s-PROCESSING FROM MHD-INDUCED MIXING AND ISOTOPIC ABUNDANCES IN PRESOLAR SiC GRAINS

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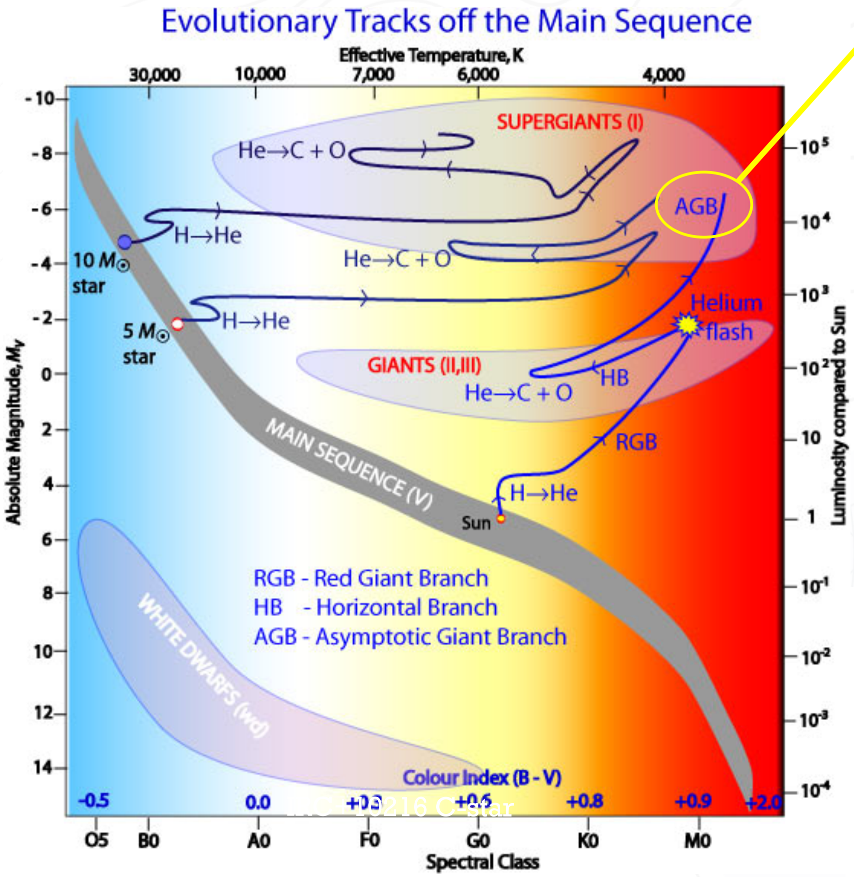
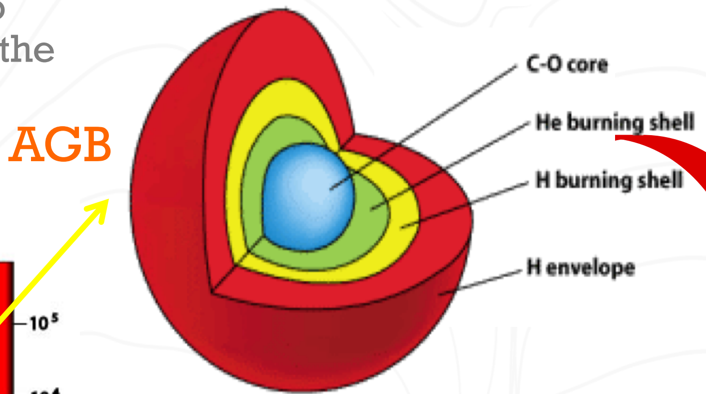
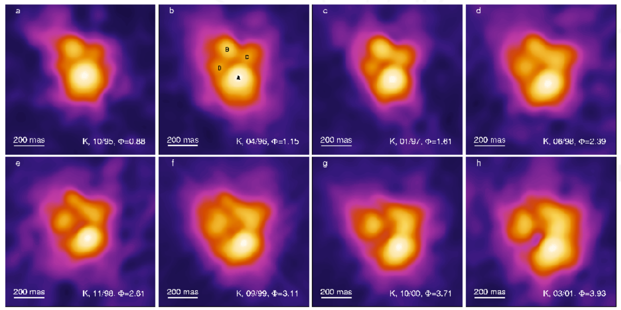
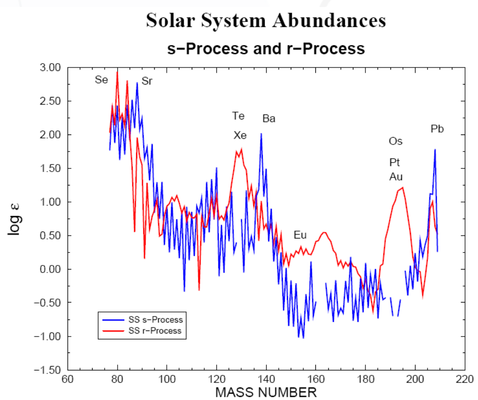
CONTRIBUTION OF LMS TO GCE

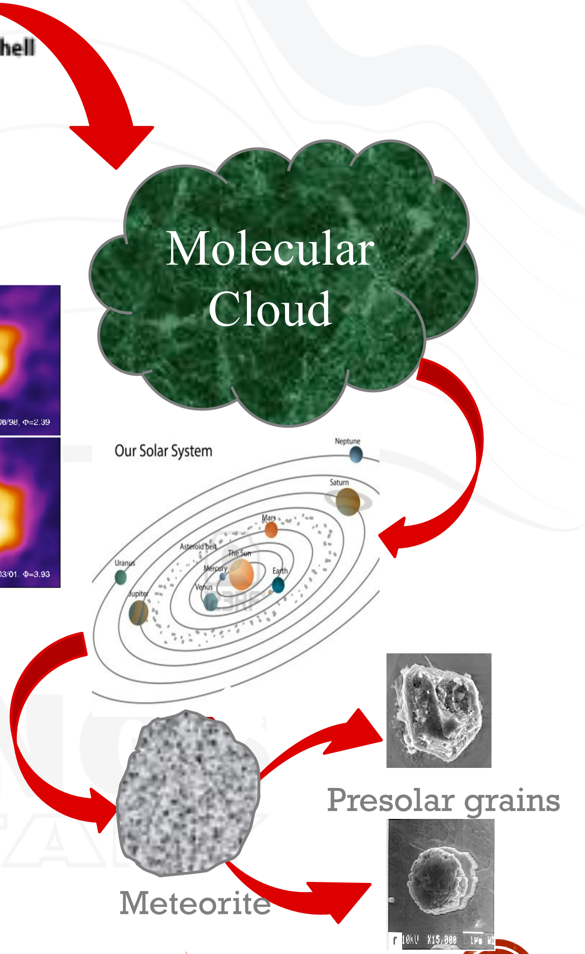
Despite their low masses LMS are so numerous to contribute for 75% to the total mass return from stars to the ISM (Sedlmayr 1994);









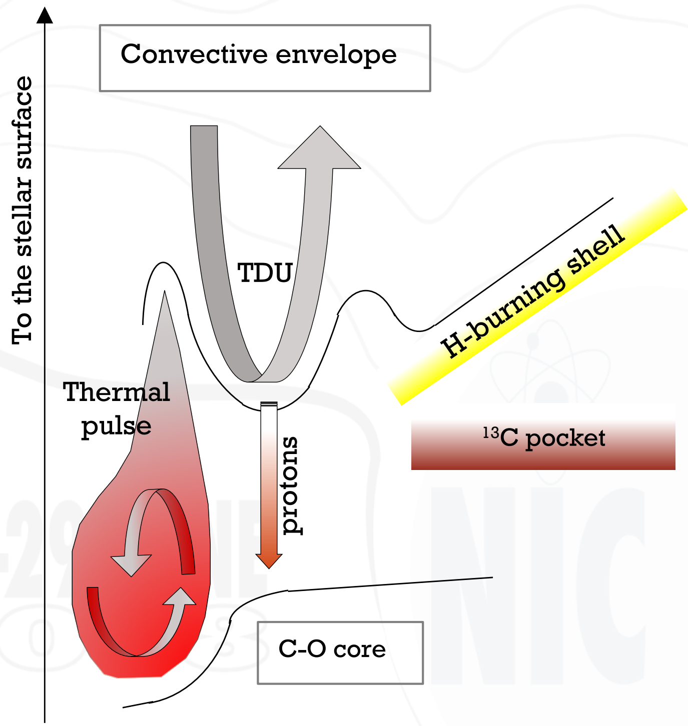


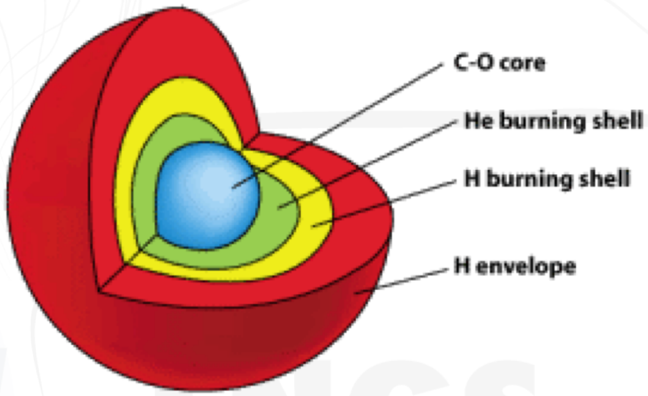
WHAT ARE WE LOOKING FOR?

A physical mechanism that allows: the formation of the ^{13}C pocket

→ proton penetration from the envelop during the TDU → $^{12}C(p,\gamma)^{13}N(\beta^+ \nu)^{13}C$

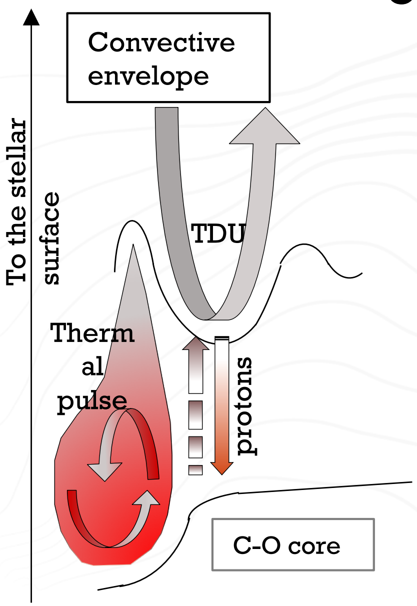
→ ^{14}N is the most important neutron poison.





MIGHT STELLAR MAGNETIC FIELDS TRIGGER THE FORMATION OF A 13C-POCKET SUITABLE TO ADDRESS OBSERVATIONAL CONSTRAINTS?

(MHD) 13C-POCKET FORMATION:
UP-FLOW OF MAGNETISED MATERIAL



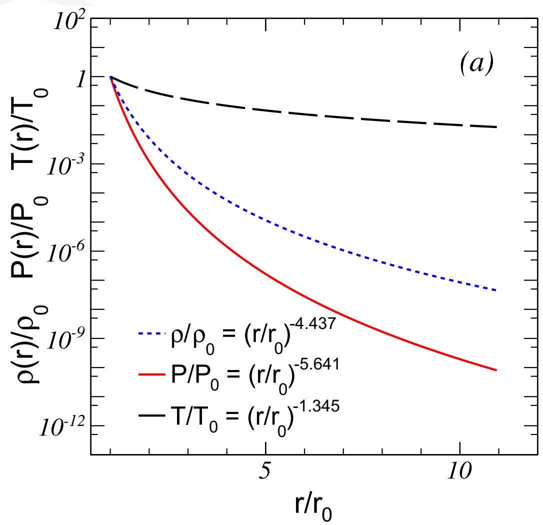
$\rho \propto r^k$, $k < -1$;
$P_m > 1$
Small magnetic diffusivity ν_m

$$v_r = \Gamma r^{-(k+1)}$$

$$\Gamma = v_p r_p^{k+1}.$$

$$v_r = v_P \left(\frac{r_P}{r}\right)^{-(k+1)}$$

Simplest and FASTEST solution satisfying boundary conditions



$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0 \qquad (1)$$

$$\rho \left[\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla)\mathbf{v} - c_d \mathbf{v} + \nabla \Psi \right] - \mu \Delta \mathbf{v} + \nabla P + \frac{1}{4\pi} \mathbf{B} \times (\nabla \times \mathbf{B}) = 0 \qquad (2)$$

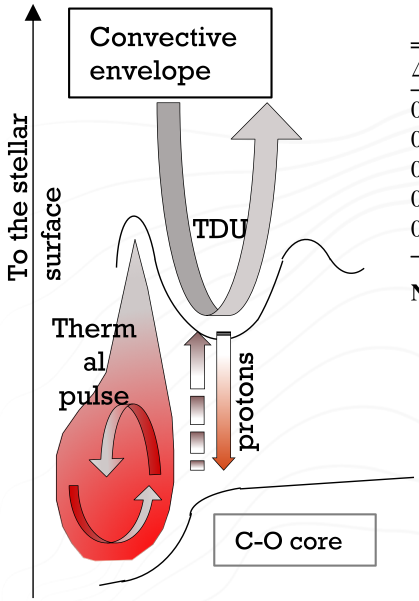
$$\frac{\partial \mathbf{B}}{\partial t} - \nabla \times (\mathbf{v} \times \mathbf{B}) - \nu_m \Delta \mathbf{B} = 0 \qquad (3)$$

$$\nabla \cdot \mathbf{B} = 0 \qquad (4)$$

$$\rho \left[\frac{\partial \epsilon}{\partial t} + (\mathbf{v} \cdot \nabla)\epsilon \right] + P \nabla \cdot \mathbf{v} - \nabla \cdot (\kappa \nabla T) + \frac{\nu_m}{4\pi} (\nabla \times \mathbf{B})^2 = 0. \qquad (5)$$

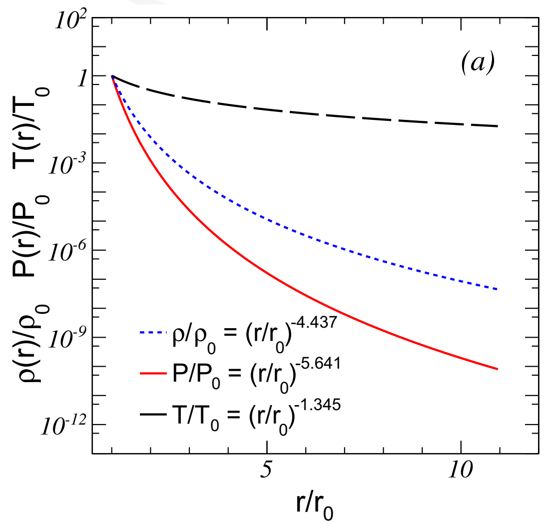
NUCCI & BUSSO 2014

(MHD) 13C-POCKET FORMATION



ΔM ($M_\odot$)	Radius/R_*	Mass ($M_\odot$)	P (dyn cm^{-2})	$T(K)$	ρ (g cm^{-3})	μ	P_m
0.000	8.25×10^{-4}	0.61934	3.34×10^{11}	2.94×10^{6}	9.83×10^{-4}	4.0×10^{-6}	4.7
0.001	2.89×10^{-4}	0.61835	2.70×10^{14}	1.68×10^{7}	0.39	4.3×10^{-4}	12.8
0.004	1.37×10^{-4}	0.61534	2.80×10^{16}	4.29×10^{7}	7.81	0.016	27.0
0.005	1.09×10^{-4}	0.61434	8.47×10^{16}	5.58×10^{7}	18.58	0.041	32.5
0.010	5.78×10^{-5}	0.60434	1.82×10^{18}	1.12×10^{8}	222.18	0.440	52.3

Note. Data refer to the sixth TDU episode for the model star of $M = 1.5\,M_\odot$, $Z = Z_\odot$ as discussed in Busso et al. (2007).



The **density of envelope** material injected (downflow mass) into the He-layers will vary as:

$$d\rho_d/\rho_d = +\alpha dr$$

corresponding to an **exponential profile**:

$$\rho_d(r) = \rho_{d,0} e^{-\alpha(r_e - r)}$$

We multiplied for the infinitesimal **element of volume**:

$$dM_d(r) = 4\pi r^2 \rho_e e^{-\alpha(r_e - r)} dr.$$

After **integration** between envelope border and the innest layer, we obtain:

$$\Delta M_d^H \simeq 0.714 \frac{4\pi \rho_E}{\alpha} \left\{ \left[r_e^2 - \frac{2}{\alpha} r_e + \frac{2}{\alpha^2} \right] - \left[r_p^2 - \frac{2}{\alpha} r_p + \frac{2}{\alpha^2} \right] e^{-\alpha(r_e - r_p)} \right\}$$

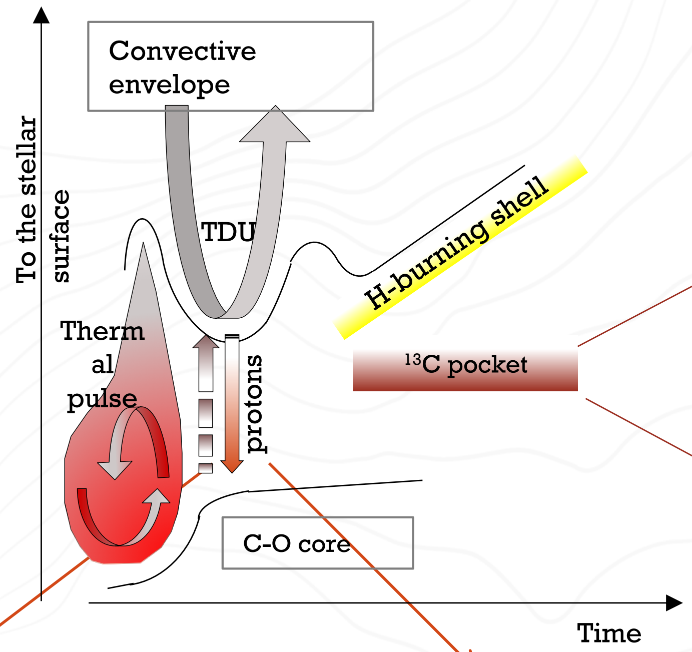
Comparing this result with the **mass transported** by magnetic buoyancy

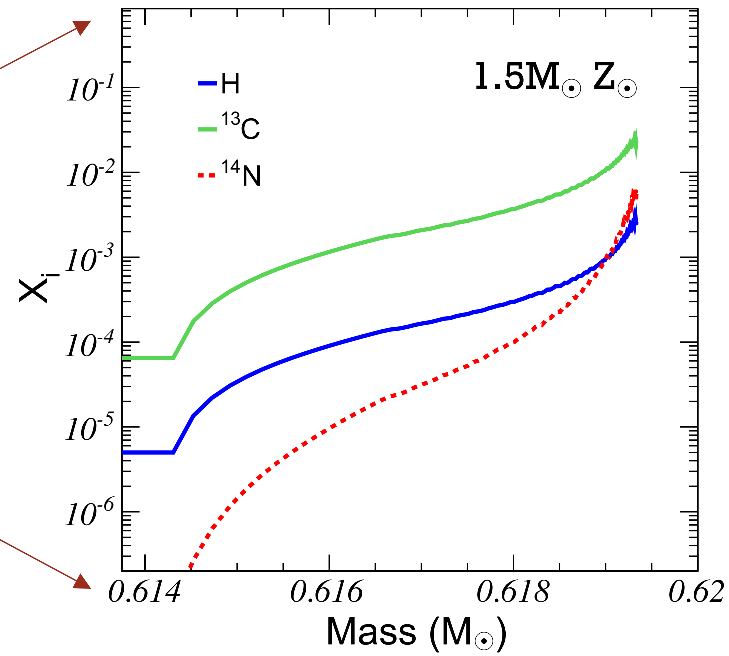
$$M_{up} = \dot{M} \cdot \Delta t = 4\pi r_e^2 \rho_e v_e f_1 f_2 \Delta t$$

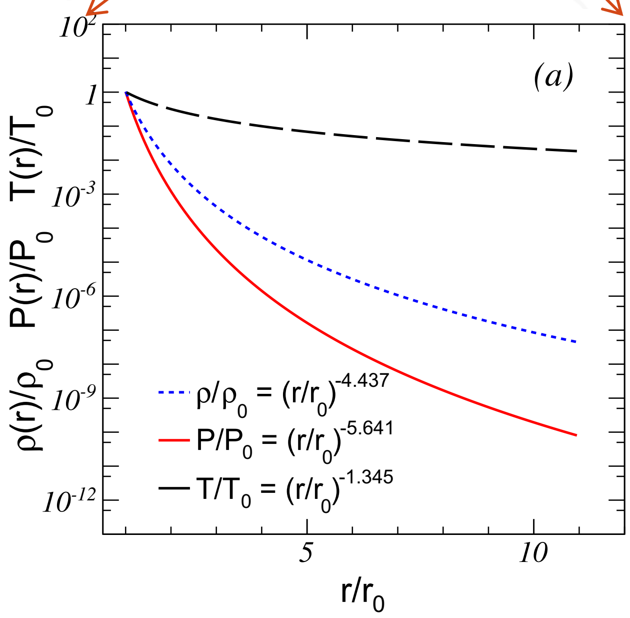
we obtain the **amount of proton injested** in the He-rich region for the formation of the ^{13}C-pocket

Courtesy of O. Trippella

(MHD) 13C-POCKET FORMATION

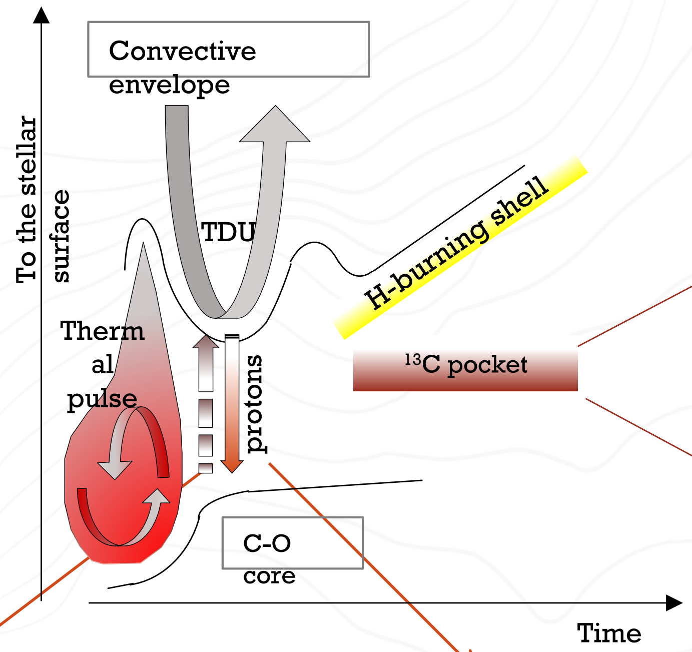


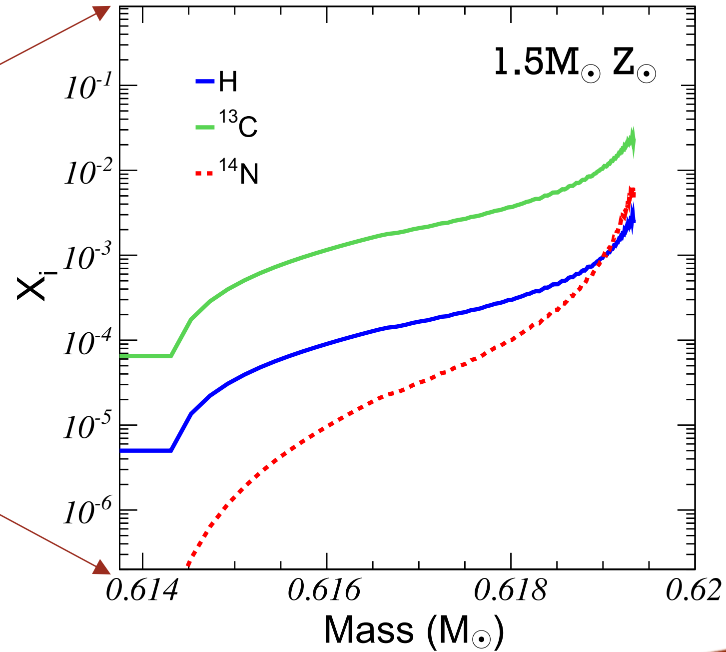


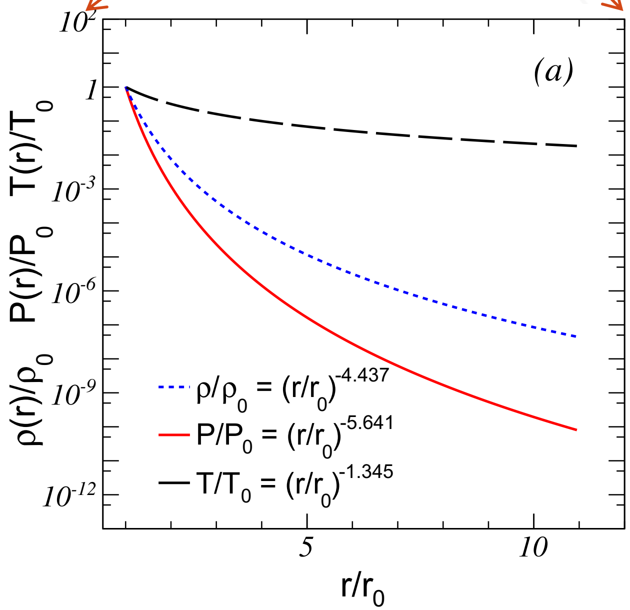


N&B conditions are satisfied → the exact analytical solutions of the MHD equations are held. → the formation of ^{13}C-pocket is allowed

(MHD) 13C-POCKET FORMATION



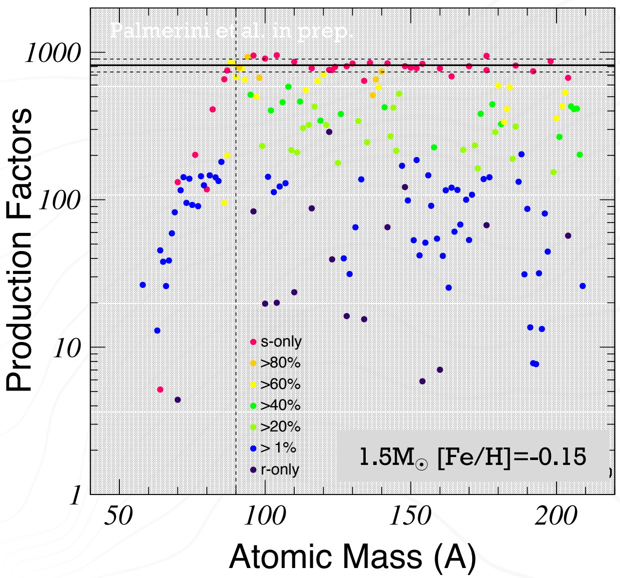




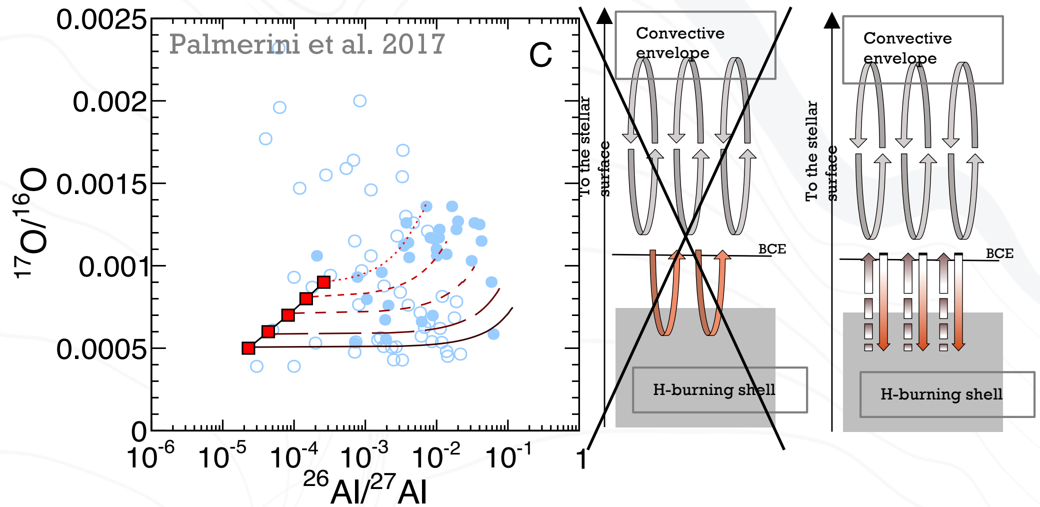
N&B conditions are satisfied

the ^{13}C-reservoir formed as a consequence of magnetic buoyancy is an almost "flat" pocket of about 5×10^{-3} M$_\odot$

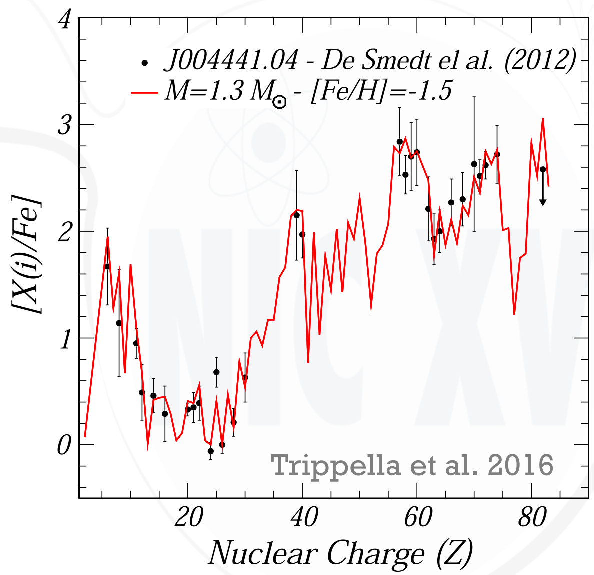
3 TESTS FOR OUR MODEL



The solar main component



A nice fit to O and Al isotopic ratio of oxide grains (group 2)



[X(i)/Fe] abundances in a post-AGB

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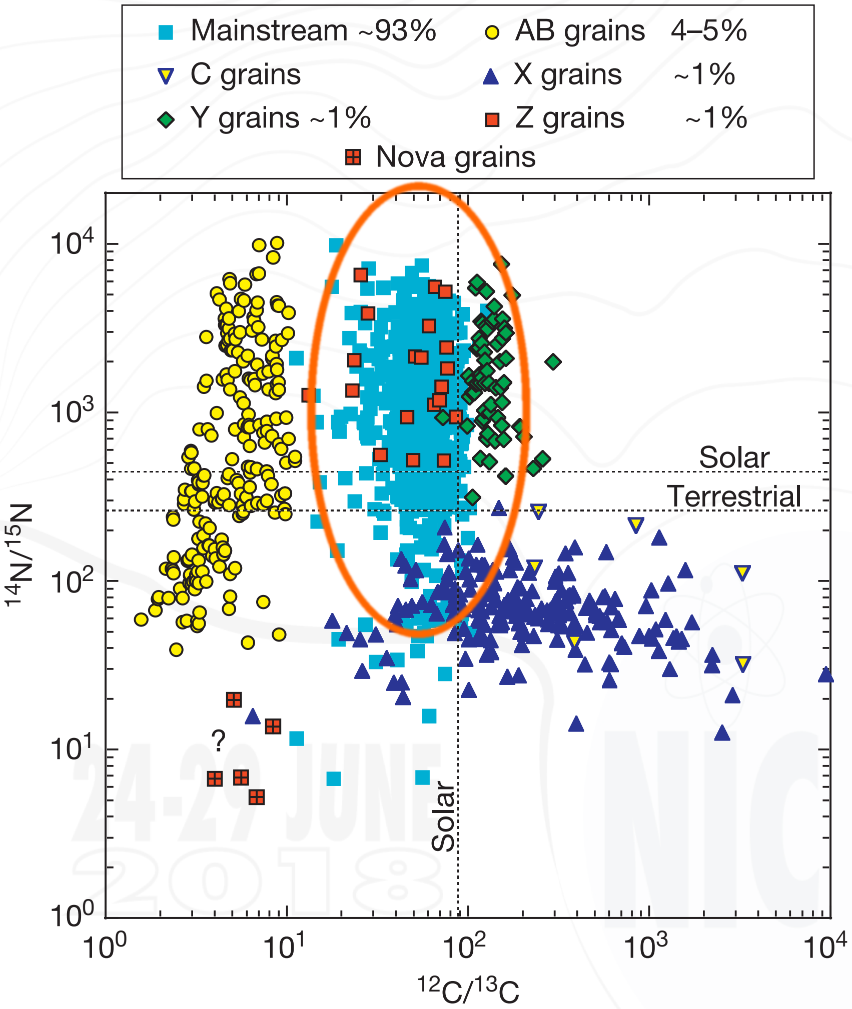
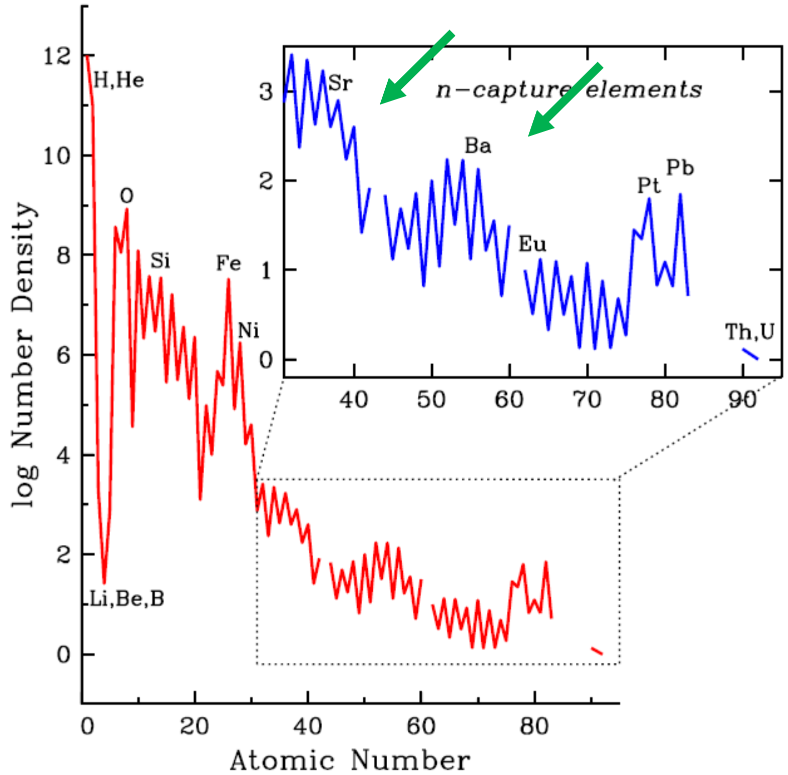
PRESOLAR GRAINS FROM AGB STARS

C/O>1 SiC grains





1.4 Presolar Grains
E Zinner, Washington University, St. Louis, MO, USA
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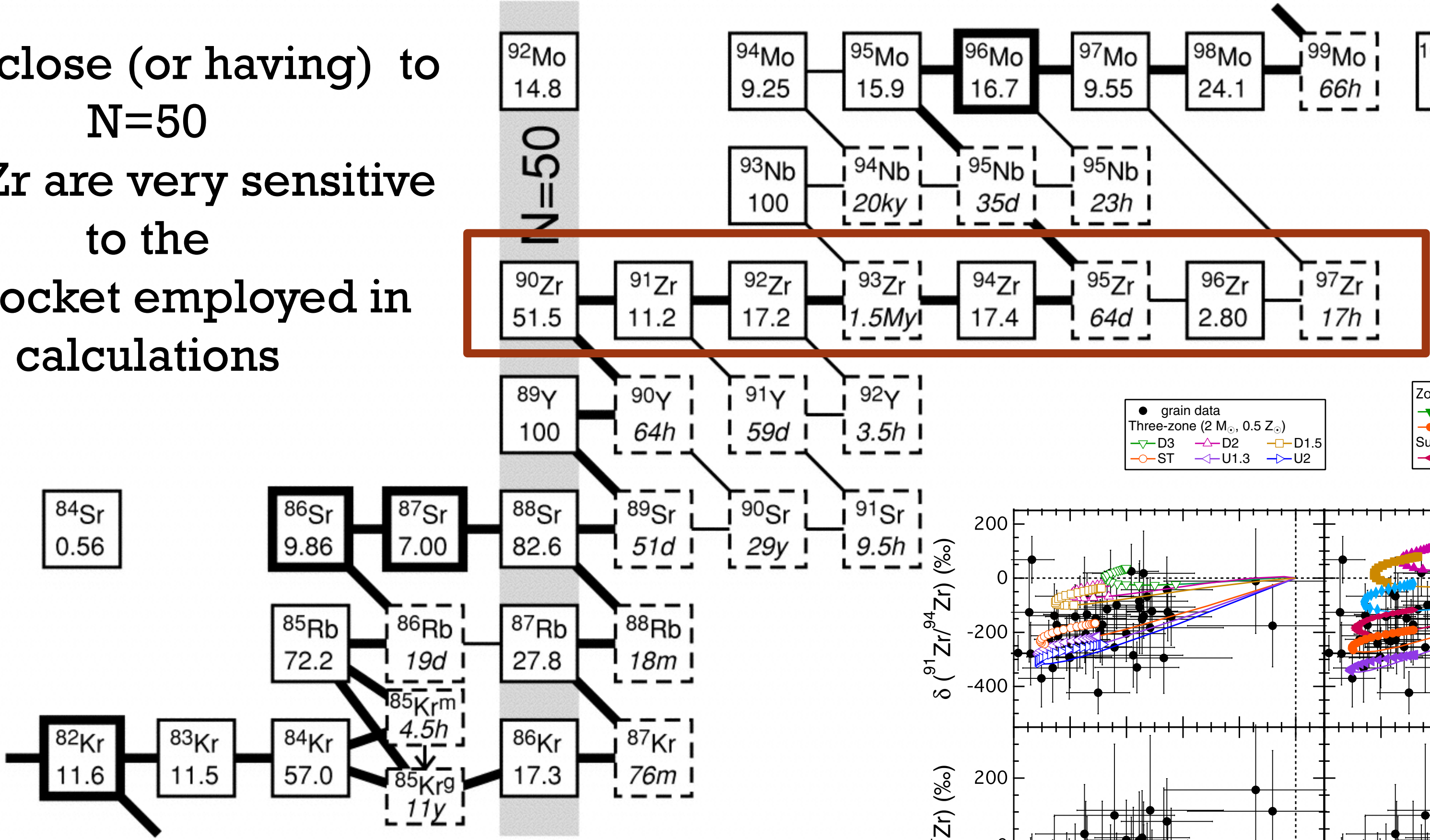
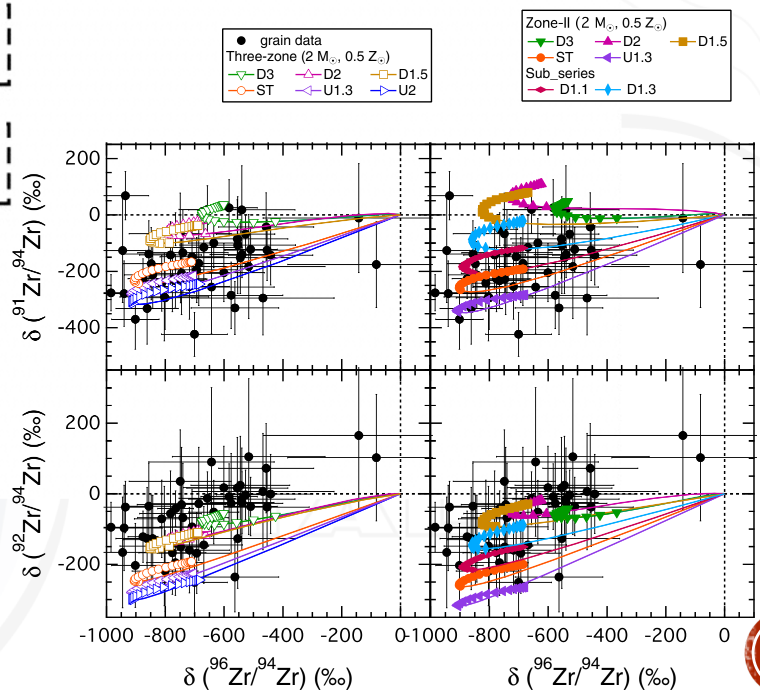
MODEL COMPARISON WITH GRAINS: ZIRCONIUM

Being close (or having) to N=50 $^{90,91,92}Zr$ are very sensitive to the ^{13}C pocket employed in calculations

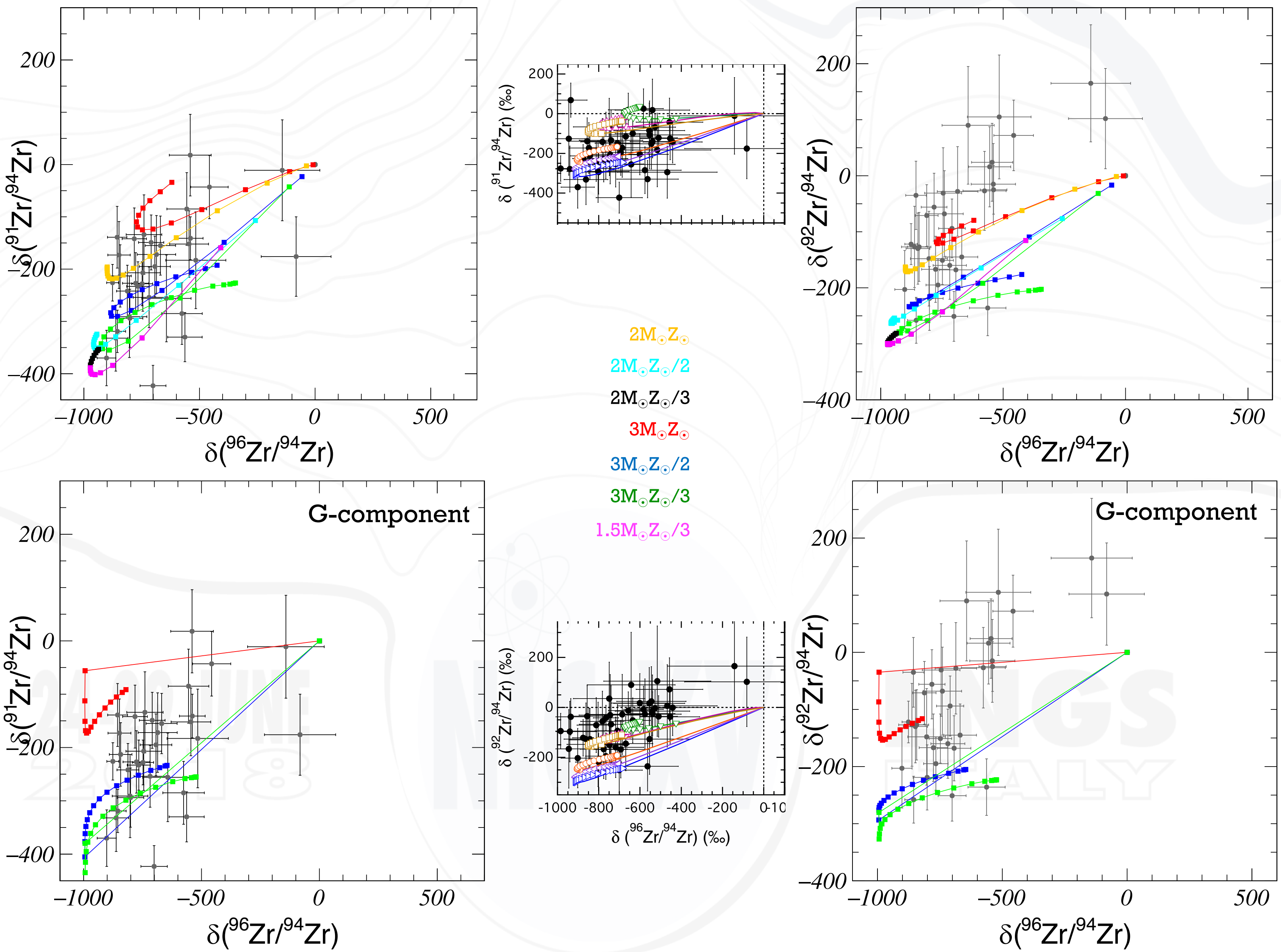


$$\delta(^iX/^kX) = \left[\frac{(^iX/^kX)_\star}{(^iX/^kX)_\odot} - 1\right] \times 1000$$

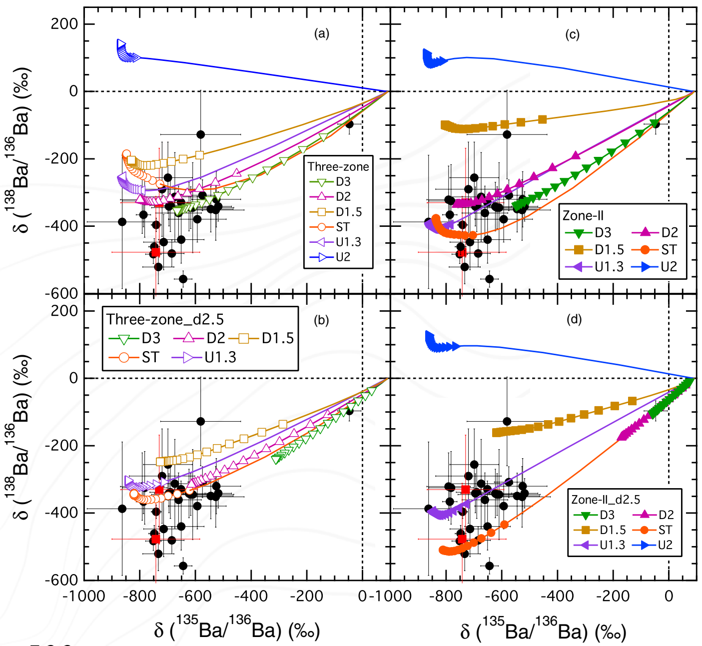


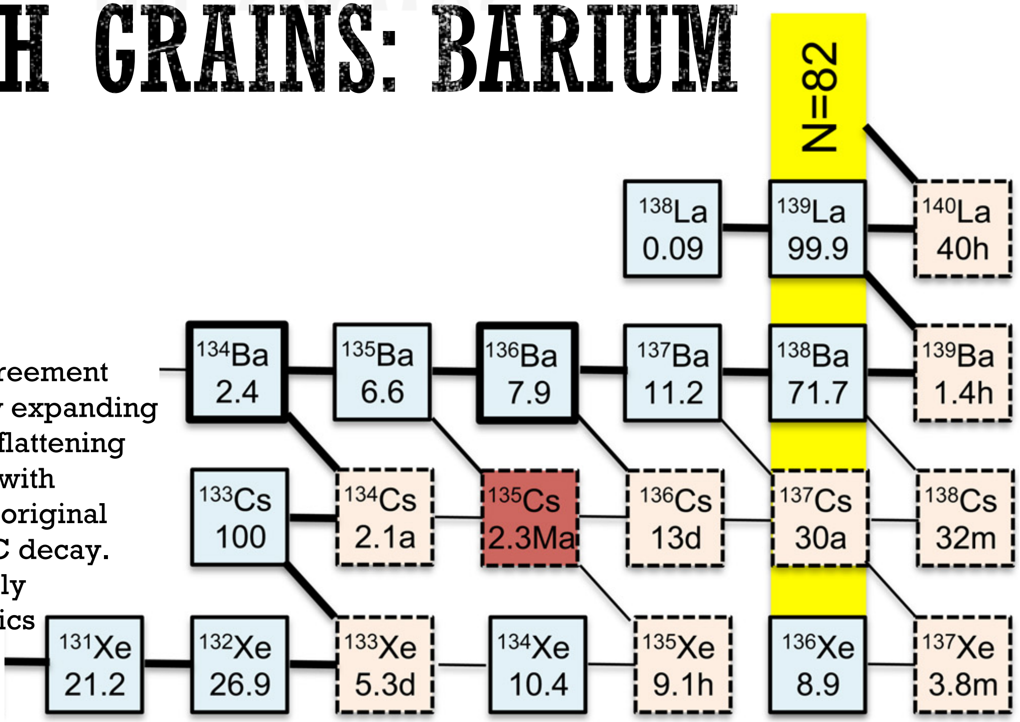
Liu et al. 2014

MODEL COMPARISON WITH GRAINS: ZIRCONIUM



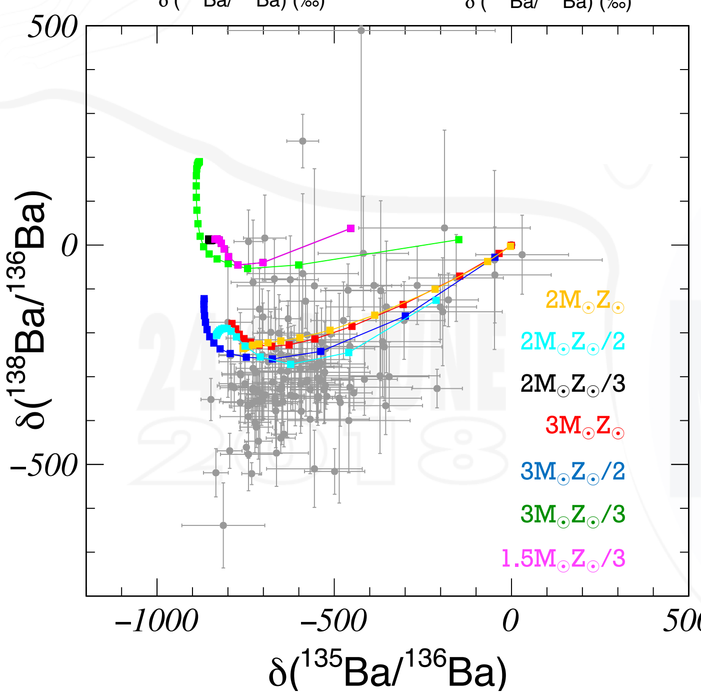
MODEL COMPARISON WITH GRAINS: BARIUM

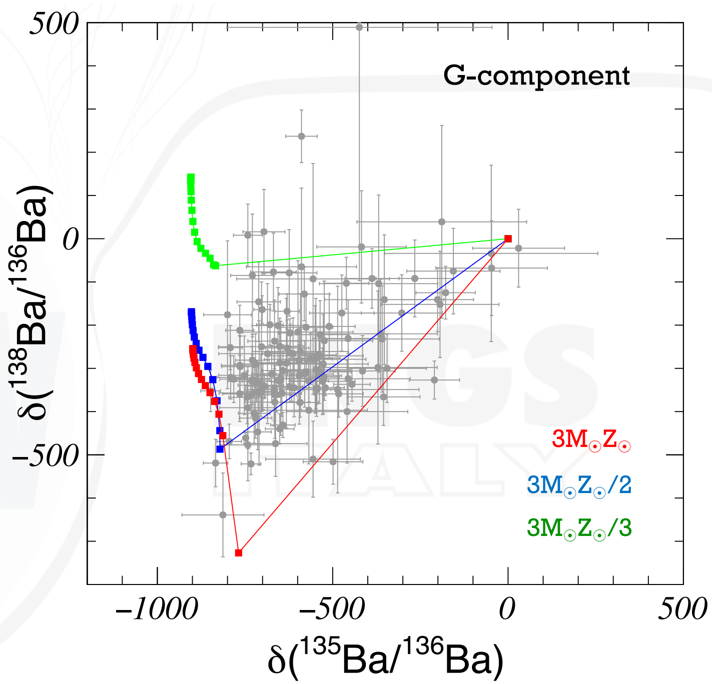




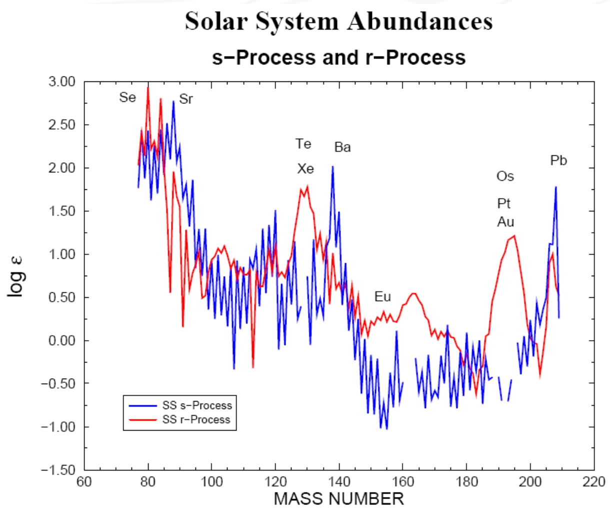
Liu et al. 2014 improve the agreement with the data by expanding the pocket and flattening the 13C profile with respect to their original exponential 13C decay. These are exactly the characteristics of "our" 13C reservoir

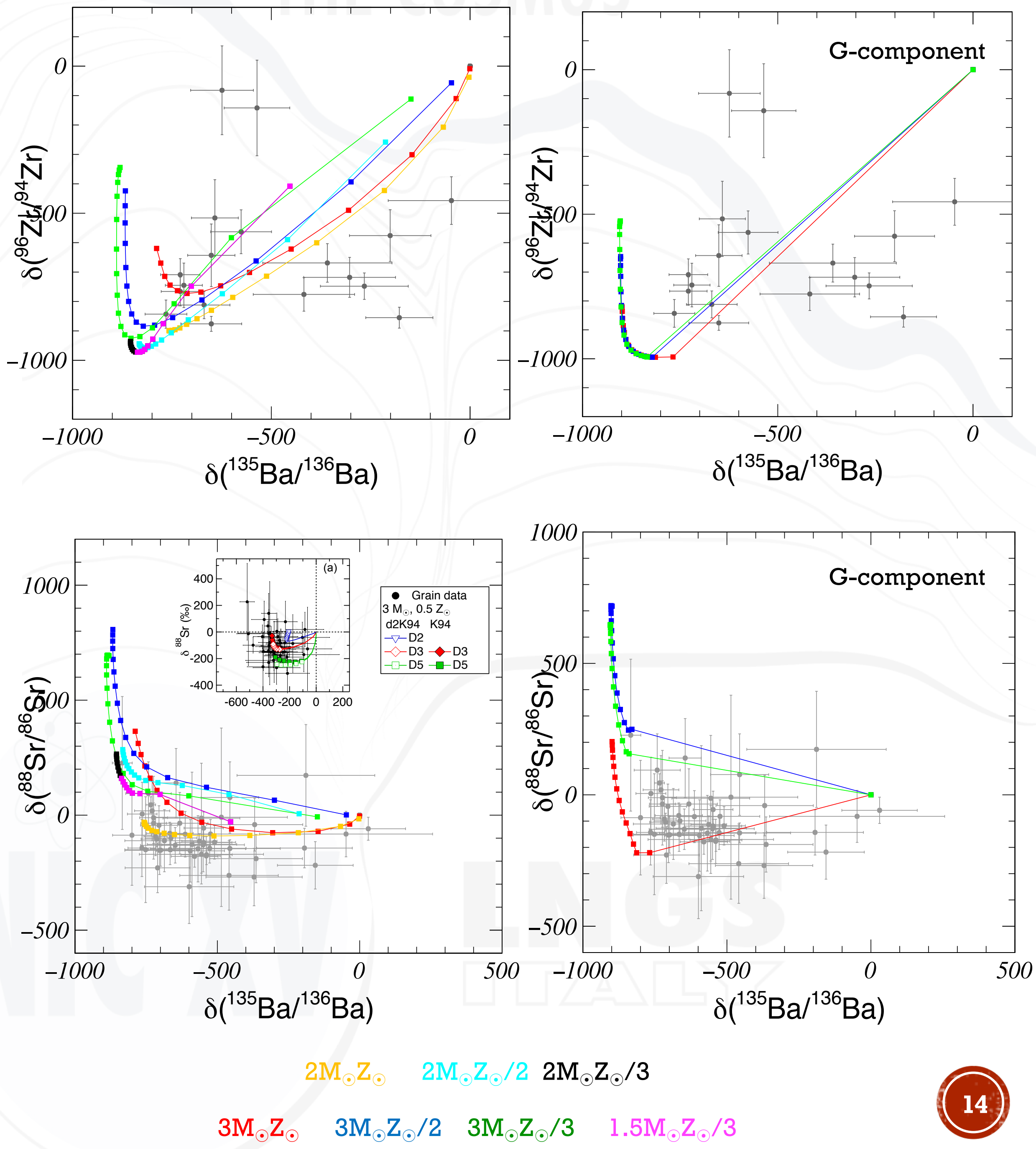
Palmerini et al. 2018 MHD





THE LAST TEST: LS VS HS





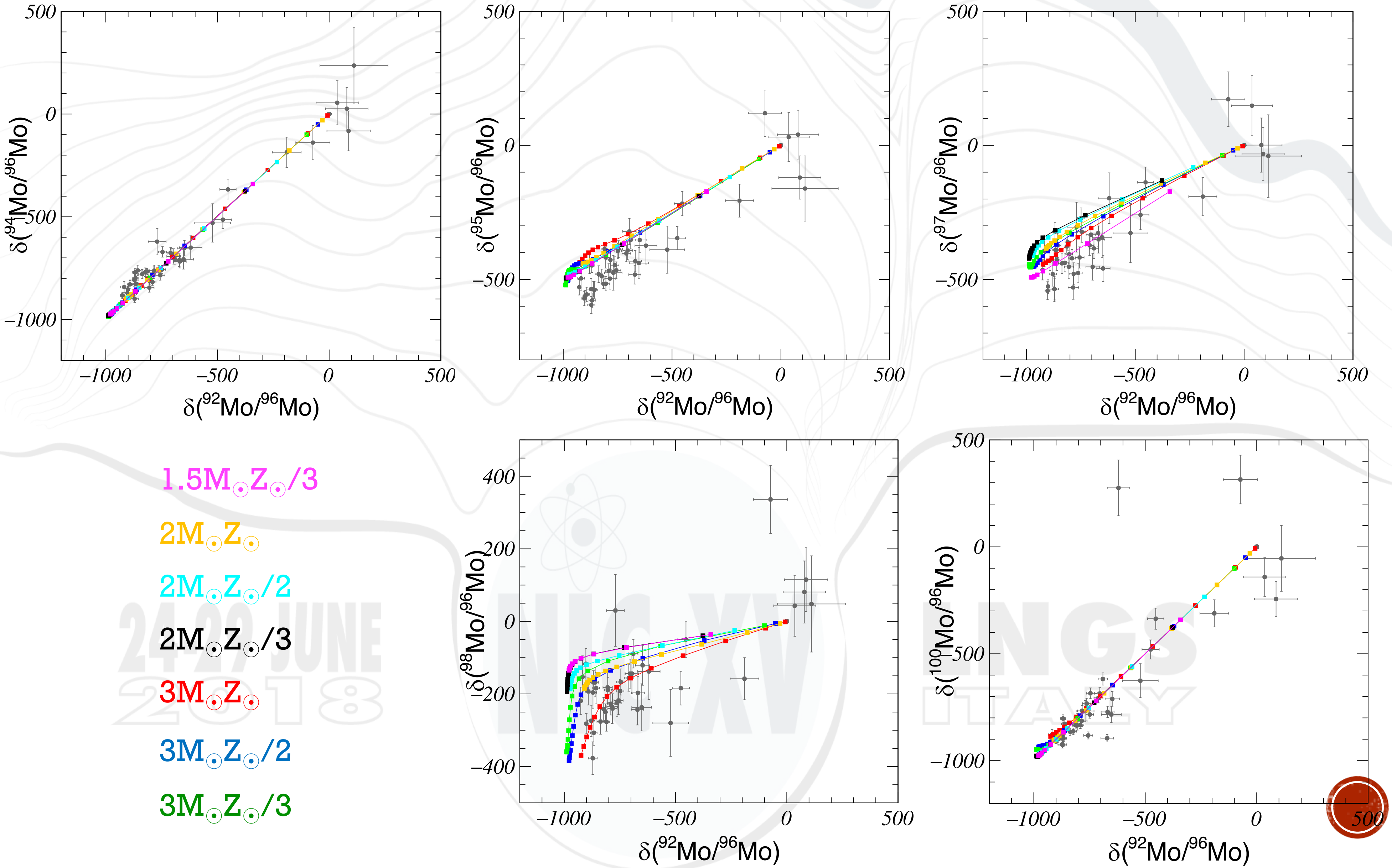
Relevant tests on the extension of the pocket and on the form of the ^{13}C distribution can then be obtained by the relative trends of ls and hs nuclei

REMARKS

- Below the convective envelopes of low mass red giant stars (AGB and RGB) the exact analytical solutions of the MHD equations are held.
- The physical conditions of the region below the convective envelope (during TDU) allow the buoyancy of magnetized structures which mighr drive the formation of a ^{13}C-pocket suitable to account for the s-isotope abundances found in MS presolar SiC grains (fits are in general of a quality comparable to the best ones in literature).
- The MHD mixing parameters are related to the intrinsic property of the stellar structure and linked to the particular polytropic transformation that best represents the thermodynamics of the environment .
- HOWEVER: an AGB star affected by MHD mixing cannot be responsible, by itself, for the enrichment in short lived nuclei of the Early Solar System …see poster n.89.

THANK YOU! GRAZIE!

$^{92\text{-}94\text{-}95\text{-}98\text{-}100}$MO/^{96}MO FROM MHD POCKET



$^{99\text{-}101\text{-}102}$Ru/^{100}Ru from MHD pocket