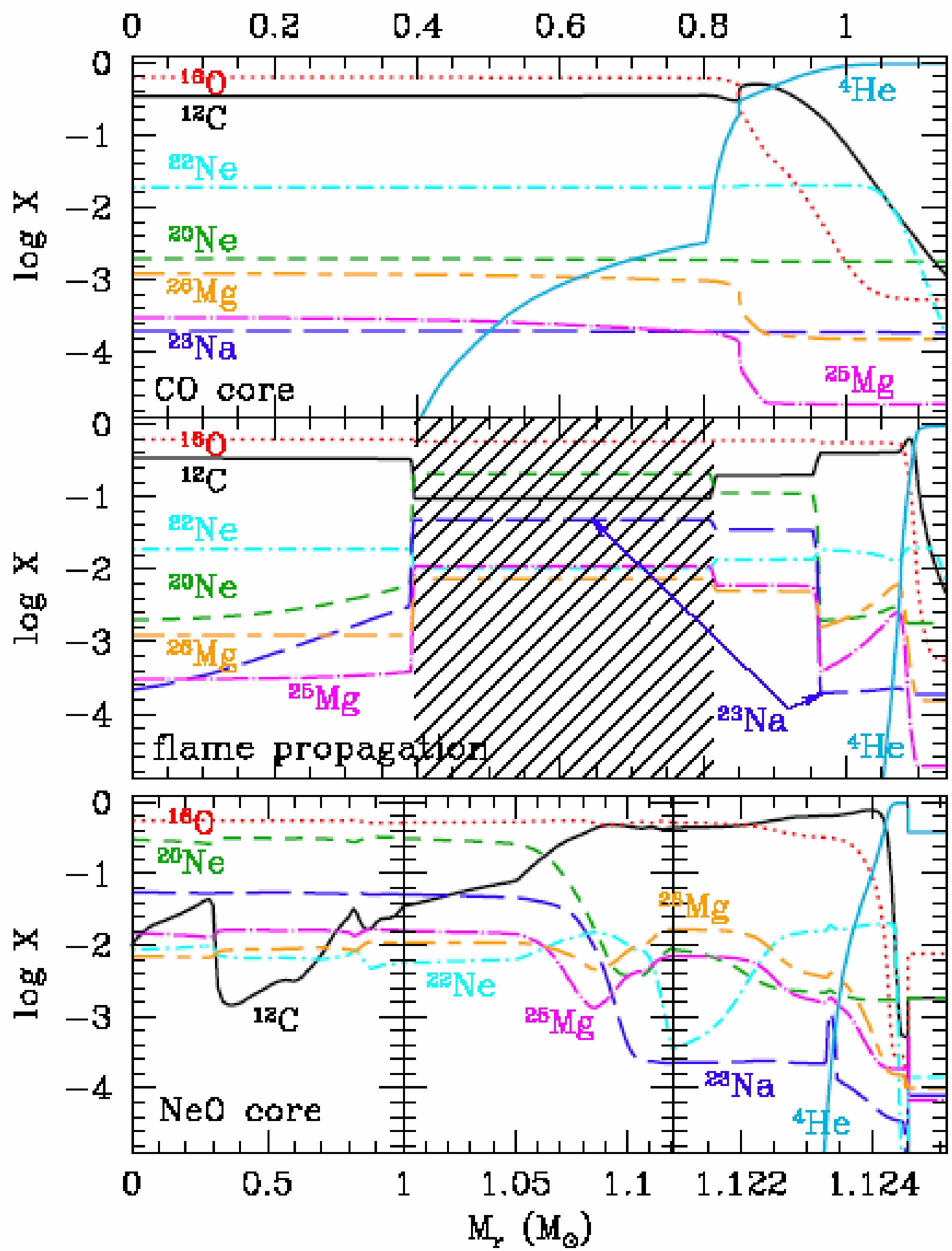
$9.5M_\odot$, $Z=Z_\odot$

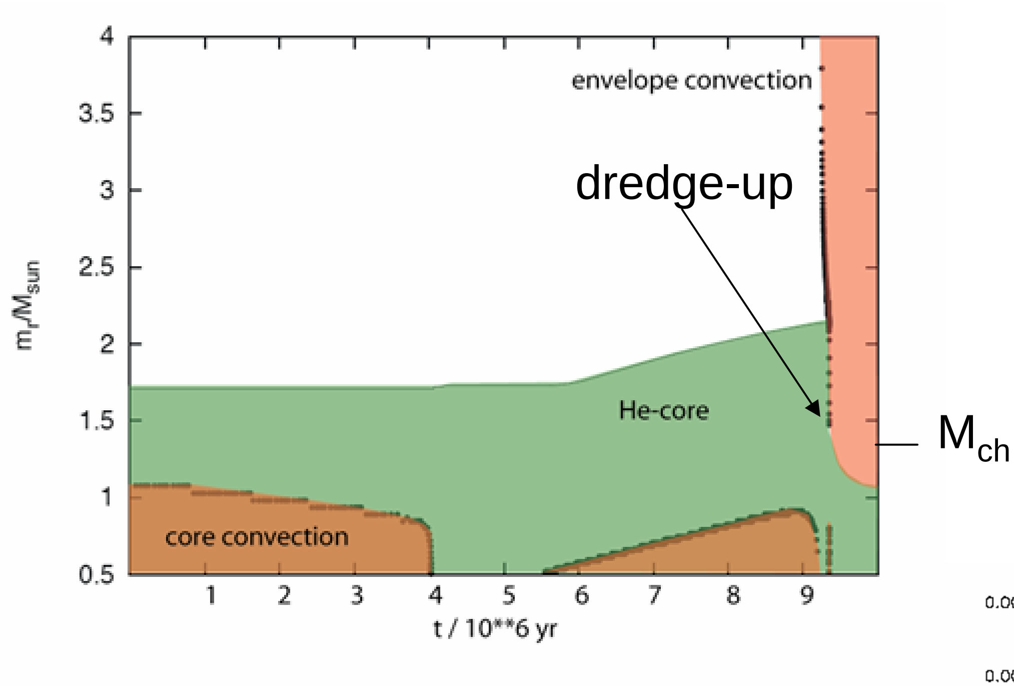
Top panel: end of core He-burning

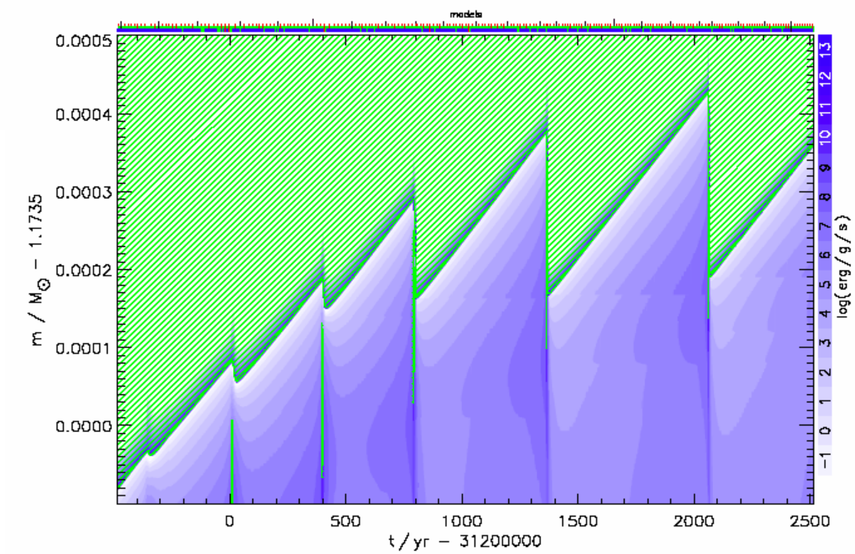
Middle panel: convective burning and C-flame propagation

Bottom panel: beginning of SAGB phase

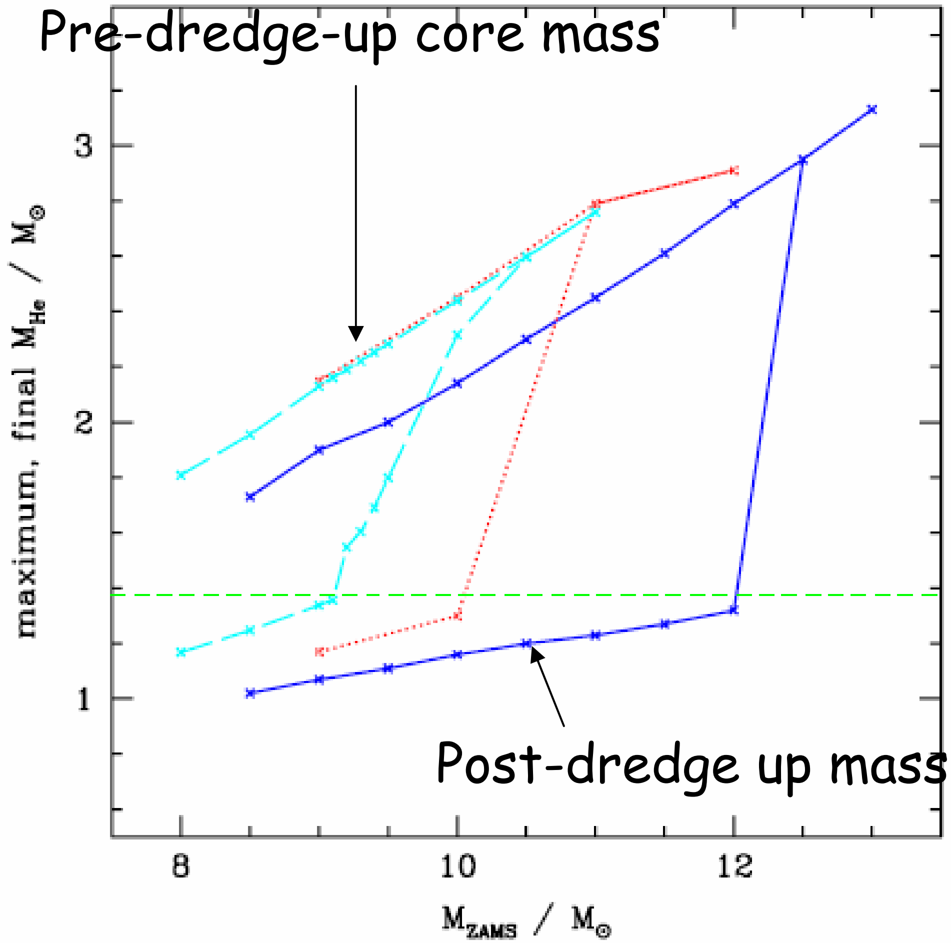
Siess (2006)




envelope convection
dredge-up
He-core
core convection
M_ch
m_r/M_sun
t / 10**6 yr


models
m / M_⊙ − 1.1735
t / yr − 31200000
log(erg / g / s)

Super-AGB stars



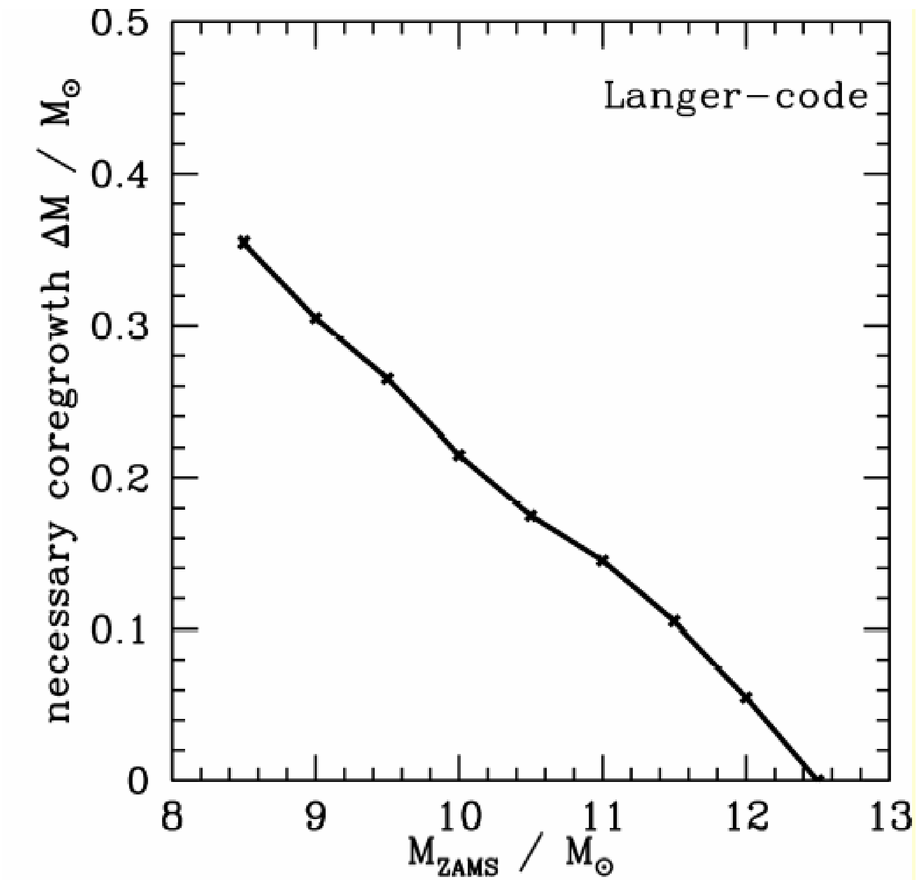
Initial mass range depends sensitively on mixing during He-core burning phase, AND on metallcity!

This determines ratio of ONe vs. Fe CC SNe.

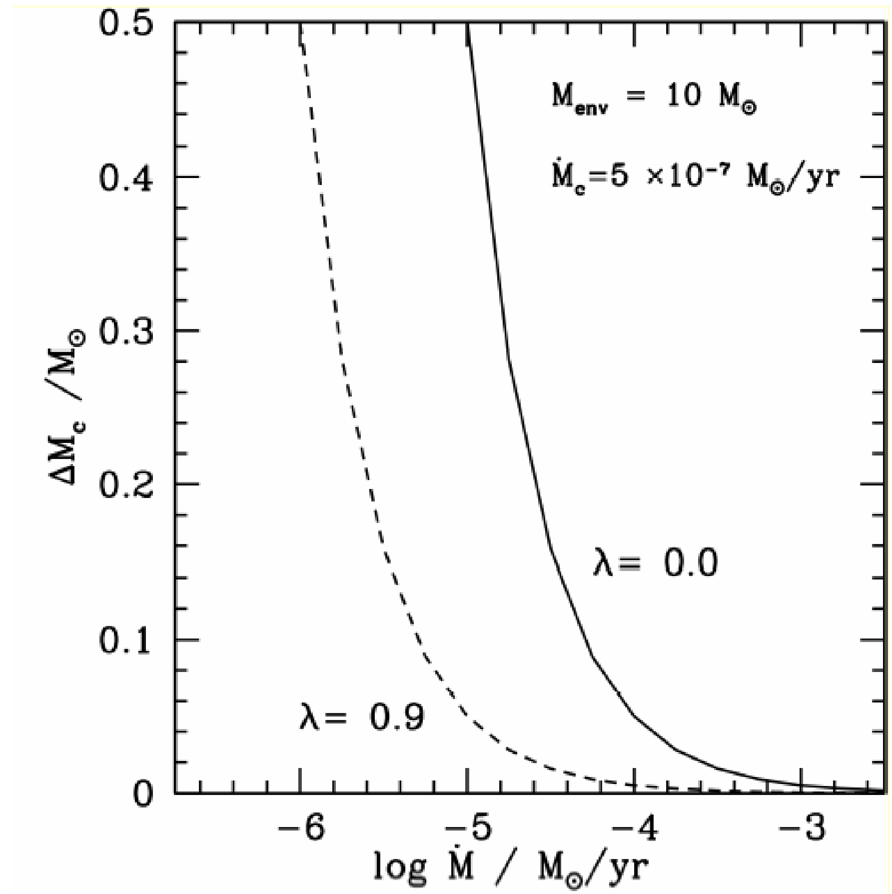
Fraction ONe SNe larger at lower Z.

Super-AGB stars

Core mass needed to grow to reach M_{ch} for a given initial mass



For a given mass and effective core growth rate: total mass added as a function of mass loss.

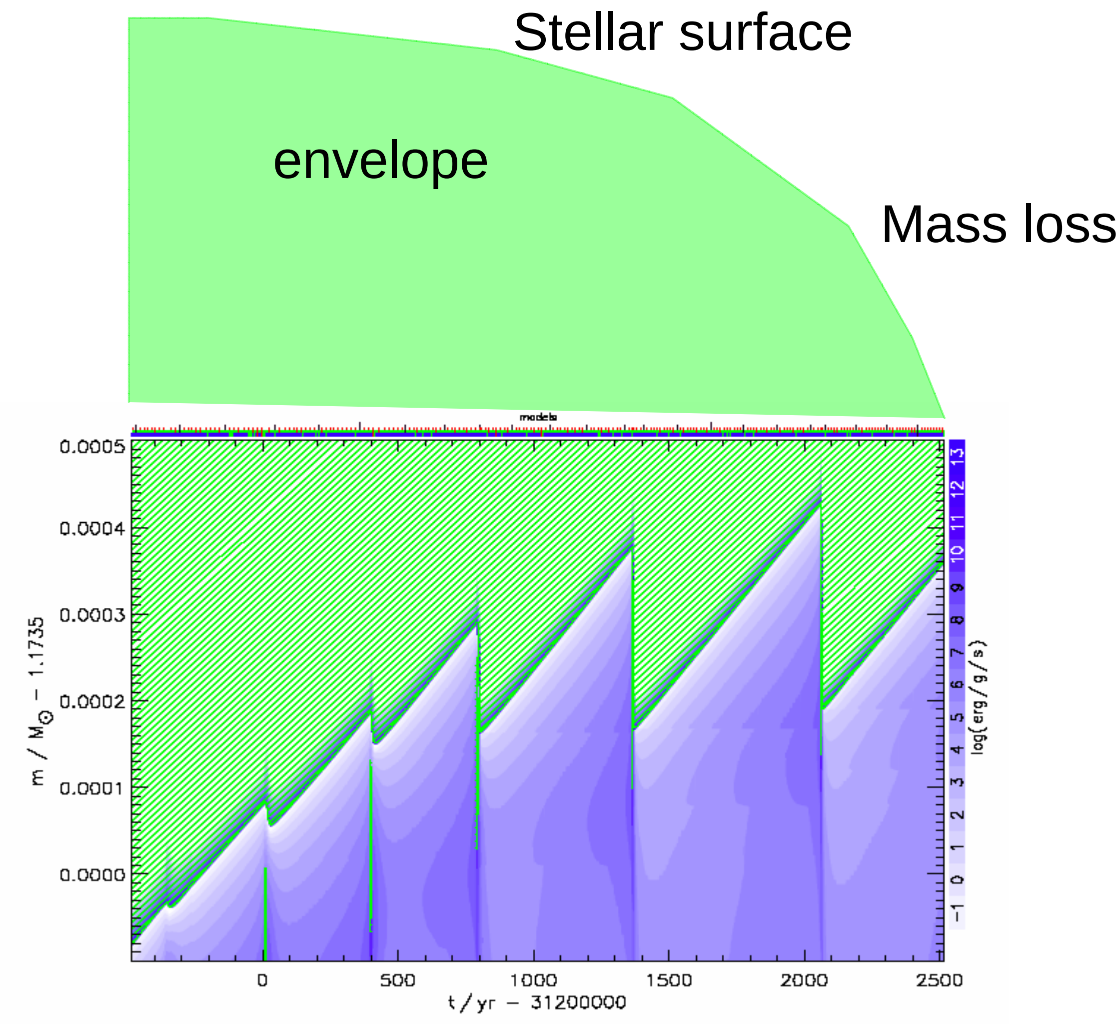


The fraction of ONe SN

Some numbers:
ONe/Fe CC SNe ratio for observational van Loon mass loss rate

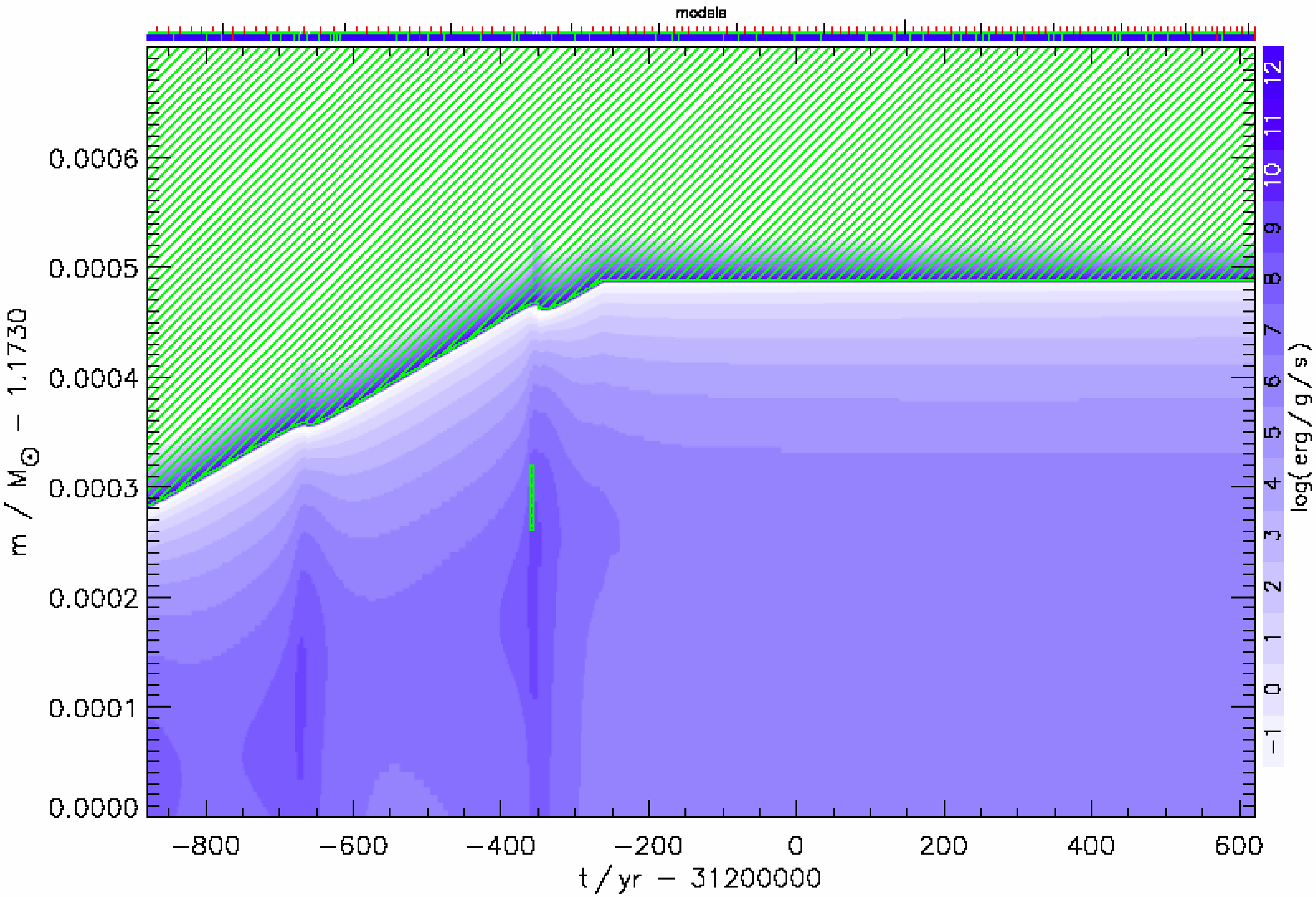
	standard	shifted M_{ini} range shifted
Lambda = 0	1 : 4	1 : 2
Lambda = 0.9	1:30	1:20

A very large fraction of CC SNe may be One cores, fraction increases with decreasing metallicity.



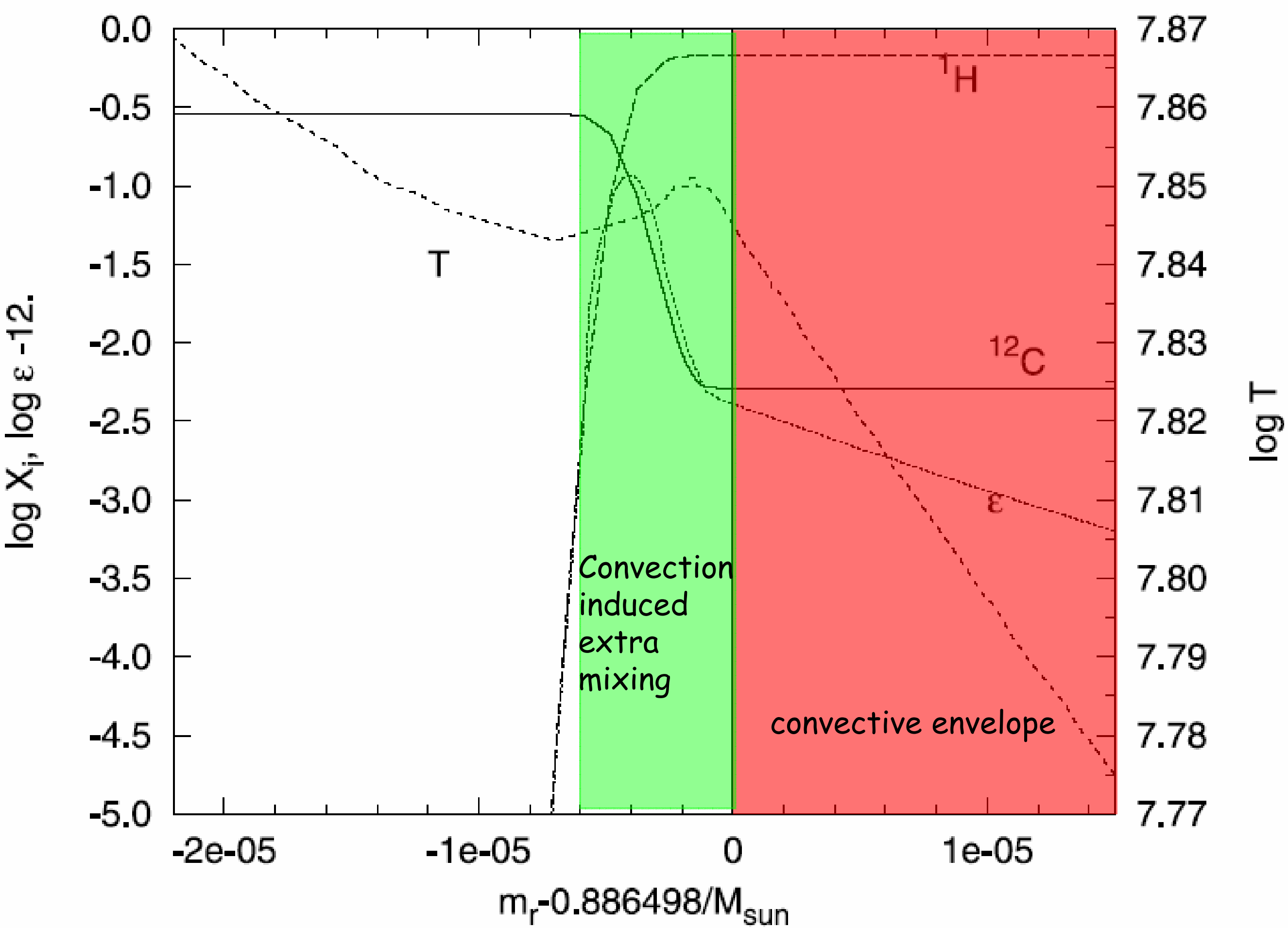
- Mass loss: How much time is there to grow the core to CC?
- How fast does the core grow?
    - Dredge-up: depends on convection and nuclear physics
    - Hot-bottom burning: depends on convection

•Hot-bottom burning: depends on convection



Depending on convection parameters one might encoutner a stationary shell-burning without effective core growth at all.

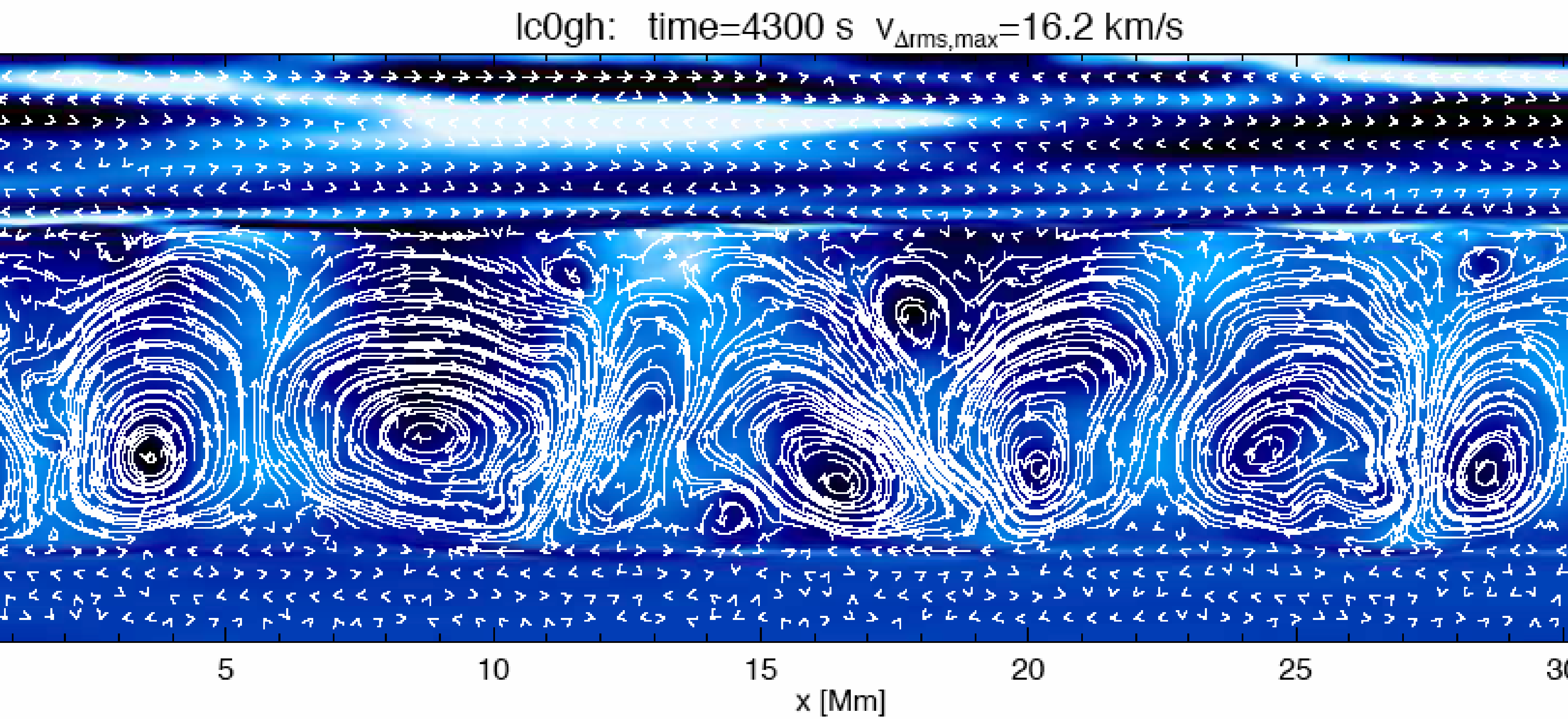
The hot dredge-up in low metallicity massive AGB stars



- Turbulent, convective mixing of H from the envelope into the hot ^{12}C-rich core:
- Corrosive H-flame burning
- Details of convective-reactive flow determine the dredge-up

Herwig 2004, ApJ.

Flow pattern



Pressure fluctuations with pseudo-streamlines overplotted, 2D, 1200x600, enhanced heating (30x) (lc0gh)

Hydrodynamics of He-shell flash convection

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

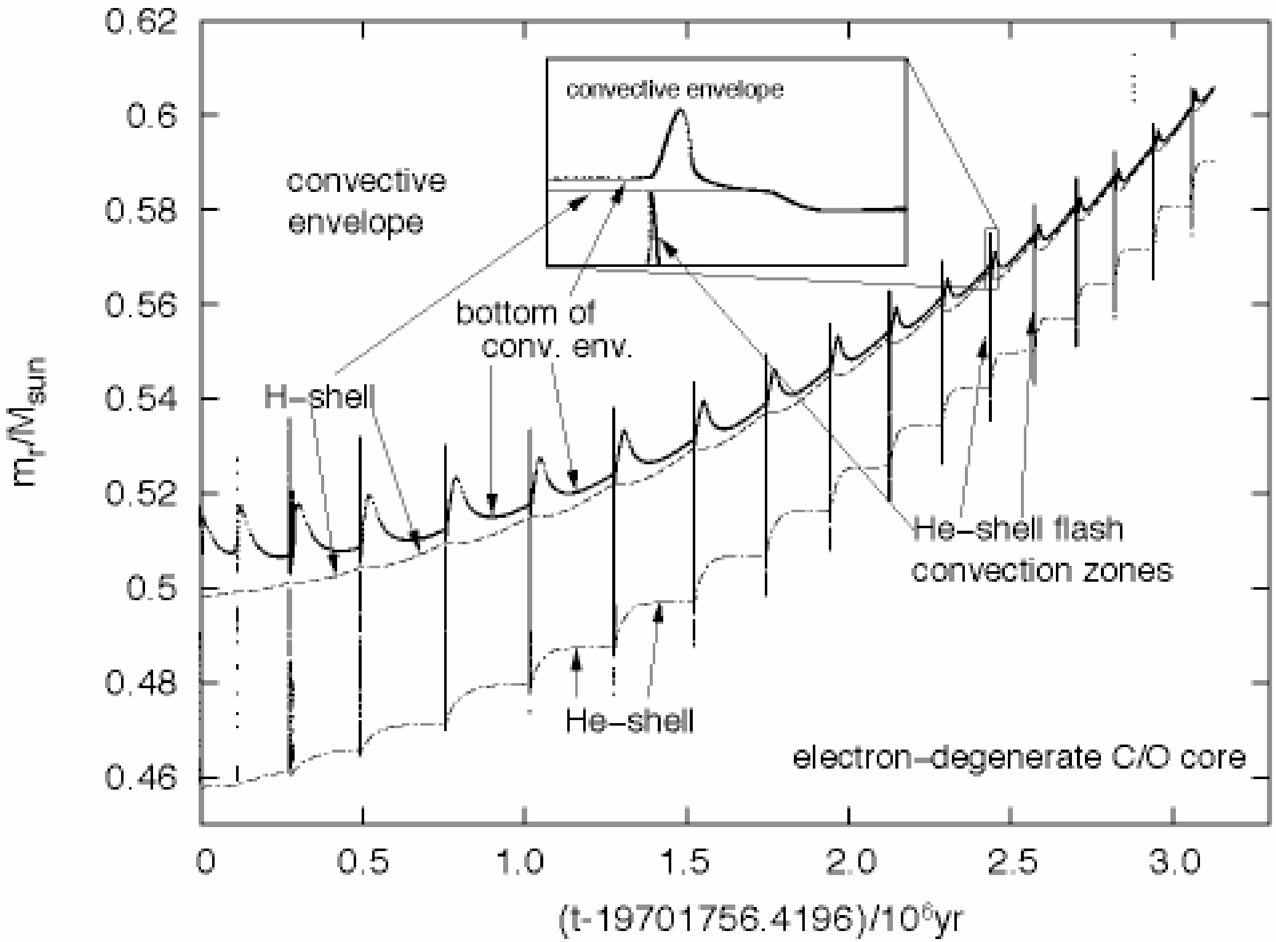
2D, 1200x400, standard heating (lc0gh)

He-shell flash convection with HIF (toy model)

QuickTime™ and a
decompressor
are needed to see this picture.

Left to right, top to bottom: four horizontal layers from top to bottom, red - H, blue - ^{12}C, same setup as before, 3D, 150^2x100, enhanced rate and energy generation (sbm04)

Nuclear physics input and dredge-up mixing in AGB stars



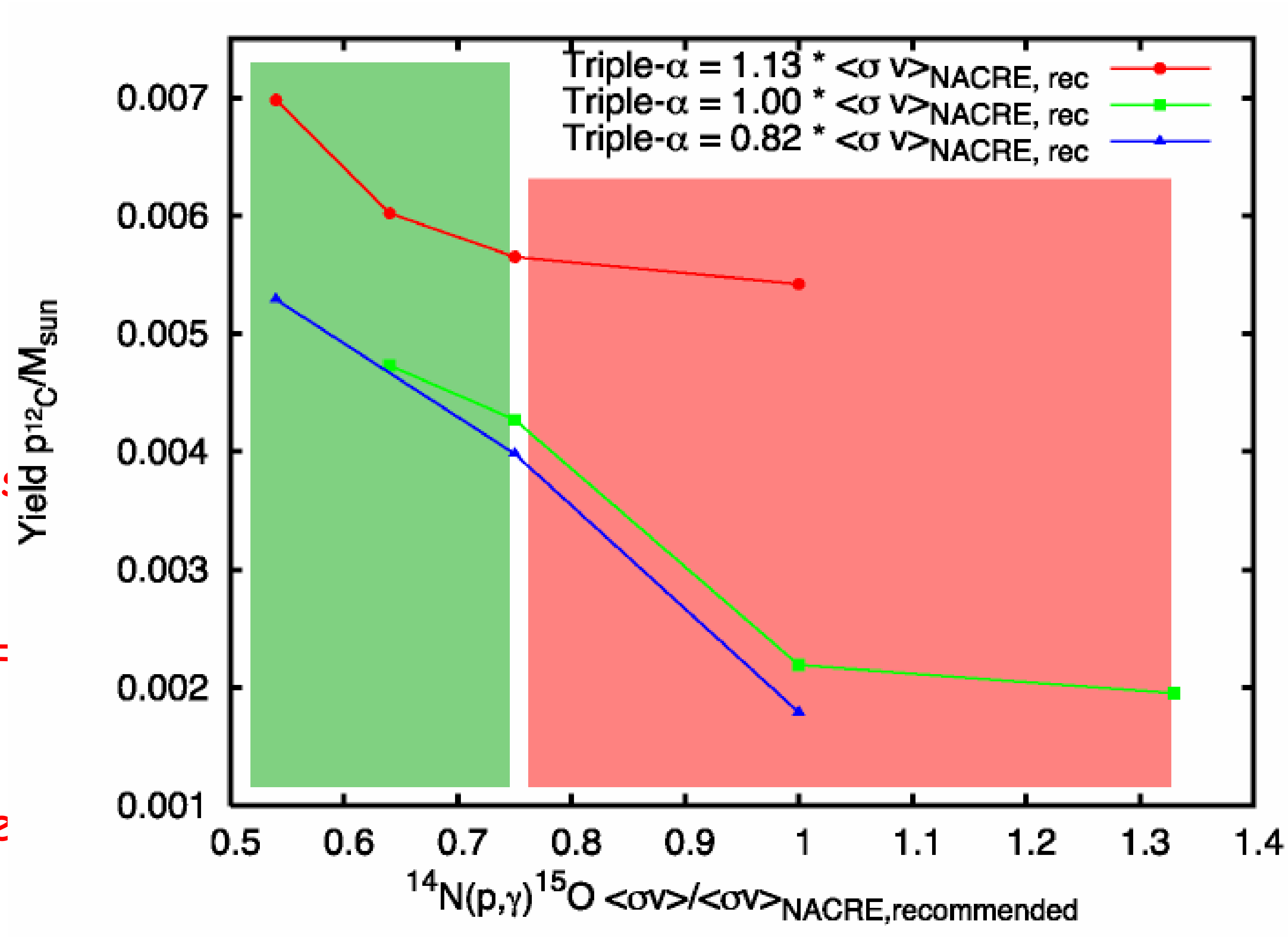
Herwig & Austin 2004, ApJ 613, L73,

Herwig, Austin & Lattanzio, 2006, PRC, in press.

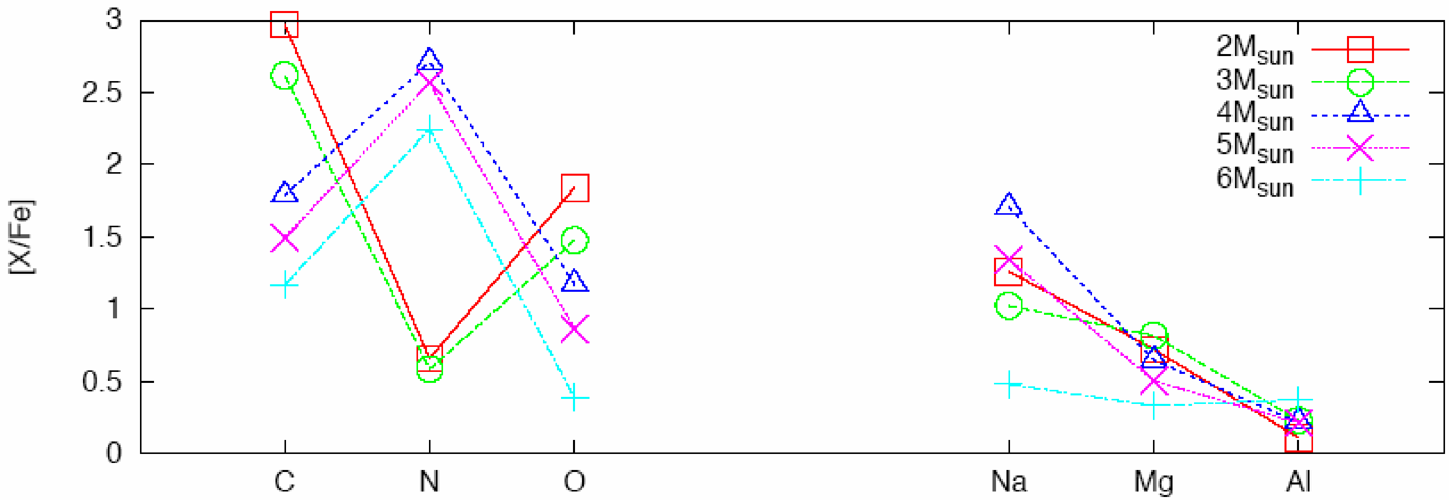
A JINA project.

Dredge-up mixing in AGB stars and nuclear reaction rates

Total C yield as a function of nuclear reaction rate = what one 2M$_\odot$ star of 0.5 Z$_\odot$ ejects into the ISM.

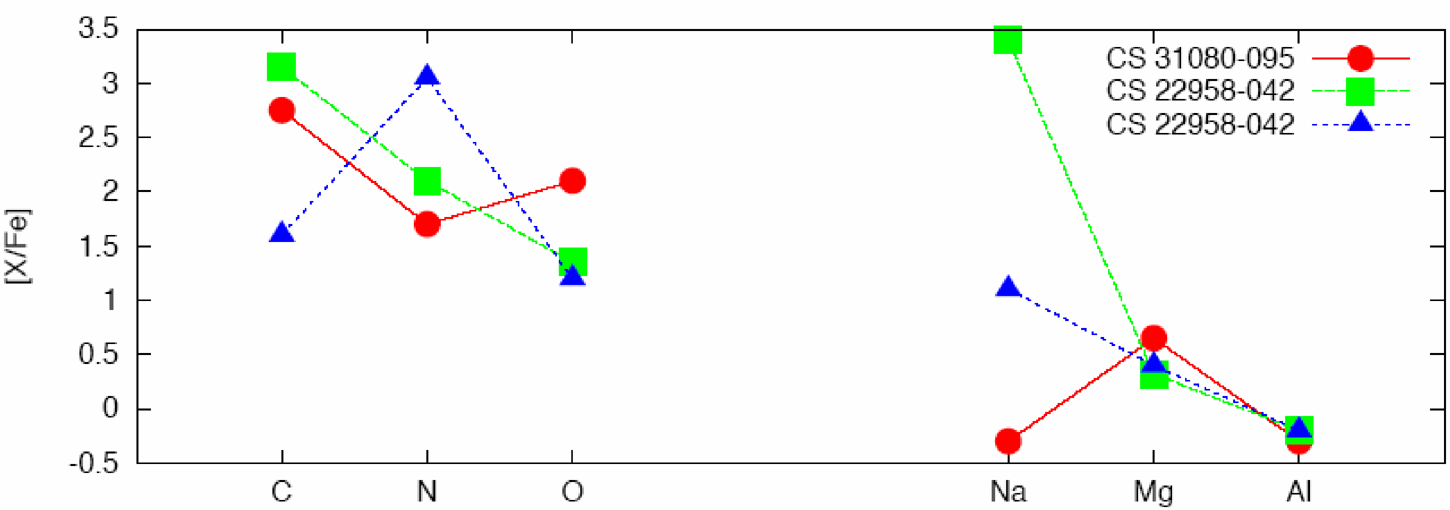


CEMP abundance signatures: Comparing models to observations



[Fe/H]

Models:
-2.3



-2.85
-2.85
-3.3

A JINA project with T. Beers. Sivarani etal 2006

Conclusions

- Our models of massive AGB stars can explain at least one EMP star very well - without any parameter fitting!

- Assuming a universal IMF down to some limiting Z the fraction of CCSN with SAGB progenitor increases with decreasing Z.
- Observational data on mass loss of RSG indicates that the details of dredge-up and effective core-growth are important for determining the initial mass range of SAGB-Sne.
- Dredge-up and core-growth depend on energetic convection boundaries.