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Chemical signatures in dwarfs

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Neutron capture elements

from Truran 1981 to ~5 years ago

AIP

	s-process	Early Galaxy	r-process
site	Low-(intermediate) mass stars		Massive stars (& NS mergers)
			electron capture SN neutron stars mergers Magneto rot. driven SN ...
time scale	>300Myr		< 30Myr (excluding NS mergers)
yields	Busso et al. 2001 *Cristallo+ 2011* *Karakas+ 2012)*		....

satellite galaxies and dwarfs in the local group

First signature
Spread in the n.c. elements (Ba)

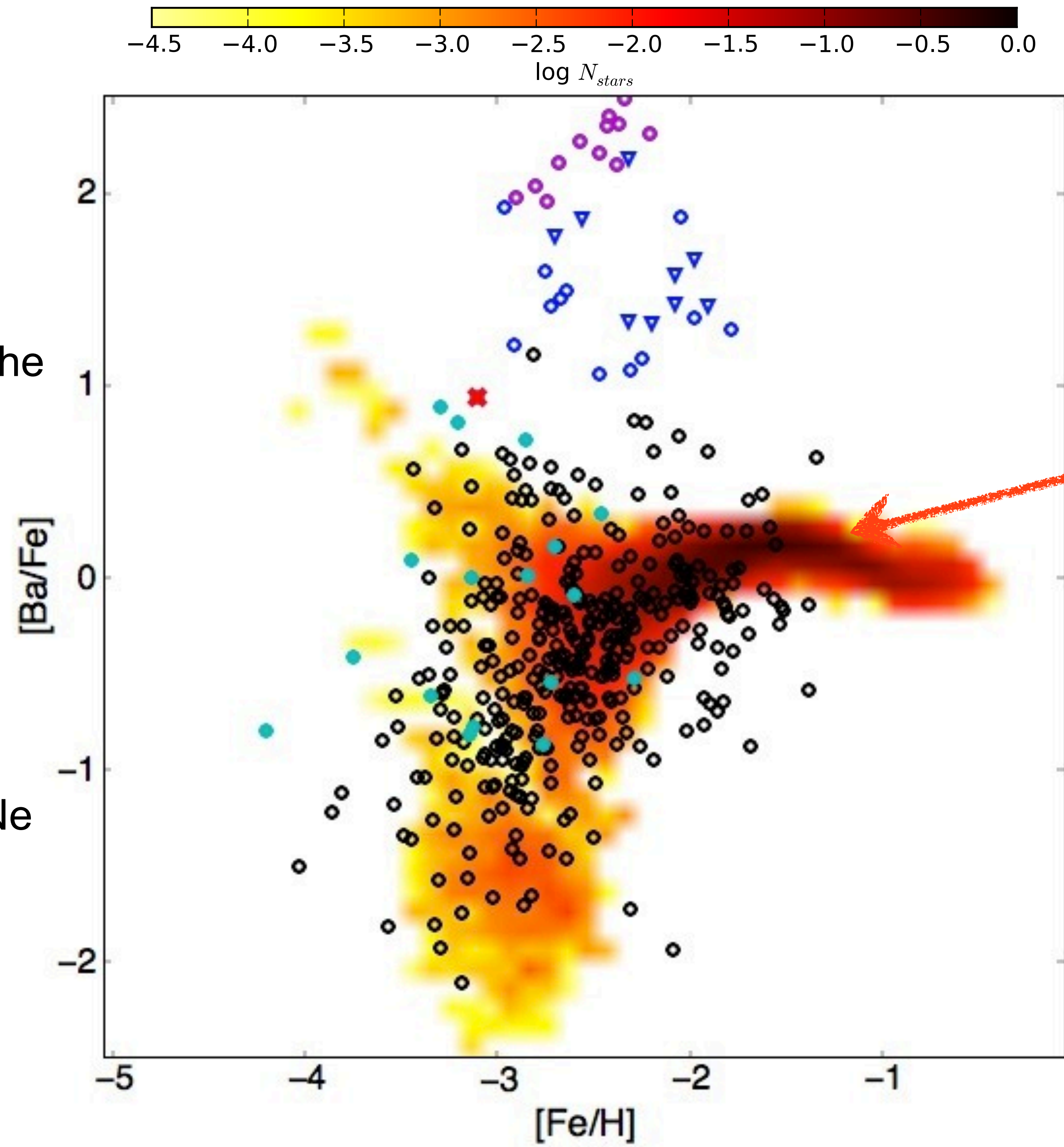
Stochastic chemical evolution model (Cescutti '08)

+

rare progenitors for the r-process events:

- small mass range as Electron capture SNe (8-10Msun)

- fraction of the SNe, as Magneto Rotational Driven SNe (5-10%)



We can reproduce this spread in the Galactic halo

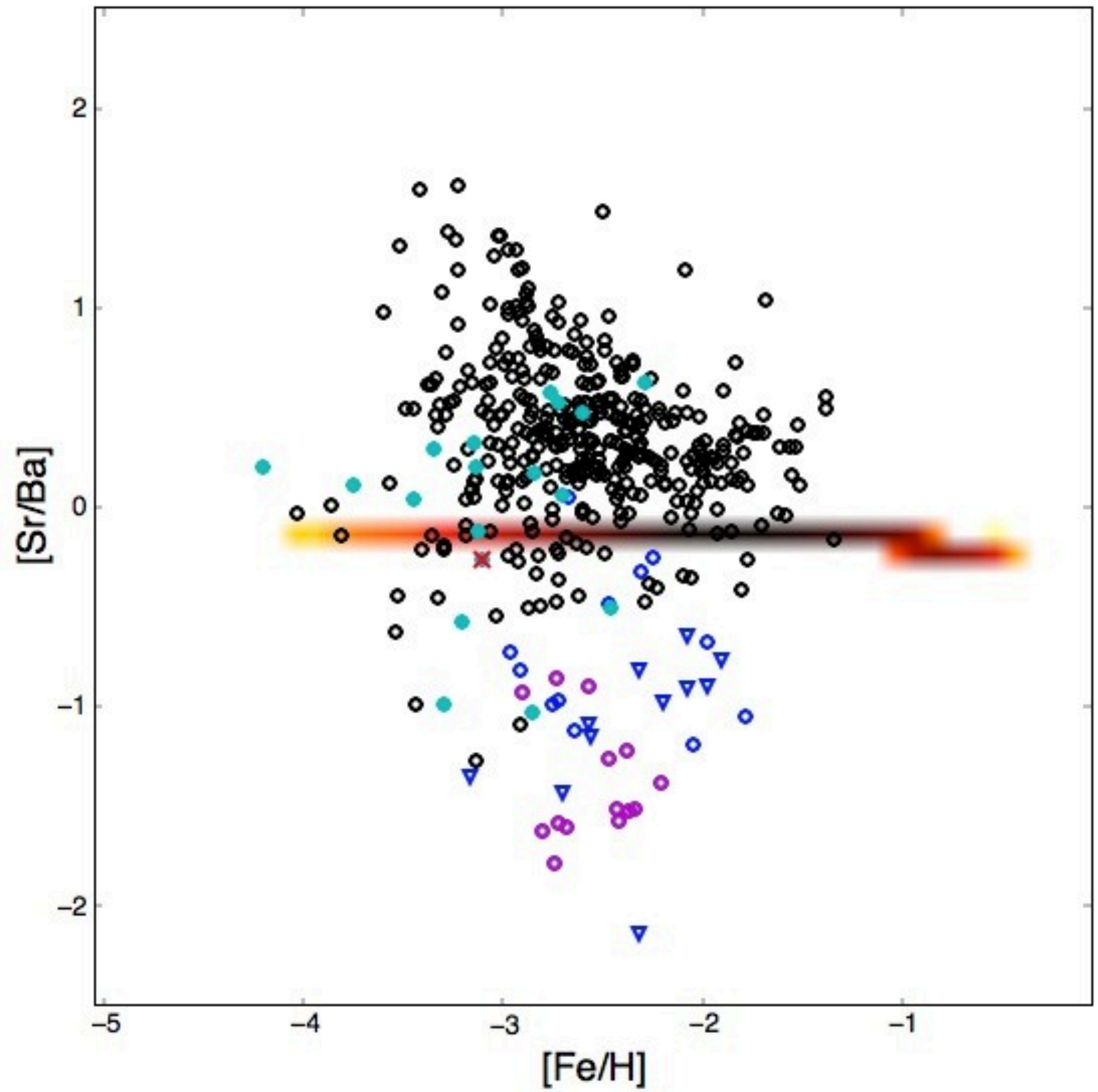
Density plot of long living stars for stochastic model

Data collected in Frebel10.

halo stars:
normal
cemp-s
cemp-no

Puzzling result for the "heavy to light" n.c. element ratio

For Sr yields: scaled Ba yields according to the r-process signature of the solar system (Sneden et al '08)



It is impossible to reproduce the data, assuming only the r-process component, enriching at low metallicity.
Well known issue (see Sneden+ 03, François+07, Montes+07)

halo stars:
normal
cemp-s
cemp-no

Signatures of Fast Rotators found in the Galactic Halo

(1) Large amounts of N in the early Universe (Chiappini et al. 2006 A&A Letters)

(2) Increase in the C/O ratio in the early Universe

(3) Large amounts of ^{13}C in the early Universe (Chiappini et al. 2008 A&A Letters)

(4) Early production of Be and B by cosmic ray spallation (Prantzos 2012)

5

Early production of neutron capture elements through a boosted s-process (Sr,Ba,...)

Neutron capture elements

The picture since Chiappini+2011 (Nature)

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Early Galaxy

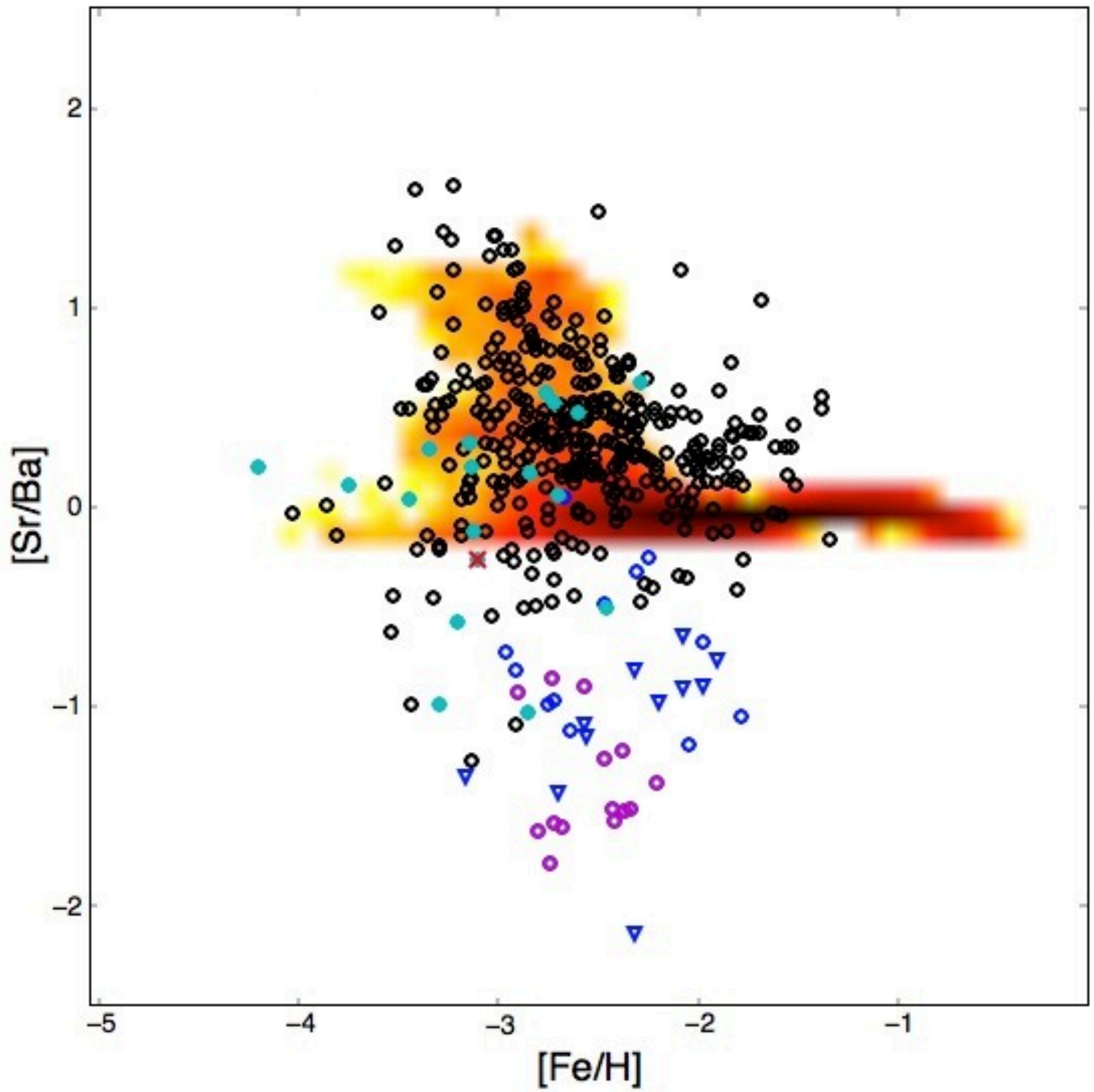
	s-process		r-process
site	Low-(intermediate) mass stars	rotating Massive stars	Massive stars (& NS mergers)
			O-Ne-Mg core explosions? NS stars mergers?Magneto rot. driven SN? many scenarios...
time scale	>300Myr	< 30Myr	< 30Myr (excluding NS mergers)
yields	Busso+ 2001	Frischknecht+ 2012	....
	Cristallo+ 2011 *Karakas+ 2012*	*Pignatari+ 2008,* *Limongi yields still unpublished*	

Second signature

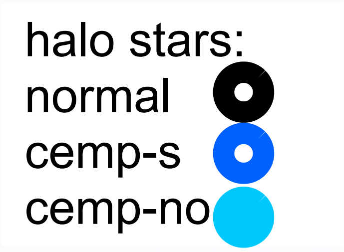
Spread in the light to heavy s-process elements

s-process from fast rotators
+
EC SN (or MRD) as r-process site

It is possible to reproduce the Galactic halo data



Cescutti, Chiappini, Hirschi, Meynet and Frischknecht (2013)



The dSph satellites of our Galaxy

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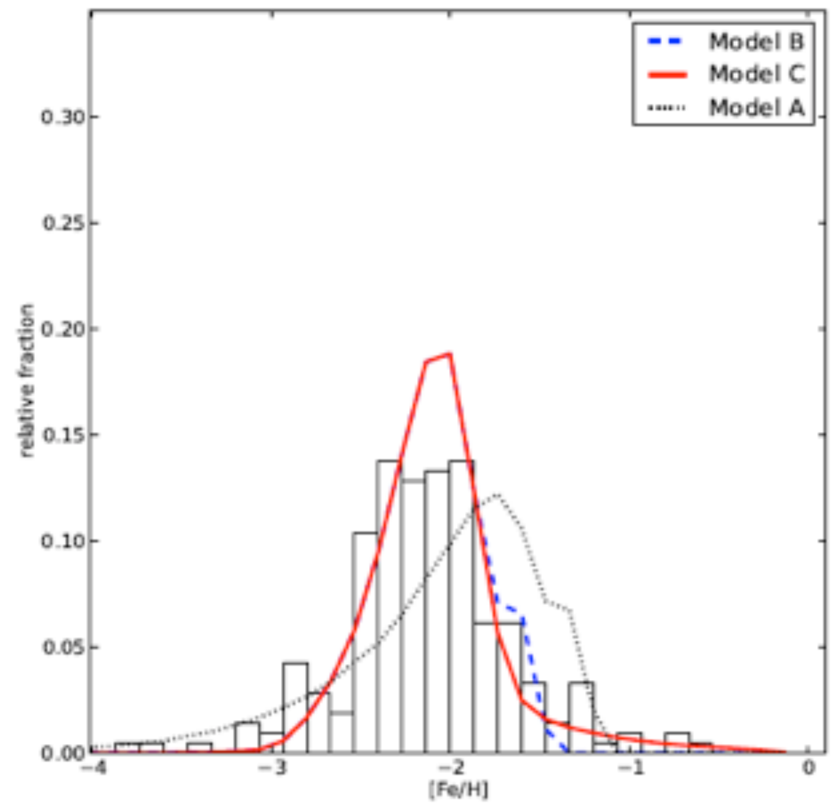
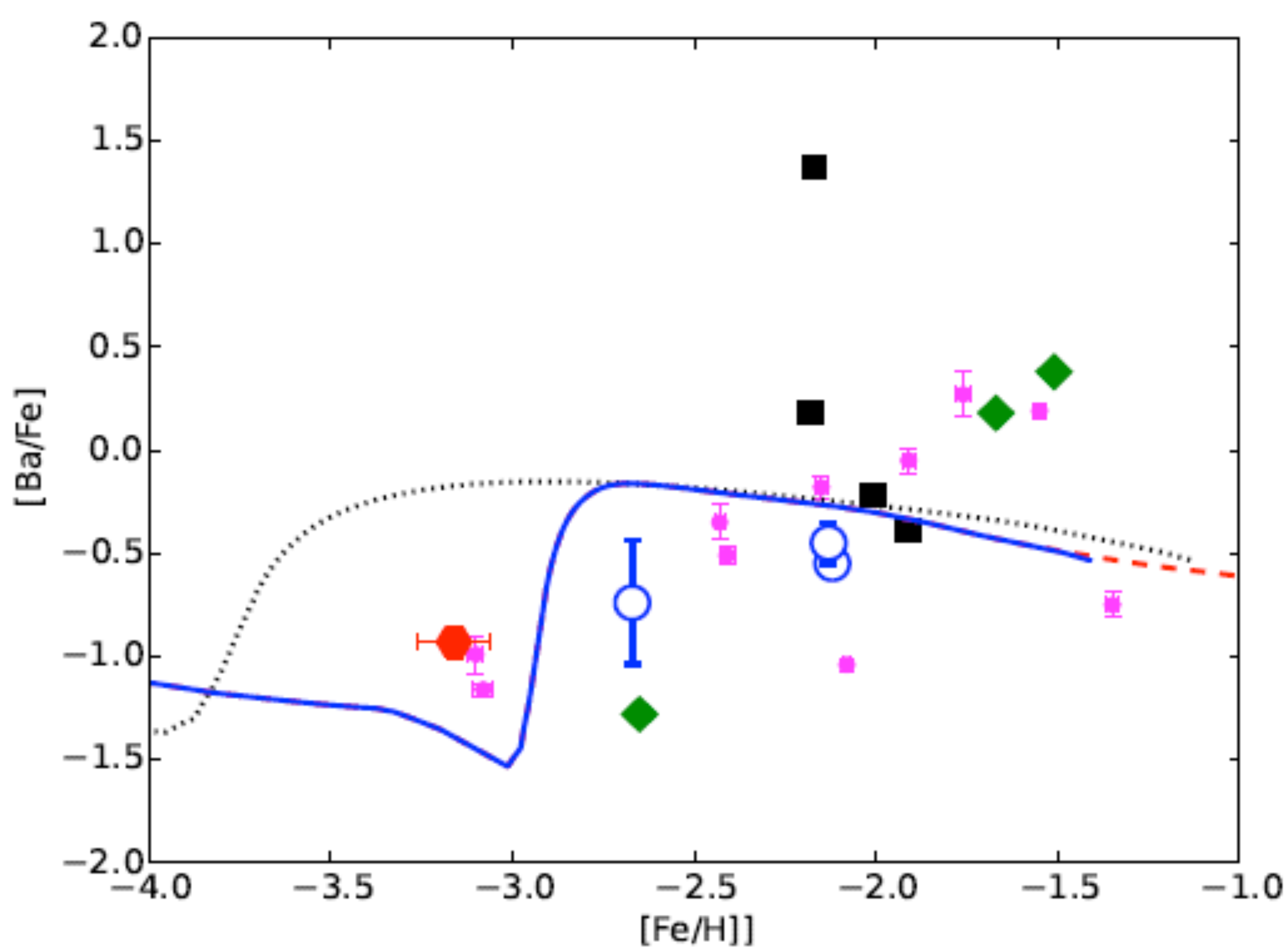
Ural, GC, Koch et al. (2014, MNRAS submitted)

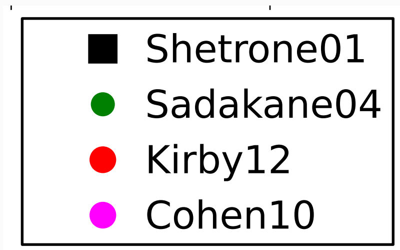
We have developed recently a model for **Ursa minor.**
Each dSph shows a different star formation history. The model assumes the observed SF by Carrera+02 and fix the infall timescale to match the MDF.

The nucleosynthesis is exactly the same as the halo one





new data by Ural+2014

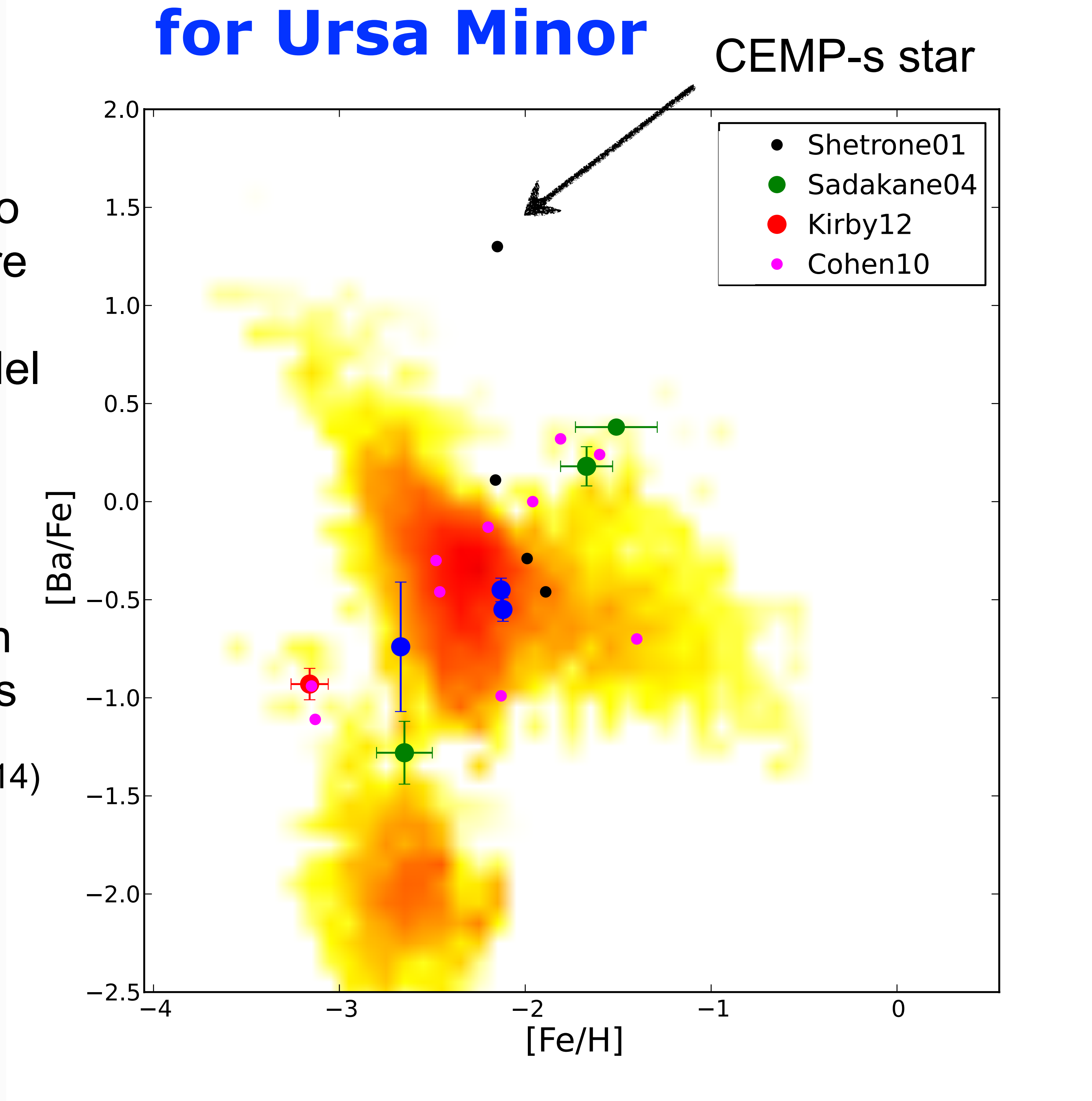


First signature
Spread in the n.c. elements (Ba) for Ursa Minor

The stochastic model is able to reproduce all the data (they are in the colored area).
In this case, we show the model for MRD (10%).

More data are important to understand if the distribution of modeled stars in [Ba/H] is in agreement with observed stars
(in the case of the halo we have also investigate this see Cescutti&Chiappini'14)

Cescutti et al. in prep

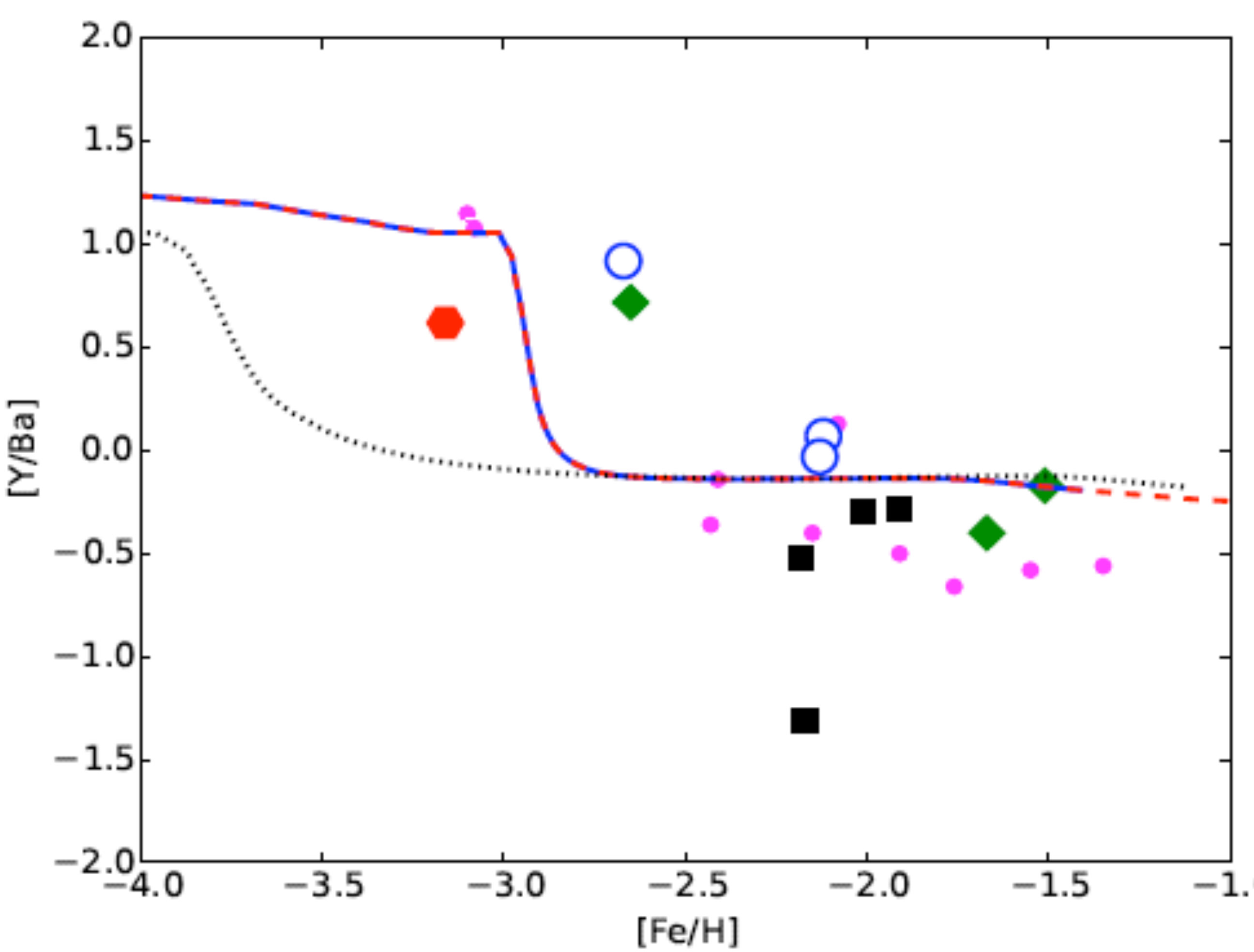


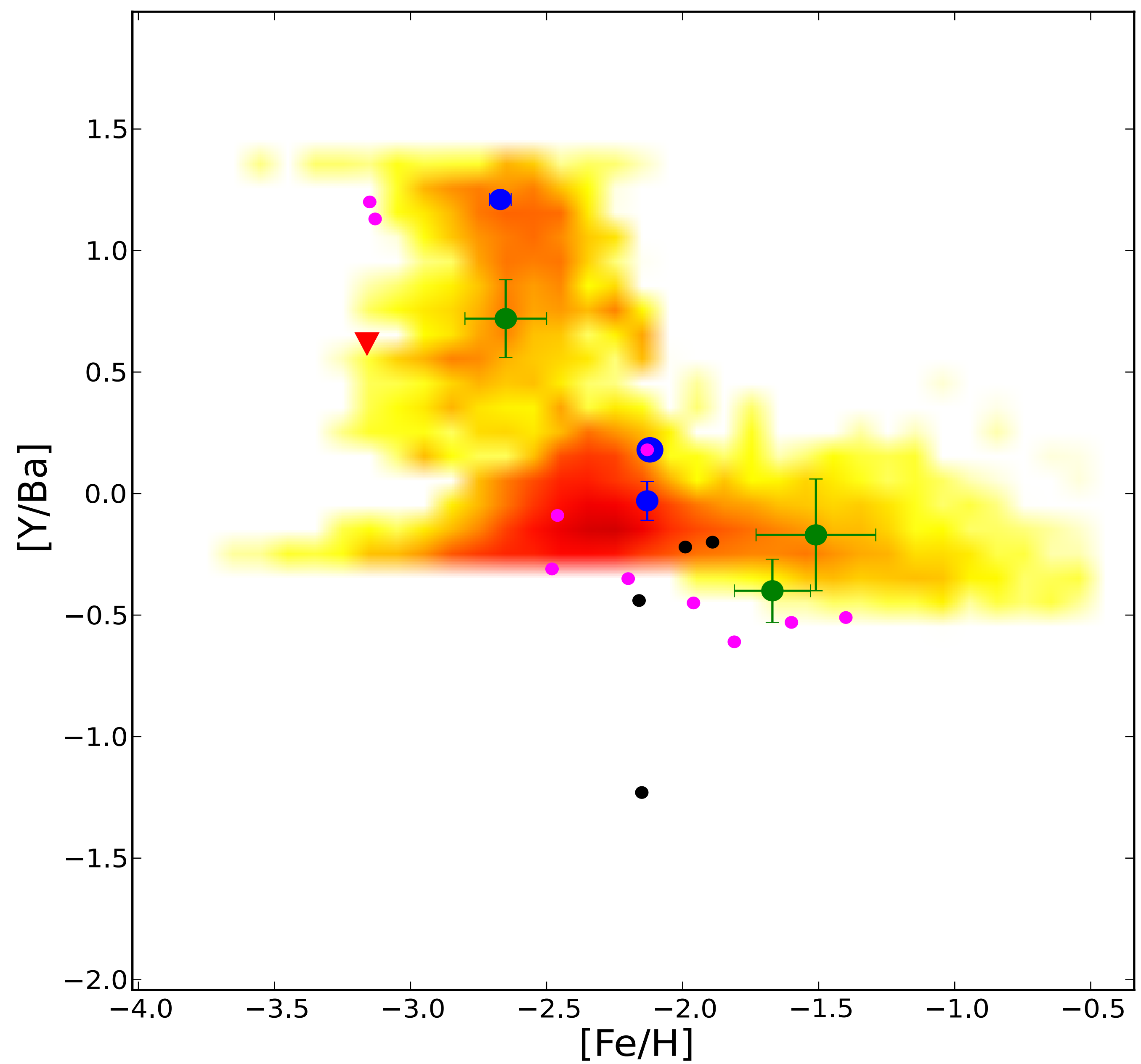
new data by Ural+2014

Second signature
spread in the light to heavy s-process elements in Ursa Minor

AIP

We can confirm that the spinstars are important for this dwarf galaxy to explain the spread in [Y/Ba].
No peculiar signature compared to Galactic halo
(at least not for this dwarf and with the present data)

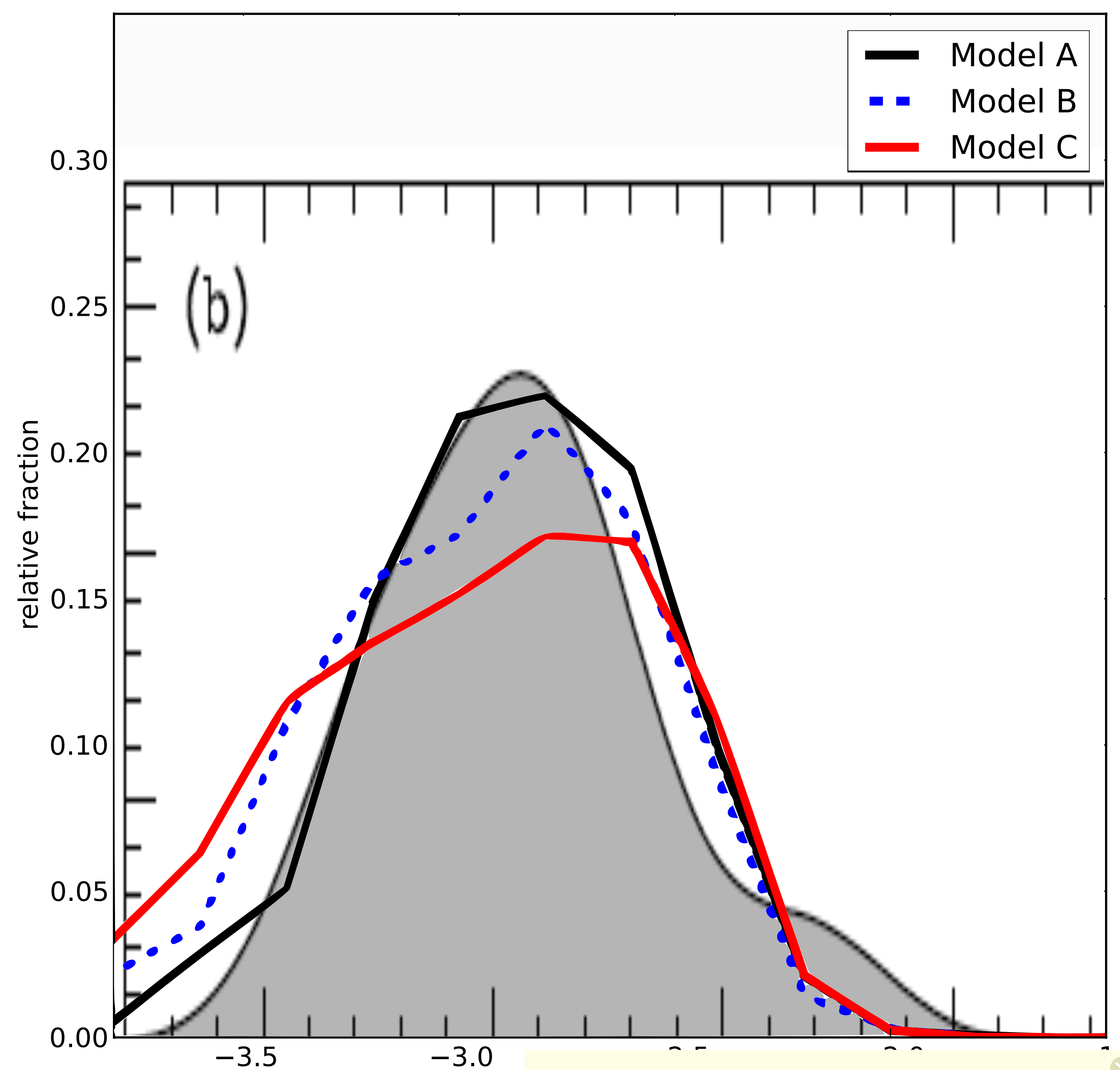




The model for an ultra faint dwarf: Hercules

- short SF history (<200Myr)
- strong winds

We constrain the model to match the MDF
(and the total stellar mass)
The nucleosynthesis is **exactly the same as the halo**.
We test two different (initial) total mass of gas.
A :1 10^5 Msun
B: 2 105 Msun
(C : 5 105 Msun)
preliminary model



Aden+11

0.04Msun/pc2
0.08Msun/pc2
1 10^5Msun gas
2 10^2Msun
stelle 0.002

stelle 0.037 ^6 Msun
dinamica 2.6 ^6Msun
~0.01

First signature

Spread in the n.c. elements (Ba) for Hercules (case B)

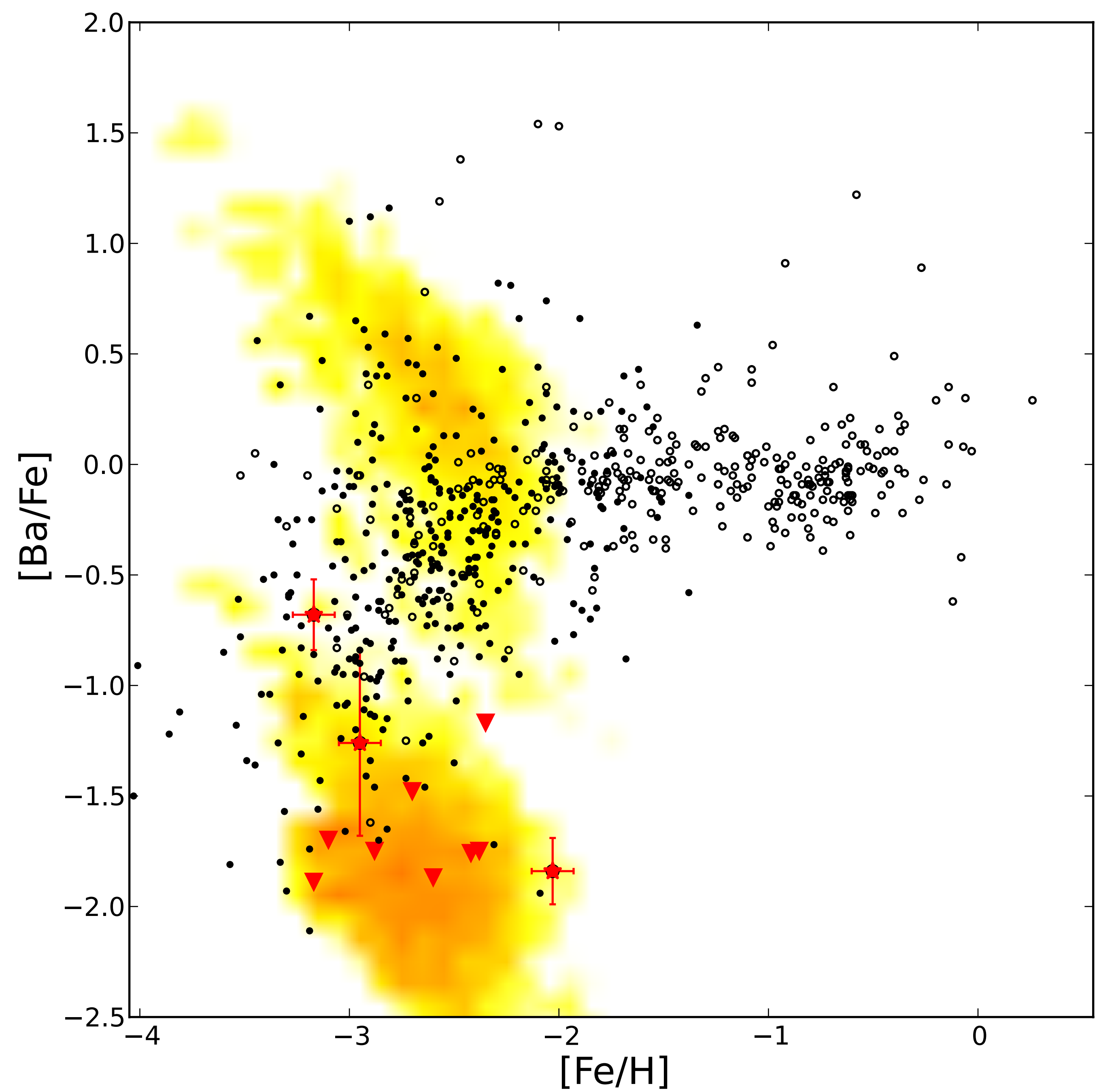
MRD scenario:
10% of SNe produce r-process

SF is very low due
low density in this system

rate of massive stars is low

tiny probability to produce a r-process event

Enriched manly by spinstars, with a low enrichment of Ba.



Koch+2013 data &
upper limits

First signature
Spread in the n.c. elements (Ba) for Hercules (case A)

Model with half of the gas mass compared to model B

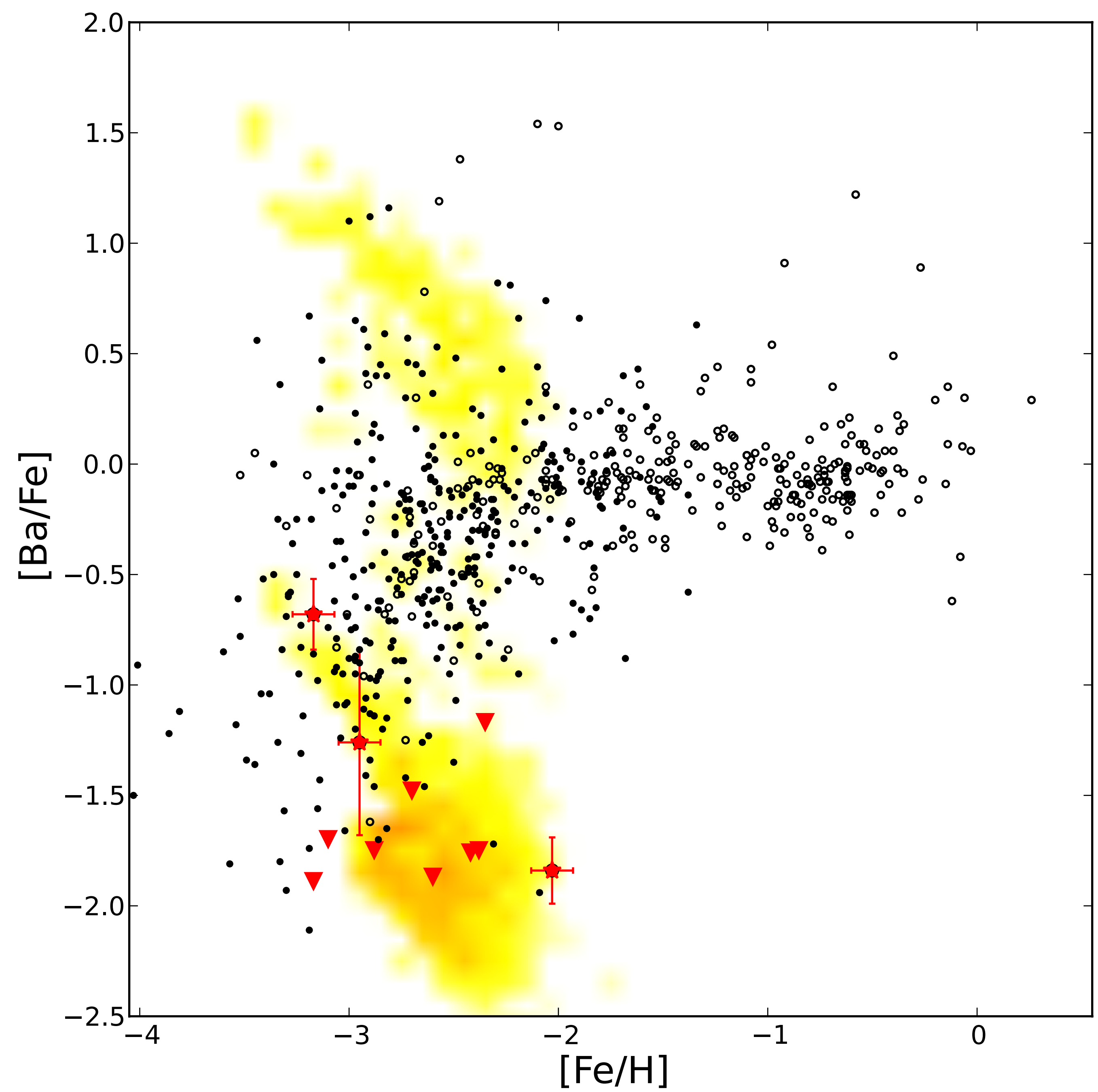
Lower SF rate

Formation of r-process event has an extremely low rate

lower fraction of r-process rich stars

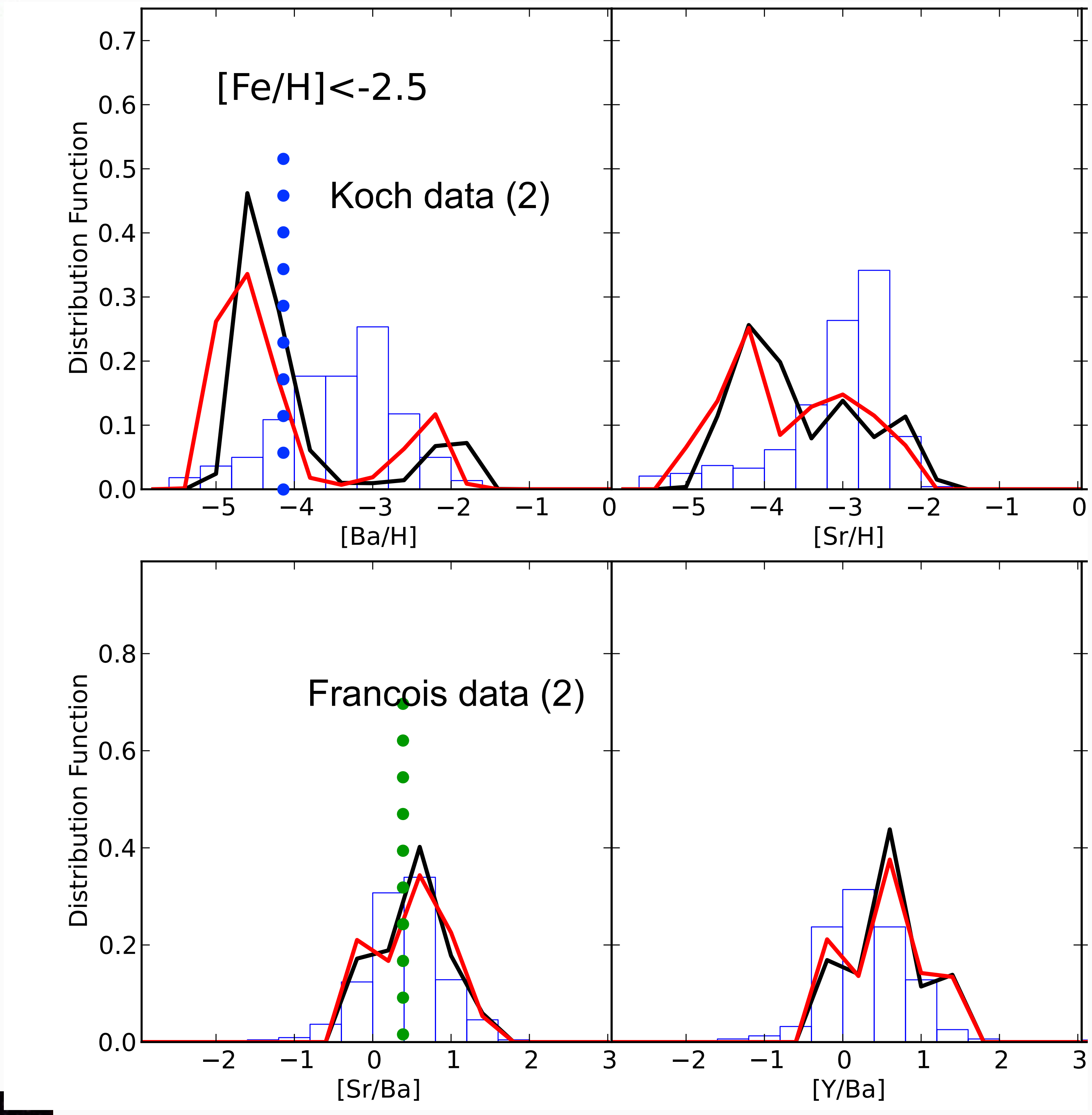
Different from the present data (no observations) but the trend is recovered.

The signature of neutron capture elements does show that UF cannot have formed the Galactich halo.

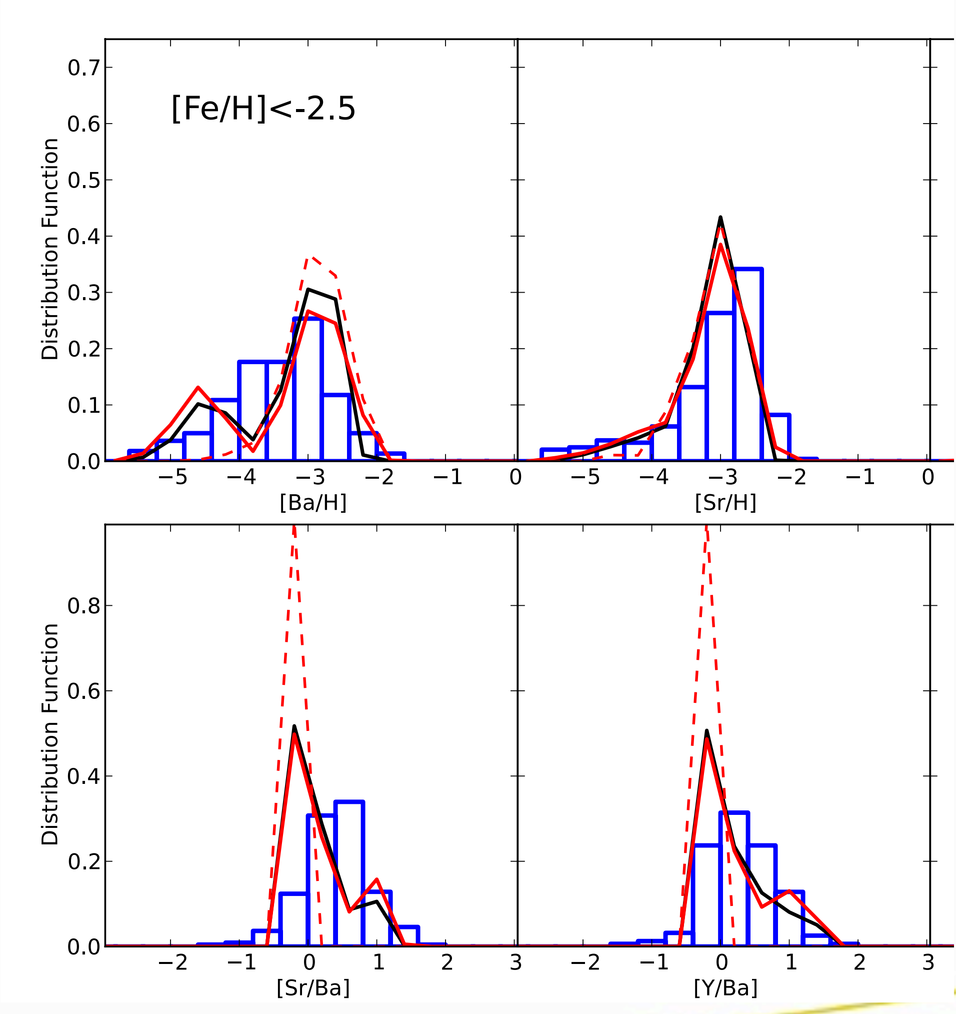


Hercules

Distribution functions model A and B



Results in the halo
Cescutti&Chiappini'14



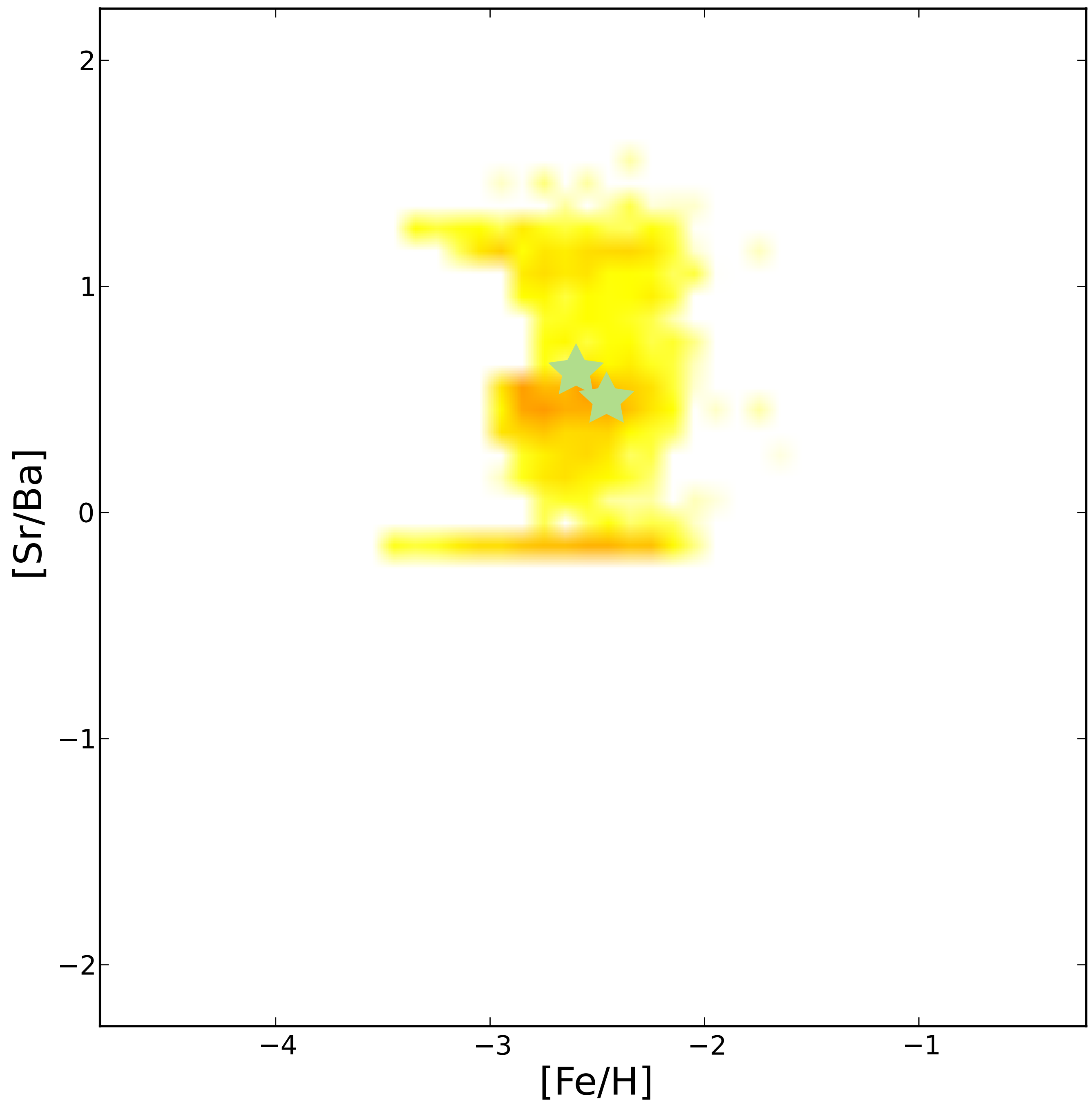
Second signature
spread in the light to heavy s-process elements in Hercules

Francois+2012

Difficult to make any strong statement, just 2 data points for Hercules
(but similar characteristics are observed in other UF dwarfs - Frebel talk)

At the present, the data we have confirm the necessity to have an s-process production by fast rotating massive stars.

So maybe the first generation(s) of stars was really fast rotating!



Conclusions

The case of Ursa minor (and at the present of Hercules too) suggests that the contribution of s-process by spinstars is important to explain the observed abundances as in the Galactic halo (more investigation on other dSph needed).

→ First Stars should have been fast rotating.

The neutron capture elements in Hercules ([Ba/Fe] [Sr/Fe]) tends to be lower compared to the Galactic halo. This signature is present also in the others UF dwarfs.

→ Only a small fraction can have contributed to the formation of the Galactic halo

The case of the Hercules (and in general UF dwarfs) is interesting also because they can help constrain the rate of r-process events.