

NUCLEAR UNCERTAINTIES ON PRE-EXPLOSIVE ^{26}Al NUCLEOSYNTHESIS

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Collaboration with

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^{26}Al Sources

- O-Ne-Mg novae (white dwarfs)
- Core collapse SN (massive stars)
- Wolf Rayet stars
- AGB stars (Cristallo, Busso talks)
- Cosmic ray nuclear reactions

(Diehl et al 1994)

• Several stellar models have predicted ^{26}Al pre SN nucleosynthesis on massive stars

(Woosley-Weaver 1995, Chieffi et al 1997, Woosley-Heger 2002...)

^{26}Al Observations

- Excess of ^{26}Mg in presolar stardusts grains.
- Evidence of ^{26}Al in the Early Solar System found in meteorites.
- Galactic 1.809 MeV γ ray emission line.

(Diehl et al. 1995, Prantzos 2004)

Advanced Stellar Nucleosynthesis

On massive stars

In advanced stages, burning can go simultaneously in the center of the star and in multiple shells; structure and composition become quite complex.

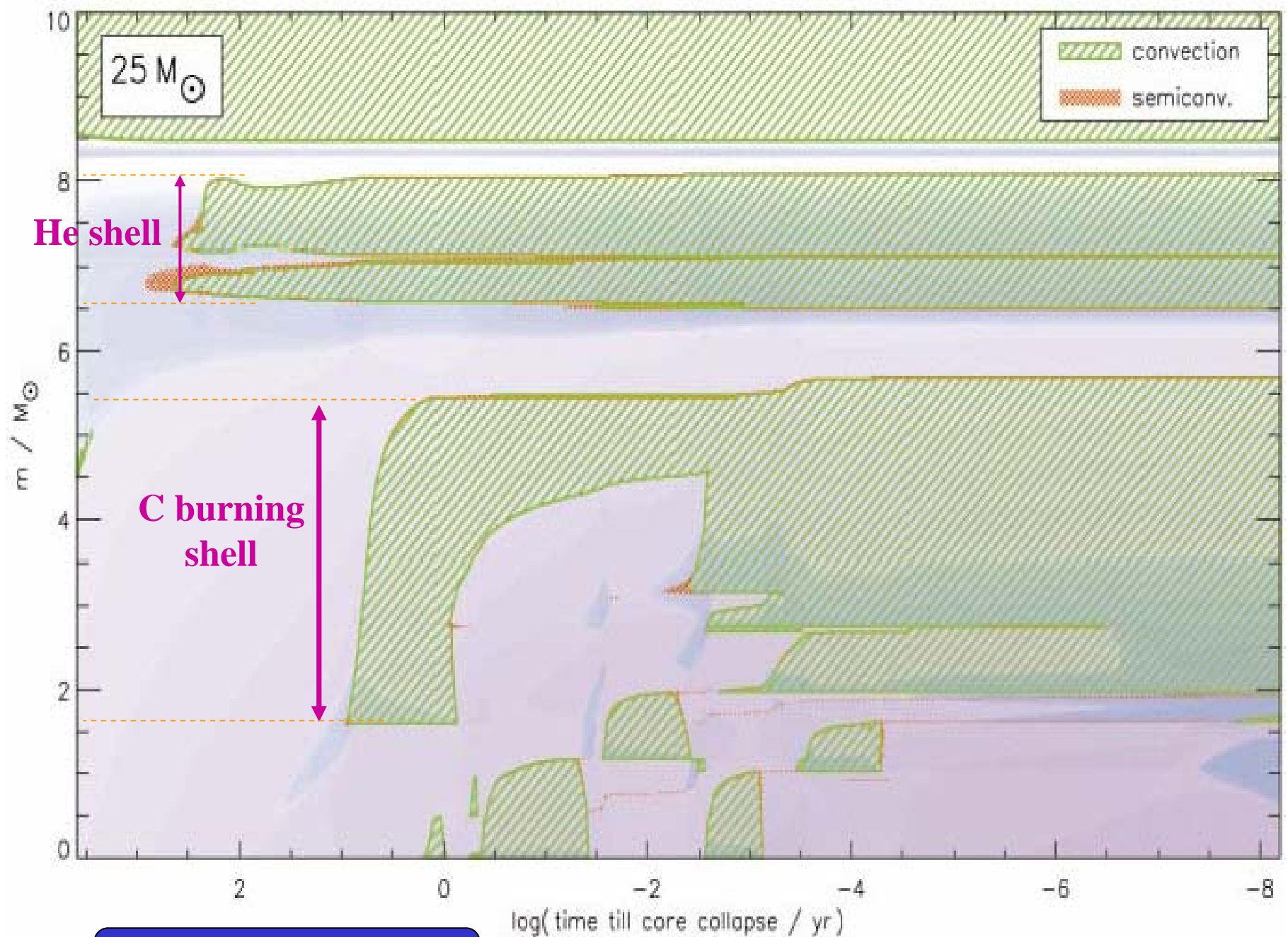
For the study of ^{26}Al , we look at

Convective Shell Carbon Burning

Most abundant products

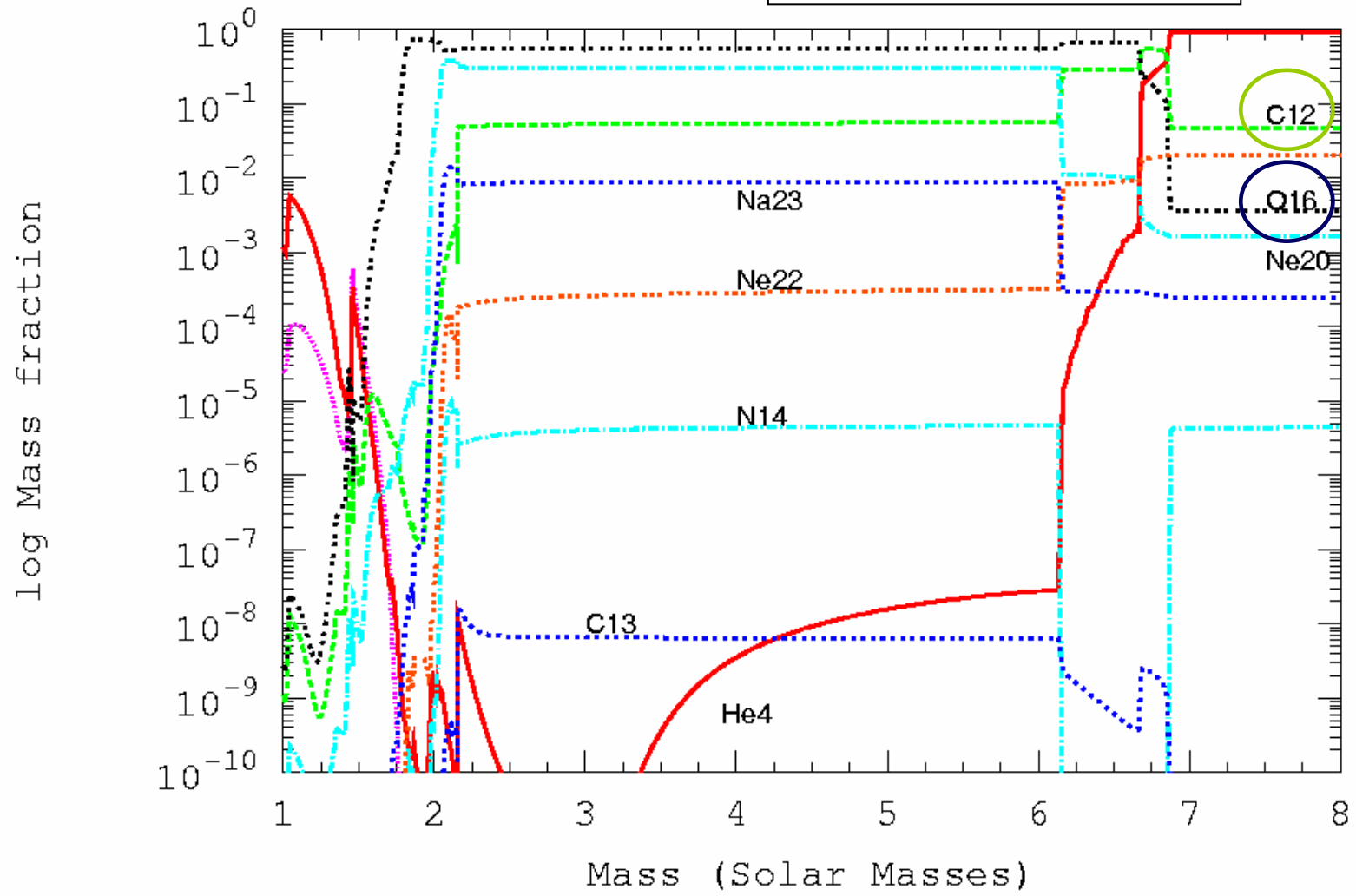
^{23}Na , ^{20}Ne



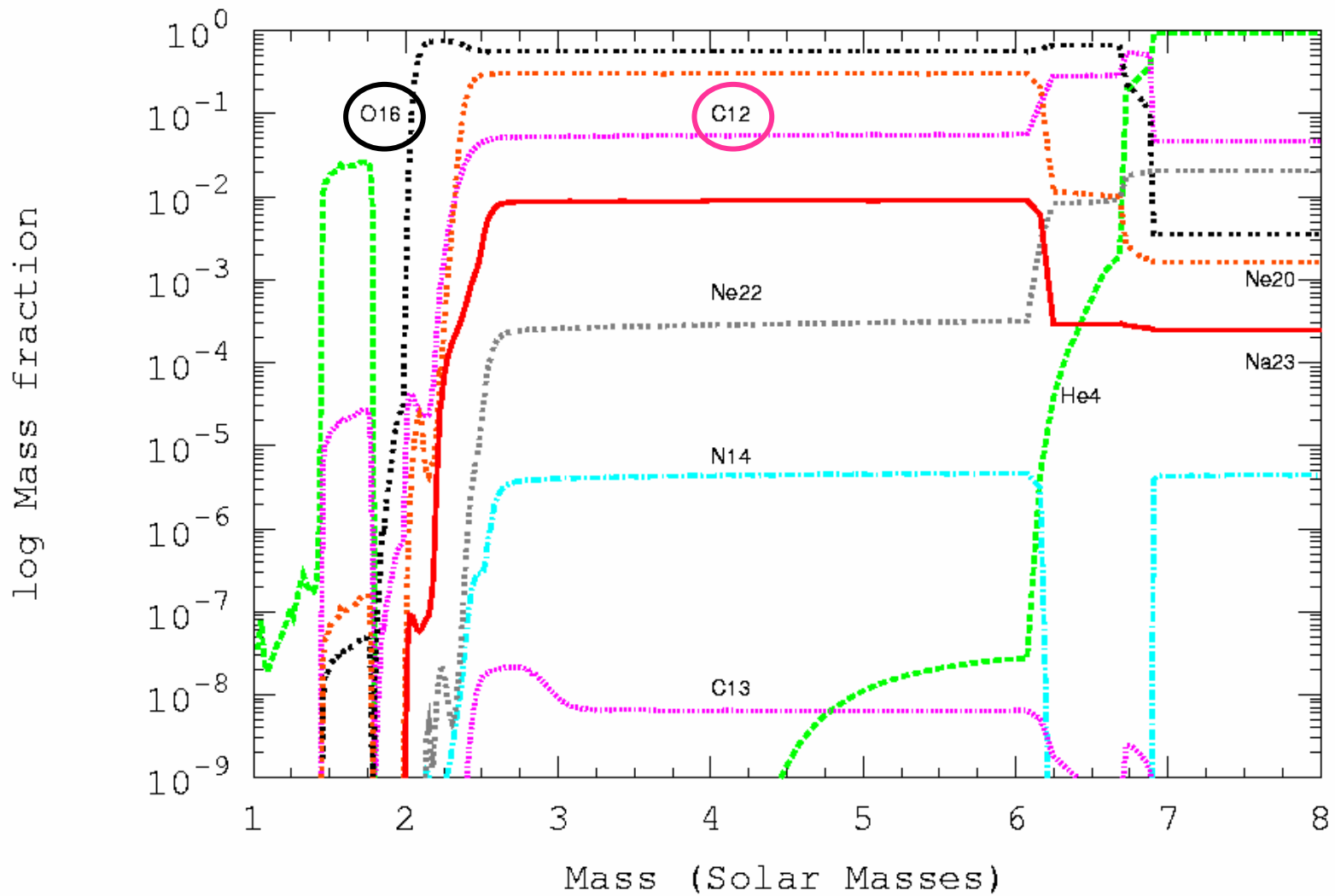


Pre SN - 25 M_{sun}

Limongi homepage



PostSN (9.2e4 s) - 25 M_{sun}



<p>Si 26 2,21 s</p> <p>μ^+ 3,8... γ 829; 1622... 11)</p>	<p>Si 27 4,13 s</p> <p>β^+ γ 40</p> <p>(p, γ)</p>	<p>Si 28 92,23</p> <p>σ 0,17</p>
<p>Al 25 7,18 s</p> <p>β^+ 3,3... γ (1612...)</p>	<p>Al 26 8,35 s</p> <p>σ 3,2</p>	<p>Al 27 100</p> <p>σ 0,280</p> <p>(n, γ)</p>
<p>Mg 24 (n, α)</p> <p>σ 0,053</p>	<p>Mg 25 10,00</p> <p>(p, γ)</p> <p>σ 0,17</p>	<p>Mg 26 11,01</p> <p>(n, p)</p> <p>β^+</p>
<p>Na 23 100</p> <p>σ 0,43 + 0,1</p>	<p>Na 24 20 ms</p> <p>β^- 4,72 γ 1369...</p>	<p>Na 25 59,6 s</p> <p>β^- 3,8... γ 975; 390; 585; 1612...</p>

^{26}Al mainly produced by proton captures on ^{25}Mg

Time history of ^{26}Al abundance follows the abundance of free protons

$$t_{1/2}({}^{26}\text{Al}^g) = 7.16 \cdot 10^5 \text{ yr}$$

$$t_{1/2}({}^{26}\text{Al}^m) = 6.35 \text{ s}$$

${}^{26}\text{Al}_m$ and ${}^{26}\text{Al}_g$ treated as separated nuclei $T_9 \leq 0.4$

${}^{26}\text{Al}$ thermalized $T_9 > 0.4$

Ward & Fowler 1980

$T_9(\text{K})$	1.0	1.1	1.2	1.3	1.4	1.5
$\lambda_{26} * 10^{-4}(\text{s}^{-1})$	6.998	8.880	10.82	12.78	14.73	16.65

Runkle et al 2001

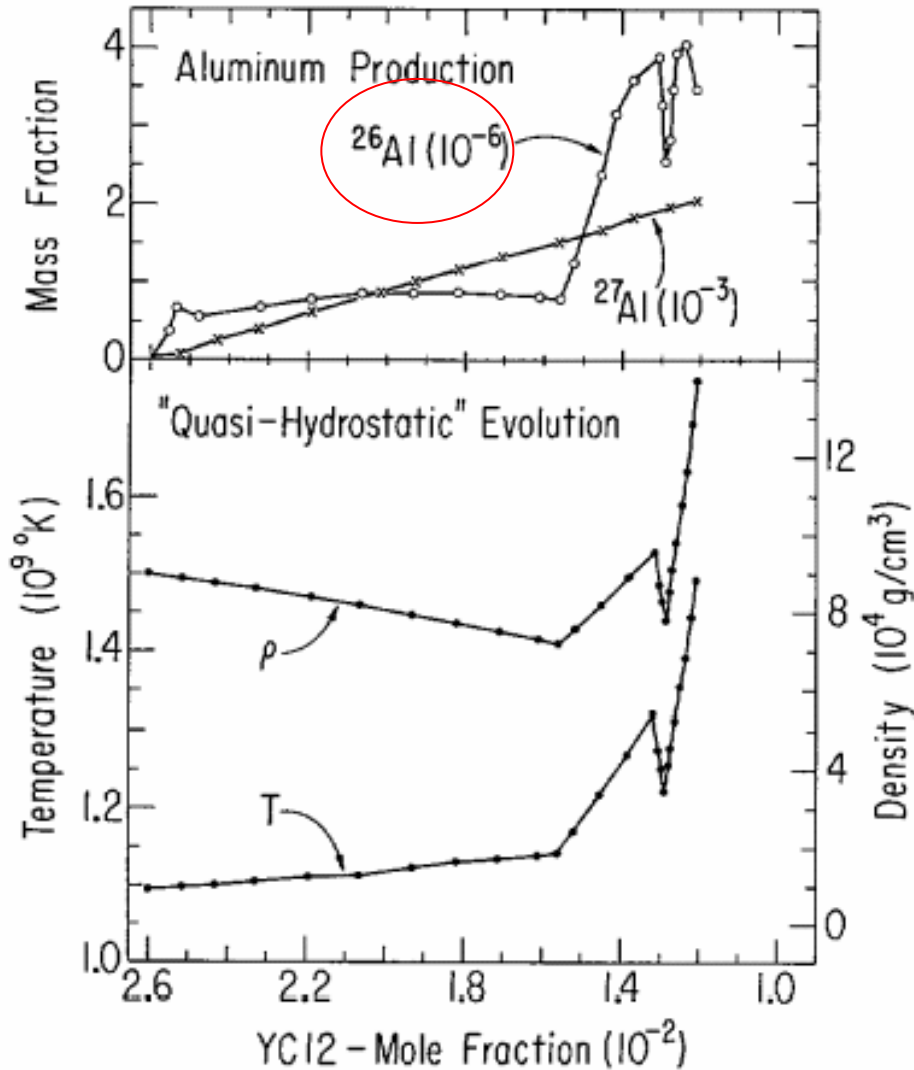
Amount of ^{26}Al depends on reaction rates used.
 Steady state approximation:

$$\frac{Y(^{26}\text{Al})}{Y(^{25}\text{Mg})} = \frac{Y(p) \rho N_A \langle \sigma v \rangle_{p,\gamma}}{\lambda_{26} + Y(n) \rho N_A \langle \sigma v \rangle_{n,p}}$$

$$Y = X_i / A_i$$

Arnett & Wefel 1978

$$Y(n) \rho N_A \langle \sigma v \rangle_{n,p} \approx 10^{-4} \quad (N_n > 10^{12} \text{ cm}^{-3})$$



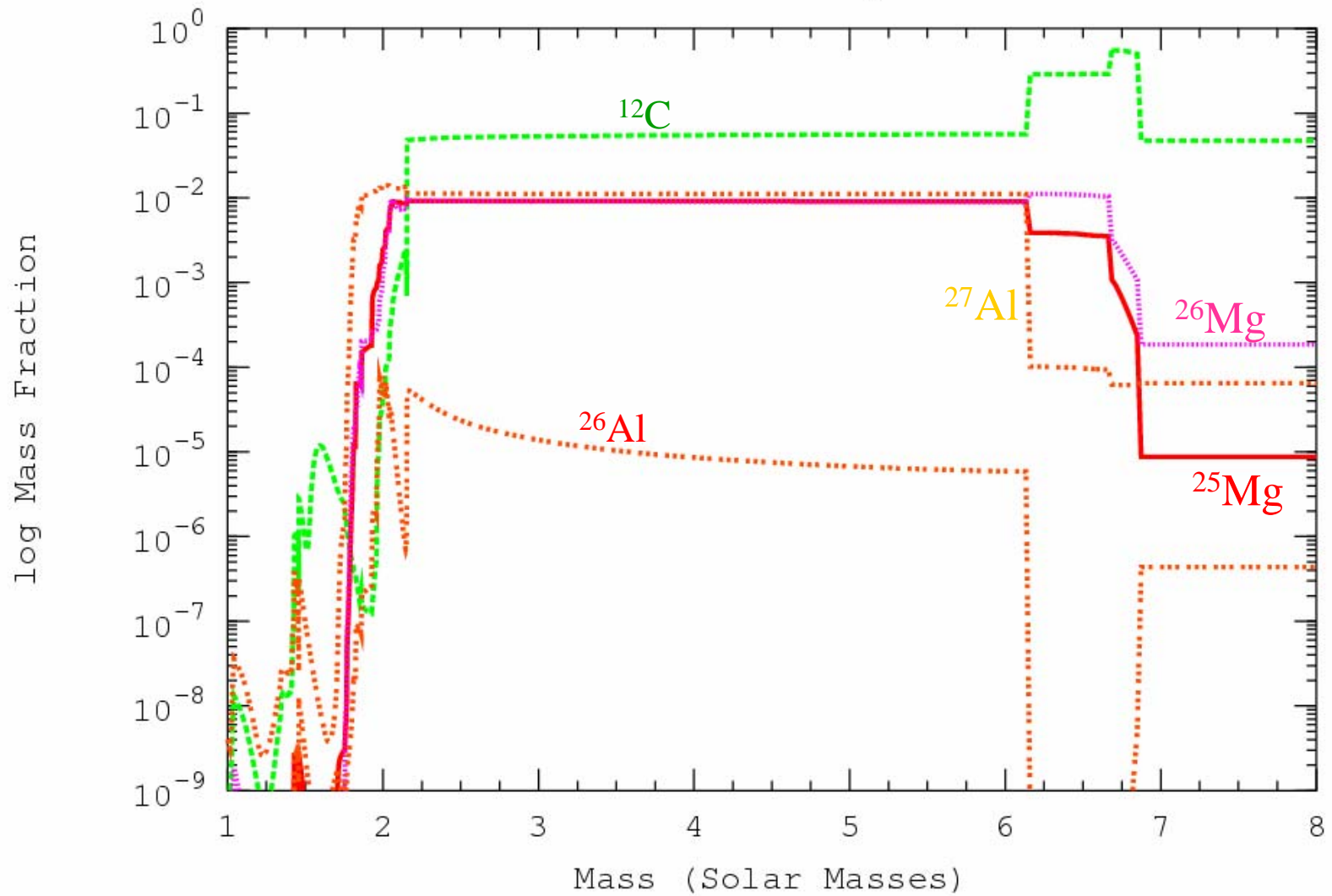
Once innermost zones undergo C burning at $T_9 \sim 1$ convective carbon shell is formed,

Convection mixes the reaction products throughout the C shell and renews the fuel.

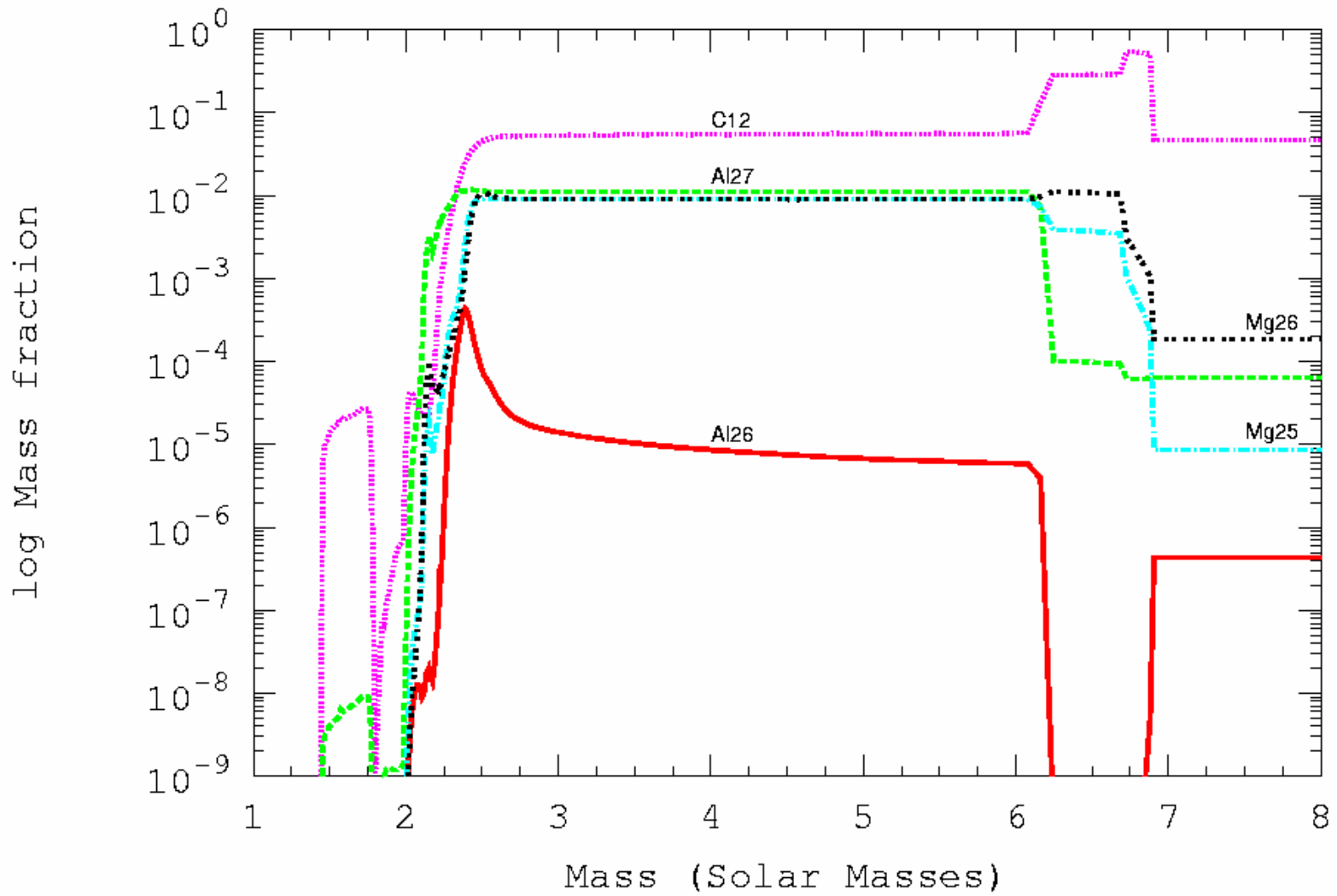
$$^{26}\text{Al}/^{27}\text{Al} = 1.7 \times 10^{-3}$$

Arnett & Wefel 1978

Pre SN $25M_{\odot}$

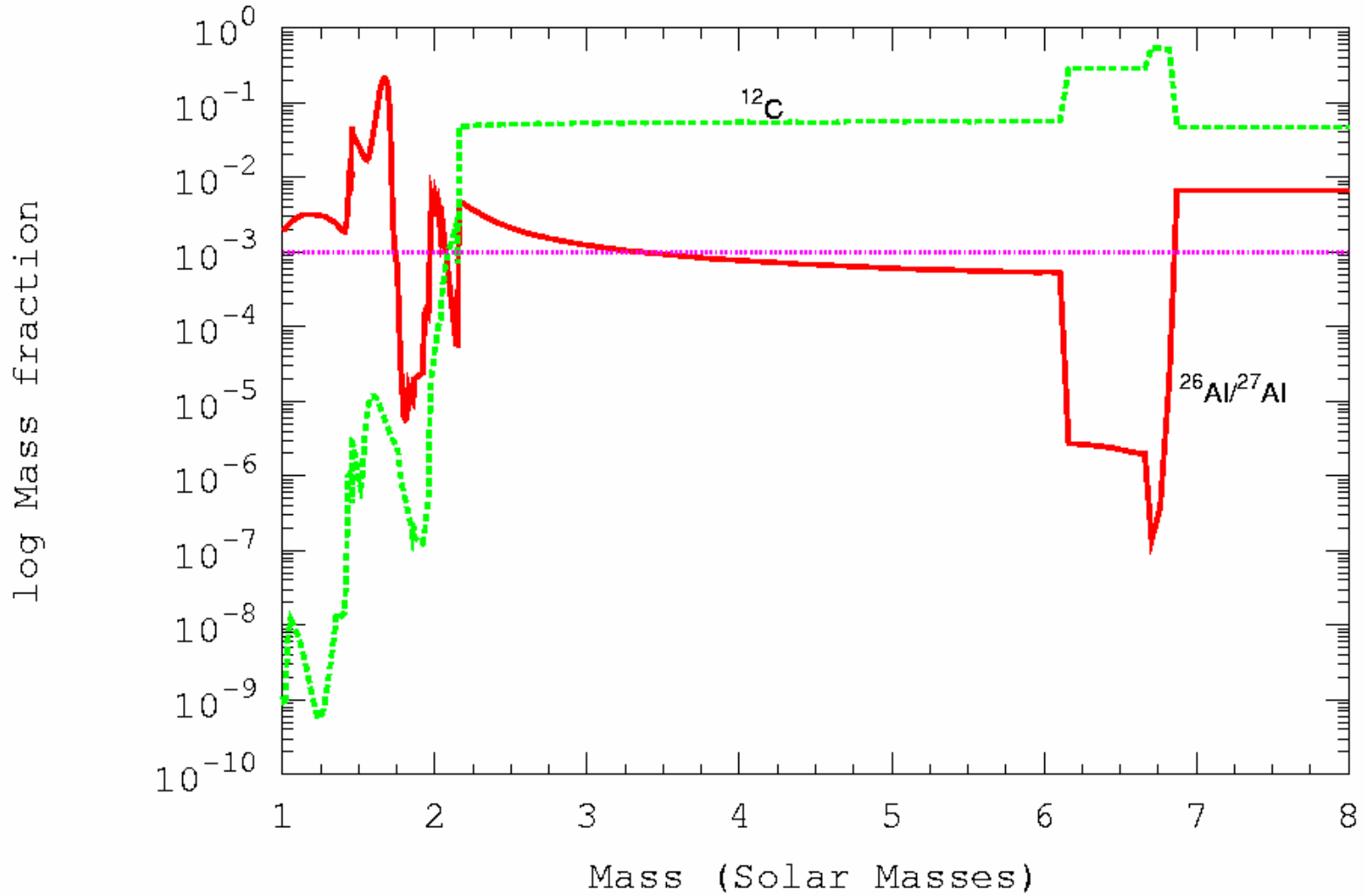


PostSN (9.2e4 s) - 25 M_{sun}



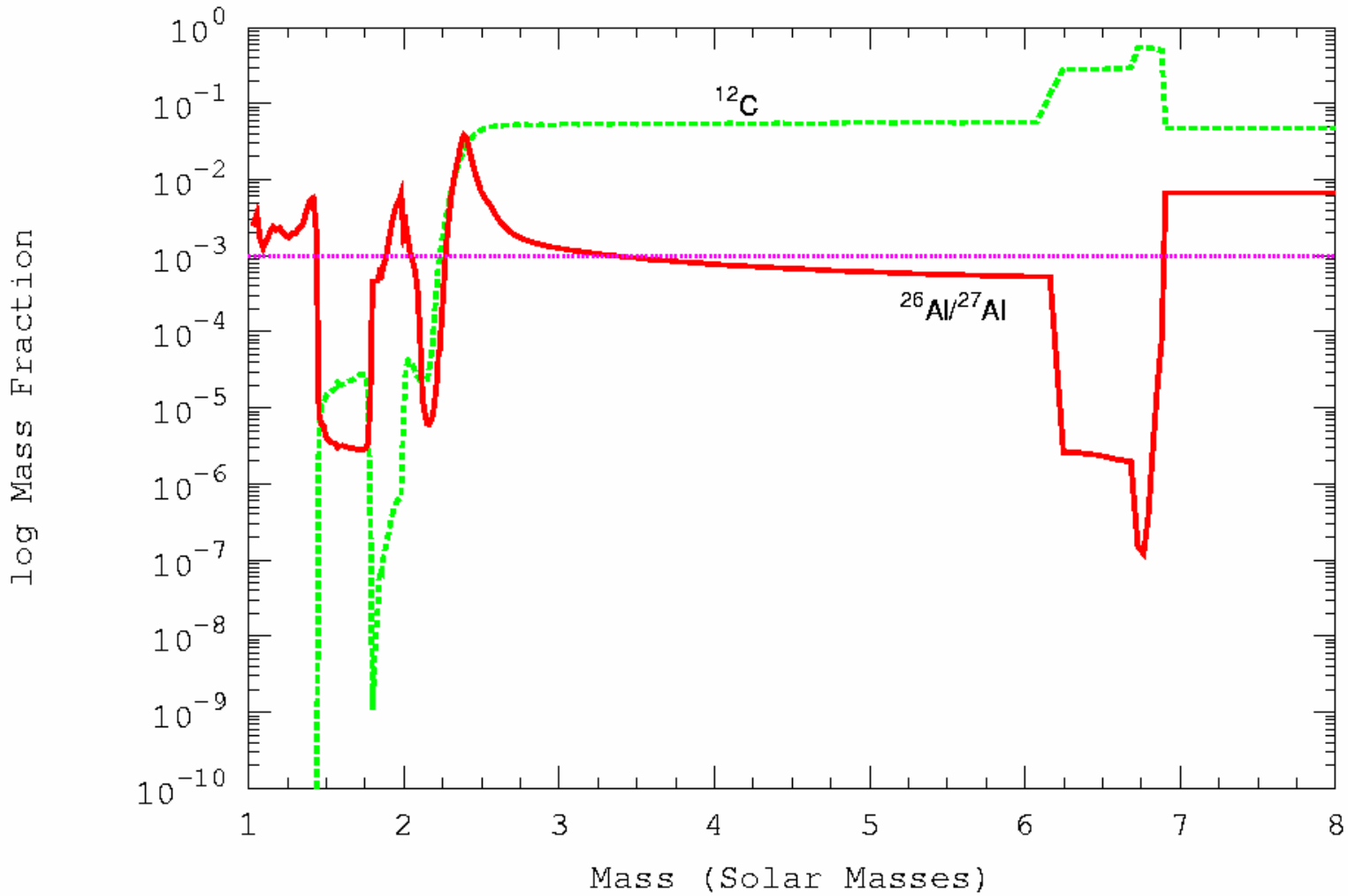
Limongi homepage

Pre SN - 25 M_{sun}



Limongi homepage

Post SN (9.2×10^4 s) $25 M_{\text{sun}}$

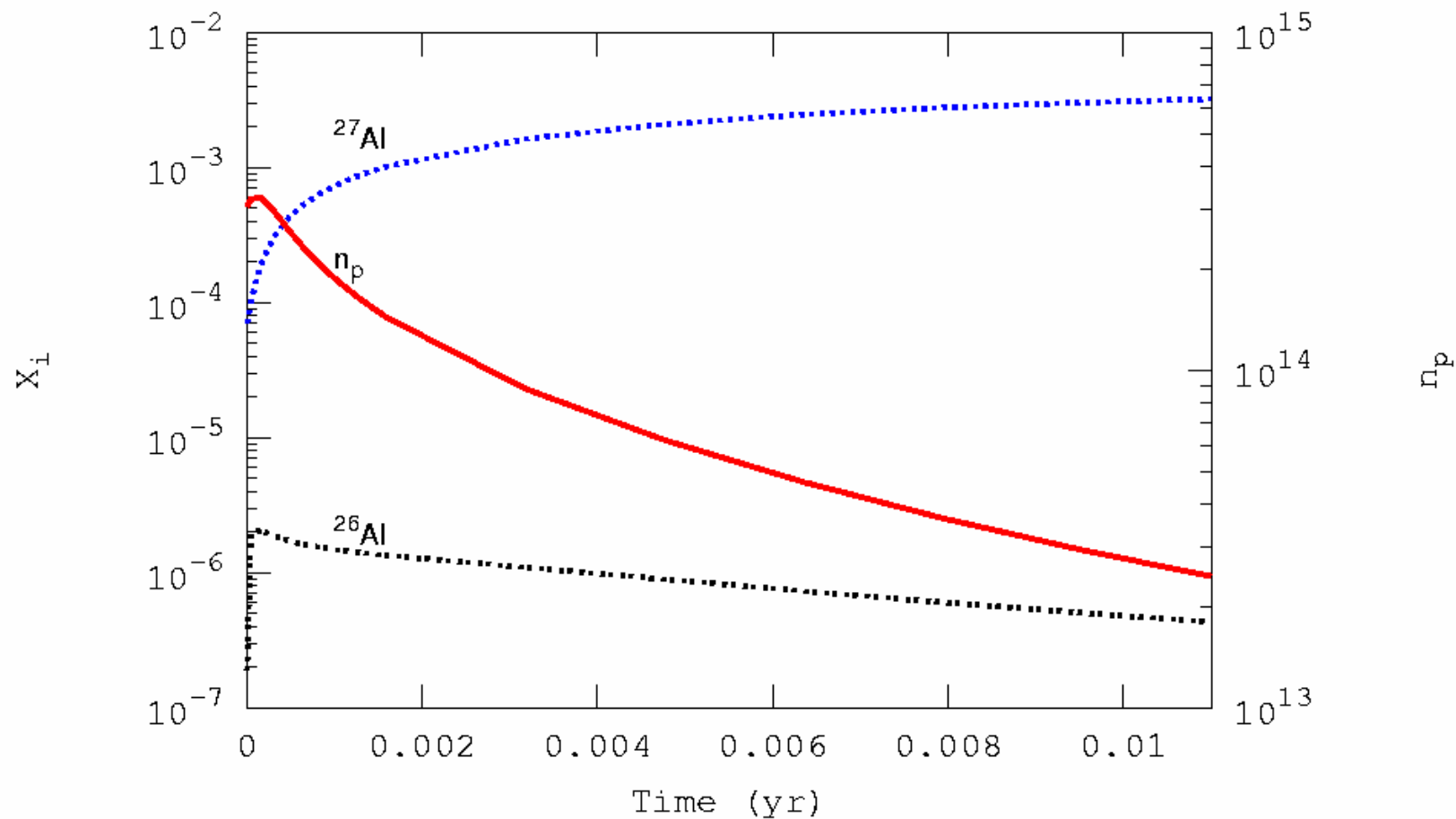


- Physics inputs from FRANEC code (Straniero et al 1989)
- Post processing model from Raiteri et al 1991

$25 M_{sun} Z=Z_{sun}$

standard case

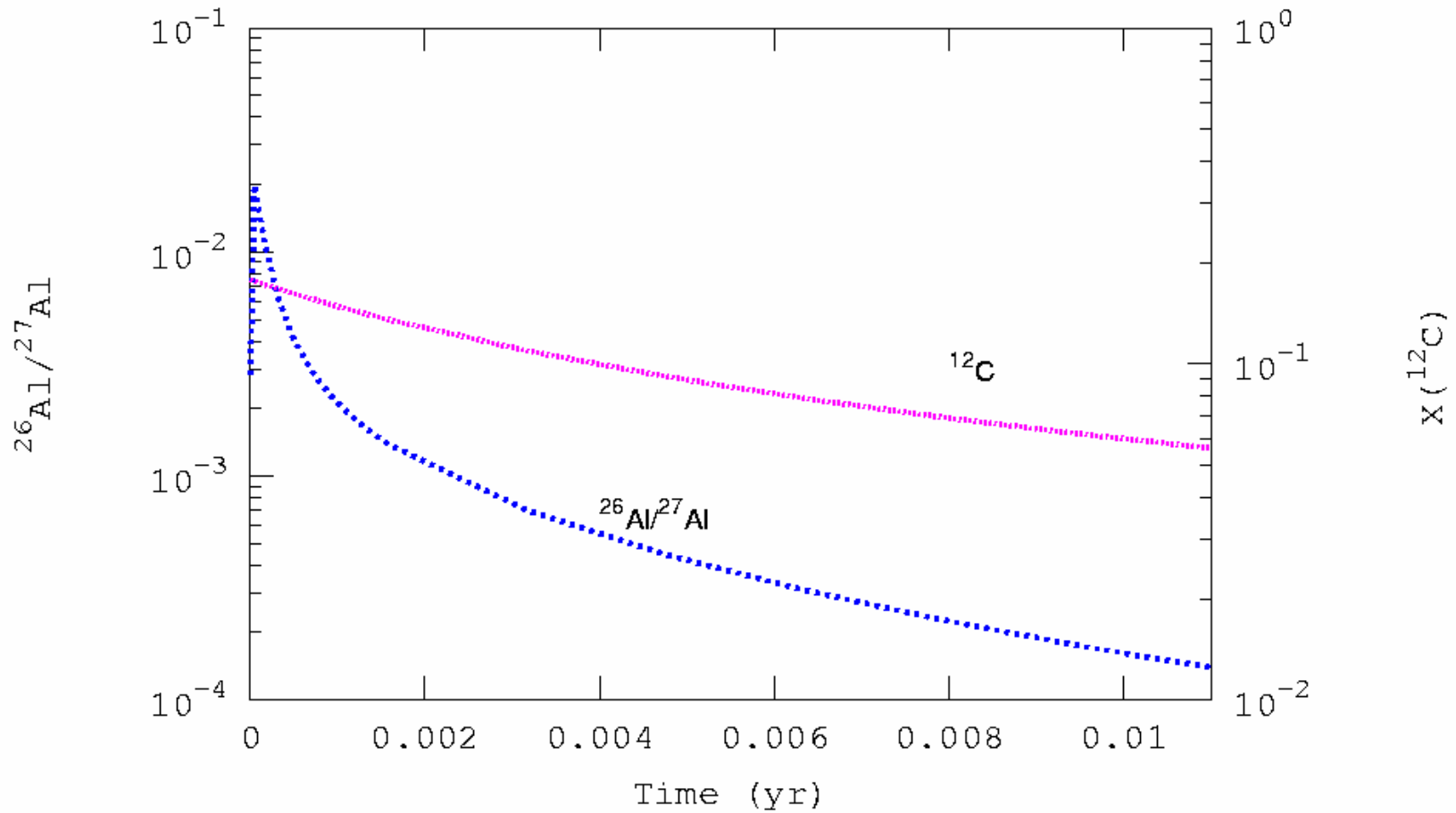
$T_{Cshell} = 1.1 * 10^9 K$



$25 M_{sun} Z=Z_{sun}$

standard case

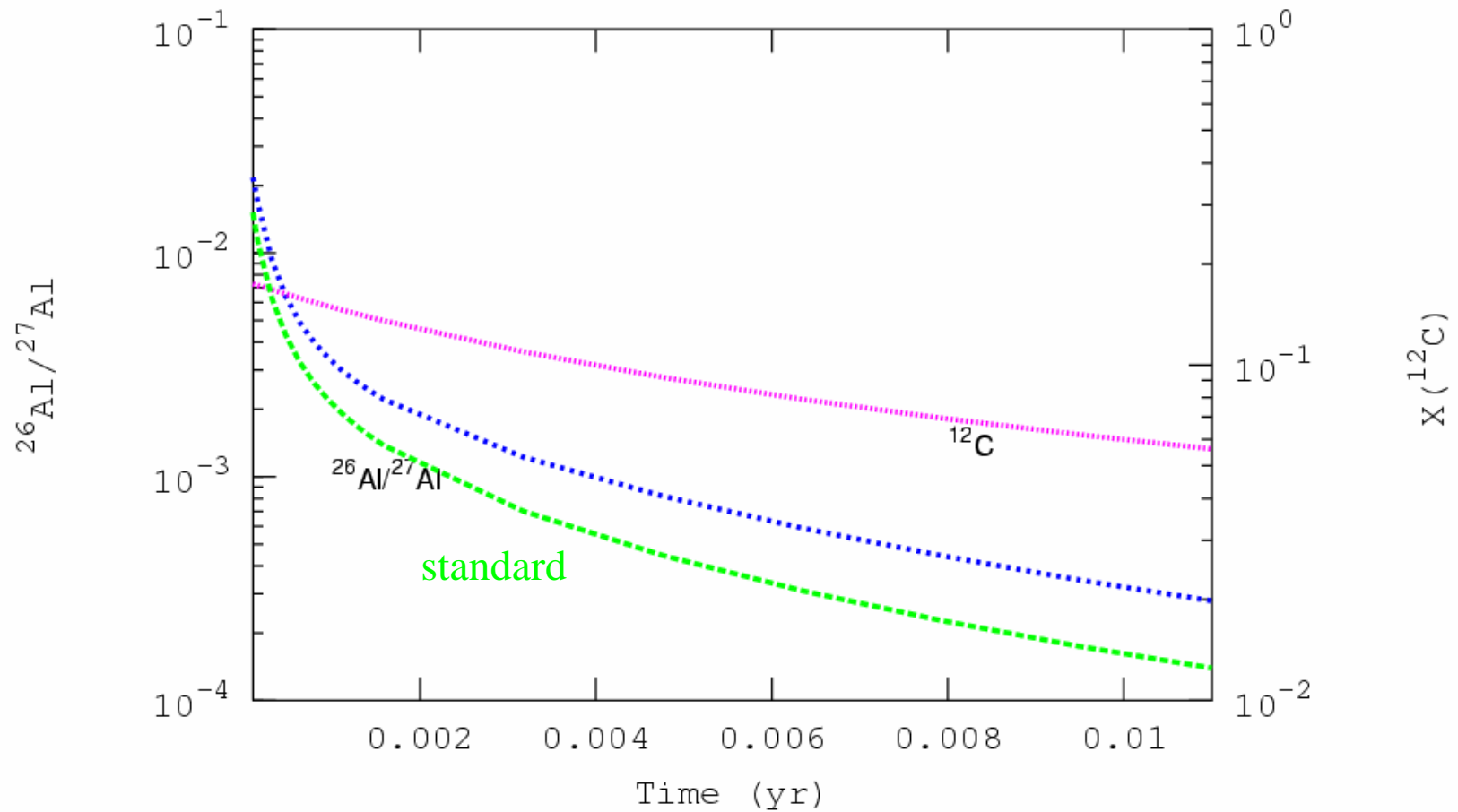
$T_{Cshell} = 1.1 * 10^9 K$



$25 M_{sun} Z=Z_{sun}$

$\lambda_{26}/2$

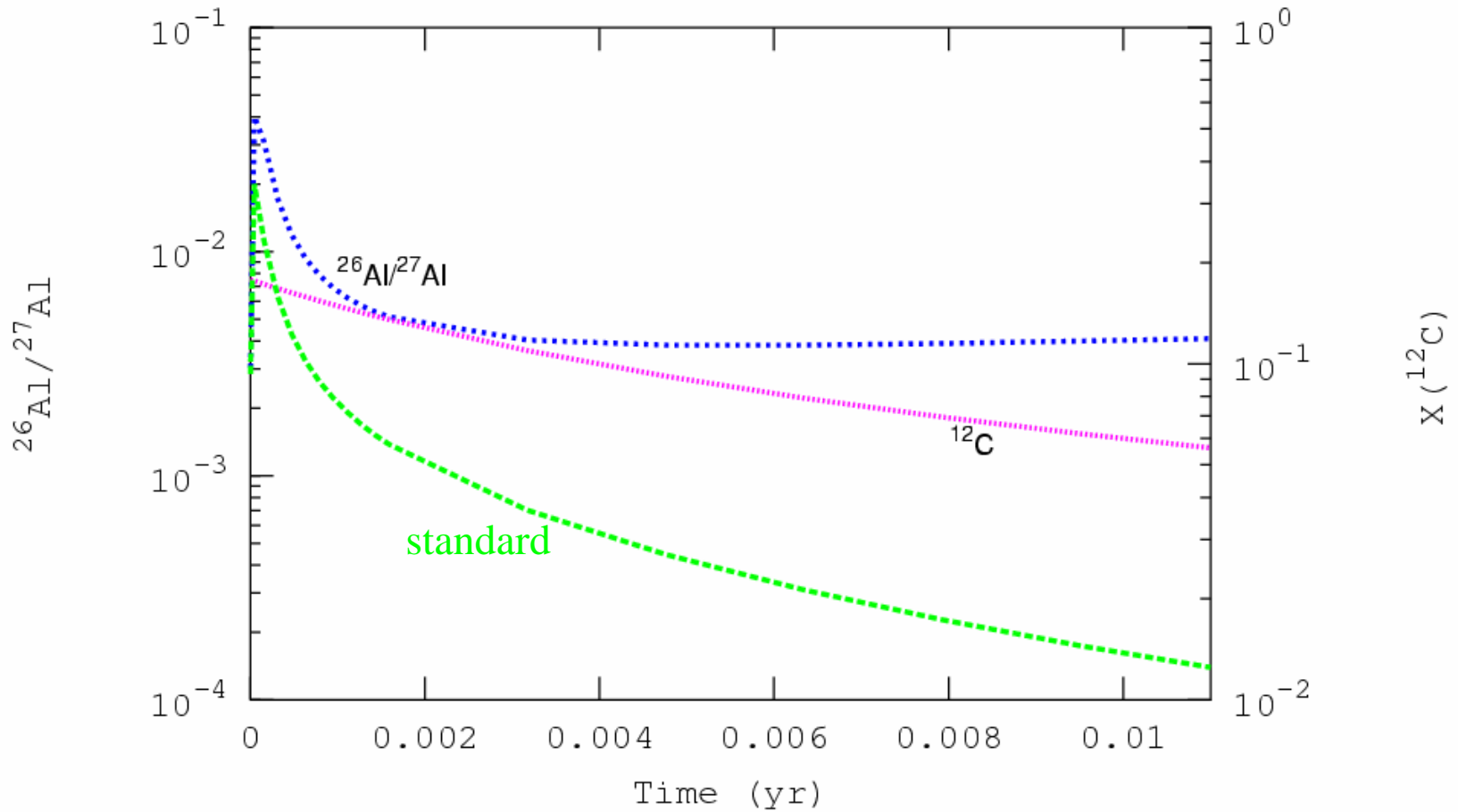
$T_{Cshell} = 1.1 * 10^9 K$



$25 M_{sun} Z=Z_{sun}$

λ_{26} earth value

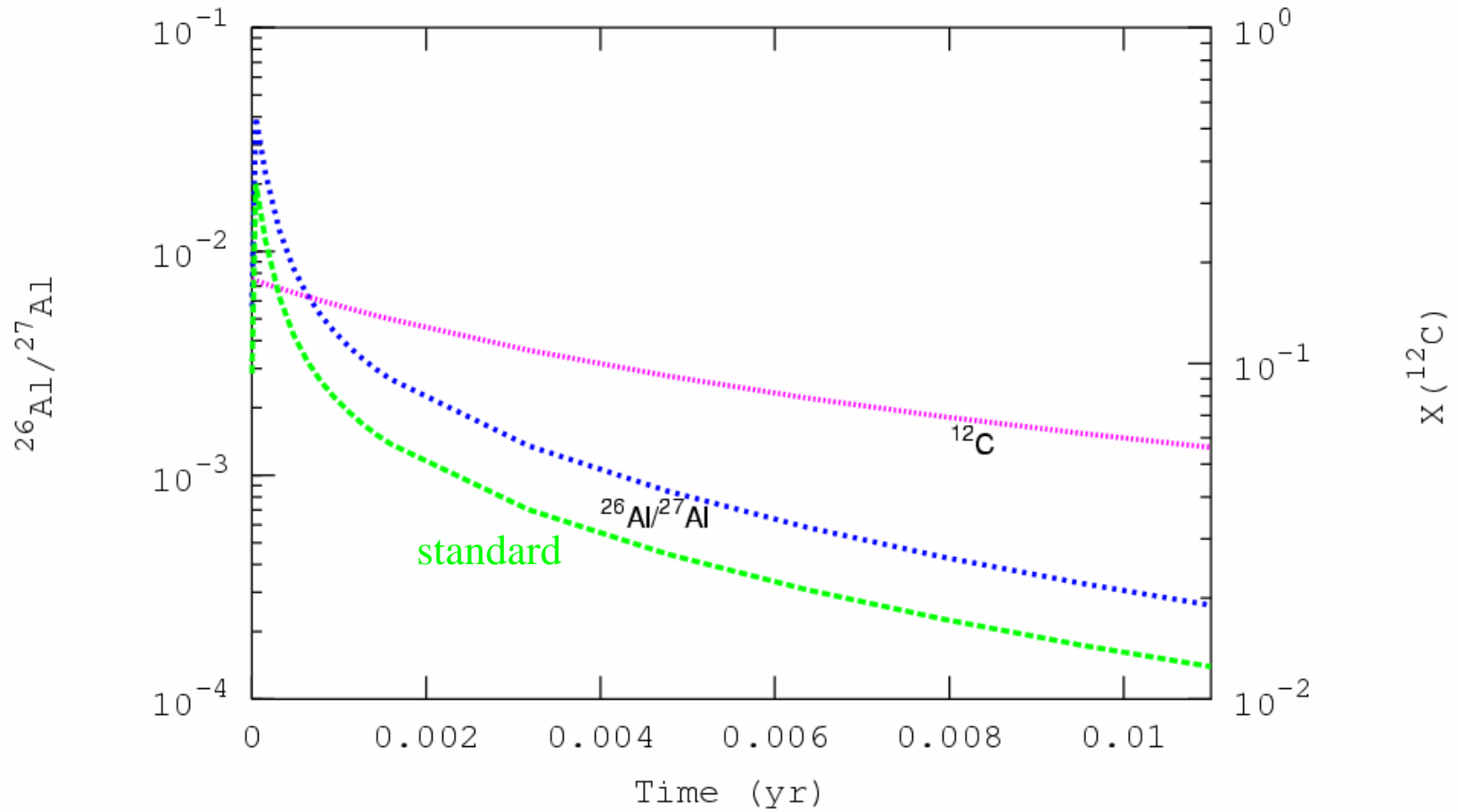
$T_{Cshell} = 1.1 * 10^9 K$



$25 M_{sun} Z=Z_{sun}$

rate $25Mg(p, \gamma)*2$

$T_{Cshell} = 1.1 * 10^9 K$



Conclusions

There is an important amount of ^{26}Al produced during the pre explosive shell Carbon burning.

Competition between production and destruction of ^{26}Al is dominated by beta decay on ^{26}Mg .

Nuclear uncertainties can contribute to improve the results, but only by factor ~2-3.