

# **News on the s-process from open clusters. Do we really need a solar LEPP?**

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**EMMI-JINA workshop:  
Nucleosynthesis beyond iron and the lighter element primary process**

**We analyzed: 18 open clusters with  
[Fe/H] = [-0.3;0.4]  
Age = [0.1;5] Gyr**

**On average 5 stars per cluster. Dwarf+RGB stars. No  
AGB**

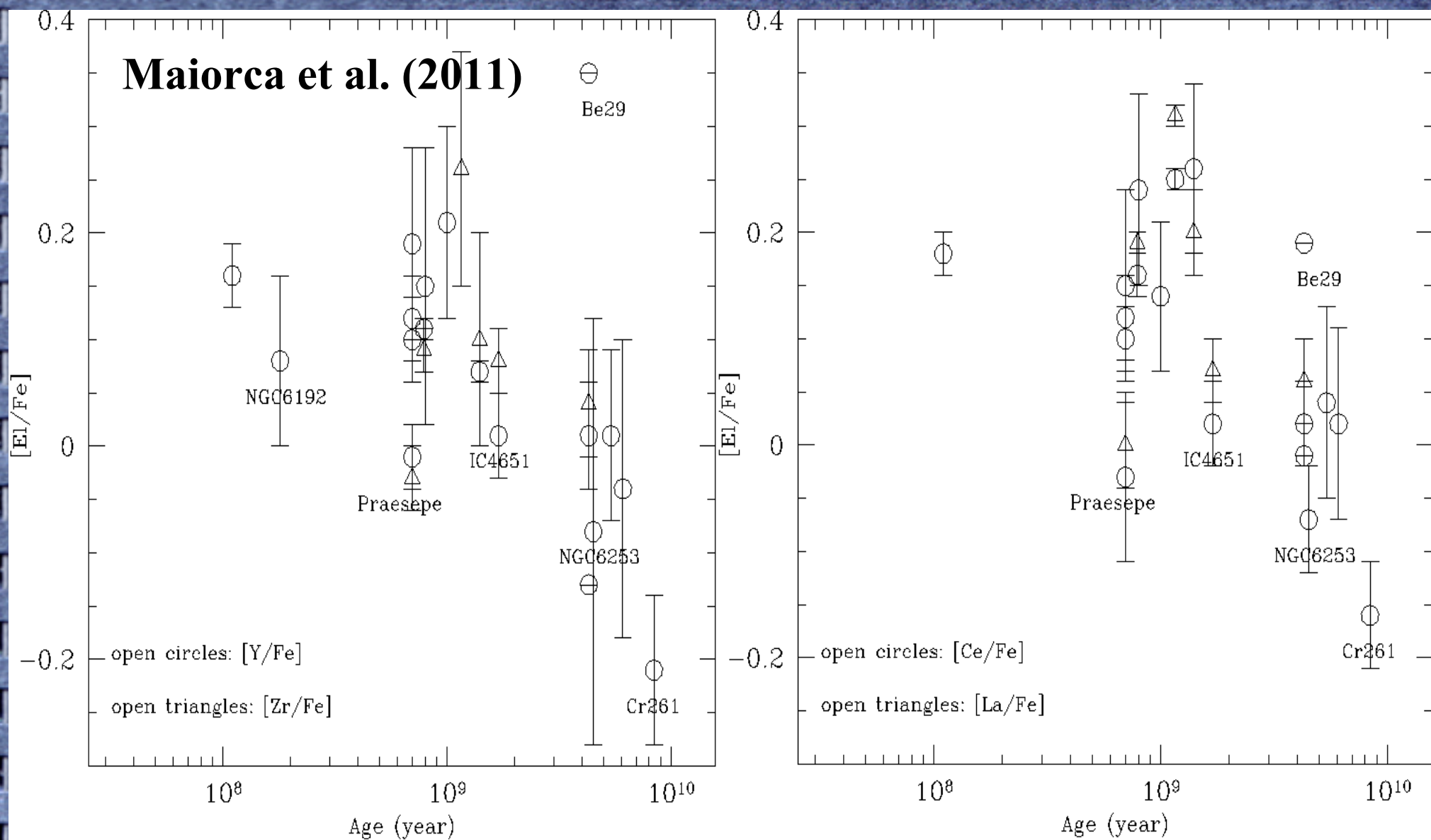
**Stellar spectra collected with the UVES spectrograph at  
VLT**

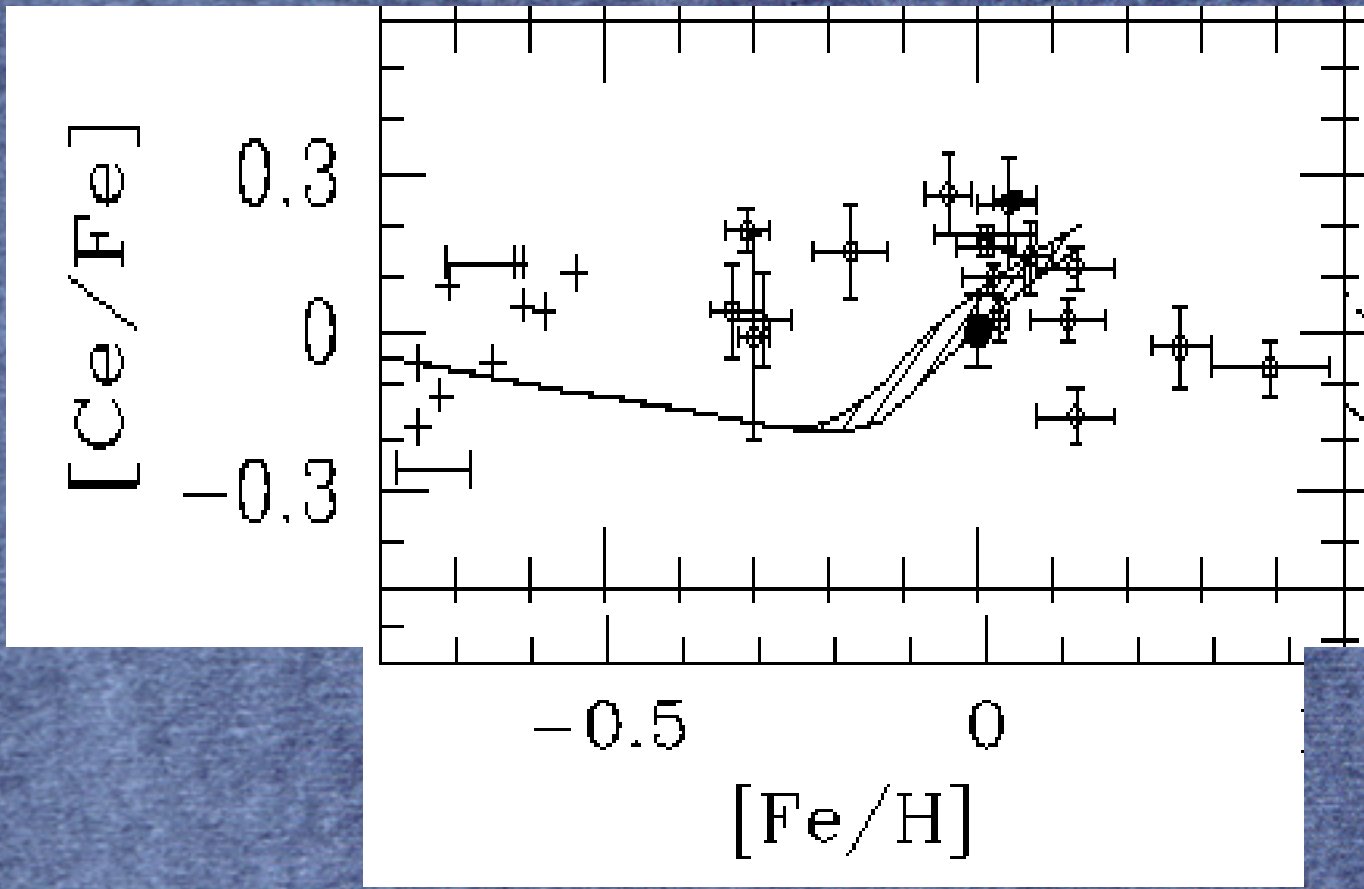
**New atomic parameters from Sneden and Lawler's  
works**

**EWs measurements+ MOOG spectrocode**

**Homogeneous sample analyzed in a homogeneous way**

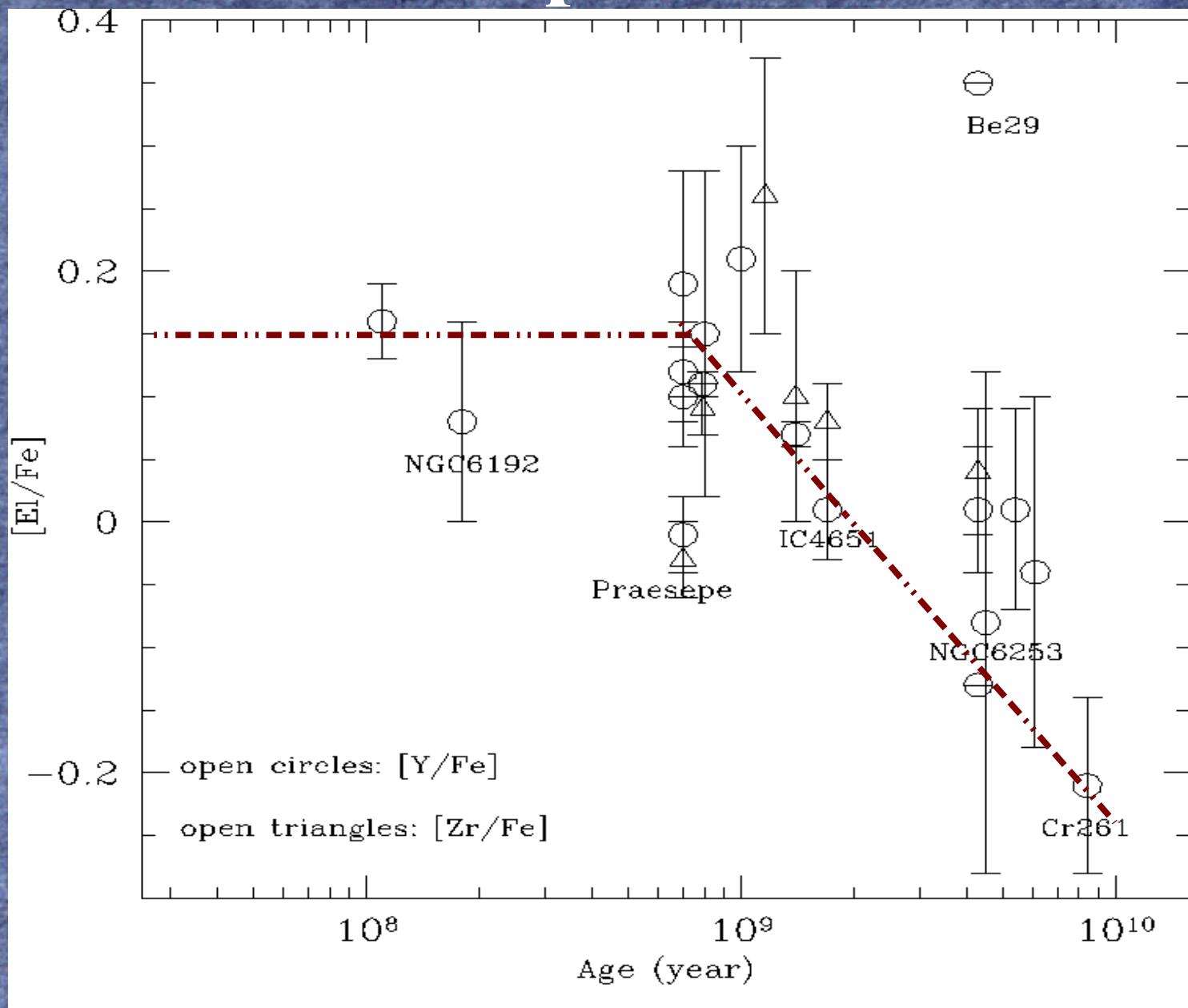
# s-elements in the thin disk: measurements from Open Clusters





# s-elements in the thin disk: measurements from Open Clusters

s-elements in OCs younger than  $\sim 1$  Gyr are systematically enriched with respect to the solar abundances by about 0.2 dex

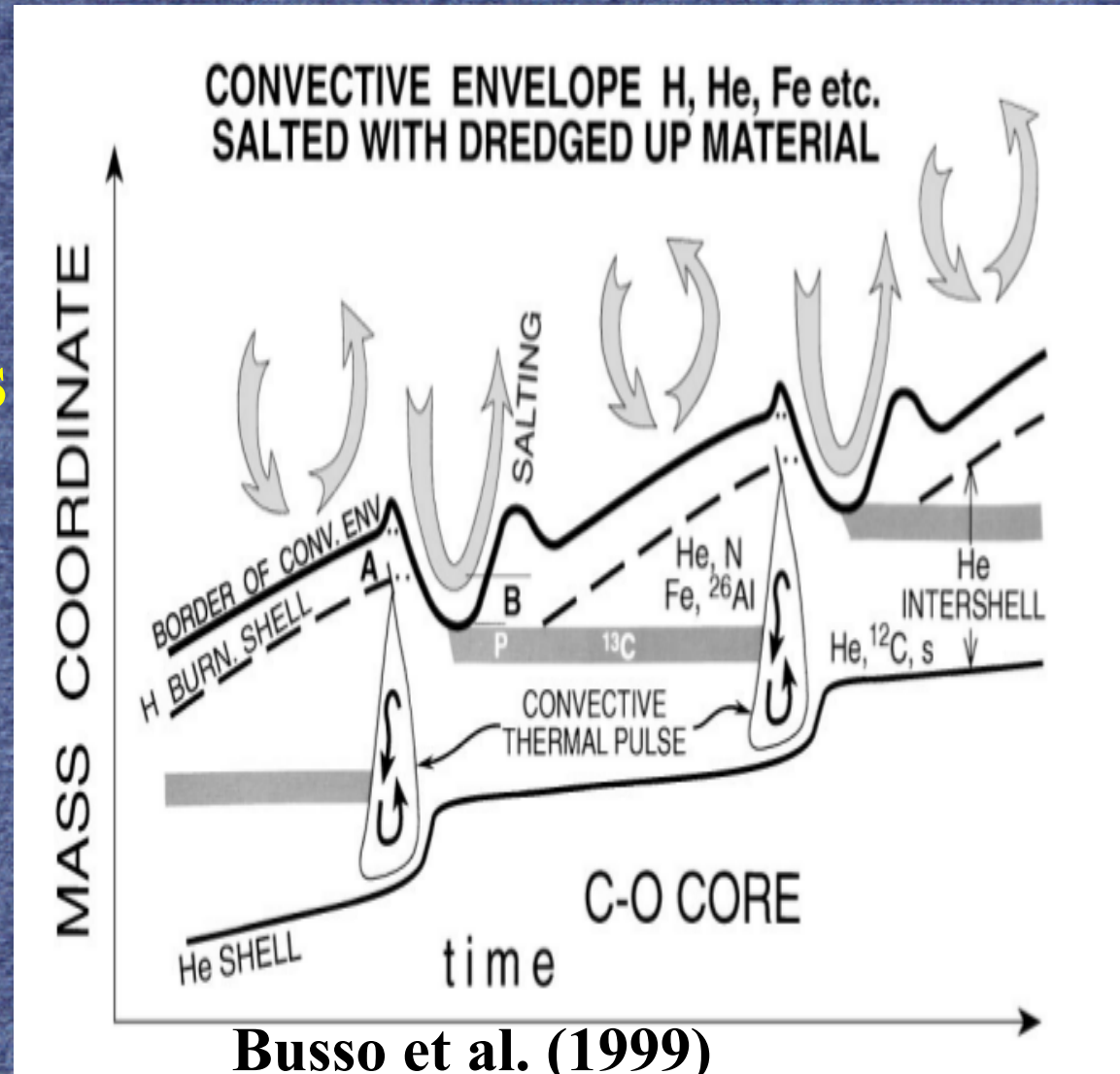


# s-process nucleosynthesis

S-process from  $^{13}\text{C}$  burning depends on:

1) the  $^{13}\text{C}$ -pocket mass

2) the  $^{13}\text{C}$  mass fraction inside the pocket



# Chemical evolution with standard $^{13}\text{C}$ -pocket: ingredients

**Stellar mass range**  
=  $[3;10]M_{\text{sun}}$

**IMS from Serminato  
et al. 2009 (case ST-  
IMS)**

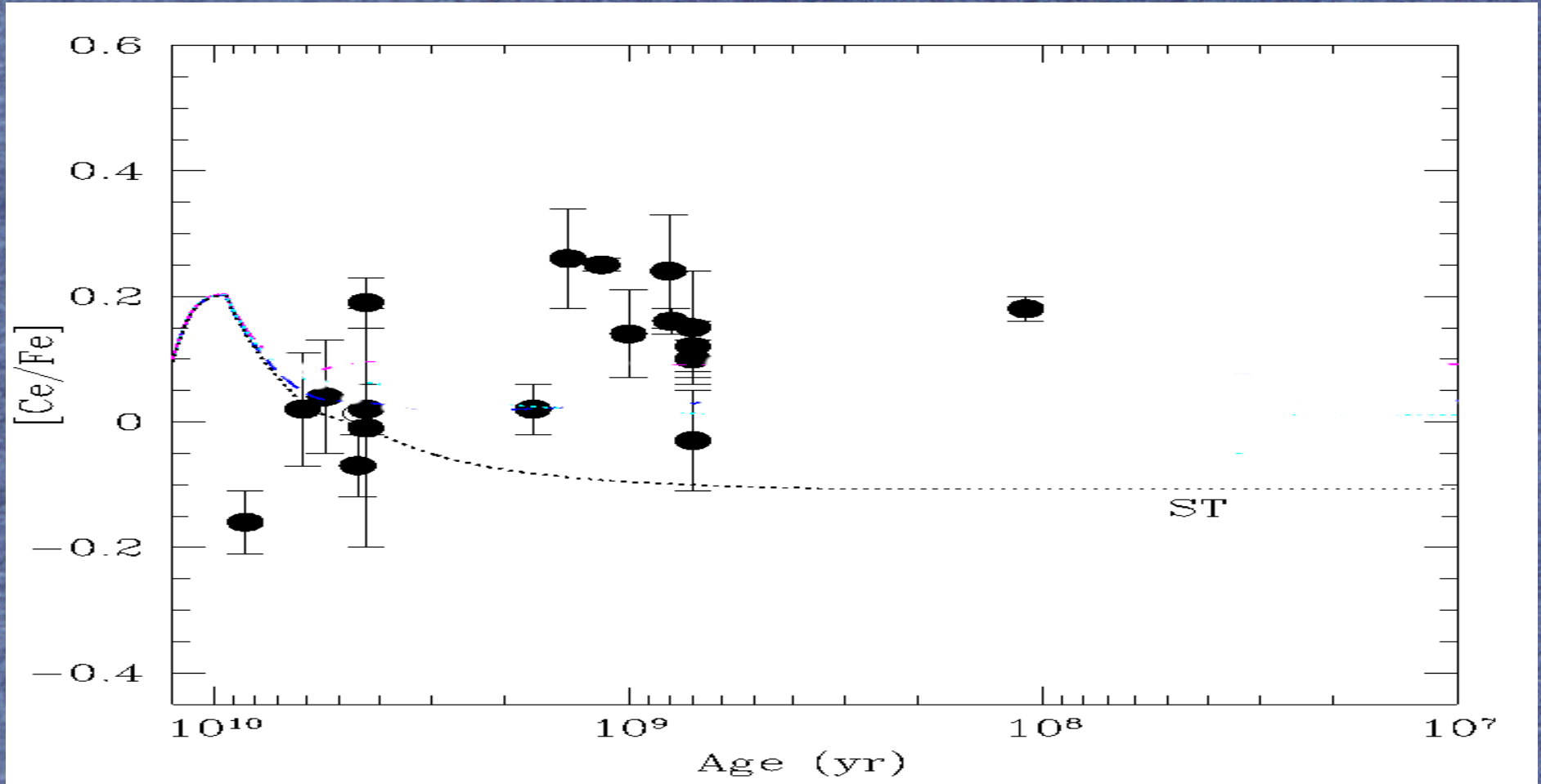
**Weak component  
from Pignatari et al.  
2010**

**Stars with  $[1.3-3]M_{\text{sun}}$   
15 bins inside the GCE**

**Stellar metallicity range  $Z =$   
 $[2e-3;24e-3]$   
7 bin inside the GCE**

**ST =>  $^{13}\text{C}$ -pocket:  
1) mass =  $1e-3M_{\text{sun}}$   
2) total  $^{13}\text{C}$  mass inside the  
 $^{13}\text{C}$ -pocket =  $3e-06 M_{\text{sun}}$   
(very close to Travaglio et al.  
2004)**

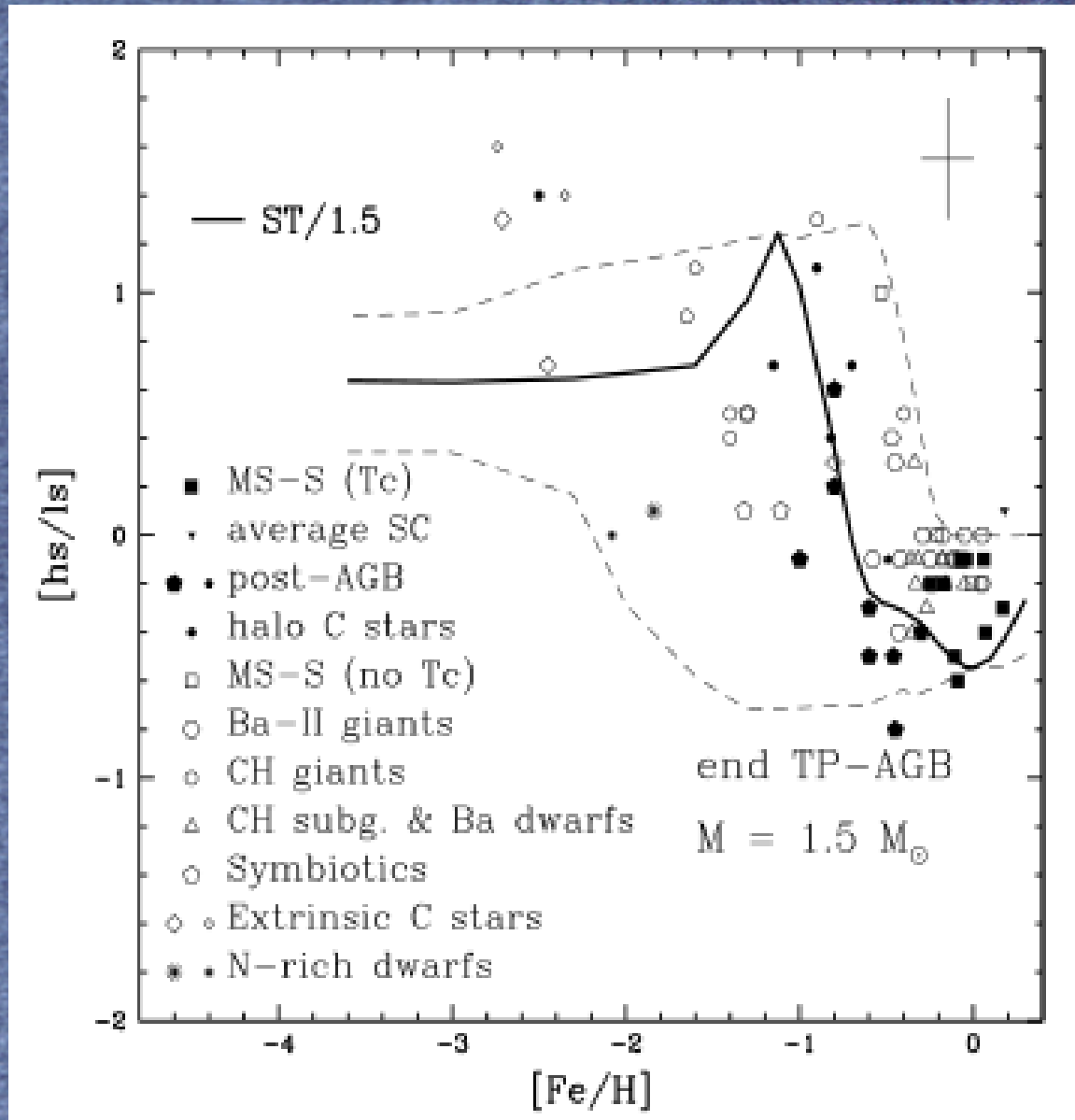
# Chemical evolution with standard $^{13}\text{C}$ -pocket: results



This is so not only for light s-elements but also for heavy ones. We need more neutrons

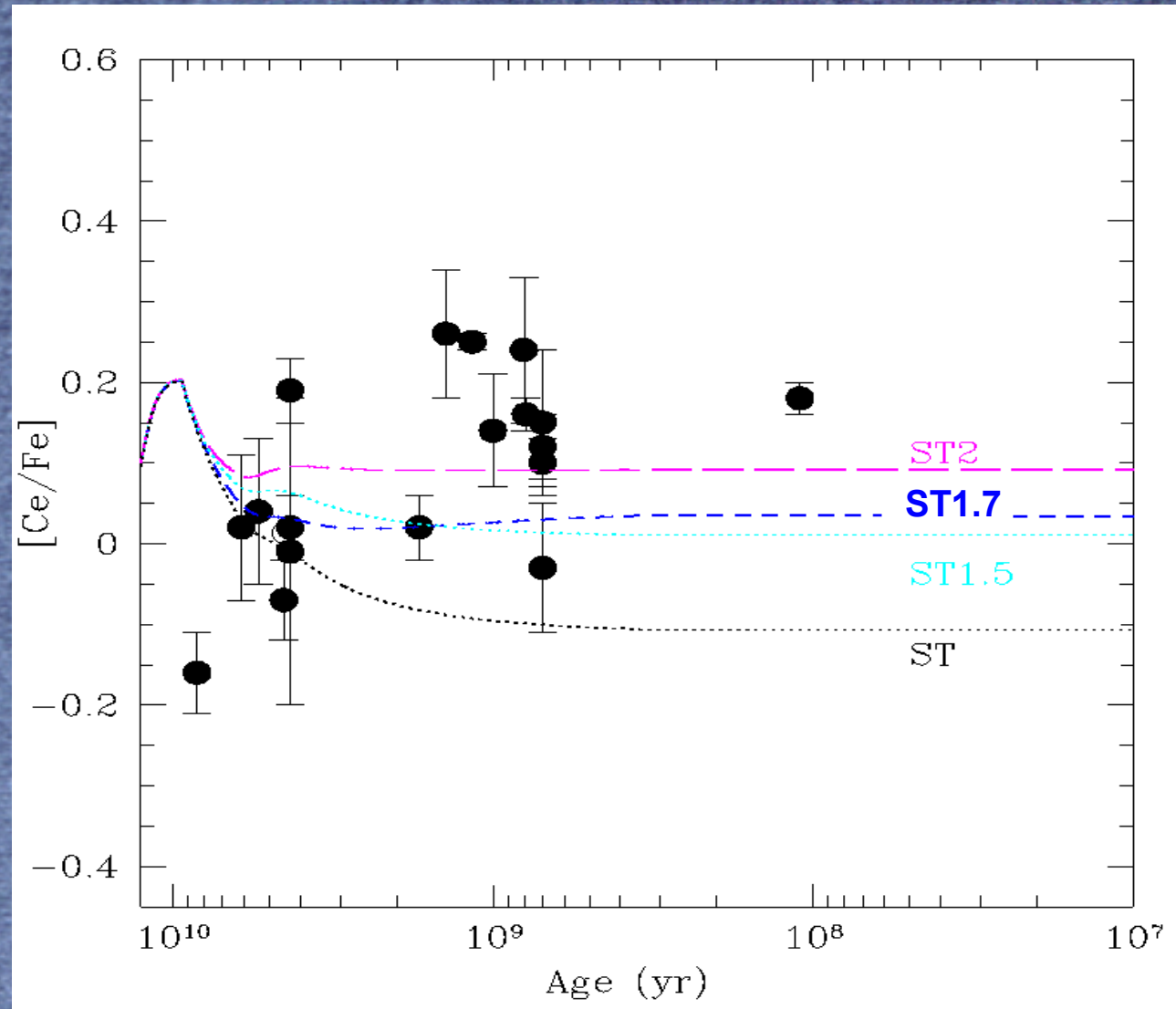


# (not) New calculations: [1.5-3]Msun



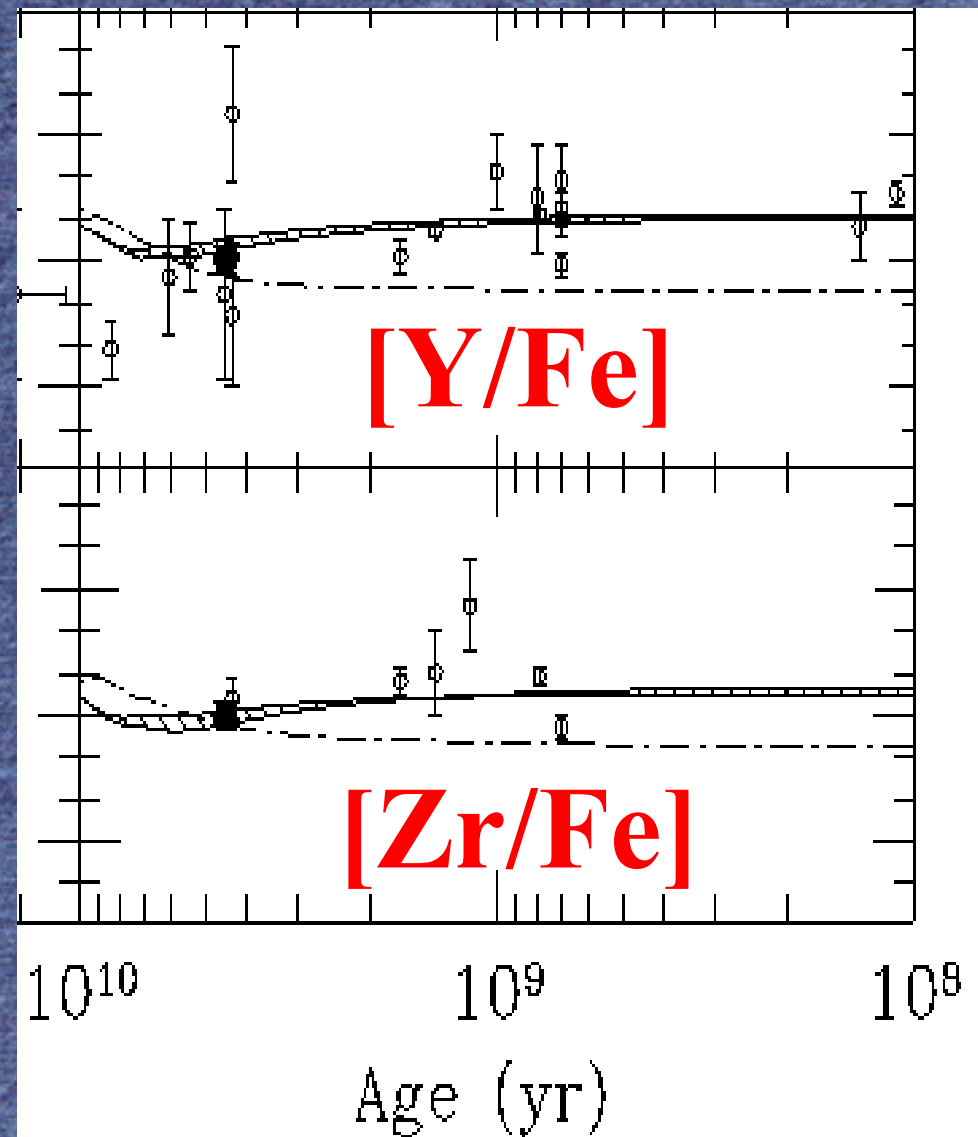
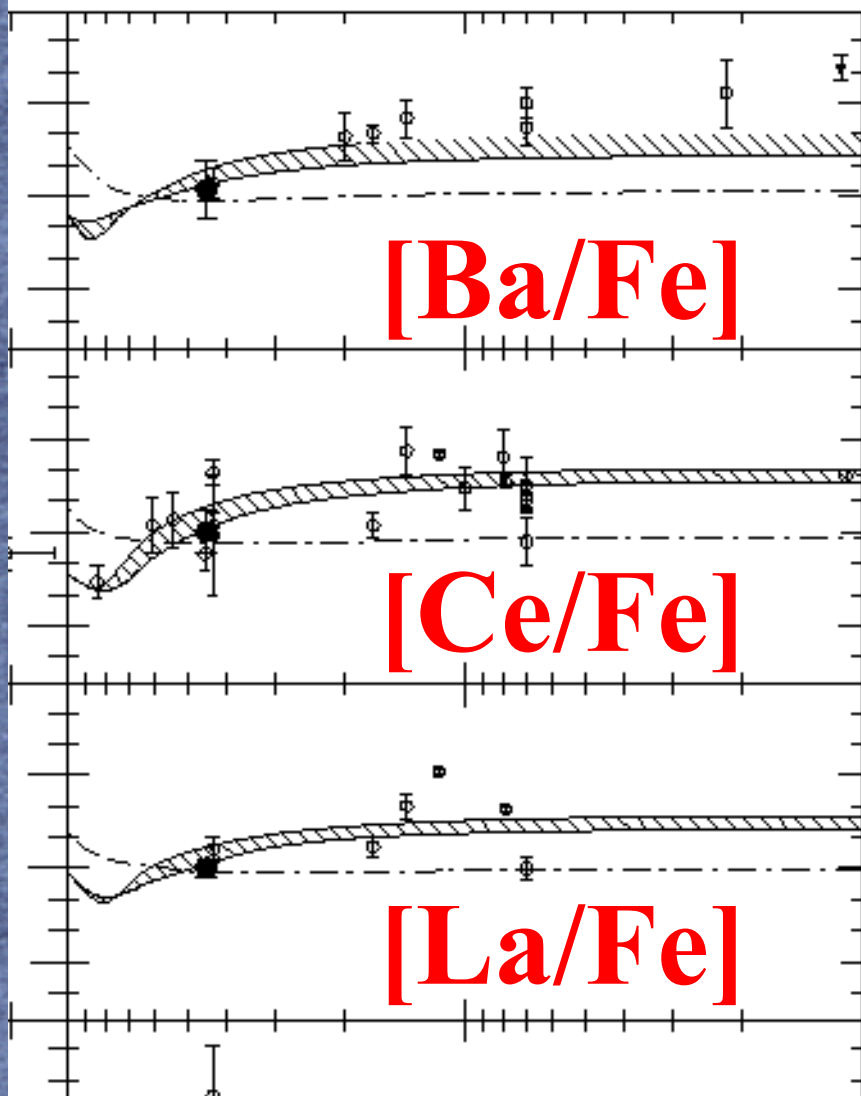
**Good agreement with  
observations of s-  
elements in AGB stars  
(Busso et al. 2001)**

# New calculations: $M < 1.5 M_{\text{sun}}$



**Enhancing the X( $^{13}\text{C}$ ) mass fraction inside the  $^{13}\text{C}$ -pocket**

# New calculations: $M < 1.5 M_{\text{sun}}$



Enlarging the  $^{13}\text{C}$ -pocket mass by a factor of 4

# New solar s-process distribution

Table 1

## Percentage Contributions to Solar Heavy Elements

(Galactic Chemical Evolution Estimates)

Element	This work: LMS	This work: non-LMS	Previous total (no LEPP) †	Literature: non-LMS (no LEPP) ‡
Yttrium	$89 \pm 1$	10-12	62	up to 15 [4(r); 7(weak); 4(IMS)]
Zirconium	$87 \pm 2$	11-15	55	up to 16 [10(r); 3(weak); 3(IMS)]
Barium	$92 \pm 3$	5-11	–	13(r)
Lanthanum	$85 \pm 3$	12-18	–	21(r)
Cerium	$94 \pm 4$	2-10	–	15(r)

† Reference: Travaglio et al. (2004); ‡ references: Bisterzo et al. (2010); Serminato et al. (2009)

## Percentage of solar s-only nuclei

(Galactic Contribution from LMS)

Isotope	Our range (LMS only)	Reference (31)
$^{100}\text{Ru}$	$93 \pm 2$	95
$^{110}\text{Cd}$	$97 \pm 2$	97
$^{124}\text{Te}$	$91 \pm 3$	91

# CONCLUSIONS

- **s-elements in young ( $\sim 1$  Gyr or less) galactic Open clusters are overabundant with respect to the Sun by about 0.2 dex**
- **GCE models can reproduce this growth assuming the Standard  $^{13}\text{C}$ -pocket in stars with  $[1.5-3] M_{\text{sun}}$  and an extended, IN MASS,  $^{13}\text{C}$ -pocket for stars with  $M < 1.5 M_{\text{sun}}$**
- **The same prescriptions lead to a solar s-process distribution in agreement with observations without the solar-LEPP requirement.**