Chemical Evolution Models in the Local Group

Cescutti Gabriele
Francesca Matteucci , Andy McWilliam,
Gustavo Lanfranchi, Patrick François , Cristina Chiappini

Astronomy Department
Trieste University

Heidelberg, 03/09/2009

Outline

- Galactic chemical evolution – brief introduction
- Main differences in the models of the studied stellar systems
- Oxygen and carbon in the Galactic bulge and in the Galactic disc
- The manganese in three stellar systems
- The neutron capture elements in the solar vicinity and in the dwarf spheroidal galaxy Sculptor
- Conclusions

Galactic chemical evolution

Stars and interstellar gas in galaxies exhibit diverse chemical element abundance patterns that are shaped by their environment and formation histories.

The aim of Galactic Chemical Evolution is to use the observed abundances in stars and the interstellar medium to reconstruct the chemical history and unlock earlier epochs in the Universe, probe the mechanisms of galaxy formation, and gain insight into the stellar evolution, costraining the stellar yields.

Models for the chemical evolution of galaxies need to account for the collapse of gas and metals into stars (star formation), the synthesis of new elements within these stars, and the subsequent release of metal-enriched gas as stars lose mass and die. An additional features are the ongoing accretion of gas from outside in the system and the presence of outflows of gas from the system.

Galactic chemical evolution

An homogeneous model follows the time evolution of the gas fraction of element A with this equation:

$$\Psi(R,t)=\nu G(R,t)^k$$

$$\dot{G}_A(R,t) =$$

$$-X_A(R,t)\Psi(R,t) + X_A^{infall}\dot{G}_{inf}(R,t) \quad -X_A(R,t)\dot{W}_A(R,t)$$

1) Locked in stars **2) Infalling in the system** **3)Flowing from the system**

$$+\int_M \Psi(R,t-\tau(\tilde{m}))\Phi(\tilde{m})(Q(\tilde{m},Z(t)))_A\, d\tilde{m}$$

Stellar nucleosynthesis!!!

3) Produced by stars

Studied stellar systems

The different stellar systems have had different evolutions.
To account for these, their models present some main differences:

	Solar vicinity	Milkyway bulge	Dwarf spheroidal galaxies
ν	1	20	<1
Wind	No	Yes	Yes
Infall Law	Two infall model (halo-disc)	One infall (short timescale!)	Depends on the dwarf spheroidal
More recent model	Cescutti et al. (2008)	Ballero et al. (2007	Lanfranchi et al (2008)

They share the same stellar nucleosynthesis!

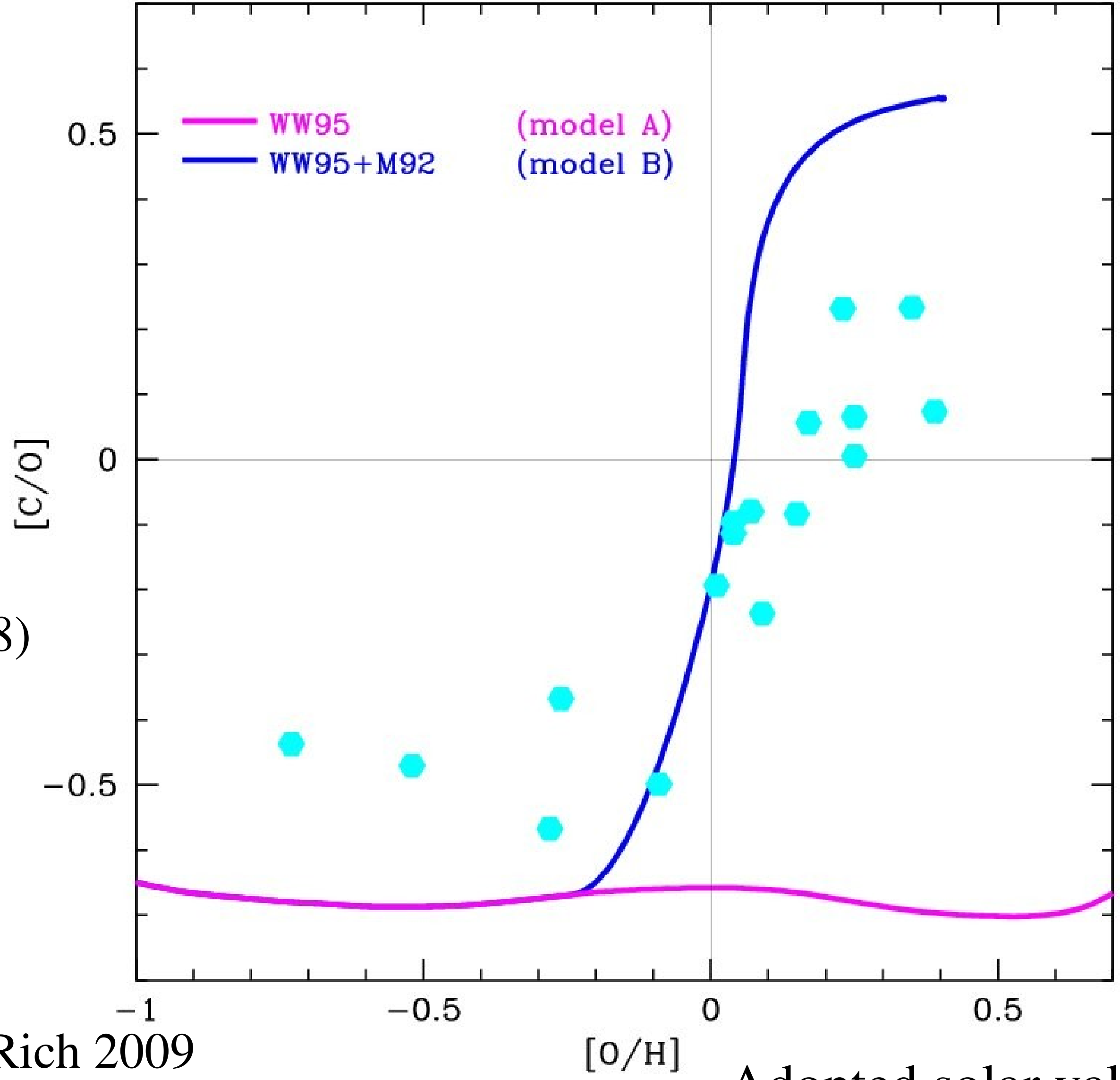
C & O in the bulge

We start with 2 nucleosynthesis prescriptions:

- Woosley&Weaver '95
  metal dependent

- Woosley and Weaver '95 +
  Maeder '92 for solar
  metallicity
  (see McWilliam et al. 2008)

Cescutti et al. (2009)



Data for the bulge

⬢ McWilliam Fulbright and Rich 2009
Melendez et al. 2008

Adopted solar values:
Asplund et al. (2005)

C & O in the bulge

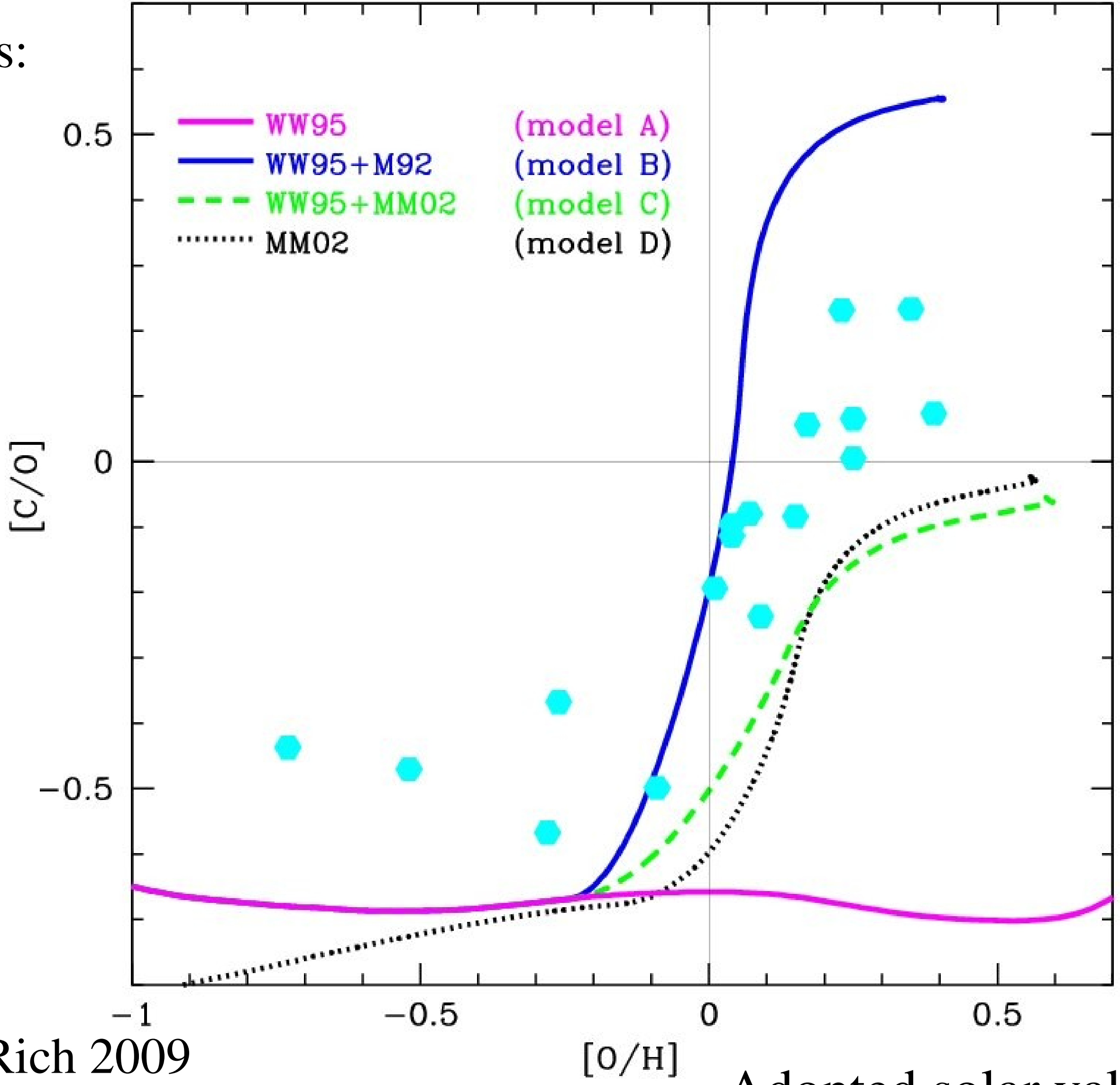
We apply two other nucleosynthesis prescriptions:

- Woosley&Weaver '95
  metal dependent +
  Meynet & Maeder '02 for
  solar metallicity

- Meynet & Meader '02
  metal dependent

We follow the trend of the data, but there is a offset.

Cescutti et al. (2009)



Data for the bulge

⬢ McWilliam Fulbright and Rich 2009
Melendez et al. 2008

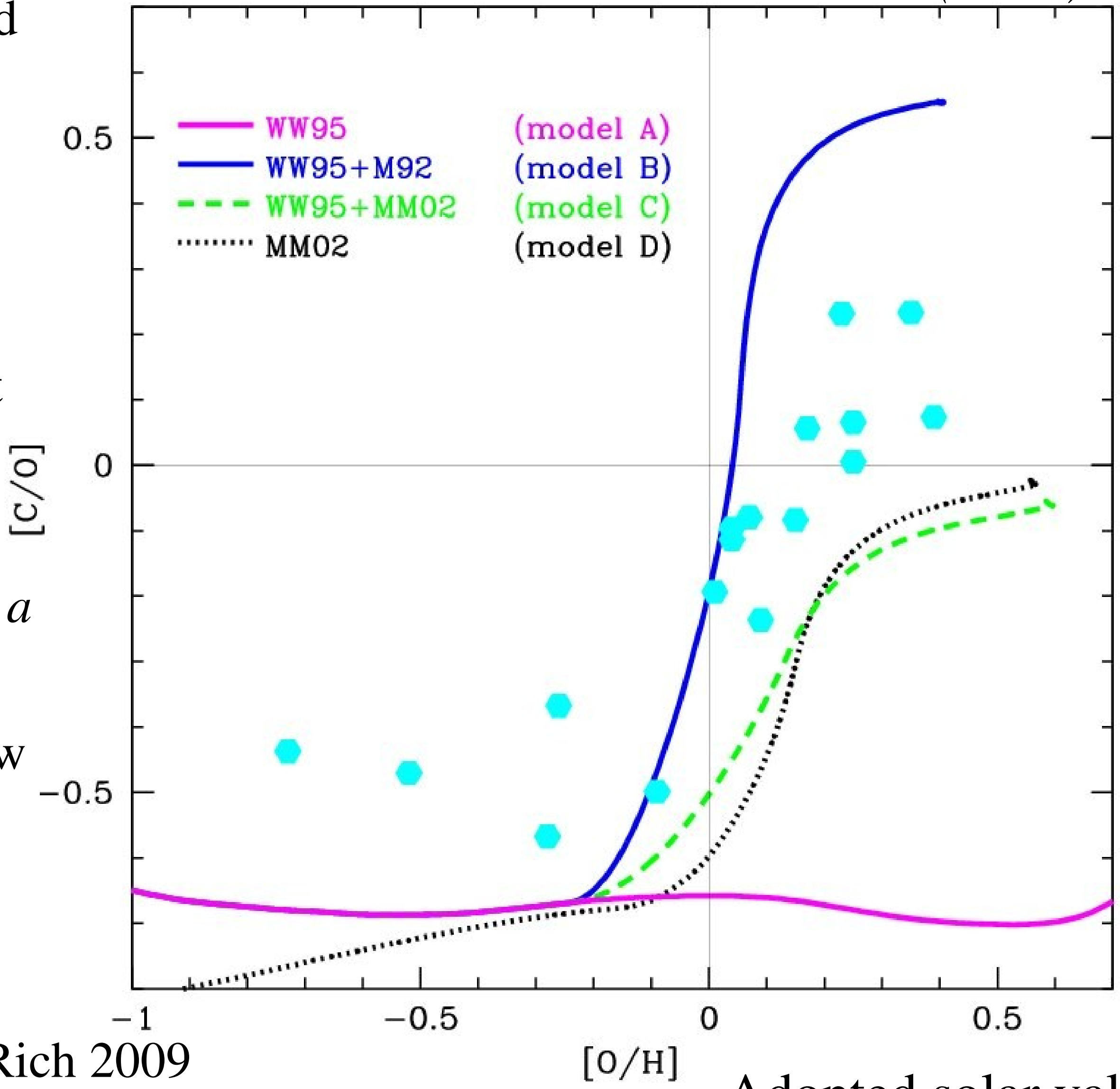
Adopted solar values:
Asplund et al. (2005)

C & O in the bulge

Explanation for the offset of 0.2 dex between the observed and predicted [C/O] ratio in the metal-poor bulge:

- IMF slope in massive stars (*but see Ballero et al. 2007*)
- C production from very fast rotating extremely metal poor stars (see Chiappini et al. 2006 *but this produces a peak rather than a plateu*)
- extra source of carbon at low metallicity provided by low metallicity massive binaries.

Cescutti et al. (2009)



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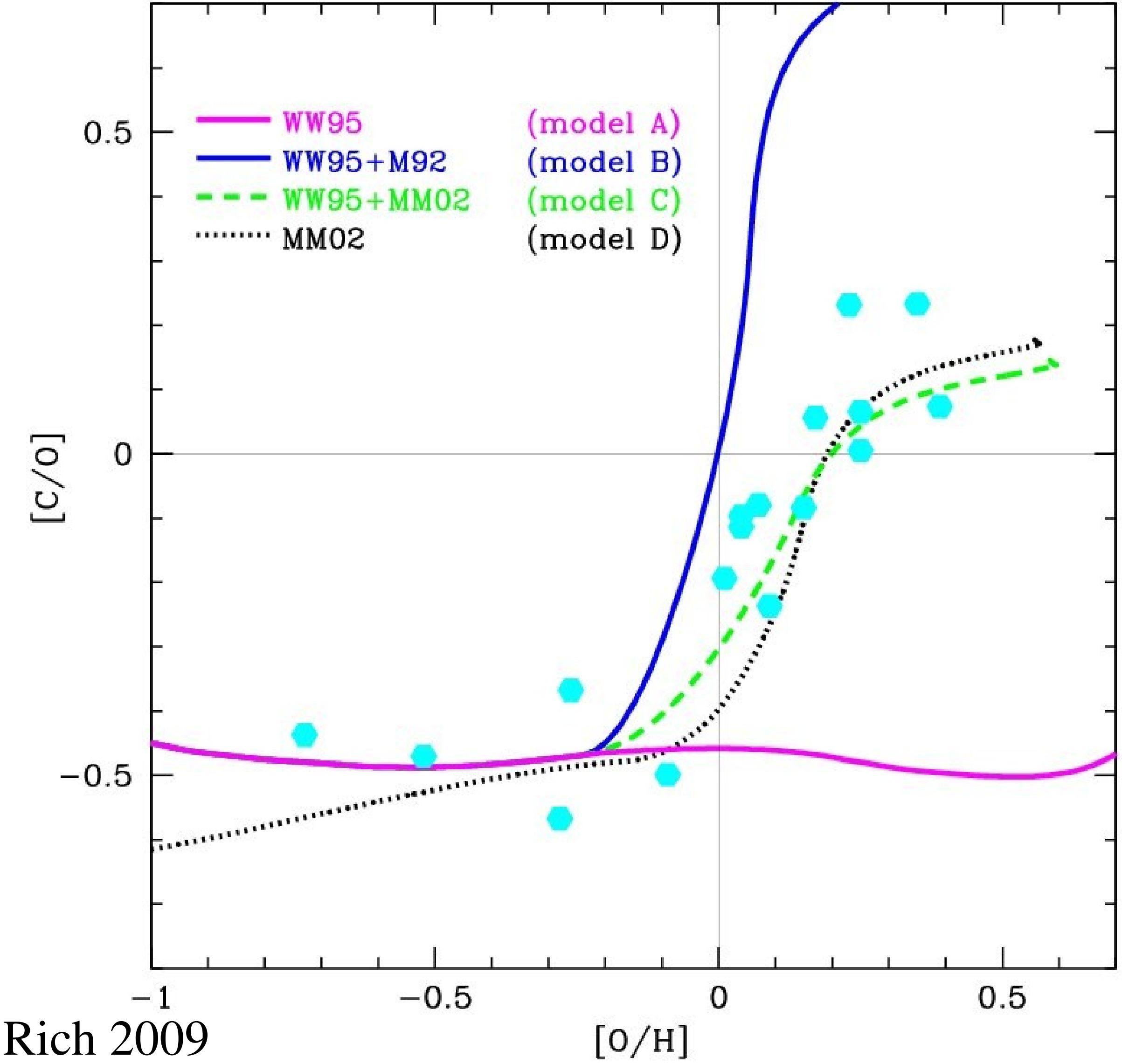
C & O in the bulge

Cescutti et al. (2009)



Data for the bulge

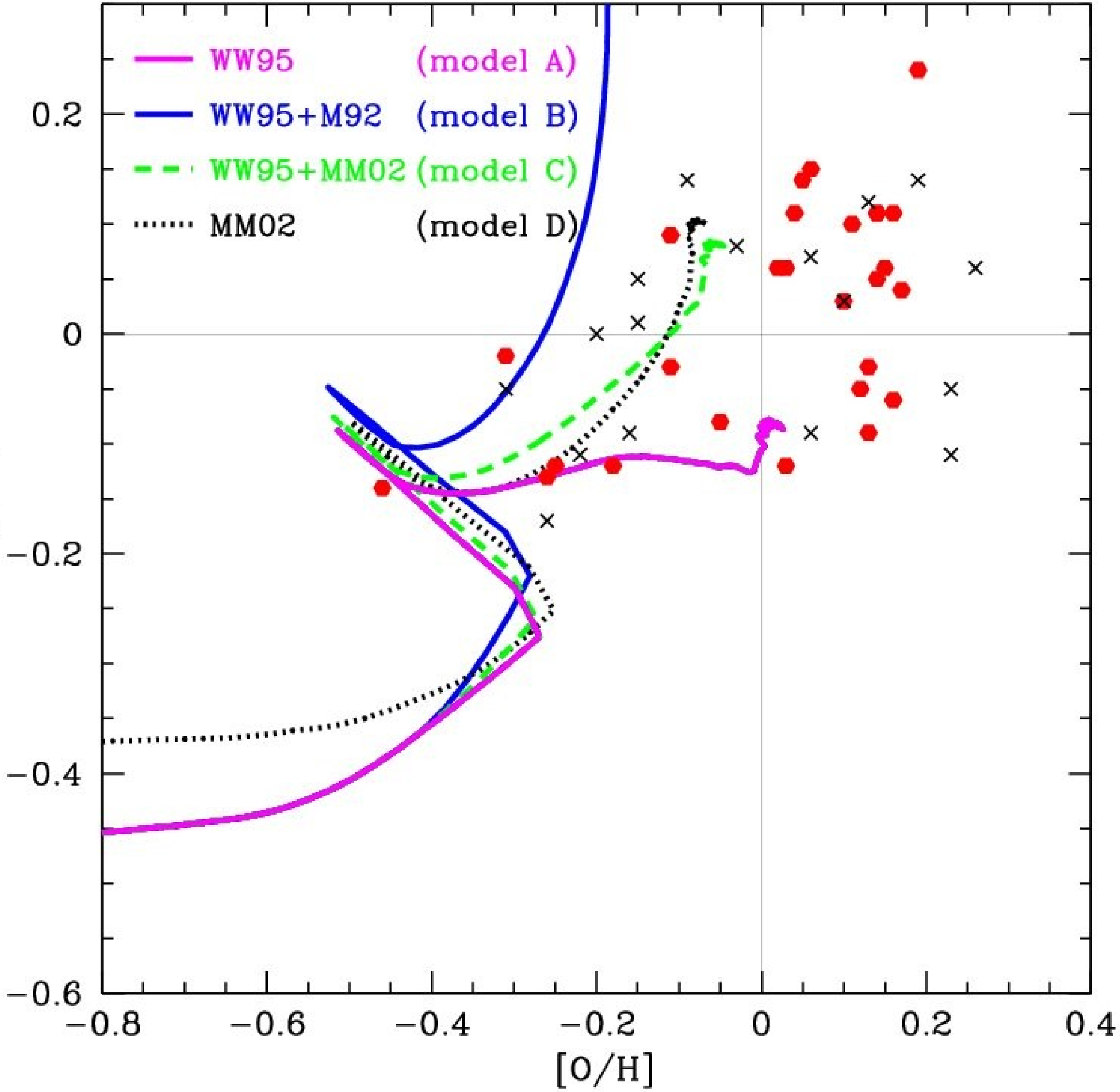
⬢ McWilliam Fulbright and Rich 2009

Melendez et al. 2008

C & O in the solar vicinity

If we apply the same nucleosynthesis sets of yields in the solar vicinity code, the models C and D are still the best to fit the data, rather than the models A and B.

Cescutti et al. (2009)



Data for the thin disc

⬢ Bensby & Feltzing (2006)

Nissen & Edvardsson (1992)

✖ Gustafsson el al. (1999)

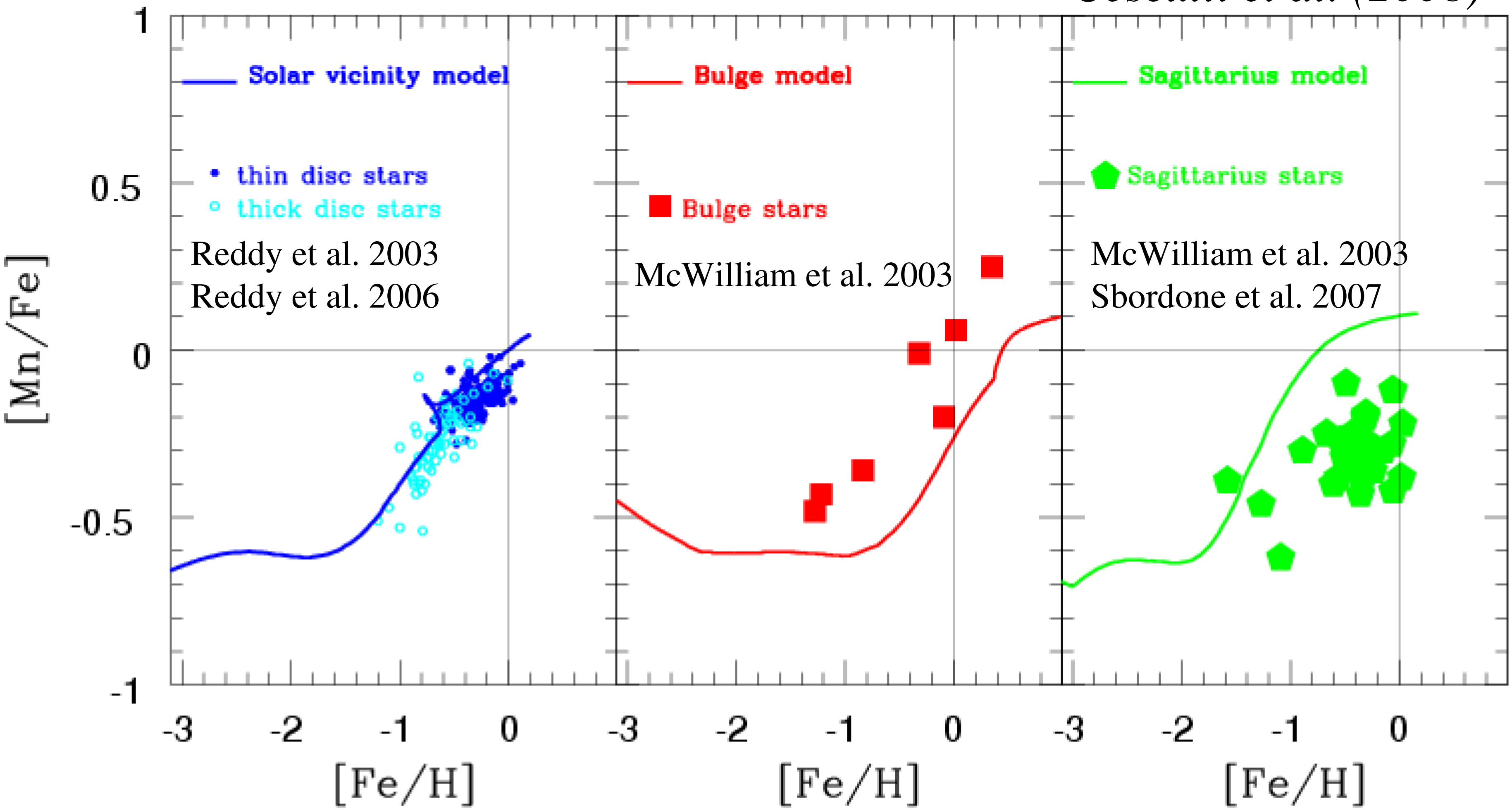
Andersson & Edvardsson (1994)

Adopted solar values:
Asplund et al. (2005)

Manganese 1

The Mn in the three systems with the yields used by François et al. (2004), to well fit the data of the MW disc (without metallicity dependence)

Cescutti et al. (2008)



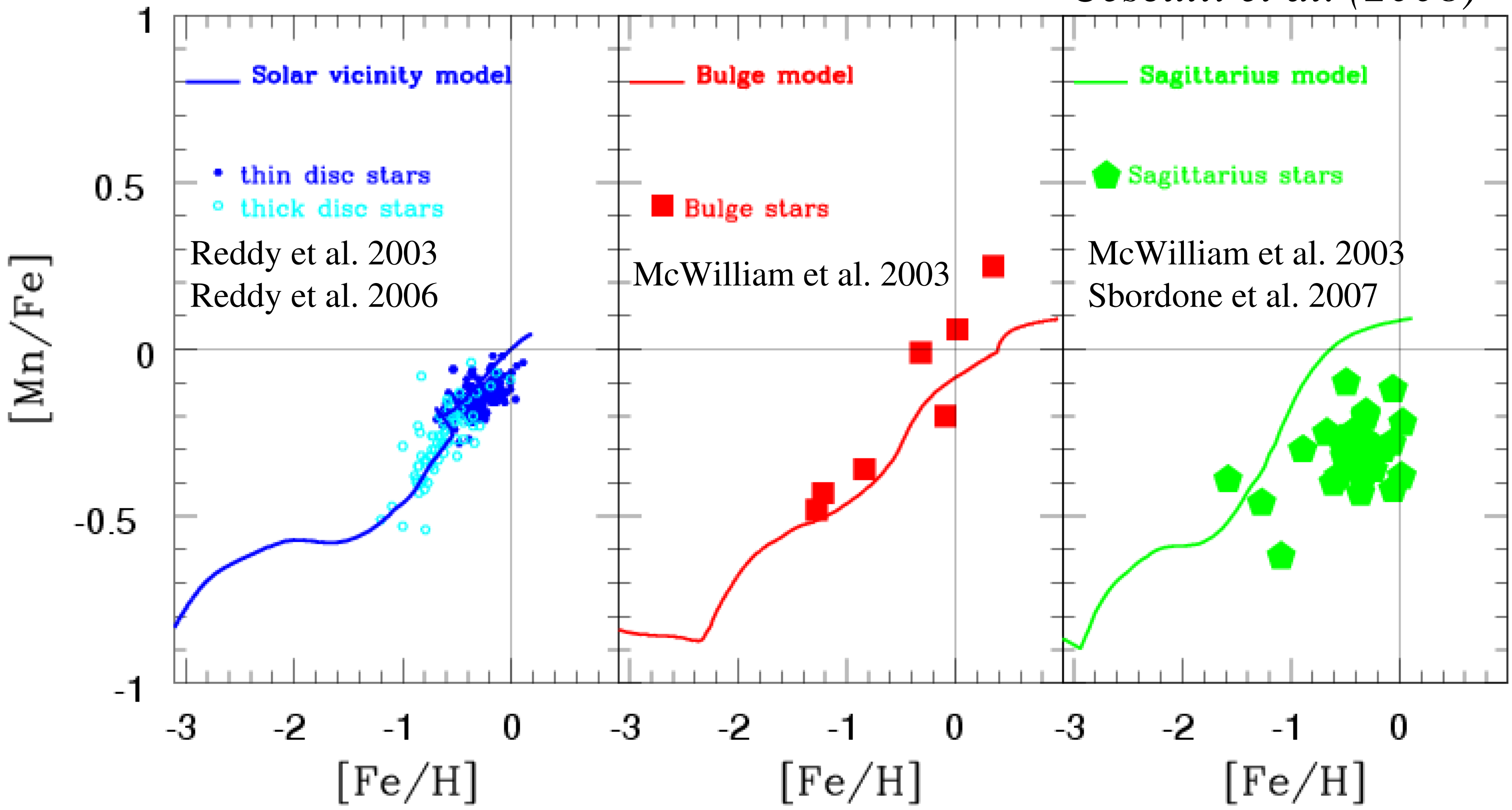
$$[A/B]=\log_{10}[N_A/N_B]_{star} - \log_{10}[N_A/N_B]_\odot$$

Adopted solar values:
Asplund et al. (2005)

Manganese 2

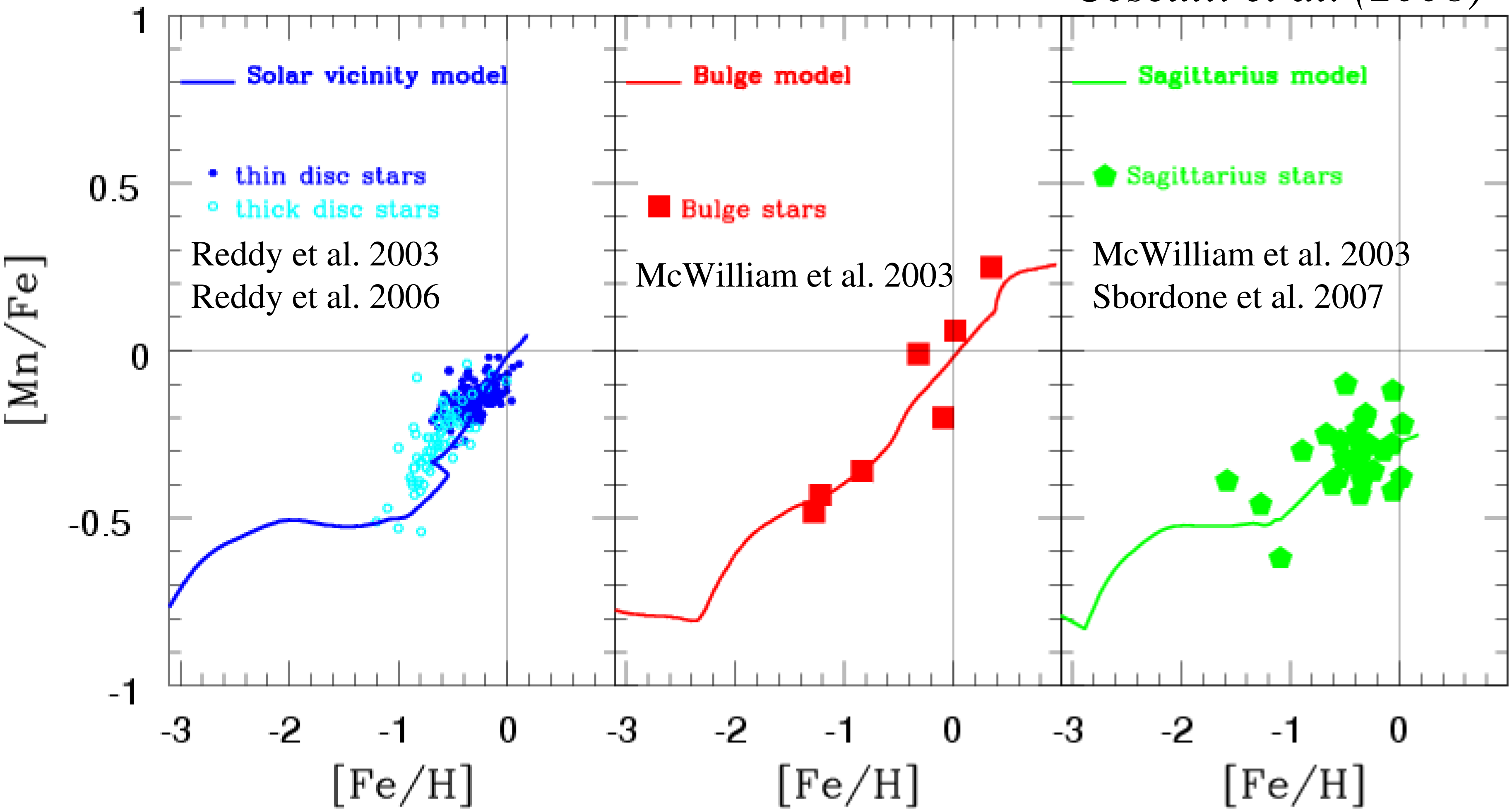
To improve the results for Mn we use the yields for SNII computed by the whole set of Woosley & Weaver (1995), with metallicity dependence

Cescutti et al. (2008)



Manganese 3

We explore the role of the yields for SNIa, adopting yields again depending to the metallicity : $Z/Z_{\odot}^{0.65}$ (cfr Badenes et al. 2008)



Cescutti et al. (2008)

This solution to the Mn problem in Sagittarius was suggested by McWilliam et al. (2003)

Neutron capture elements

The elements beyond the iron peak (A>60) are formed through neutron capture on seed nuclei (iron and silicon).

Two cases:

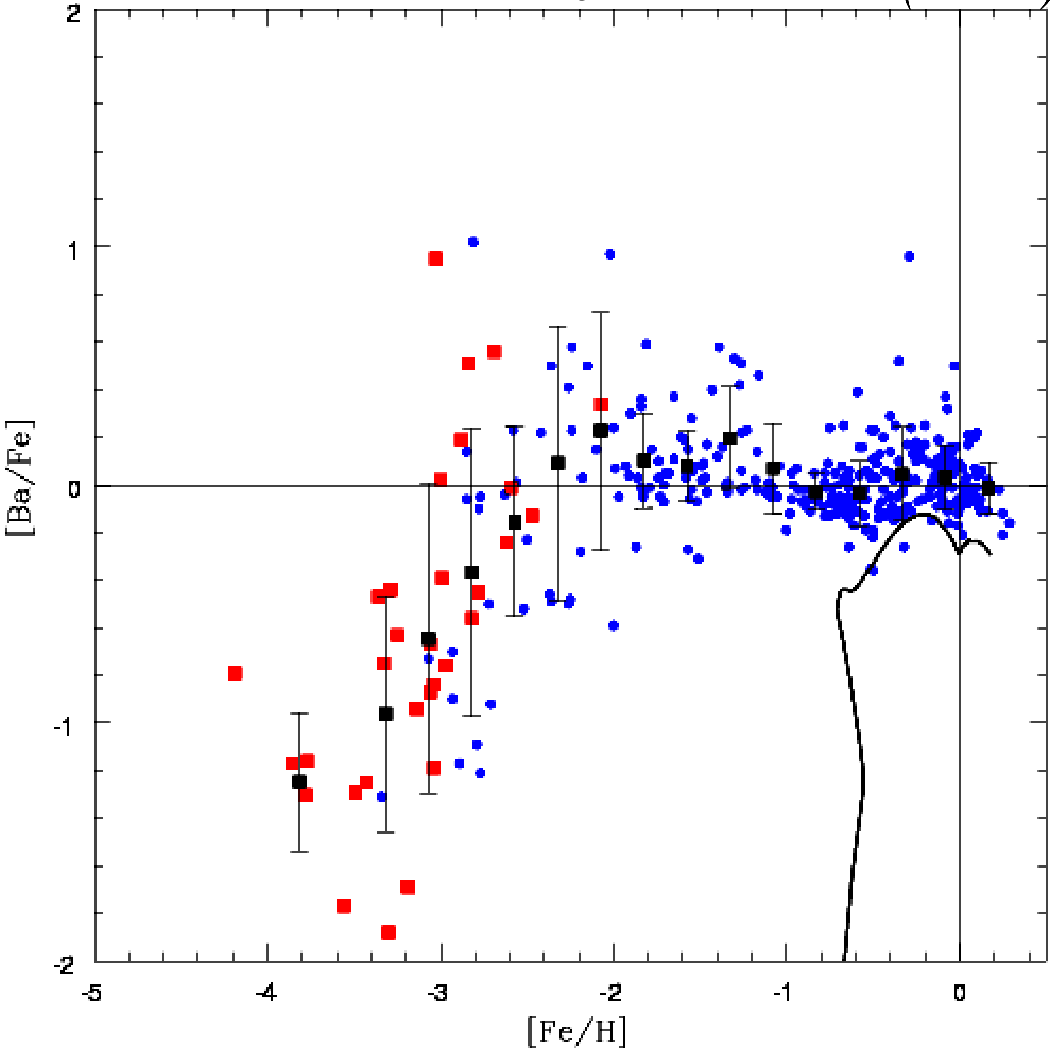
s-process:		r-process:
low mass AGB stars	where	explosions of SNe II (?)
Busso et al. (2001) for Ba, La, Sr, Y & Zr	Nuclesynthesis prescriptions	No theoretical computations Set empirically to best fit the abundances of these elements in the solar vicinity low metallicity stars

M_{star}	Q_{Sr}	Q_{Y}	Q_{Zr}	Q_{Ba}	Q_{La}	Q_{Eu}
$10M_\odot$	$1.62\cdot10^{-6}$	$8.60\cdot10^{-7}$	$1.80\cdot10^{-6}$	$9.00\cdot10^{-7}$	$9.00\cdot10^{-8}$	$4.50\cdot10^{-8}$
$15M_\odot$	$5.40\cdot10^{-8}$	$1.20\cdot10^{-8}$	$1.80\cdot10^{-7}$	$3.00\cdot10^{-8}$	$3.00\cdot10^{-9}$	$3.00\cdot10^{-8}$
$30M_\odot$	$3.25\cdot10^{-9}$	$1.00\cdot10^{-9}$	$5.00\cdot10^{-9}$	$1.00\cdot10^{-9}$	$1.00\cdot10^{-10}$	$5.00\cdot10^{-10}$

Barium

s-process
low mass stars
1-3$M_\odot$
Busso et al.

Cescutti et al. (2006)



Observational data:

🟥 François et al. (2007)

● Honda et al (2004) & other authors

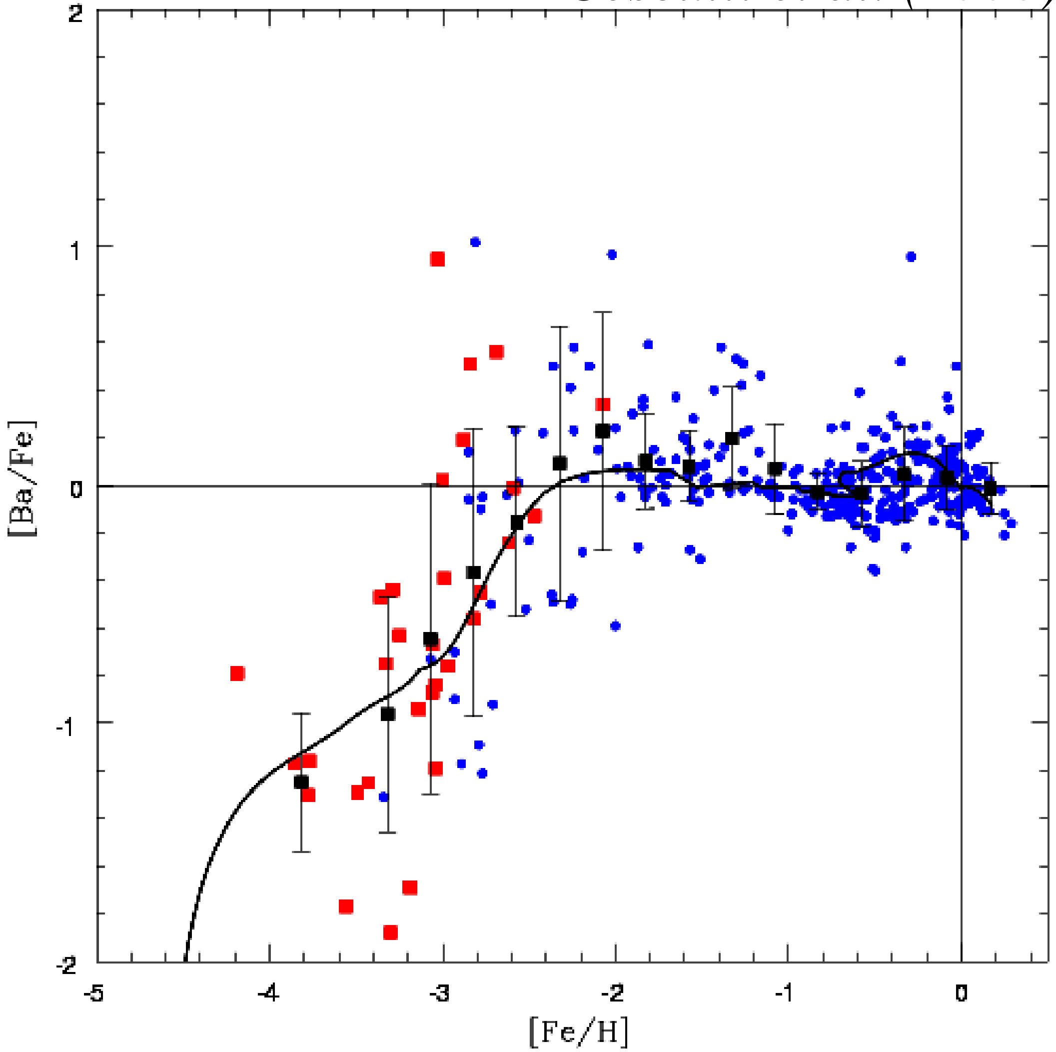
Barium

s-process
low mass stars
1-3$M_{\odot}$
Busso et al.

+

r-process
massive star
10-30$M_{\odot}$
(previous table)

Cescutti et al. (2006)



Observational data:

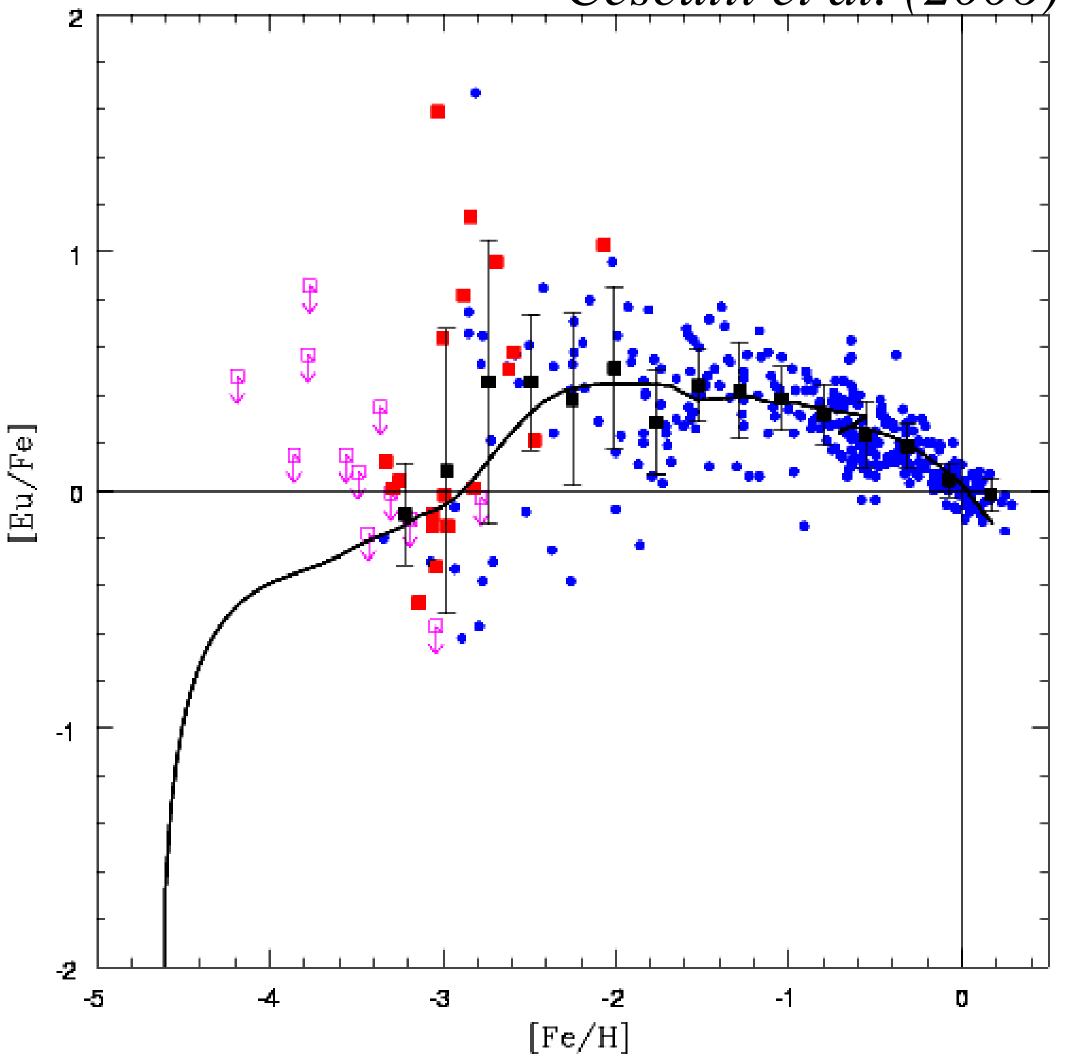
🟥 François et al. (2007)

● Honda et al (2004) & other authors

Europium

r-process
massive star
10-30M⊙
(previous table)

Cescutti et al. (2006)

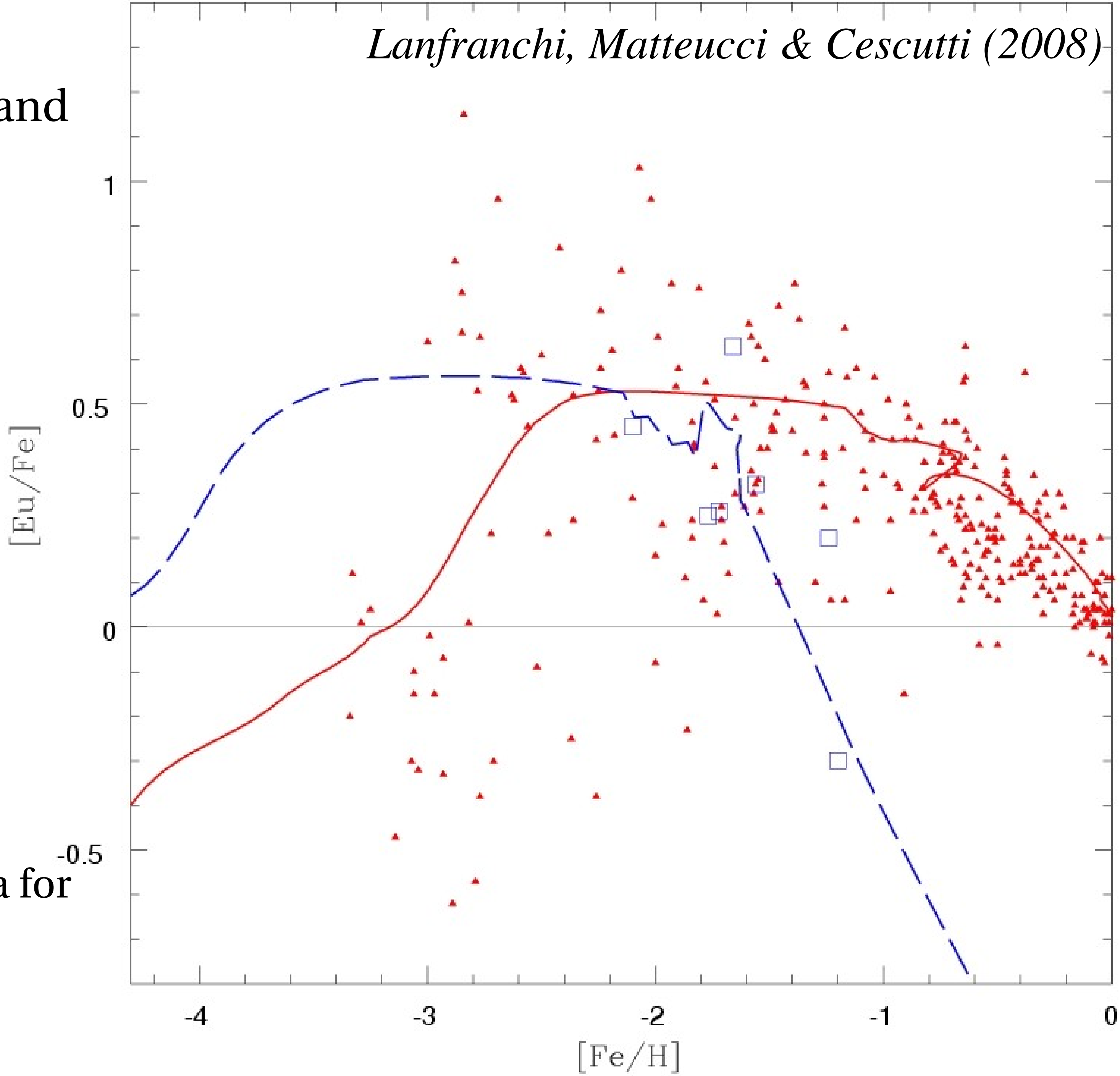


Observational data:

- 🟥 François et al.(2007)
- ☐ upper limits
- ● Honda et al (2004) & other authors

Europium in Sculptor

The galactic wind and the different star formation, produce different chemical evolution, in particular in the case of ratio of [Eu/Fe], there is a strong decrease at [Fe/H] ~ -2

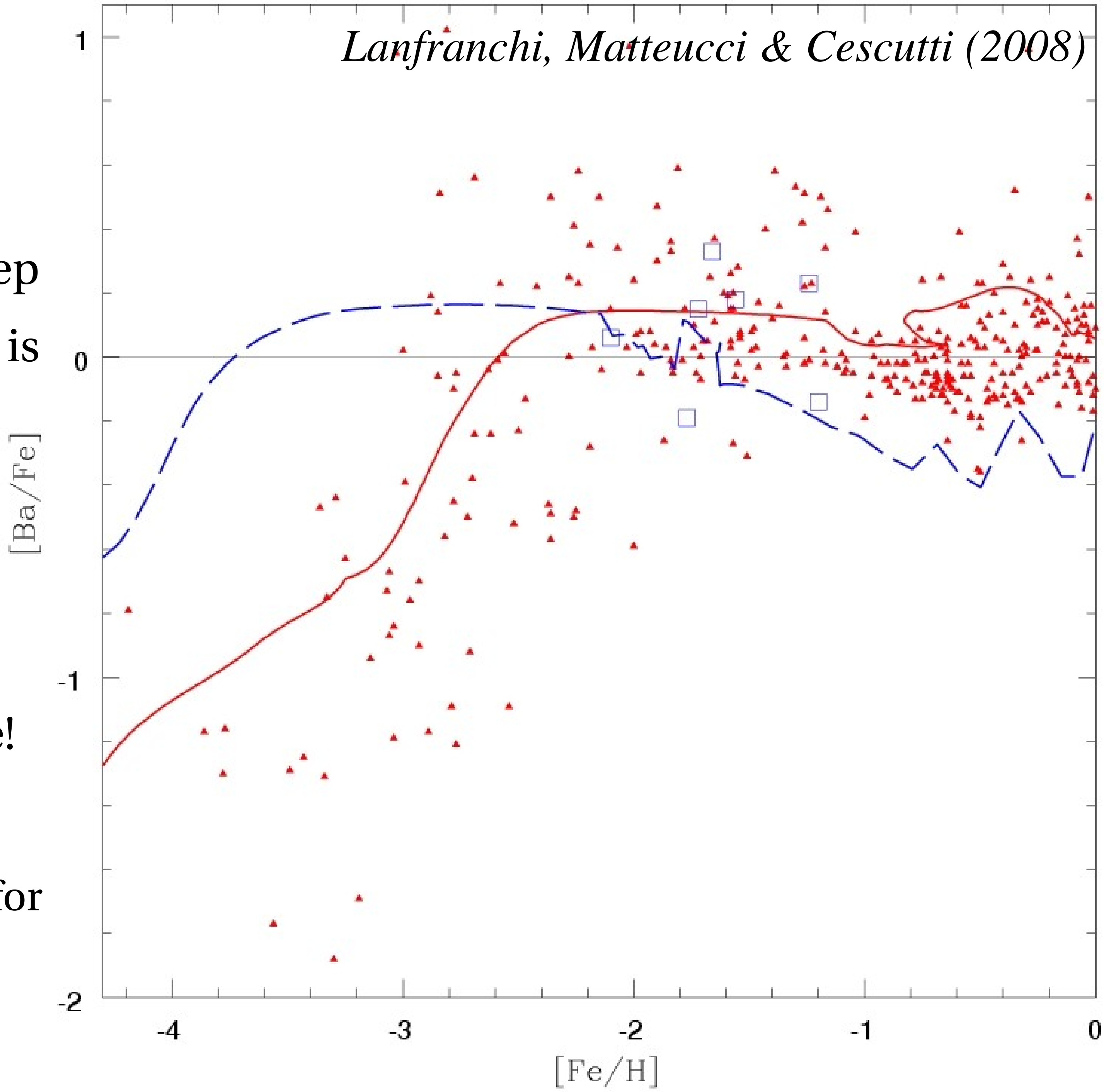

Lanfranchi, Matteucci & Cescutti (2008)

□ Venn et al. 2004 data for the dSph Sculptor

▲ MW's data

Barium in Sculptor

For [Ba/Fe] the decrease is not so steep as for Eu because it is produced not only by massive stars but also by s-process in low mass stars during the AGB phase!



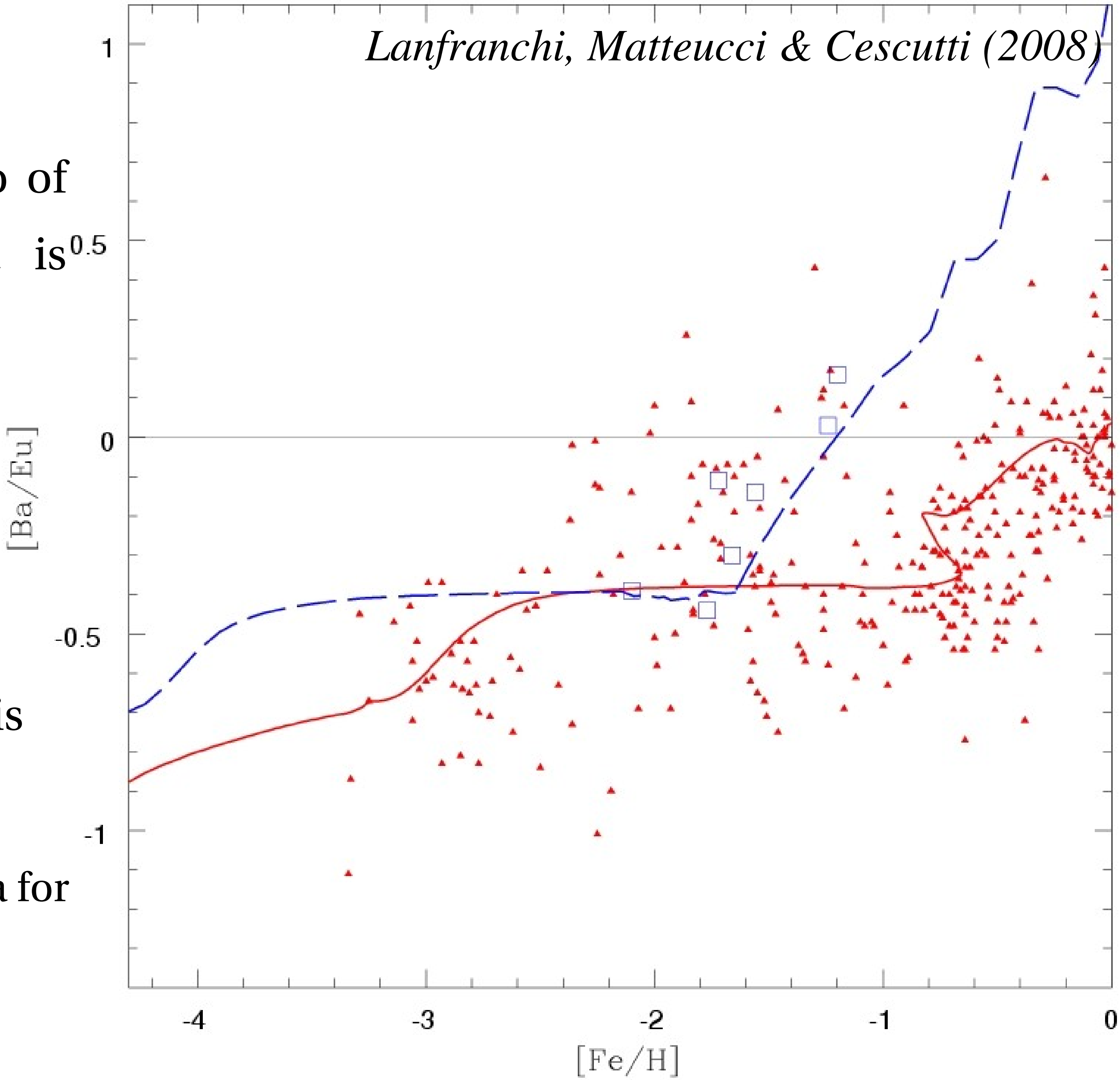
Lanfranchi, Matteucci & Cescutti (2008)

□ Venn et al. 2004 data for the dSph Sculptor

▲ MW's data

[Ba/Eu] in Sculptor

Looking at the ratio of [Ba/Eu] this effect is clear, and our nucleosynthesis applied in the chemical evolution model for Sculptor is able to explain this trend.



Lanfranchi, Matteucci & Cescutti (2008)

☐ Venn et al. 2004 data for the dSph Sculptor

▲ MW's data

Conclusions

The inclusion of metallicity-dependent carbon and oxygen yields improve the agreement of our predictions for the Galactic bulge (and for the Galactic disk); moreover our results confirms the conclusion that the bulge formed more rapidly than the disk, based on the overabundances of elements produced by massive stars.

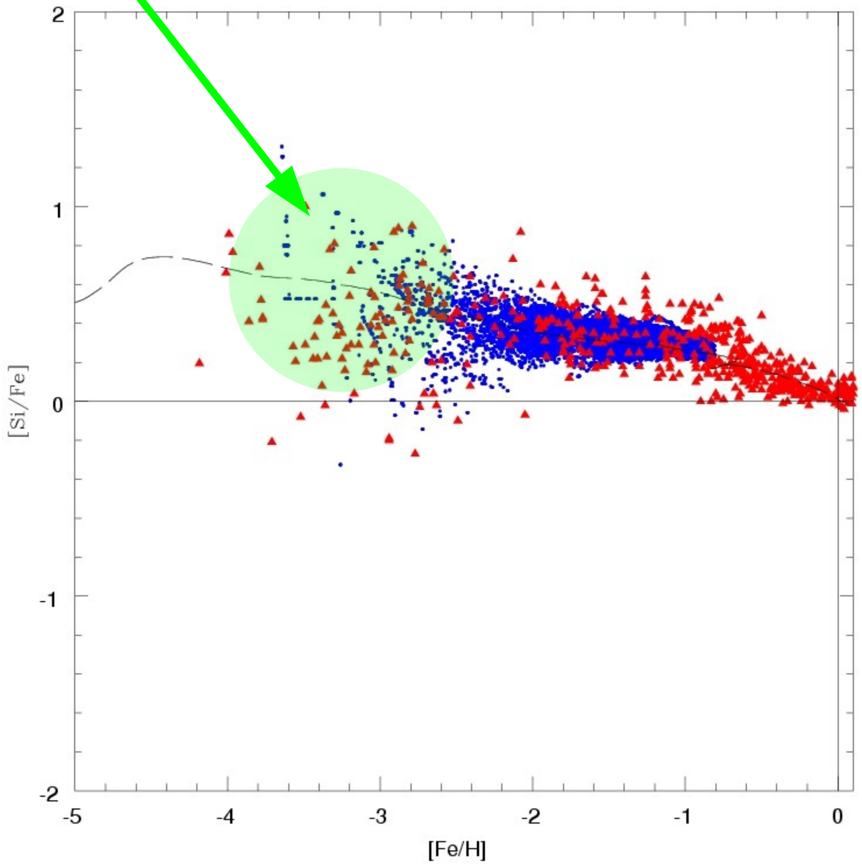
Modelling different histories of star formation in the three systems (solar neighborhood, Milky Way bulge and Sagittarius dwarf spheroidal) are insufficient to reproduce the different behaviour of the [Mn/Fe] ratio; rather, it is necessary to invoke metallicity-dependent type Ia SN Mn yields.

Comparing the models and the new data at low metallicity for neutron capture elements, we have set the r-process yields and we have concluded that Ba are produced by both (10-30$M_\odot$) and s-process in low mass stars (1-3$M_\odot$), Eu only by r-process in massive stars. The same nucleosynthesis prescriptions adopted to well fit the data in the Milky Way produce is able to explain the trends of the stellar abundances of these elements in the dwarf spheroidal galaxies.

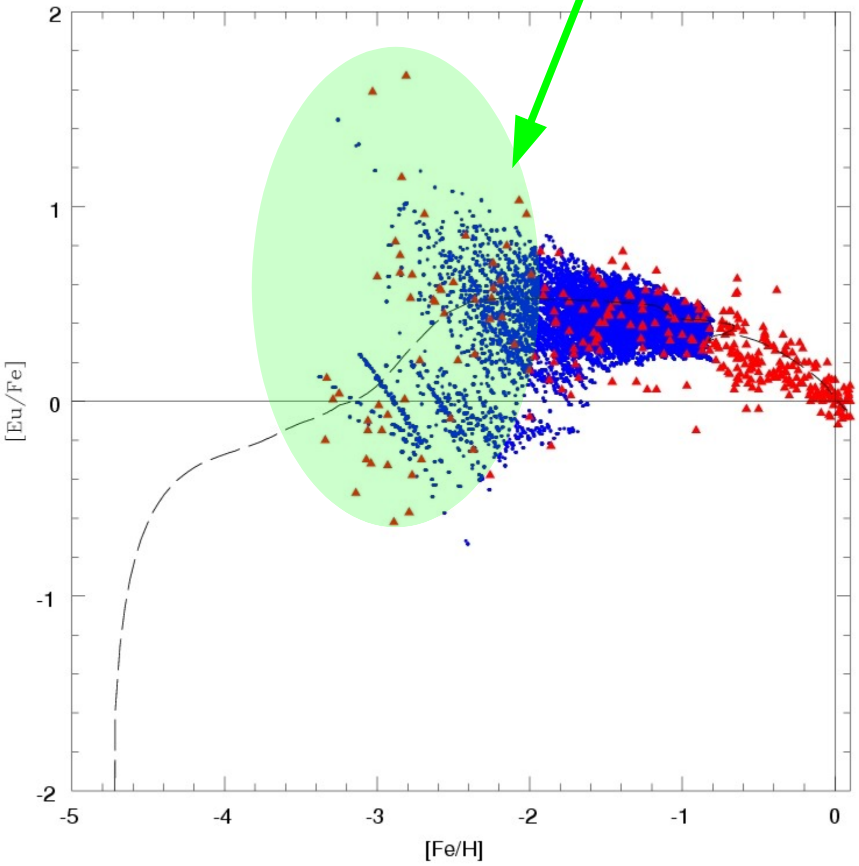
Inhomogeneous model for the Halo

Cescutti (2008)

α – elements:
small dispersion



Neutron capture: large
dispersion



▲ Milky Way data

● Model results

Inhomogeneous model for Sculptor

We apply the same inhomogenous method to a Sculptor. First results show interesting features as the presence of spread for the neutron capture elemens also in these system.