

Population Synthesis of S- process enhanced stars: Constraining ^{13}C efficiency

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Outline

- S-process enhanced stars.
- ^{13}C efficiency.
- Models.
- Population synthesis results and comparison with the observations.
- Conclusions.

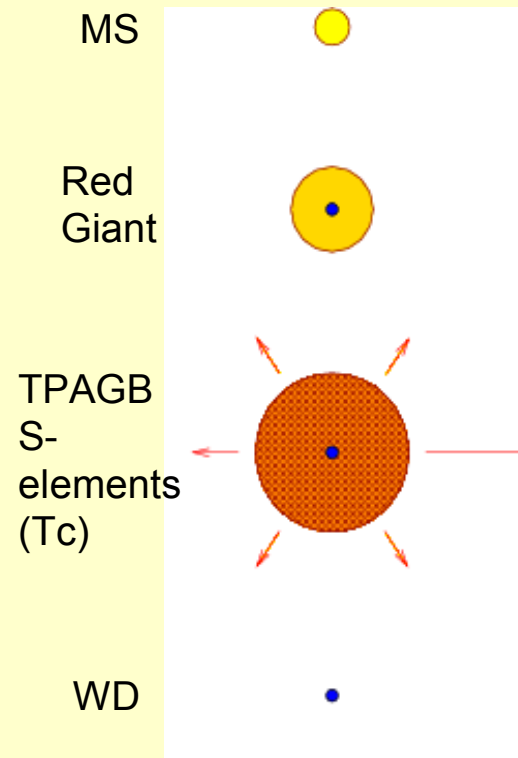
S-process enhanced Stars

- Stars which show high abundances of s-process elements compared to solar.
- Main classification:
 - Intrinsic: AGB or post-AGB stars. They produce their own s-process elements.
 - Extrinsic: dwarf or giant stars. S-process element enhancement due to accretion from an AGB companion.

Formation

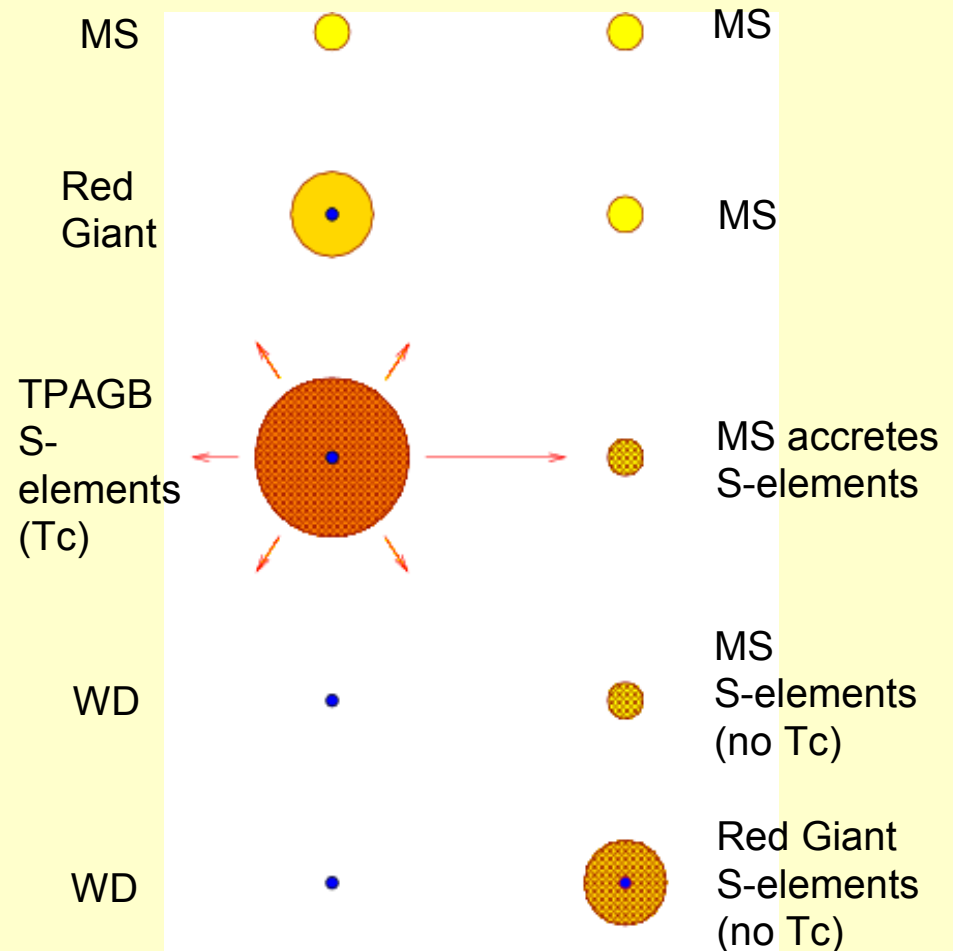
- Intrinsic:

- Star evolves until AGB phase.
- S-process elements produced in the He rich intershell.
- S-process elements mixed into envelope by 3rd dredge up.
- Star loses envelope, goes through post-AGB phase and finishes as WD.



Formation

- **Intrinsic:**
 - Star evolves until AGB phase.
 - S-process elements produced in the He rich intershell.
 - S-process elements mixed into envelope by 3rd dredge up.
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- **Extrinsic:**
 - Companion star accretes s-process element enriched matter.
 - Companion continues through normal stellar evolution phases, but enriched with S-process elements.

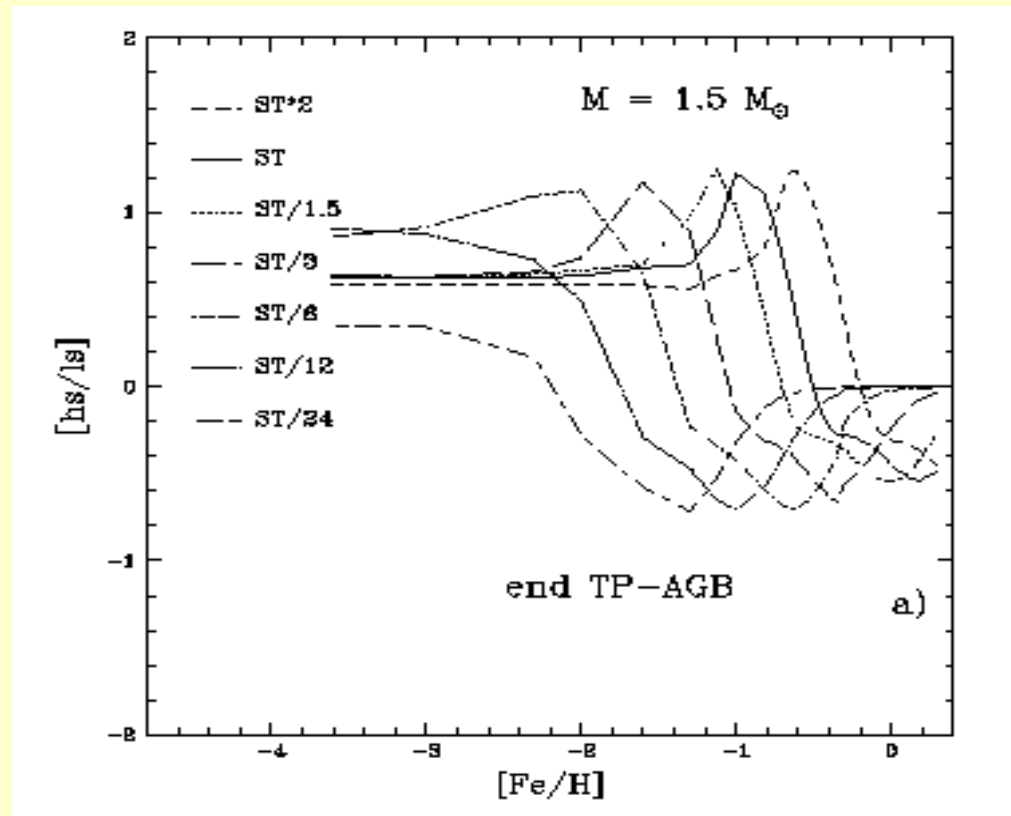


Relevance

- Intrinsic s-process enhanced stars:
 - Actual nucleosynthesis factories.
- Extrinsic s-process enhanced stars:
 - Probes for nucleosynthesis in TPAGB stars.
 - They give information about stellar interaction in wide binary systems.
- Both are the objects to be reproduced by nucleosynthesis models.

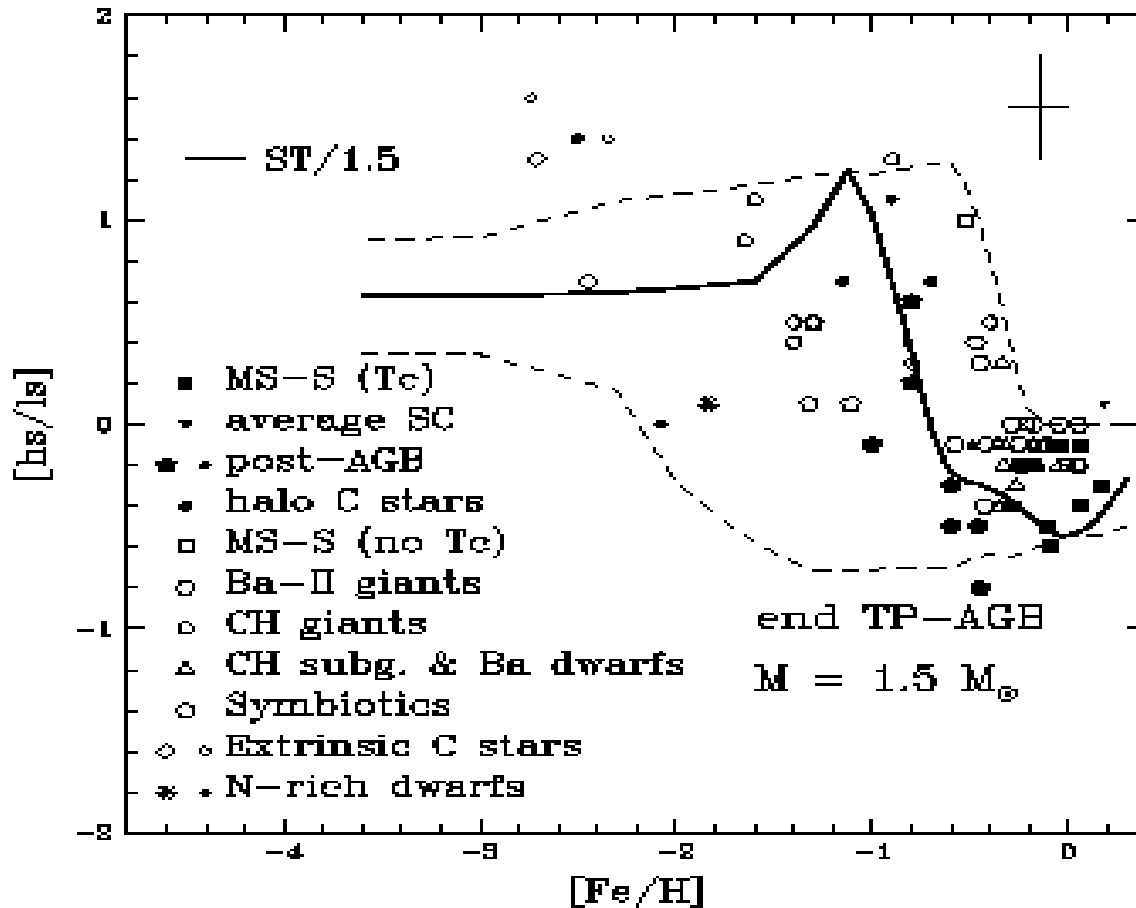
[hs/ls] and ^{13}C efficiency

- [hs/ls] ratio is basically insensitive to dilution, i.e., there is no discrimination between extrinsic and intrinsic.
- It depends strongly on the ^{13}C efficiency.
- ^{13}C efficiency parameter regulates ratio of ^{13}C to Fe
⇒ # n per Fe seed.
- ST case ($^{13}\text{C}_{\text{eff}}=1.0$):
1.5 M_{sun} star with [Fe/H]= -0.3
produces solar abundances

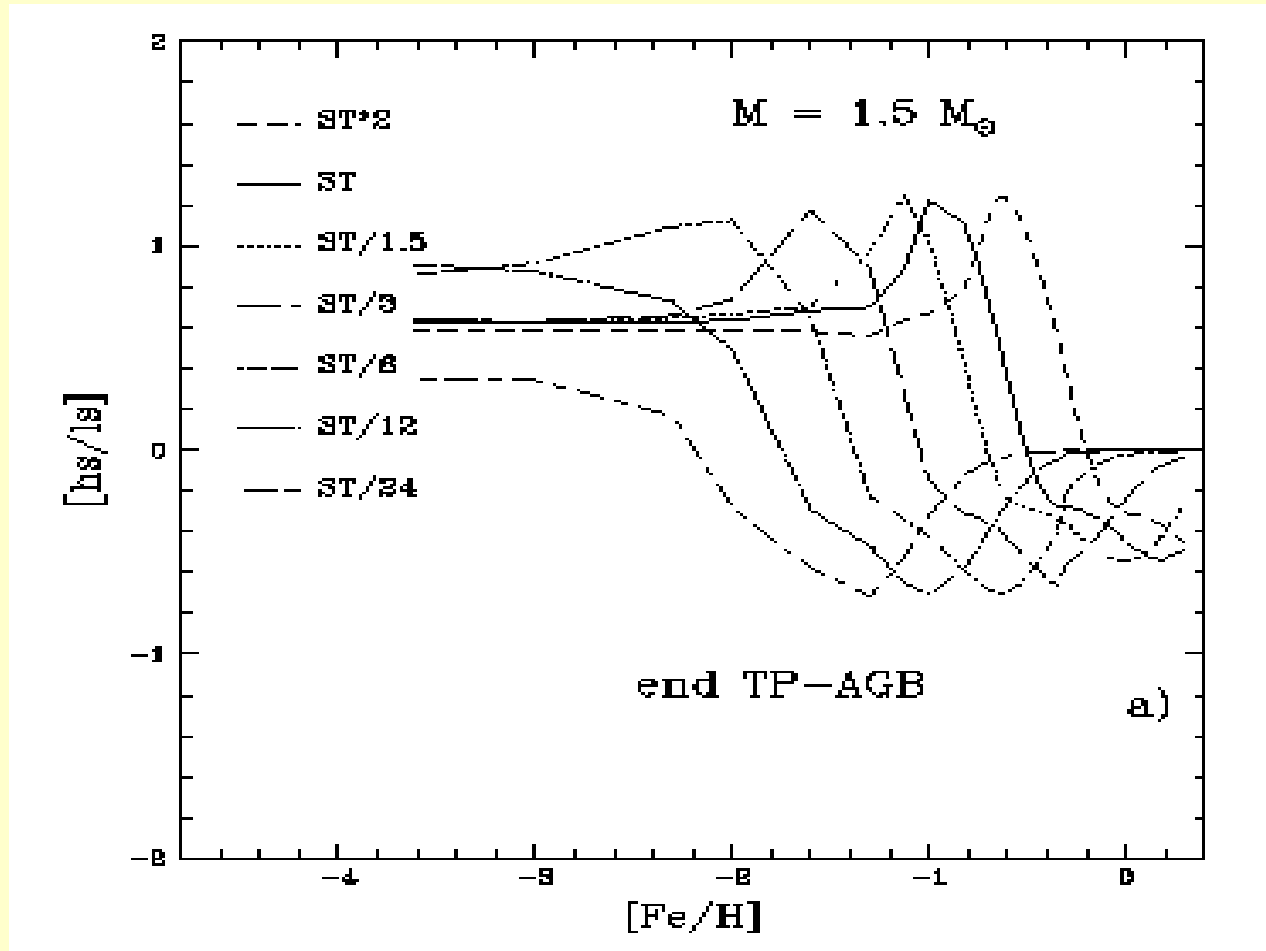


Busso et al. (2001)

[hs/ls] and ^{13}C efficiency



[hs/ls] and ^{13}C efficiency



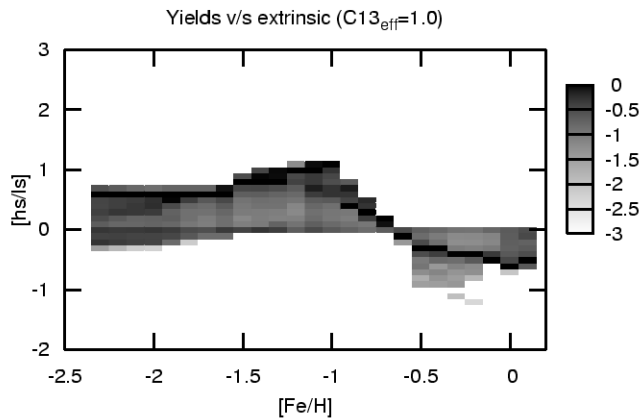
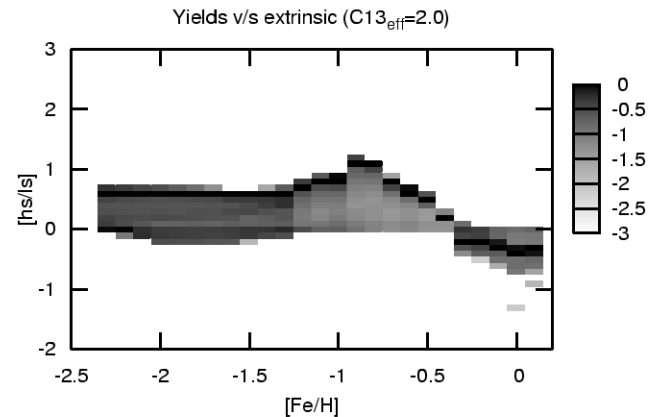
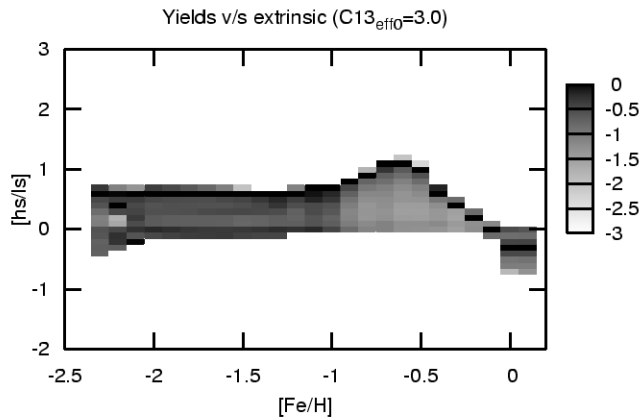
Population synthesis

- Detailed models are not too many and take time to compute.
- Abundances are chosen at a typical pulse.
- Population synthesis:
 - Fine grid of initial masses
 - Time evolution, different pulses can be followed.

Synthetic Evolutionary Code

- Bonačić, Izzard, Lugaro, Pols (in preparation):
 - Modified Izzard et al. (2004) rapid code to be more self-consistent.
 - Completely Eggleton based.
 - Smooth transition from EAGB to TPAGB.
 - Fits to luminosities in detailed models of Stancliffe et al. (2004): thermal pulses, overshooting in pre-AGB stages.
 - Interpolation of results from Gallino et al. (1998) for s-process elements nucleosynthesis .
 - $f(M, z, {}^{13}\text{C_efficiency}, \text{pulse_number})$
 - Abundances adjusted to size of intershell.

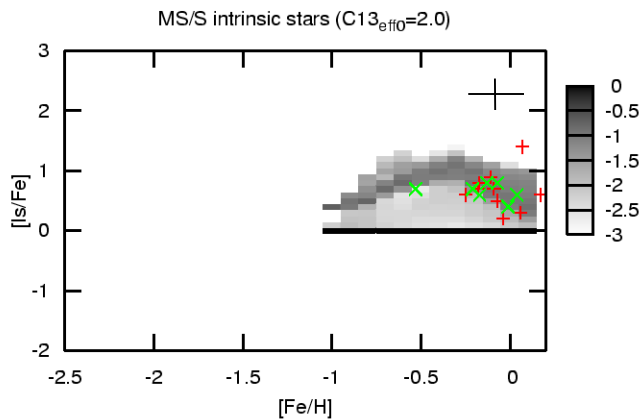
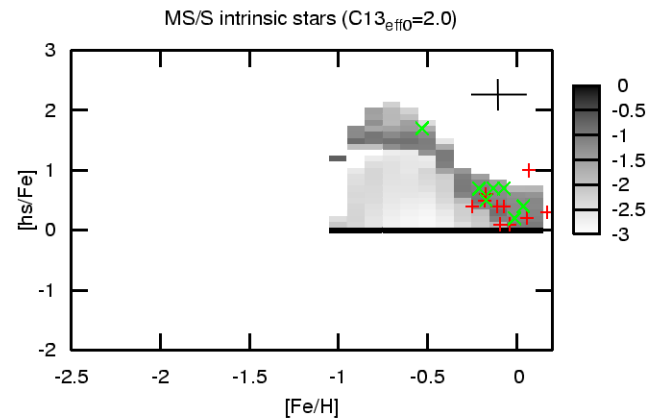
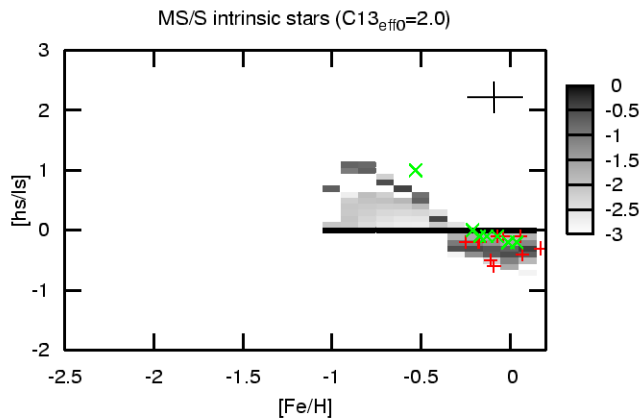
Population Synthesis Yields



- 100 stars between 1 and $8M_{\odot}$, weighted by KTG93 IMF.
- Stars in TPAGB phase.
- Gray scale shows added up mass yield, normalized to 1 in each metallicity bin.

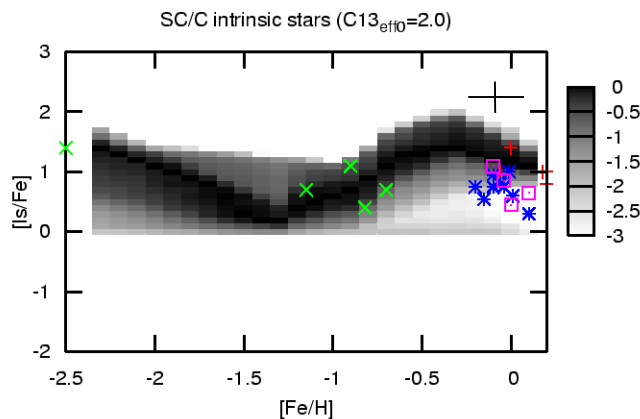
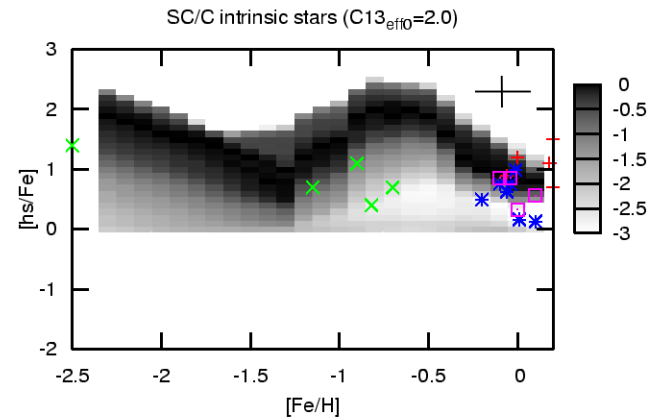
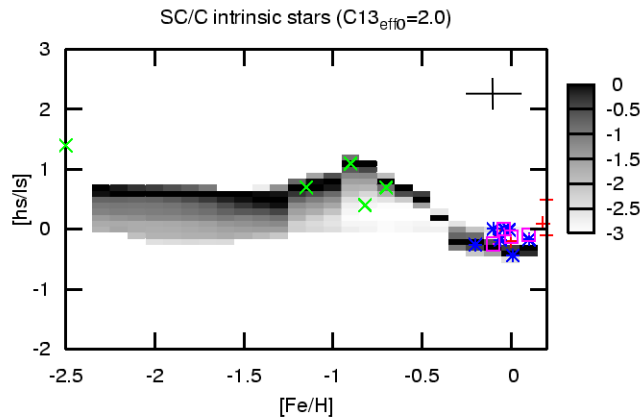
Population Synthesis

MS/S



- 100 stars between 1 and $8M_{\odot}$, weighted by KTG93 IMF.
- $T_{\text{eff}} < 3500\text{K}$
- $[C/O] < 0.95$
- Gray scale shows added up probability in time, normalized to 1 in each metallicity bin.

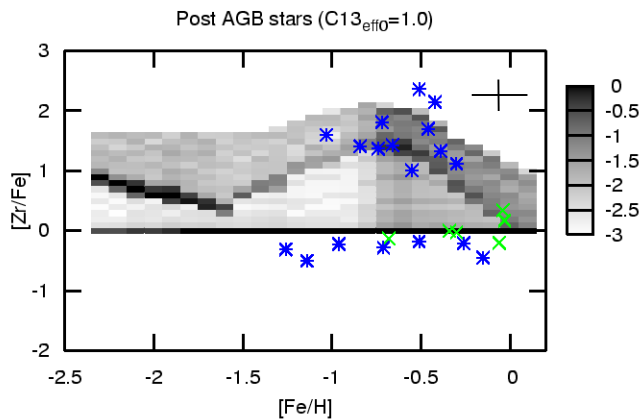
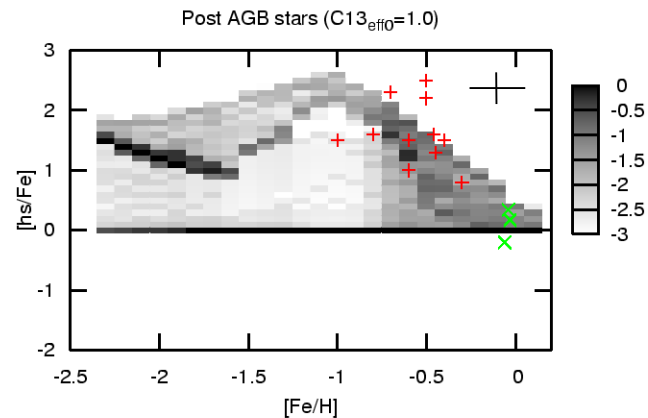
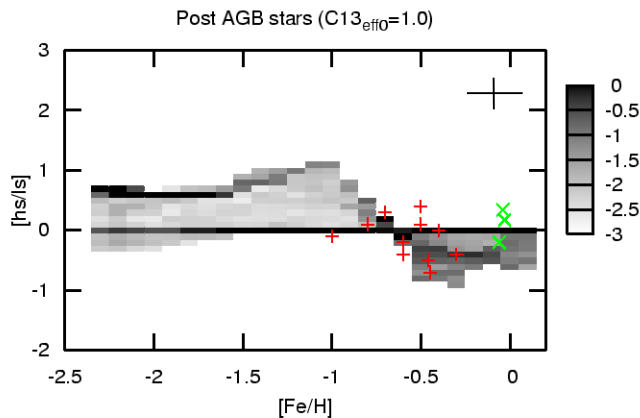
Population Synthesis SC/C



- 100 stars between 1 and $8M_{\odot}$, weighted by KTG93 IMF.
- $[C/O] > 0.95$
- Gray scale shows added up probability in time, normalized to 1 in each metallicity bin.

Population Synthesis

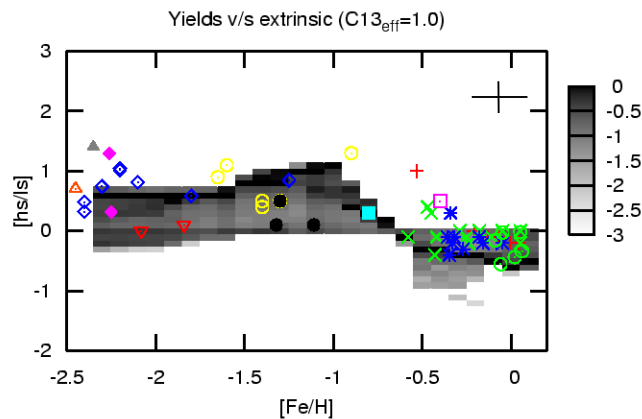
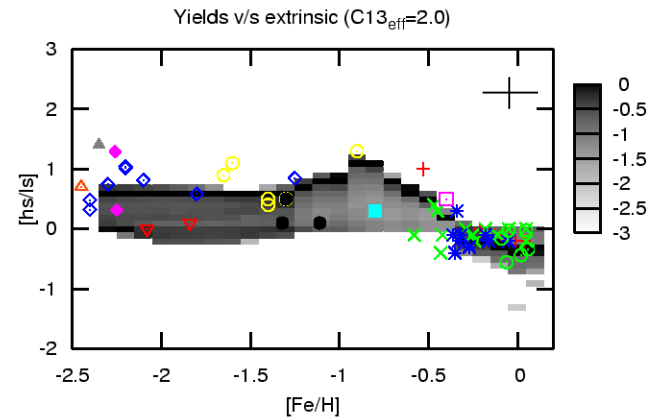
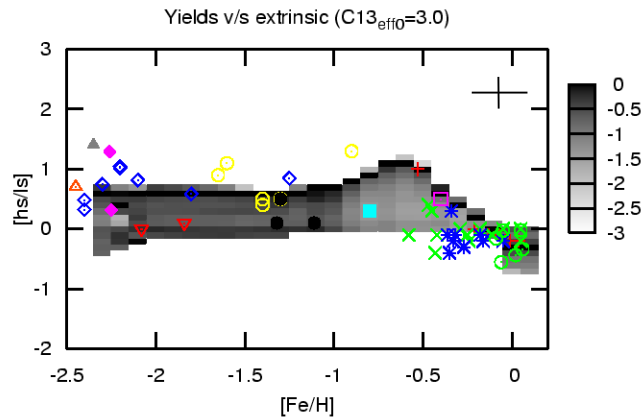
Post-AGB



- 100 stars between 1 and $8M_{\odot}$, weighted by KTG93 IMF.
- $M_{\text{env}} < 0.03 M_{\text{sun}}$
- Gray scale shows added up probability in time, normalized to 1 in each metallicity bin.

Population Synthesis

Yields v/s extrinsic stars

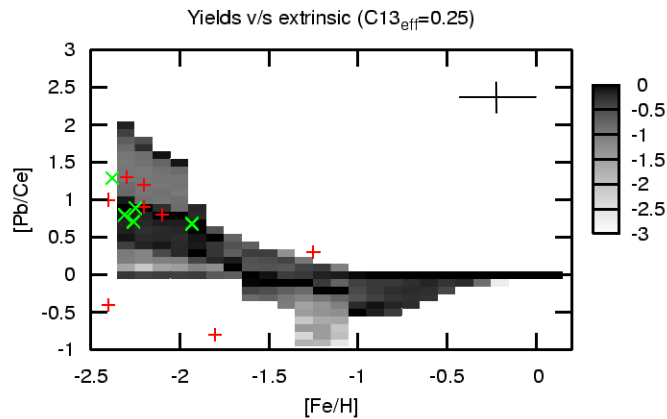
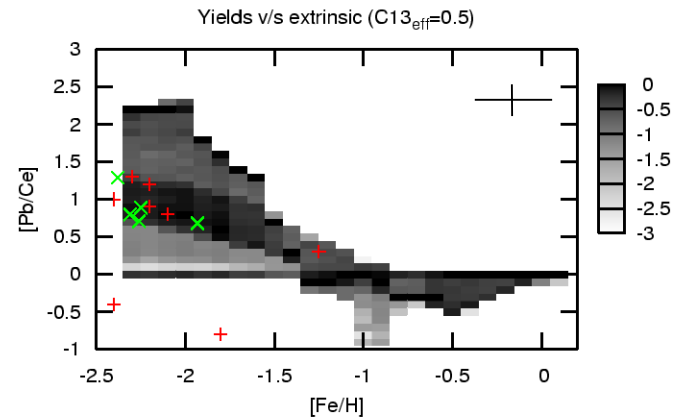
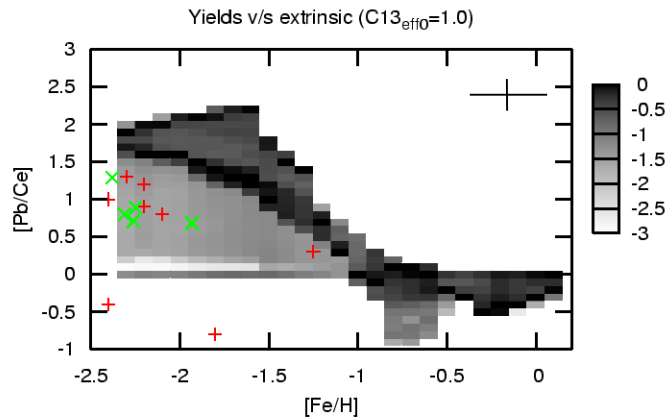


MS/S(no Tc) +
 Ba II Giant x
 CH Sub-Giant *
 CH Giant □
 C Giant ■
 halo CH Giant ○
 halo Yellow Symb. ●
 halo C-rich giant ▲
 halo C-rich subgiant ▼
 halo N-rich dwarf △
 Abia extr ○
 van Eck ◇
 Aoki ◆

- $1 < {}^{13}\text{C}_{\text{eff}} < 3$ needed for fitting observations
- Low Z side is insensitive.

Population Synthesis

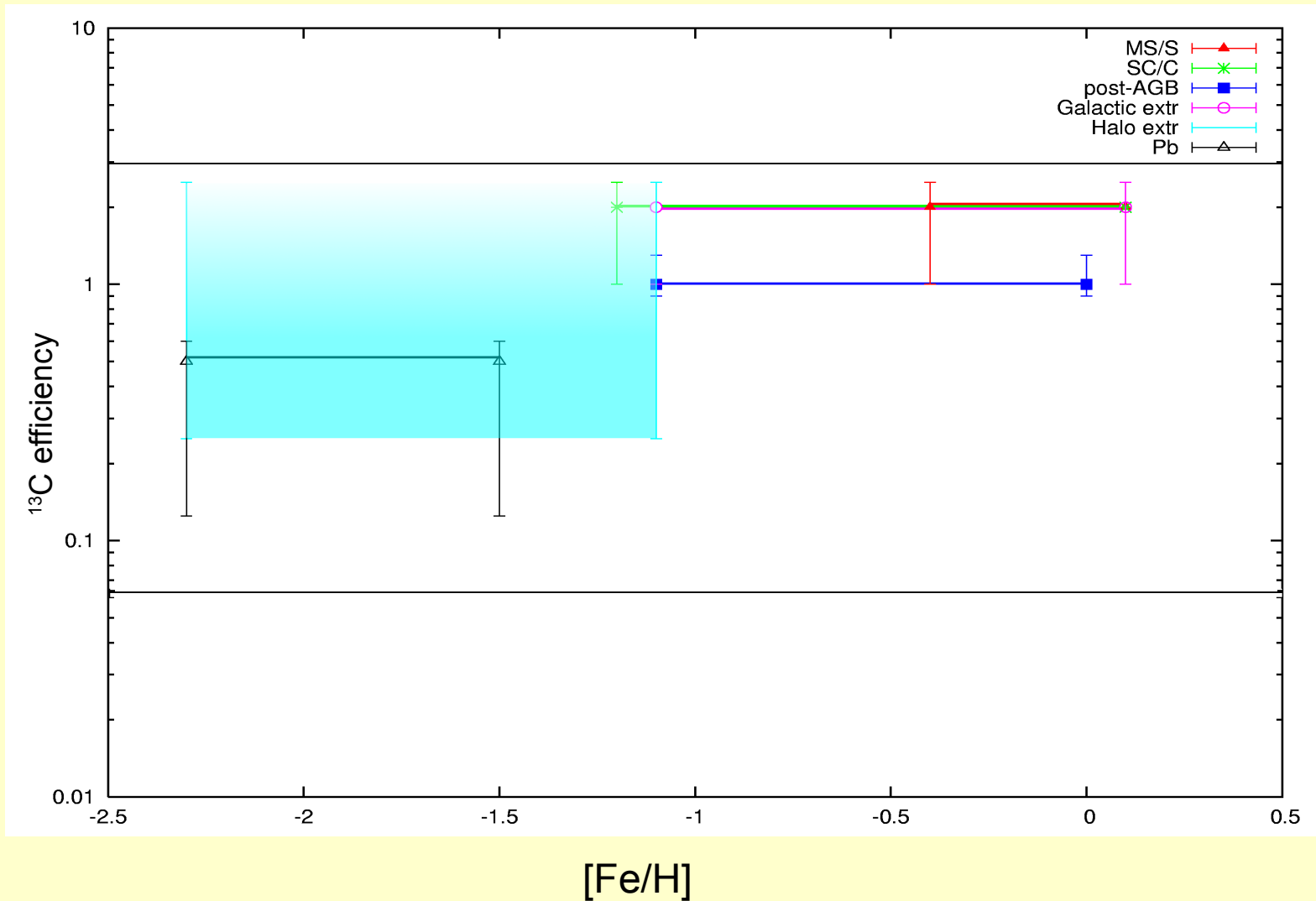
Yields v/s Pb stars



- ^{13}C efficiency $< \sim 0.5$ needed for fitting most observations.

Population Synthesis

^{13}C efficiency



Conclusions

- Different stellar masses and time evolution provide a natural spread in the [hs/l_s] ratio, which substantially reduces the range of ¹³C efficiency needed to fit observations.
- Most galactic disk objects ([Fe/H] >~ -1) are explained by $1 < {}^{13}\text{C}_{\text{eff}} < 3$.
- Halo data ([Fe/H] <~ -1) is non-sensitive to a wide range of ¹³C efficiency, but most Pb observations can be explained with ${}^{13}\text{C}_{\text{eff}} \sim 0.5$.
- Work to follow:
 - Once calibrated SSE, carry out binary population synthesis for comparing data from extrinsic objects in a more proper way.

(Por) FIN!