Sezione d'urto della reazione $^{17}O(p,\alpha)^{14}N$ come chiave di lettura della composizione di grani meteoritici

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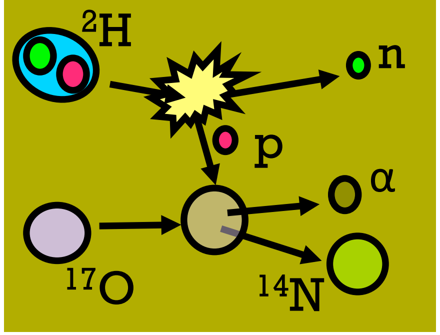
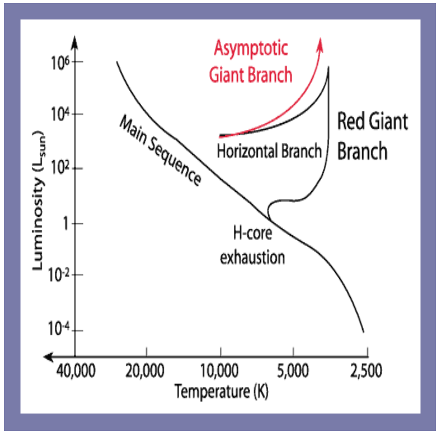
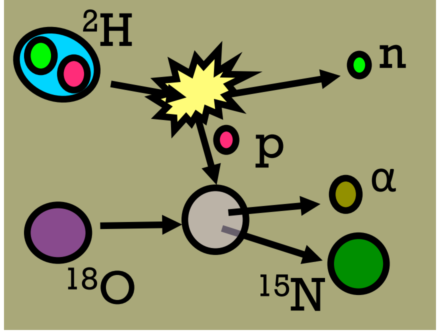
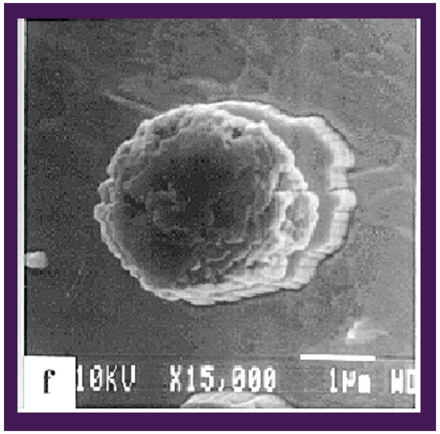
$^2H(^{17}O,\alpha^{14}N)n$:

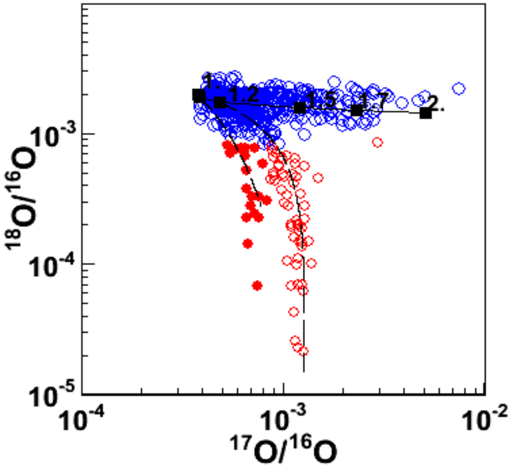




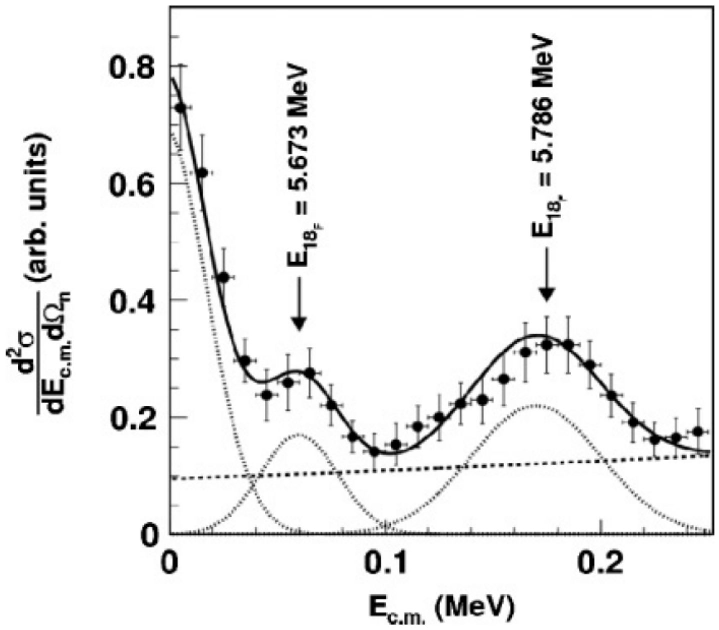
$^2H(^{18}O,\alpha^{15}N)n$:

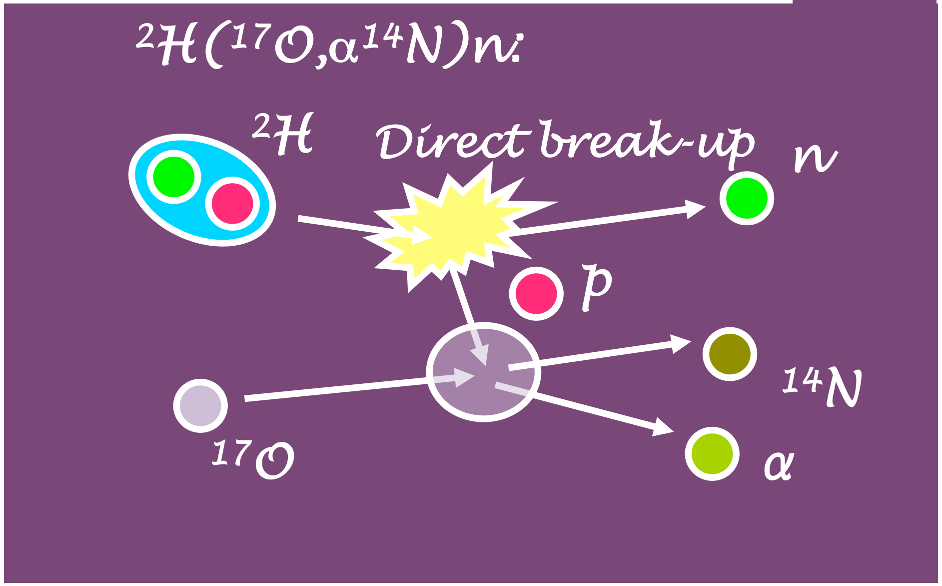






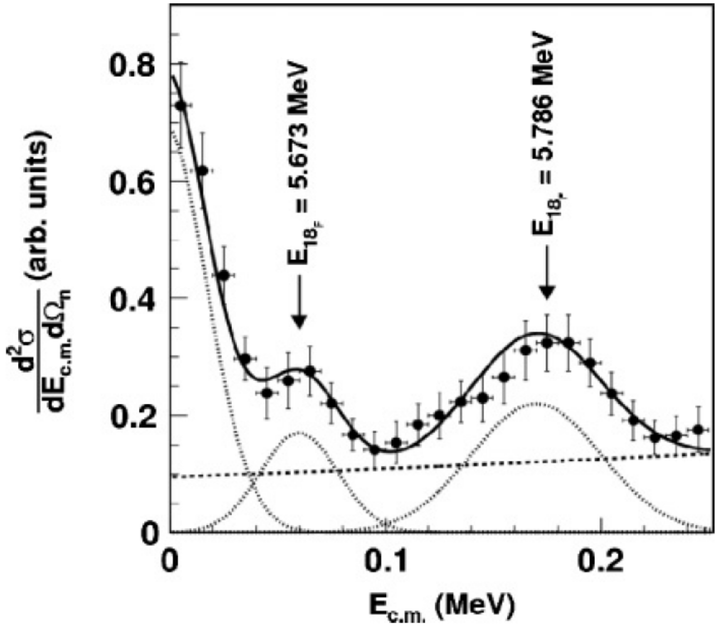
+ $^{17}O(p,\alpha)^{14}N$ fusion reaction measured by THM

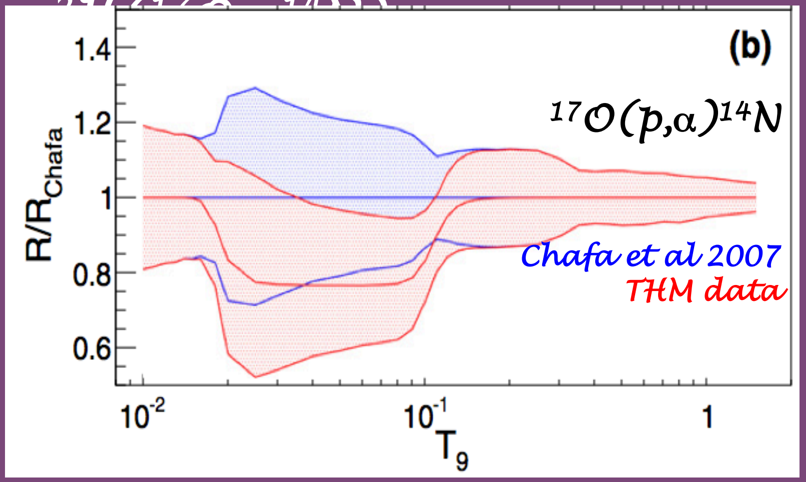



$^2H(^{17}O,\alpha^{14}N)n$:

ωγ (eV)	Sergi et al.2010 THM	Chafa et al. 2007	NACRE
65 keV	$3.4 \pm 0.6\ 10^{-6}$	$4.7 \pm 0.8 \cdot 10^{-9}$	$5.5^{+1.8}_{-1.0} \cdot 10^{-9}$
183 keV	$1.16 \pm 0.1\ 10^{-3}$	$1.66 \pm 0.1\ 10^{-3}$	$5.8^{+5.2}_{-5.8} \cdot 10^{-5}$

+ $^{17}O(p,\alpha)^{14}N$ fusion reaction measured by THM





Reaction rate reduction of 30%

ωγ (eV)	Sergi et al.2010 THM	Chafa et al. 2007	NACRE
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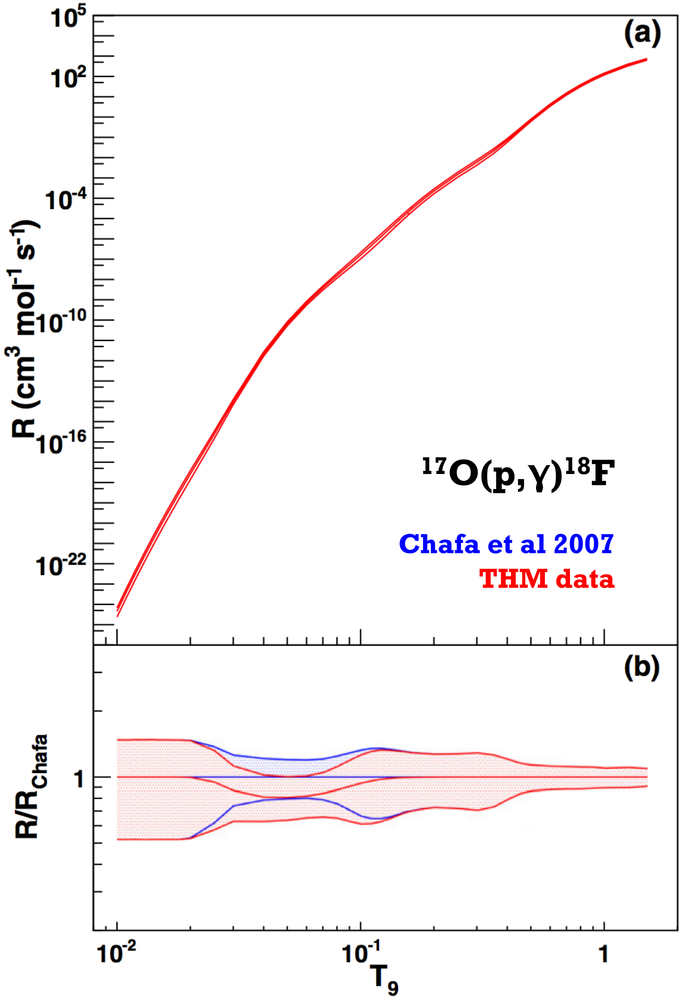
+ $^{17}O(p,\gamma)^{18}F$ Reaction rate determination …. from the strength definition:

$$(\omega\gamma)_i = \frac{2J_{^{18}F_i}+1}{(2J_{^{17}O}+1)(2J_p+1)}\,\frac{\Gamma_{(p^{17}O)_i}(E_{R_i})\,\Gamma_{(\alpha^{14}N)_i}(E_{R_i})}{\Gamma_i(E_{R_i})}$$



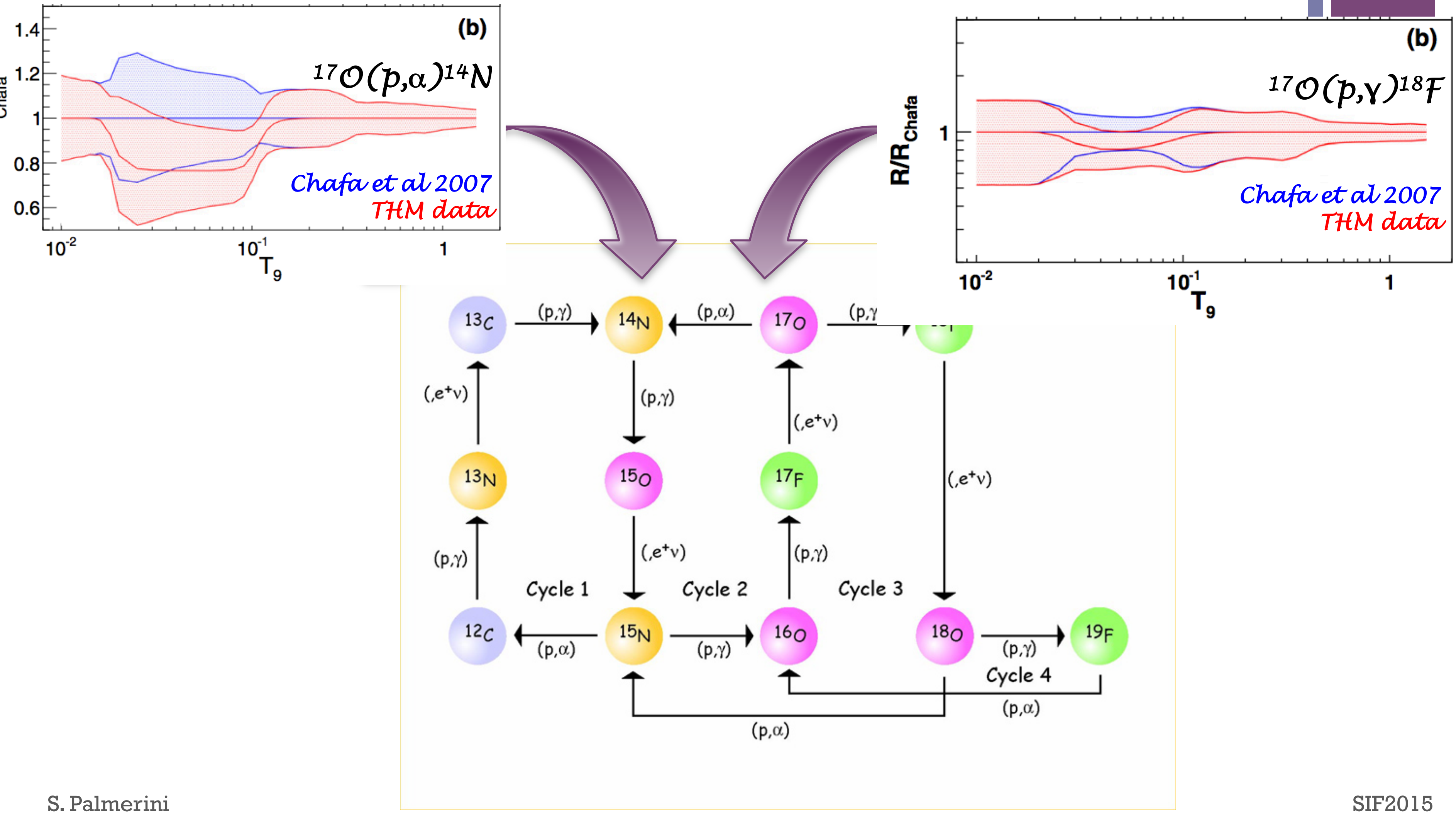
$$\Rightarrow \quad (\omega\gamma)^{THM}_{p\gamma} = (\omega\gamma)^{THM}_{p\alpha}\,\frac{\Gamma_\gamma}{\Gamma_\alpha}$$

$$(\omega\gamma)^{THM}_{p\gamma} = (1.18 \pm 0.22)\times 10^{-11}\,eV$$

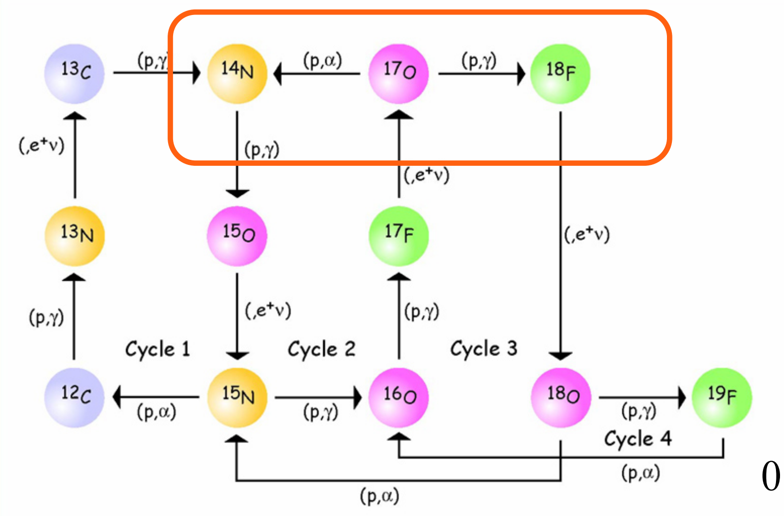
$$(\omega\gamma)_{p\gamma} = (1.64 \pm 0.28)\times 10^{-11}\,eV$$

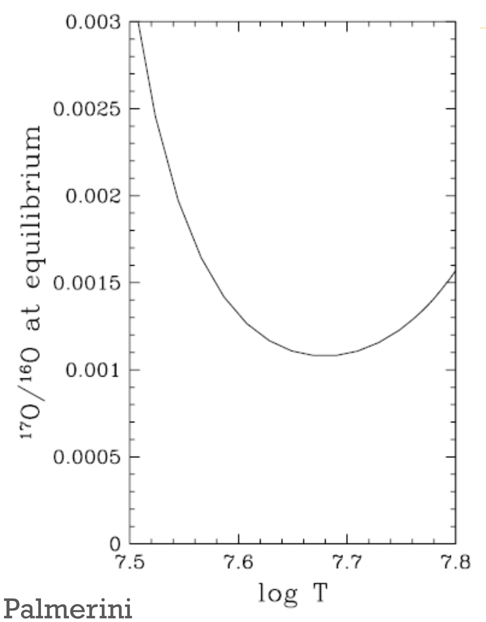
T=0.03-0.09 GK: the differences between the rate adopted in literature and the total rate calculated, if one considers the $N_A<\sigma v>_{65}^{THM}$ extracted as explained before, is ~25%.

+ $^{17}O(p,\alpha)^{14}N$ & $^{17}O(p,\gamma)^{18}F$ in stellar H-burning



+ $^{17}O/^{16}O$ as a stellar thermometer





$$\frac{dY_{^{17}O}}{dt} = Y_{^{16}O} Y_H N_A \langle\sigma v\rangle_{^{16}O(p,\gamma)^{17}F}\,\rho$$
$$-Y_{^{17}O} Y_H N_A \left(\langle\sigma v\rangle_{^{16}O(p,\gamma)^{17}F} + \langle\sigma v\rangle_{^{16}O(p,\alpha)^{14}N}\right)\rho$$

Equilibrium conditions:

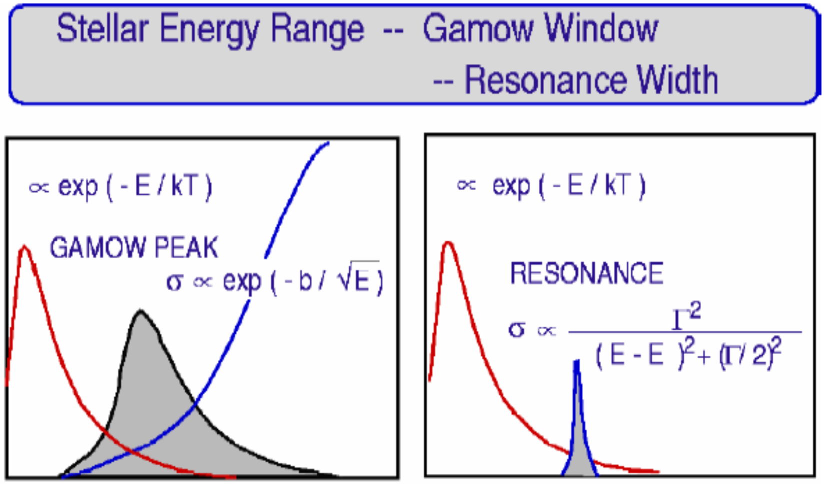
$$0 = Y_{^{16}O} Y_H N_A \langle\sigma v\rangle_{^{16}O(p,\gamma)^{17}F}\,\rho - Y_{^{17}O} Y_H N_A \left(\langle\sigma v\rangle_{^{17}O(p,\gamma)^{18}F} + \langle\sigma v\rangle_{^{17}O(p,\alpha)^{14}N}\right)\rho$$

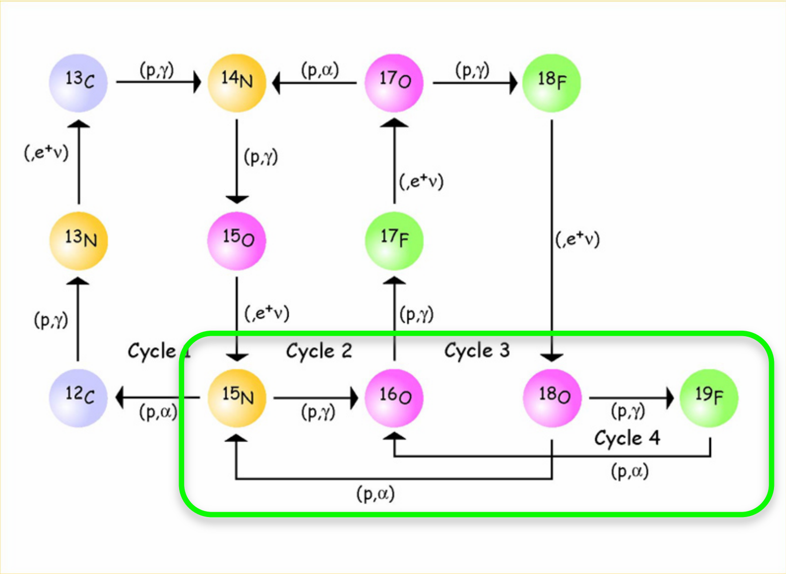
$$Y_{^{16}O} Y_H N_A \langle\sigma v\rangle_{^{16}O(p,\gamma)^{17}F}\,\rho = Y_{^{17}O} Y_H N_A \left(\langle\sigma v\rangle_{^{17}O(p,\gamma)^{18}F} + \langle\sigma v\rangle_{^{17}O(p,\alpha)^{14}N}\right)\rho$$

$$\boxed{\frac{Y_{^{16}O}}{Y_{^{17}O}} = \frac{N_A \langle\sigma v\rangle_{^{17}O(p,\gamma)^{18}F} + N_A \langle\sigma v\rangle_{^{17}O(p,\alpha)^{14}N}}{N_A \langle\sigma v\rangle_{^{16}O(p,\gamma)^{17}F}}}$$

$^{17}O/^{16}O$ equilibrium value depends on reaction rates and gives us information about the mixing depth

+ Nuclear physics of H-burning





High uncertainties in nuclear physics input because of the low energies at which reactions take place

Temperature:

8.3 10^7 K ↔ 3 10^6K

~~Conversion Factors Between Units of Energy~~

~~3.45 kev ↔ 0.25 keV~~

Most effective energy (^{17}O +p reactions)

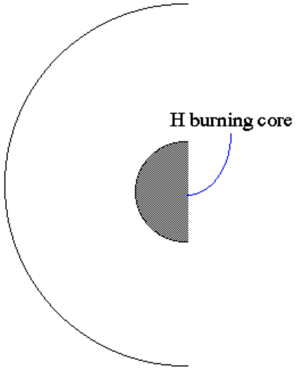
125 keV ↔ 36.5 keV

$$N_{\rm A}\langle\sigma v\rangle = N_{\rm A}\frac{(8/\pi)^{1/2}}{\mu^{1/2}(k_{\rm B}T)^{3/2}}\int_0^\infty \sigma E\exp(-E/k_{\rm B}T)\,dE,$$

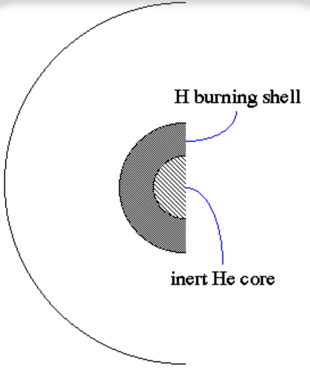
$$E_0 = \left(\frac{\mu}{2}\right)^{1/3}\left(\frac{\pi e^2 Z_1 Z_2 k_{\rm B} T}{\hbar}\right)^{2/3} = 0.1220(Z_1^2 Z_2^2 A)^{1/3} T_9^{2/3}\ \text{MeV}$$

+ Low mass star evolution: RGB and AGB phase

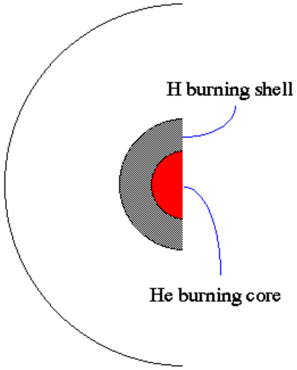
- The lower is the mass, the larger is the number of stars
- $M<3M_{\odot}$



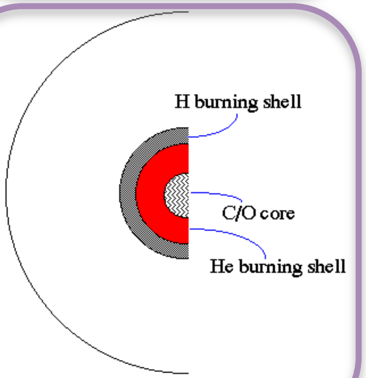
Main Sequence Star



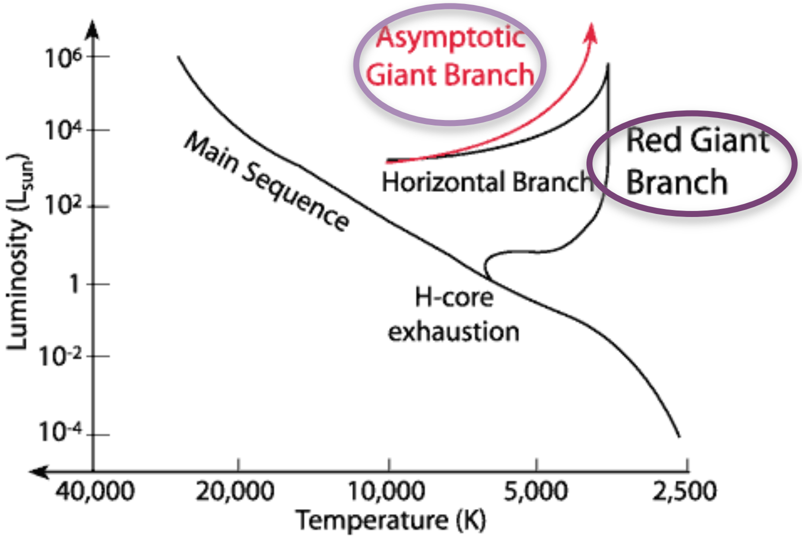
Red Giant Star

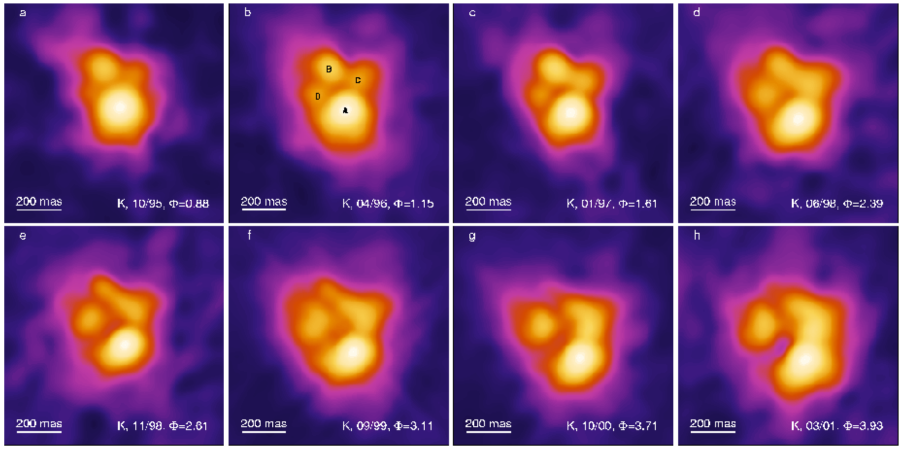


Horizontal Branch Star



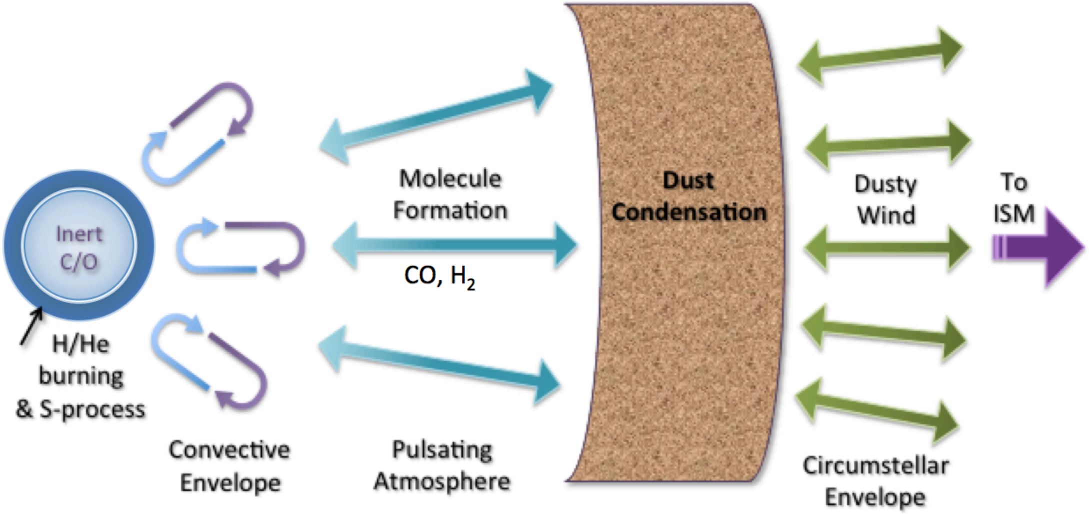
Asymptotic Giant Branch Star

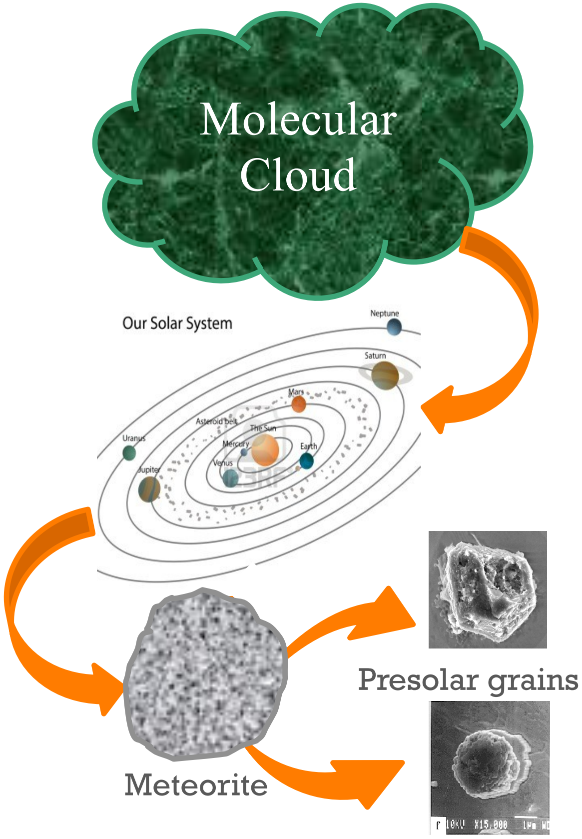


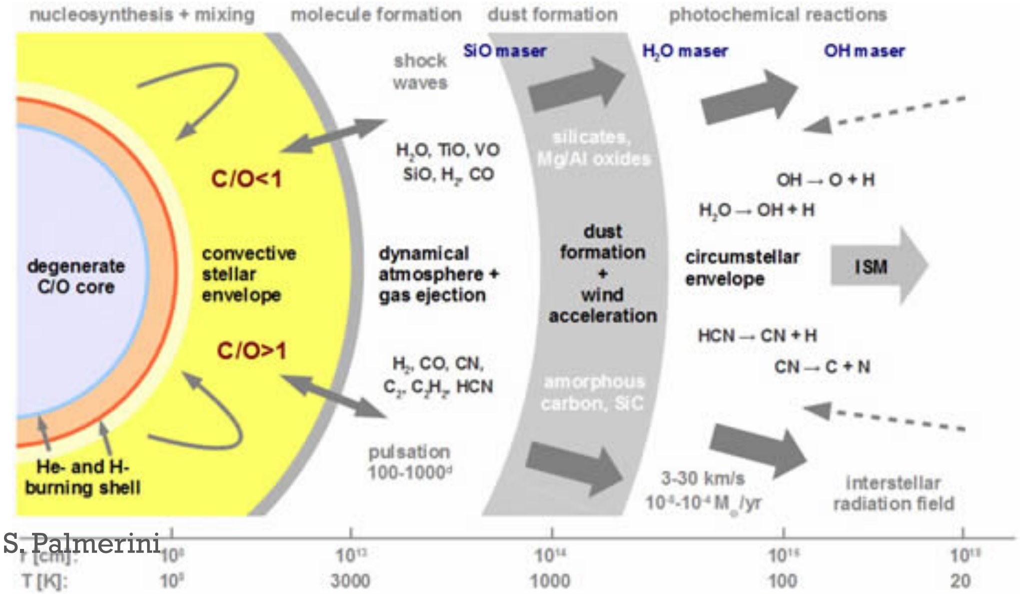


IRC+10216 C-star is the brightest object on the sky at at mid infrared

+ Red giant stars contribution to the galatic chemical evolution







+ Types of presolar grains

which can be isolated from meteorites in almost pure form by chemical and physical processing

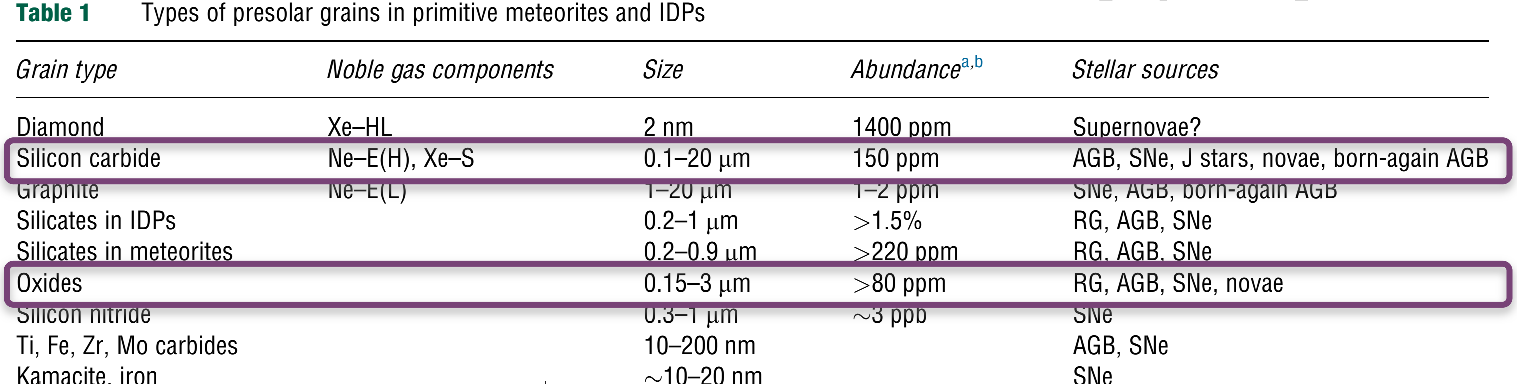


Table 1 Types of presolar grains in primitive meteorites and IDPs

Grain type	*Noble gas components*	*Size*	*Abundance*[a,b]	*Stellar sources*
Diamond	Xe–HL	2 nm	1400 ppm	Supernovae?
Silicon carbide	Ne–E(H), Xe–S	0.1–20 μm	150 ppm	AGB, SNe, J stars, novae, born-again AGB
Graphite	Ne–E(L)	1–20 μm	1–2 ppm	SNe, AGB, born-again AGB
Silicates in IDPs		0.2–1 μm	>1.5%	RG, AGB, SNe
Silicates in meteorites		0.2–0.9 μm	>220 ppm	RG, AGB, SNe
Oxides		0.15–3 μm	>80 ppm	RG, AGB, SNe, novae
Silicon nitride		0.3–1 μm	∼3 ppb	SNe
Ti, Fe, Zr, Mo carbides		10–200 nm		AGB, SNe
Kamacite, iron		∼10–20 nm		SNe

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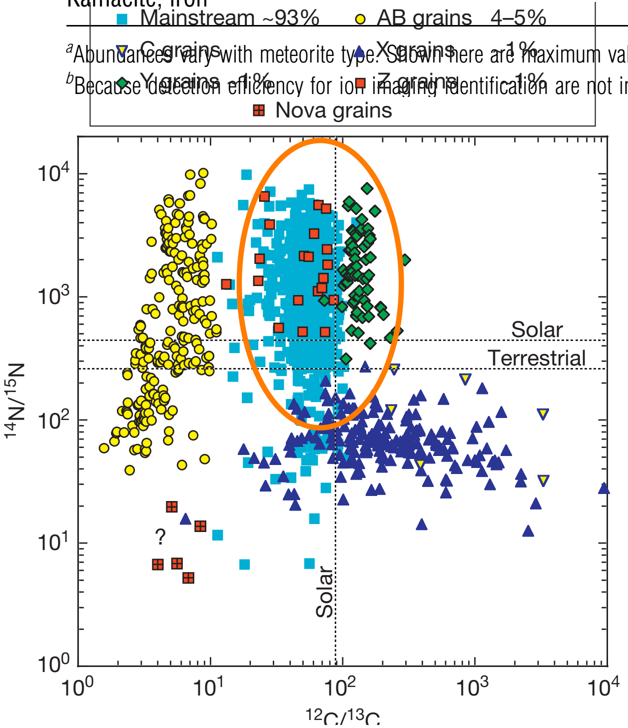
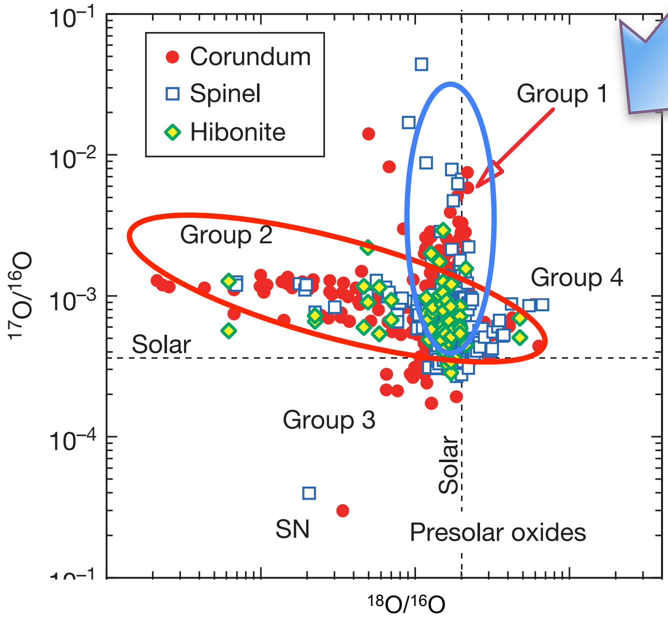
[a] Abundances vary with meteorite type. Shown here are maximum values.

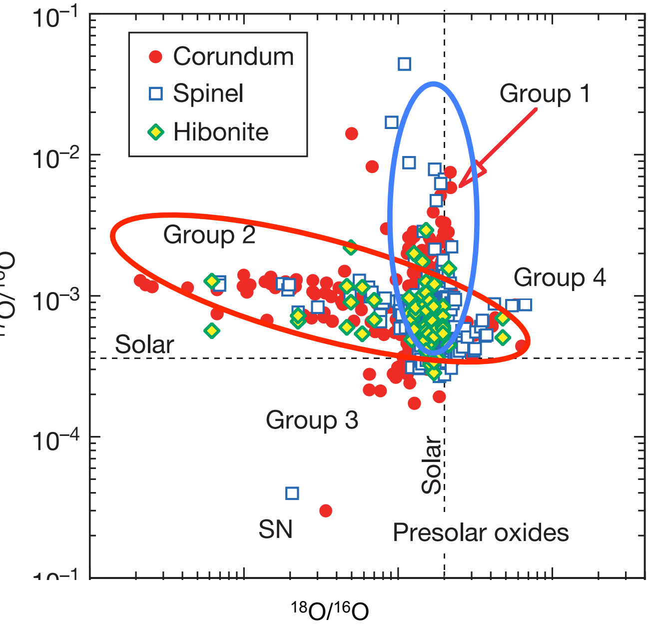
[b] Because detection efficiency for ion imaging identification are not included, given abundances are lower limits (see Nguyen et al., 2007).

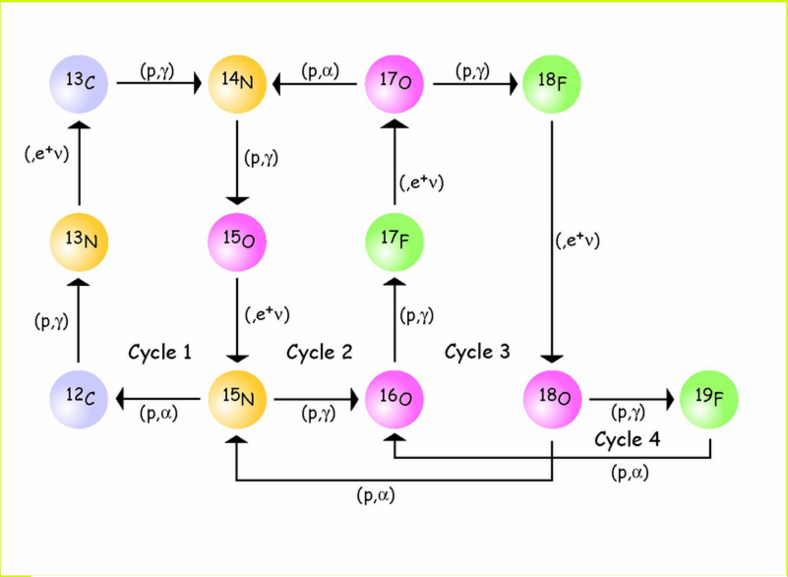


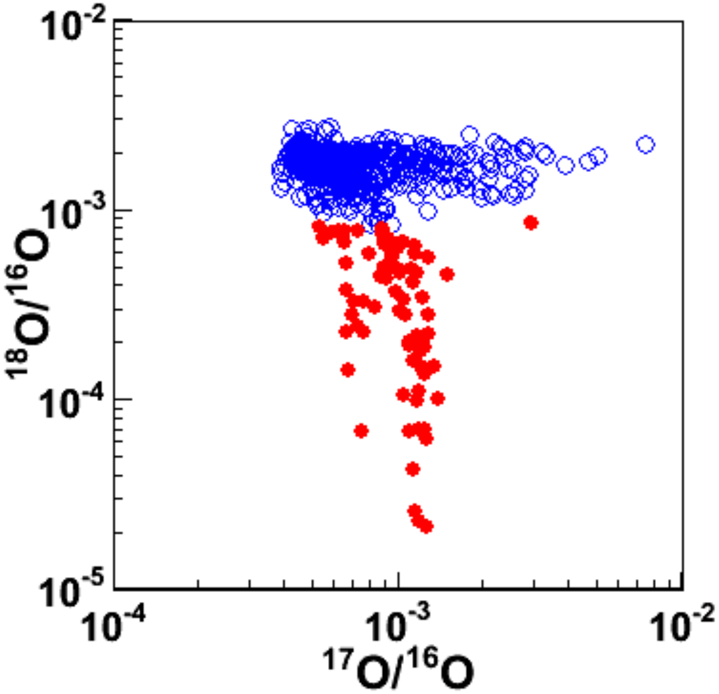


- C/O≥1 SiC grains
- C/O<1 Oxide grains

+ Grains & challenges from RGB & AGB stars



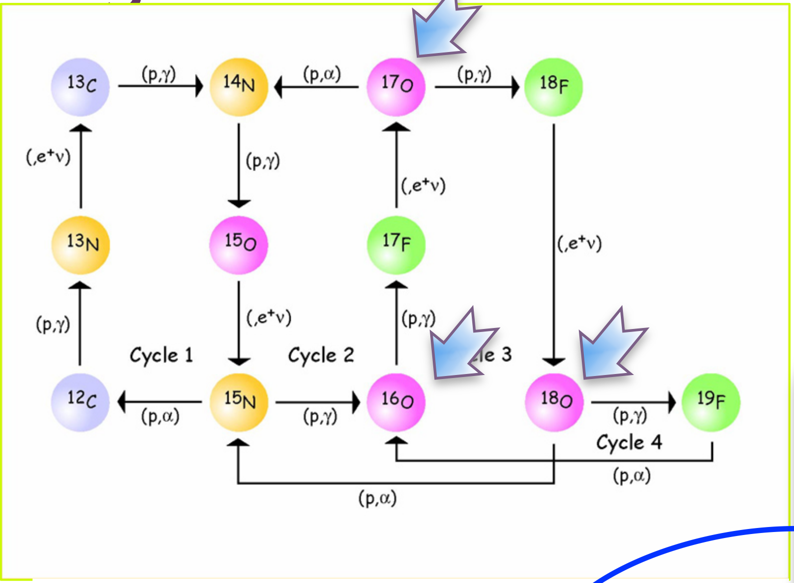


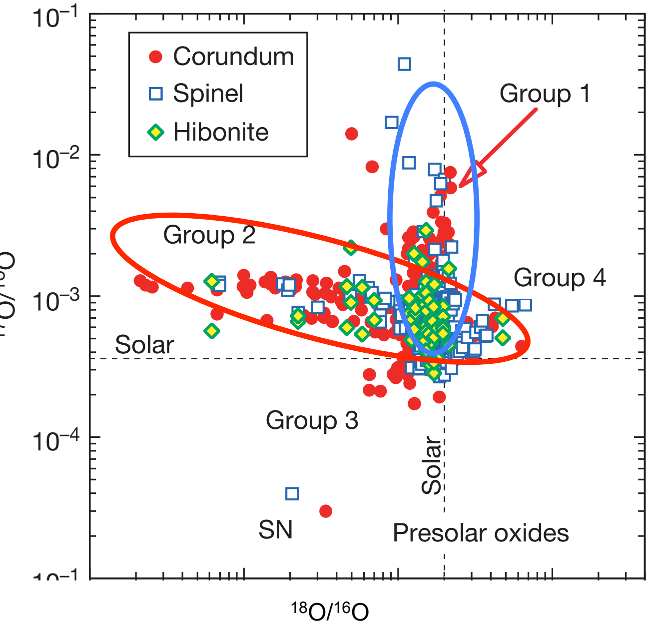


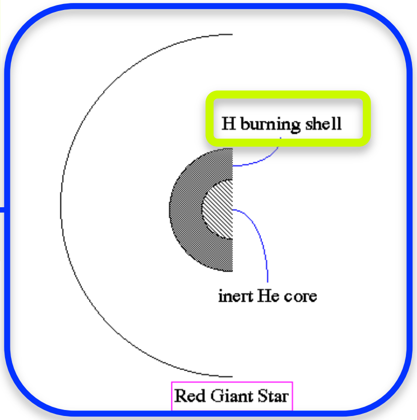
C/O<1 Oxide grains
From stars with $M<2.5M_\odot$

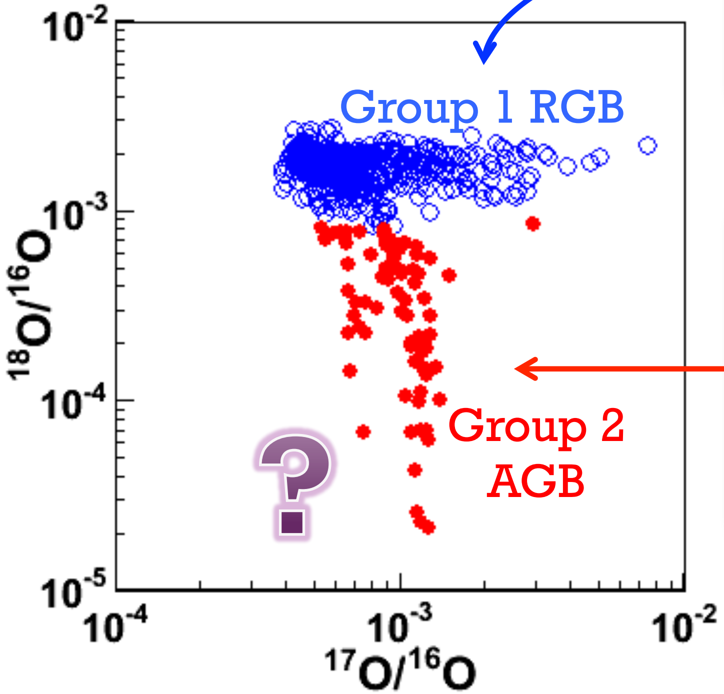
S. Palmerini

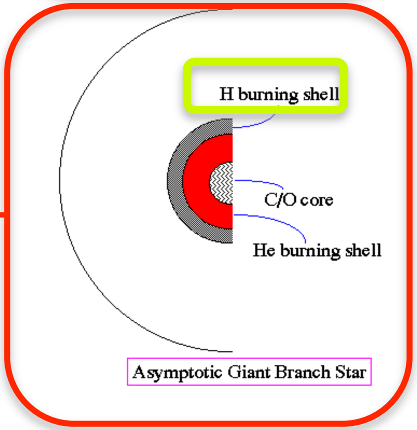
+ Grains & challenges from RGB & AGB stars





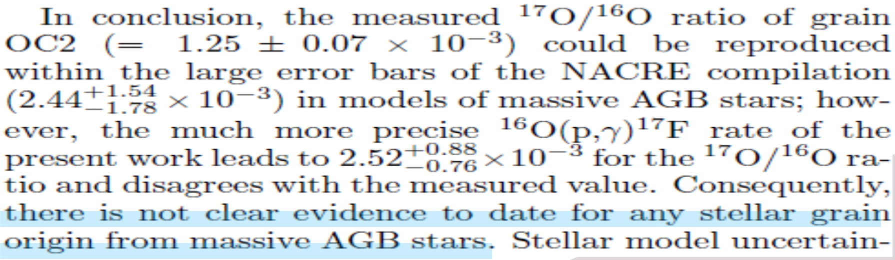






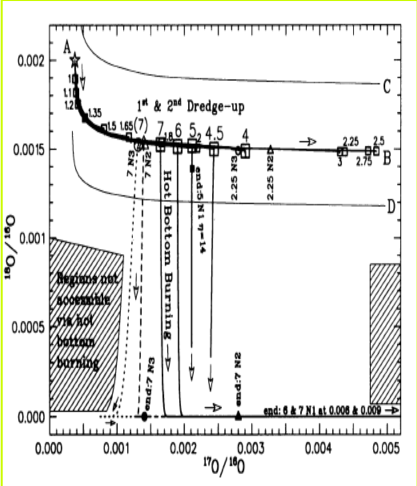
C/O<1 Oxide grains
From stars with $M<2.5M_\odot$

+ Oxide grains of AGB origin: HBB or CBP?



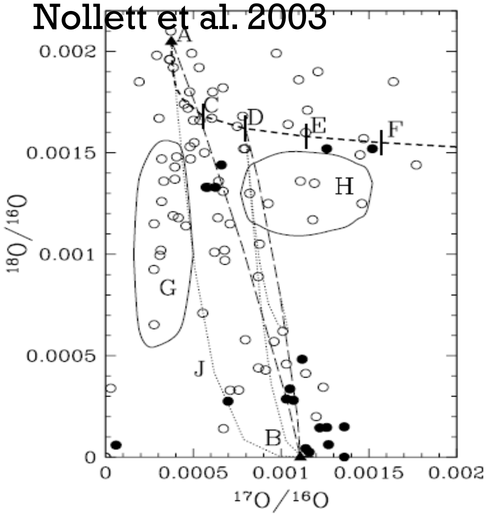
In conclusion, the measured $^{17}O/^{16}O$ ratio of grain OC2 ($= 1.25 \pm 0.07 \times 10^{-3}$) could be reproduced within the large error bars of the NACRE compilation ($2.44^{+1.54}_{-1.78} \times 10^{-3}$) in models of massive AGB stars; however, the much more precise $^{16}O(p,\gamma)^{17}F$ rate of the present work leads to $2.52^{+0.88}_{-0.76} \times 10^{-3}$ for the $^{17}O/^{16}O$ ratio and disagrees with the measured value. Consequently, there is not clear evidence to date for any stellar grain origin from massive AGB stars. Stellar model uncertain-

Iliadis et al 2008

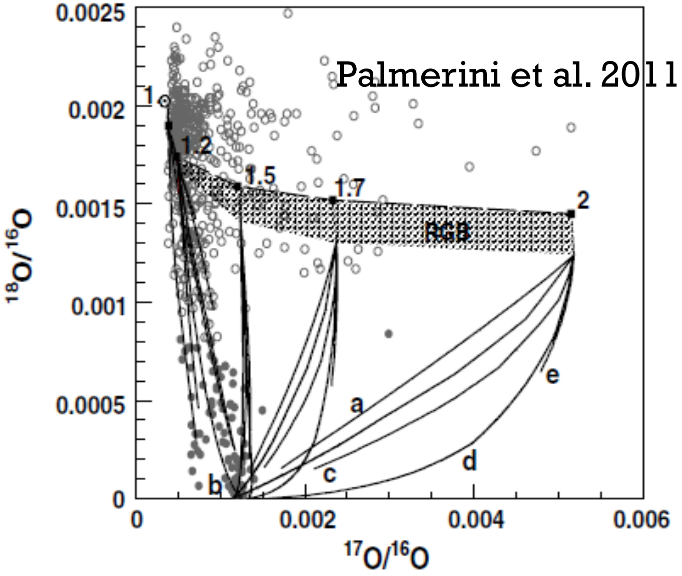


Boothroyd, Sackmann & Wasserburg 1995

Nollett et al. 2003

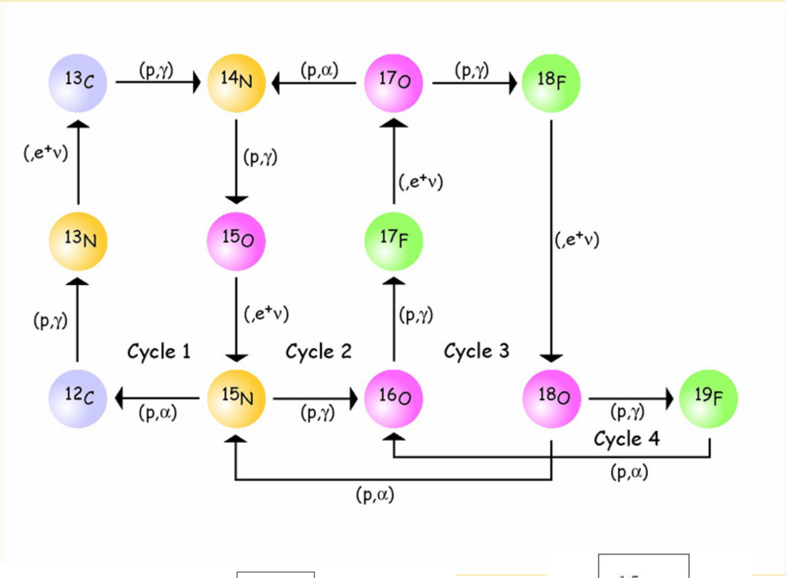


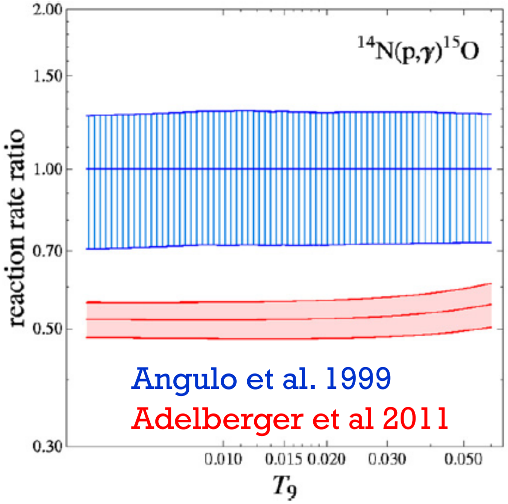
Palmerini et al. 2011

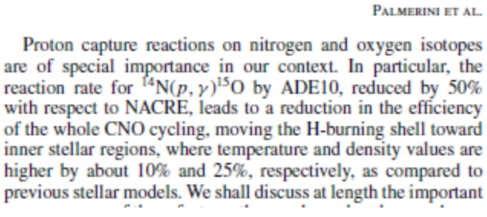


Variation of the ~~$^{14}N(p,\gamma)^{15}O$ reaction rate~~

H-burning temperture







PALMERINI ET AL.

Proton capture reactions on nitrogen and oxygen isotopes are of special importance in our context. In particular, the reaction rate for $^{14}N(p,\gamma)^{15}O$ by ADE10, reduced by 50% with respect to NACRE, leads to a reduction in the efficiency of the whole CNO cycling, moving the H-burning shell toward inner stellar regions, where temperature and density values are higher by about 10% and 25%, respectively, as compared to previous stellar models. We shall discuss at length the important

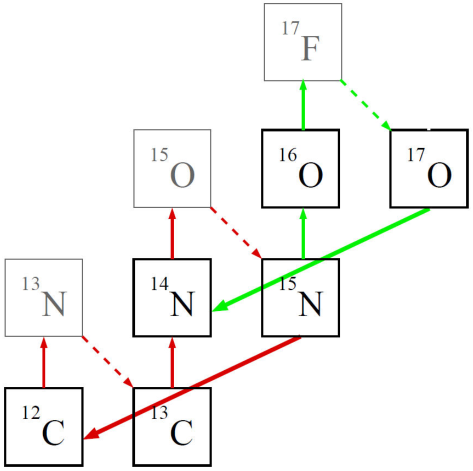


Figure: (p,γ) solid line, (p,αγ) bold and β^+ decay dashed line

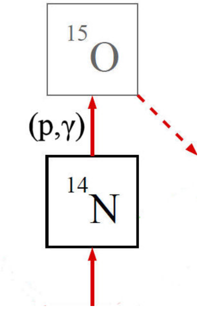
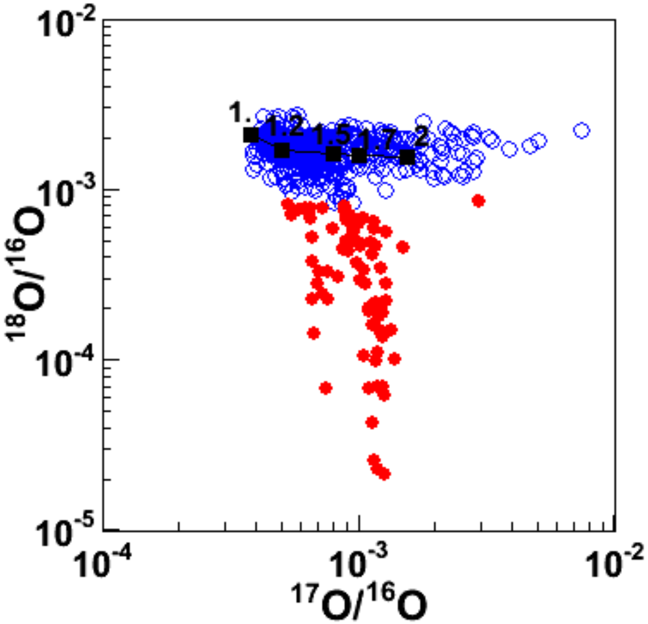
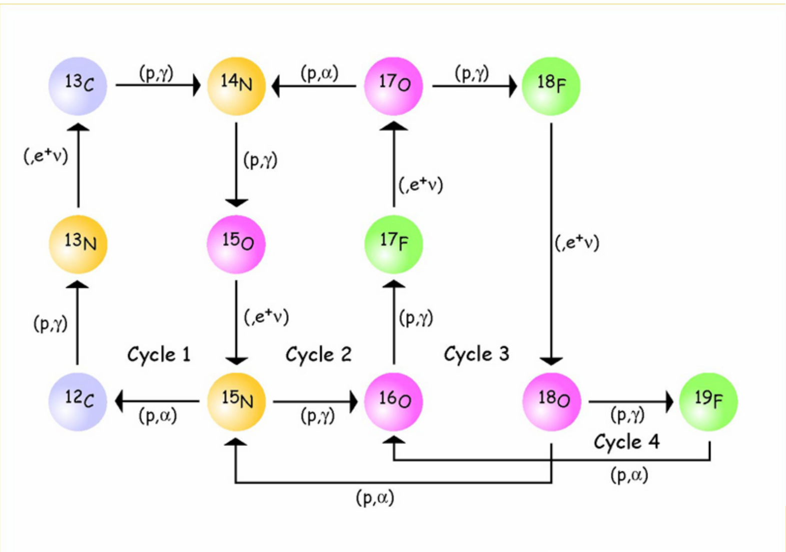


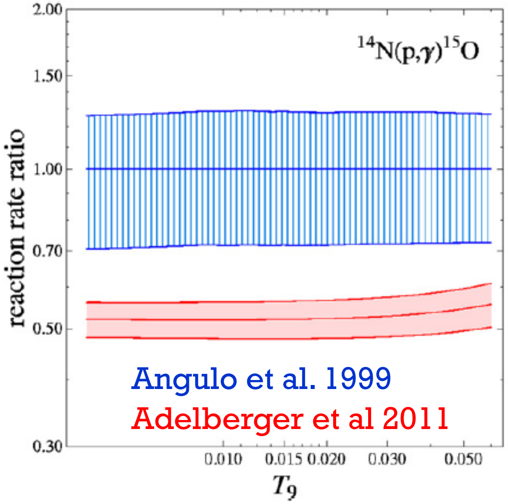
Figure:
$^{14}N + p \rightarrow ^{15}O + \gamma$

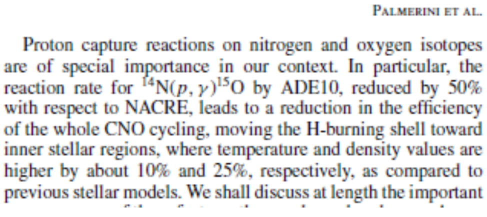


H-burning temperture

Variation of the ~~$^{14}N(p,\gamma)^{15}O$ reaction rate~~



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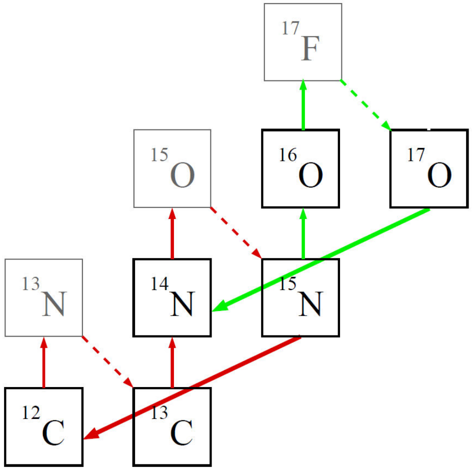


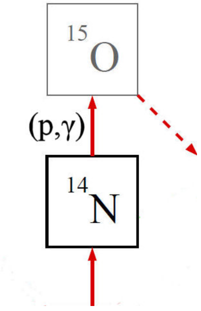


Figure:
$^{14}N + p \rightarrow ^{15}O + \gamma$

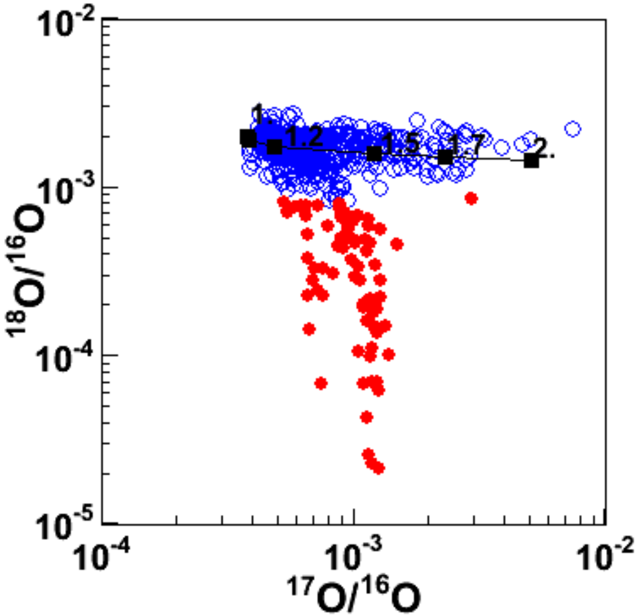
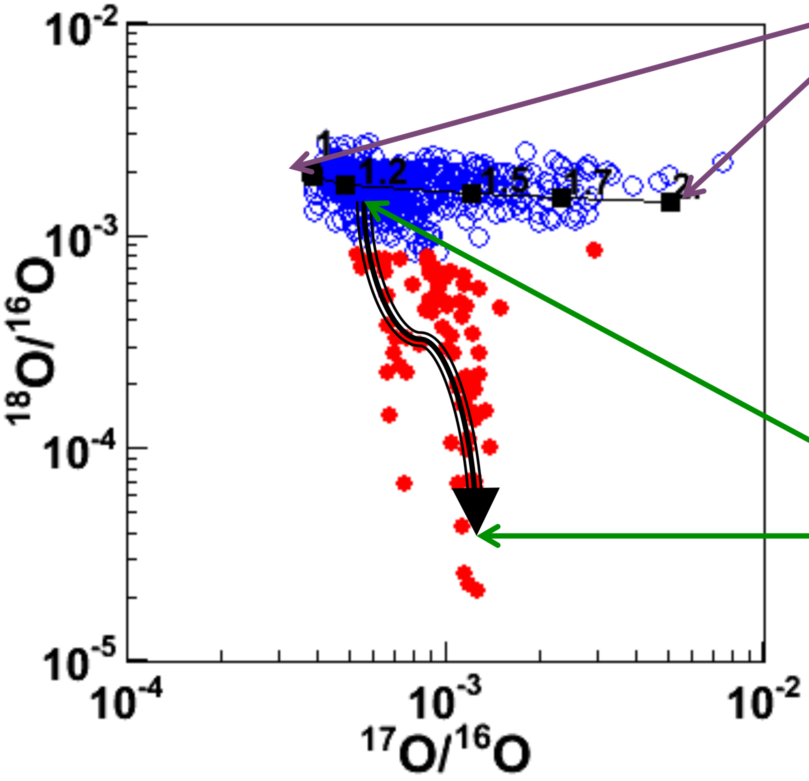
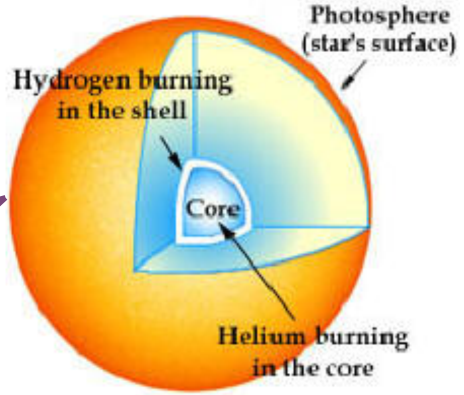


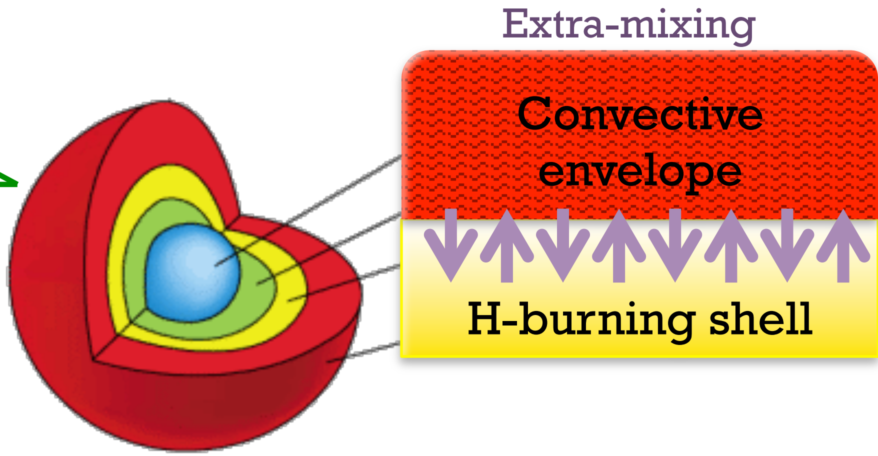
Figure: (p,γ) solid line, (p,αγ) bold and β^+ decay dashed line

$^{17}O+p$ reaction rates and Oxide grains



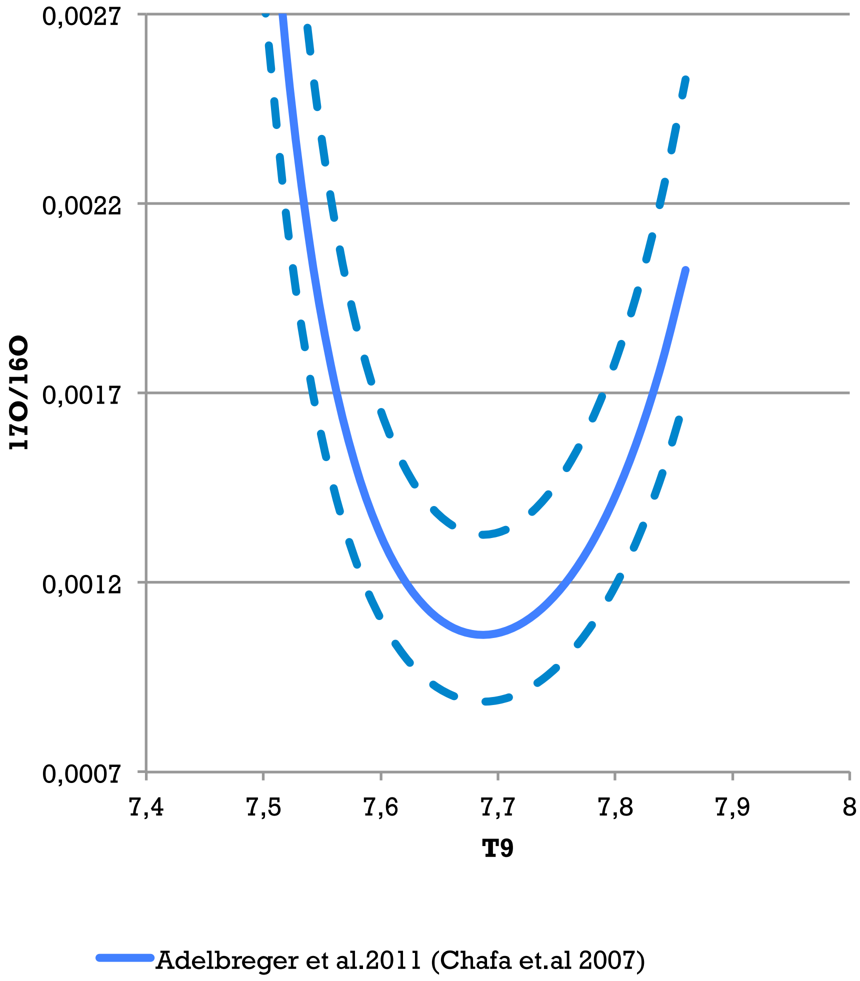


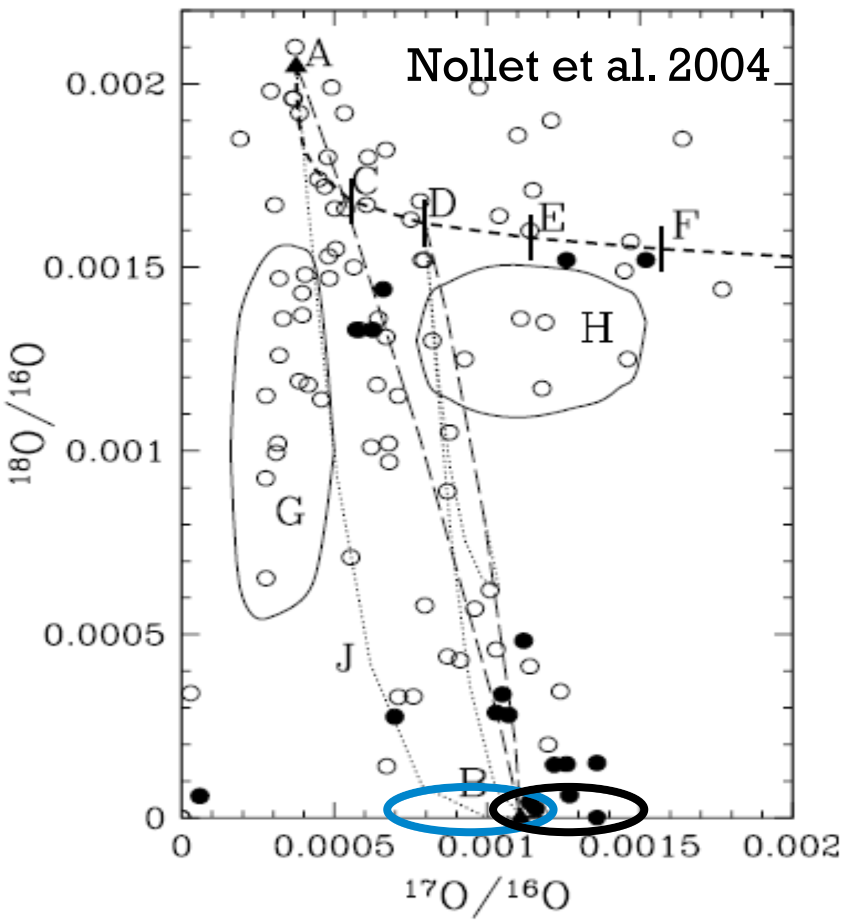
- RGB stars with $1M_{\odot}<M_{\star}<2M_{\odot}$ and solar composition



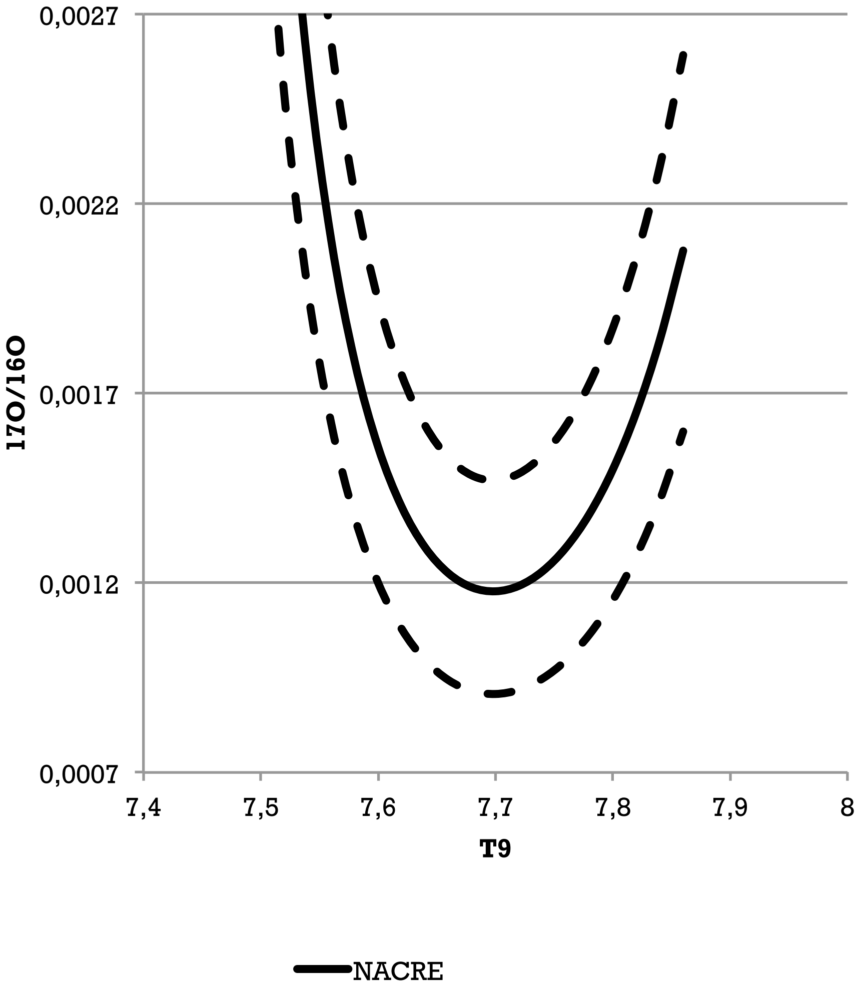
- AGB stars with $M_{\star}<2M_{\odot}$ and solar composition

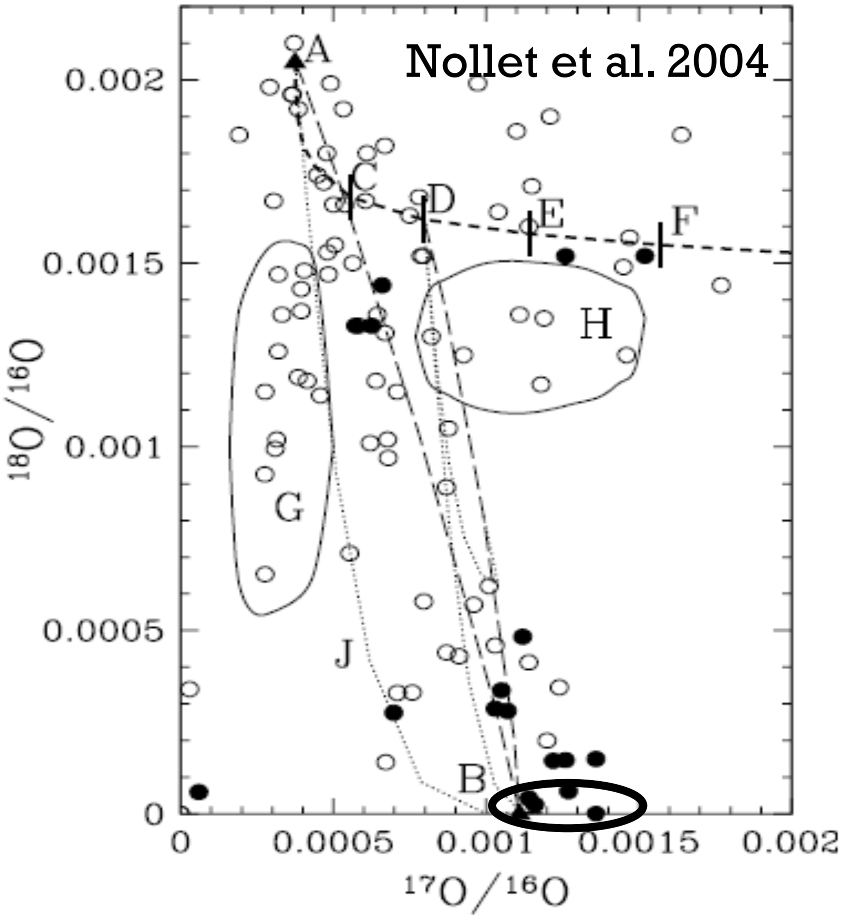
+ $^{17}O(p,\alpha)^{14}N$ reaction rate variations



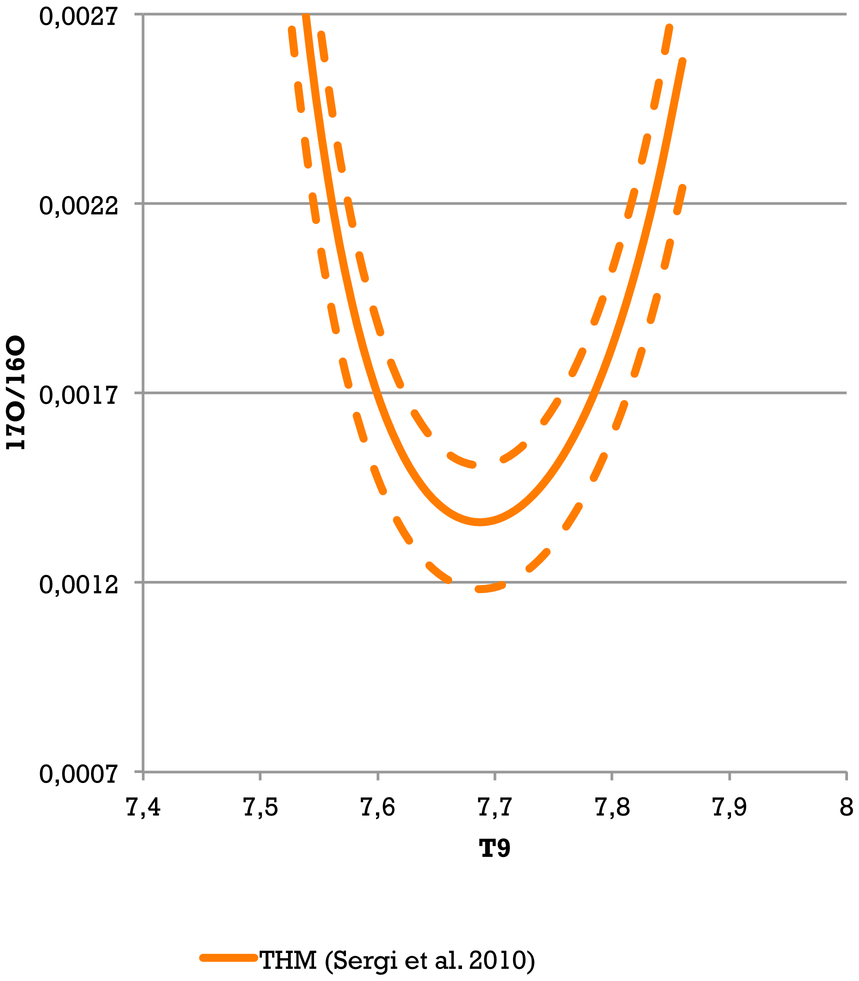


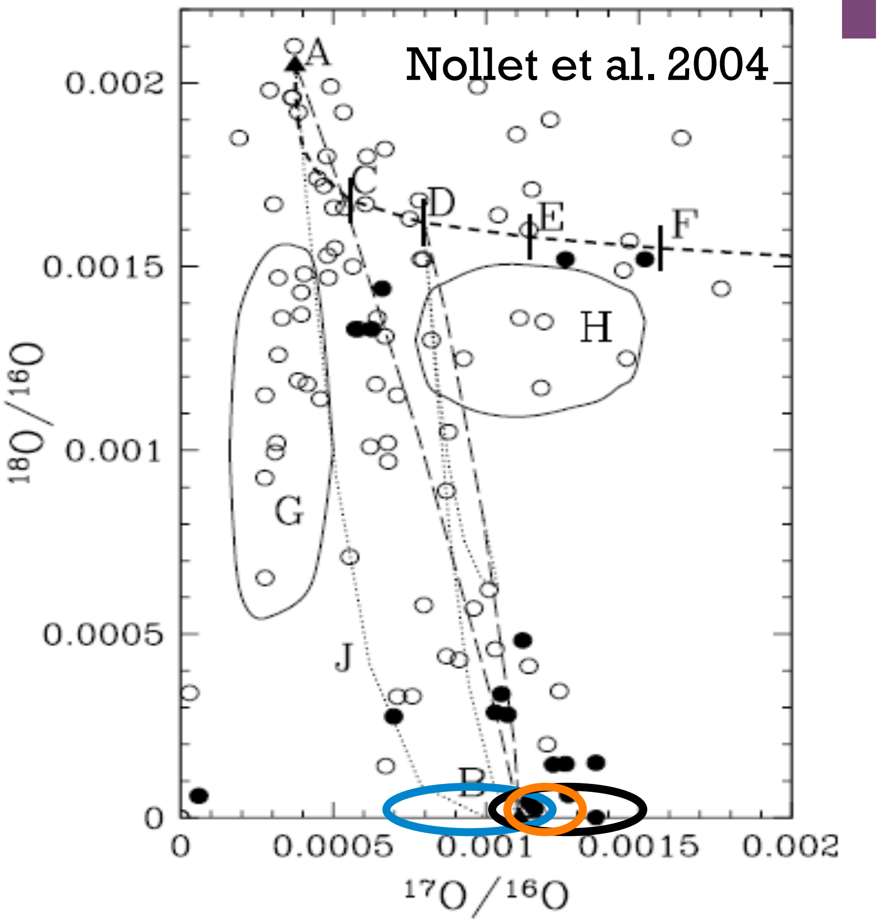
+ $^{17}O(p,\alpha)^{14}N$ reaction rate variations



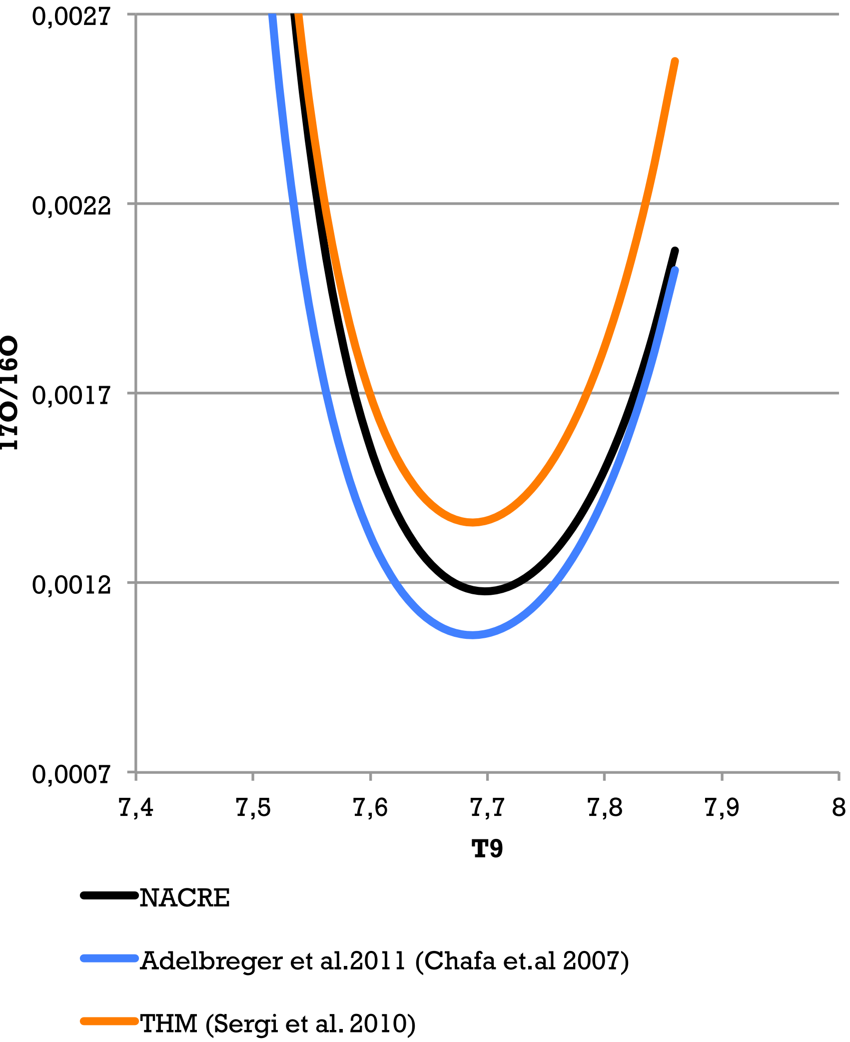


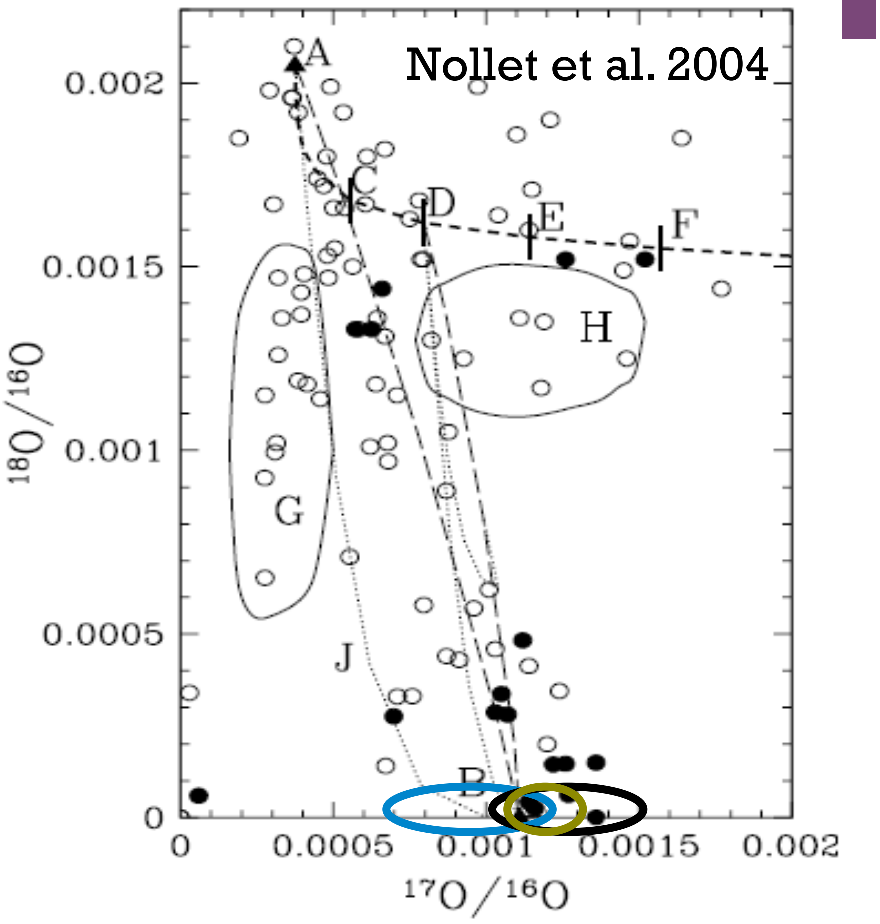
+ $^{17}O(p,\alpha)^{14}N$ reaction rate variations



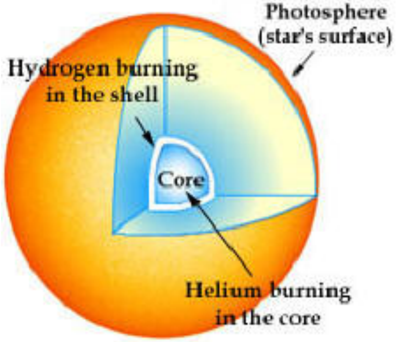


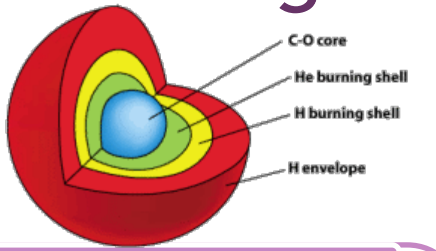
+ $^{17}O(p,\alpha)^{14}N$ reaction rate variations



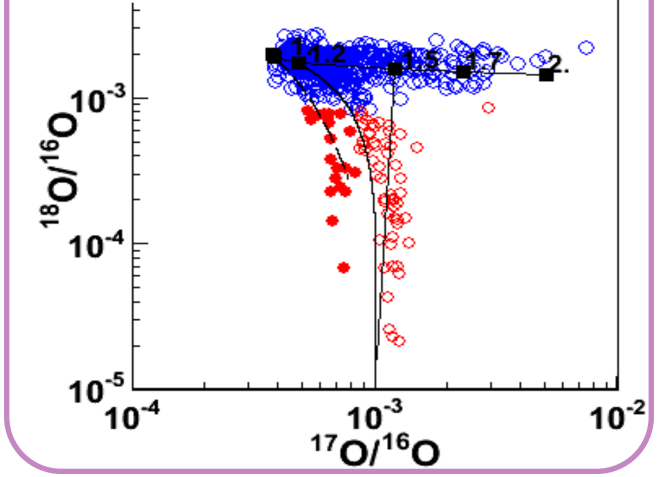


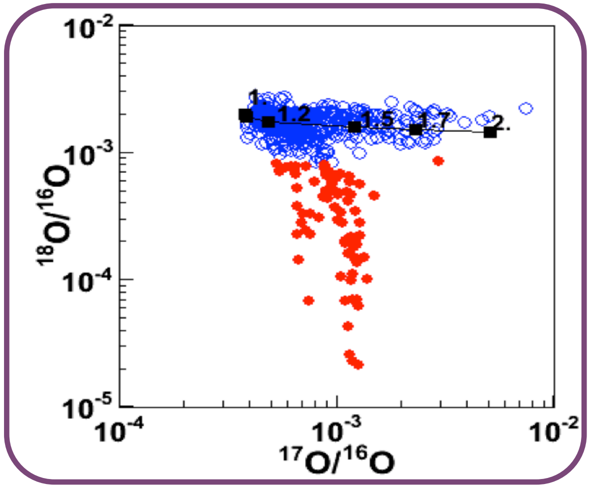
+ ^{17}O+p reaction rates and Oxide grains





Palmerini et al. 2011



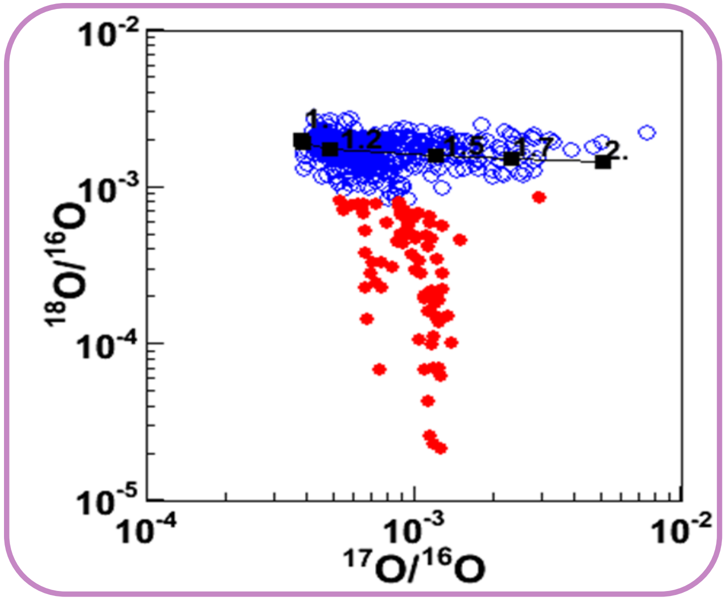


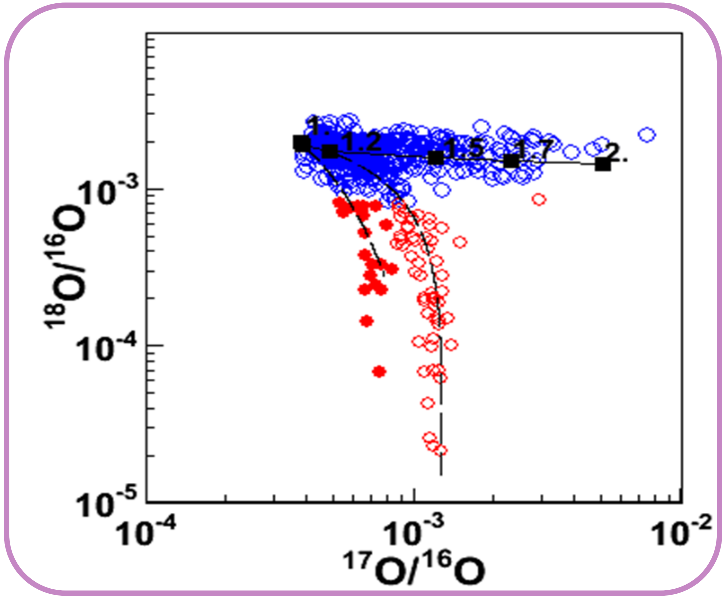
^{17}O+p from

Chafa et al. 2007

- Low mass RGB stars ($M_\star < 2M_\odot$) are progenitor of group 1 grains
- Extra-mixing in AGB stars account for isotopic composition of Group 2 oxide grains

^{17}O+p reaction rates and Oxide grains

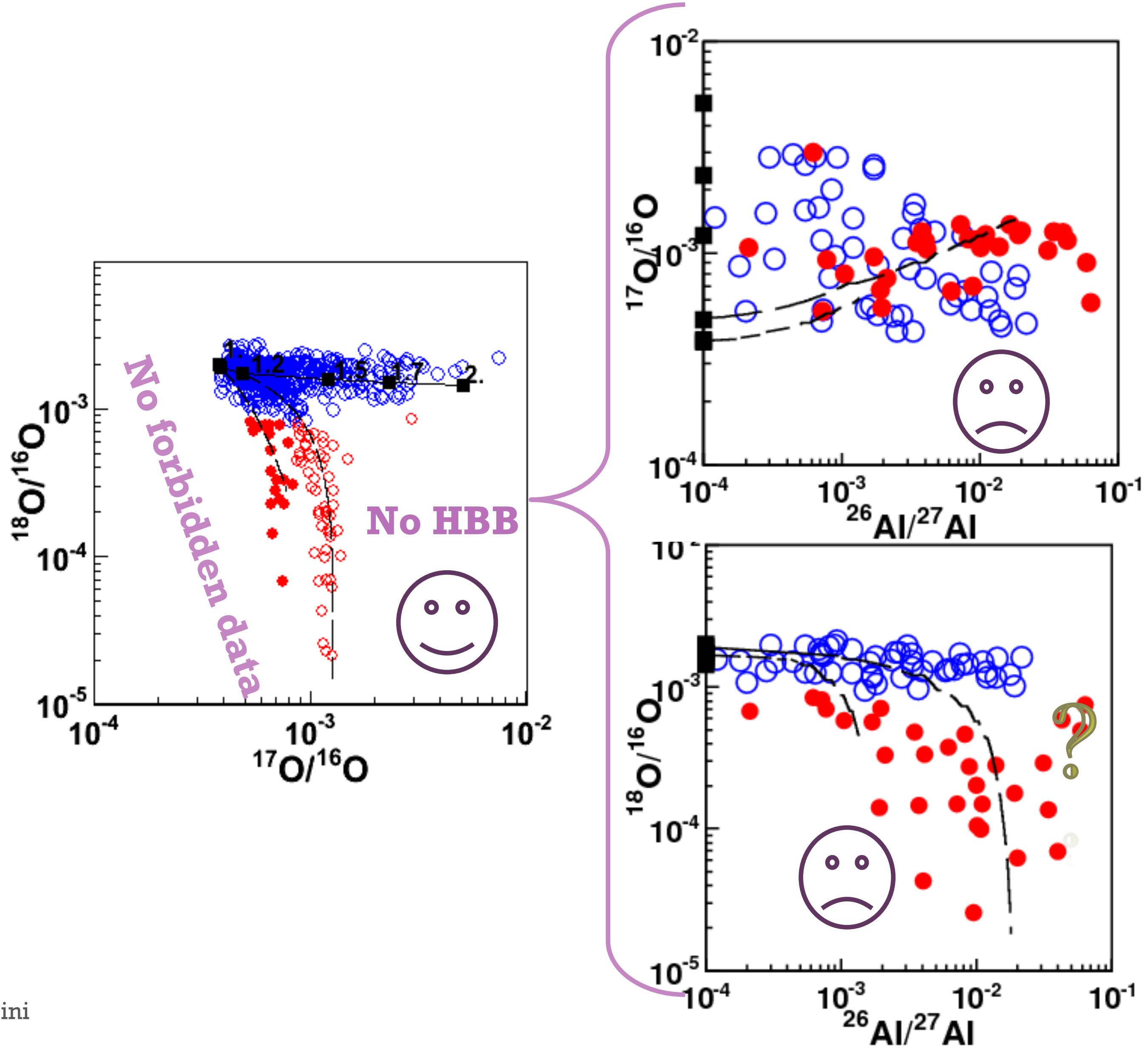




THM data

- Mass range of stellar progenitors of group 2 oxide grains is $1M_{\odot}<M_{\star}<1.2M_{\odot}$
- Group 2 grains might be divided in 2 subgroups because of the progenitor mass

+ Aluminum isotopic ratio…a challenge

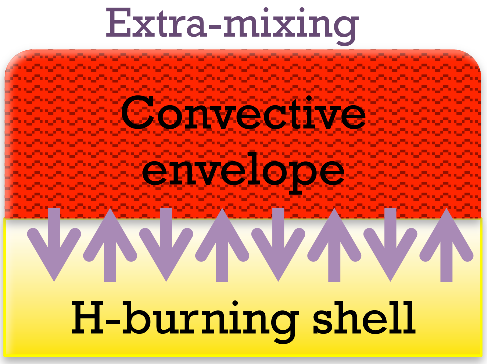


How to reach $^{26}Al/^{27}Al>0.02$ shown by part of group 2 grains?

Aluminum isotopic ratio: a possible solution from ~~nuclear~~ *stellar* physics

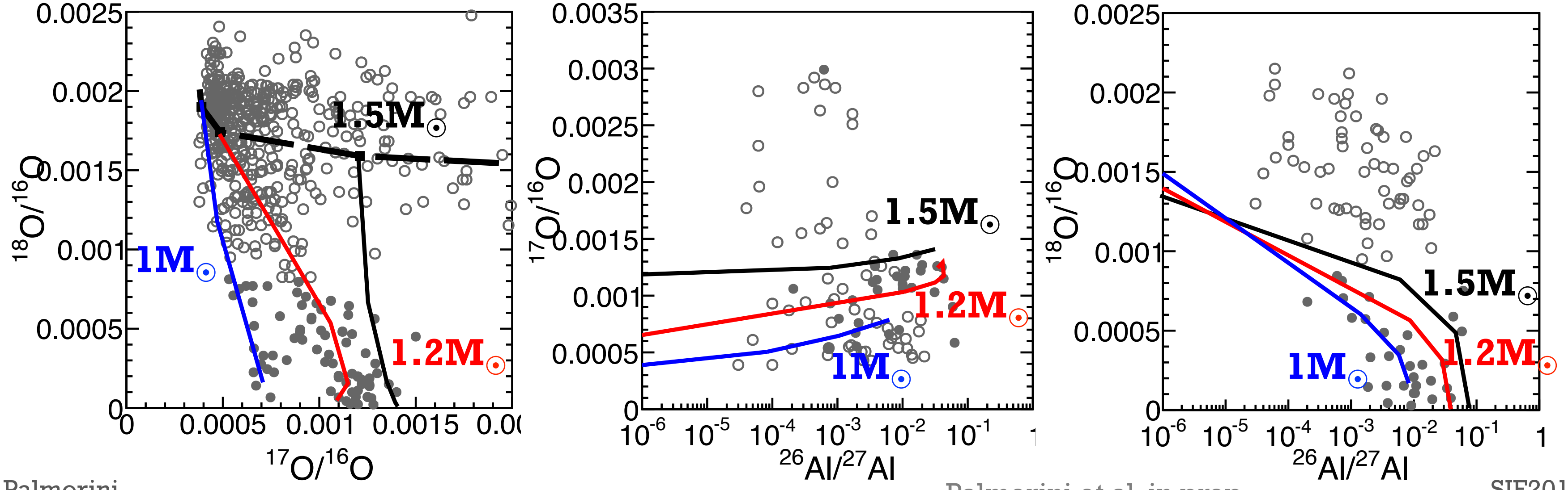
- The measurement of ^{25}Mg(p, γ)^{26}Al excludes that a solution coming from nuclear data (Strieder et al. 2012)

- What about the mixing profile?


Extra-mixing

Convective envelope

H-burning shell



Palmerini et al. in prep

In nuclear astrophysics

- Sometimes solutions come from nuclei ($^{17}O/^{16}O$ in grains)
- Sometimes solutions come from stars ($^{26}Al/^{27}Al$ in grains)
- Other times we do not know yet ($^{14}N/^{15}N$ in grains and the Li problem)
- In any case it is necessary to collaborate

GRAZIE!

THANK YOU!