Osservatorio Astronomico di Trieste
Astronomical Observatory of Trieste

Revealing the Nature of the First Stars:

the role of the chemical signatures in the primordial stars of our Galaxy

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Astro FIt 2
Astronomy Fellowships in Italy

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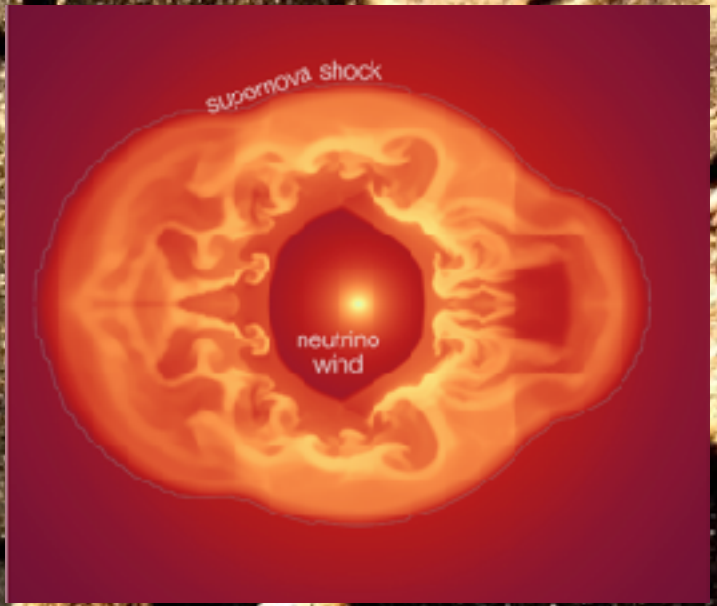
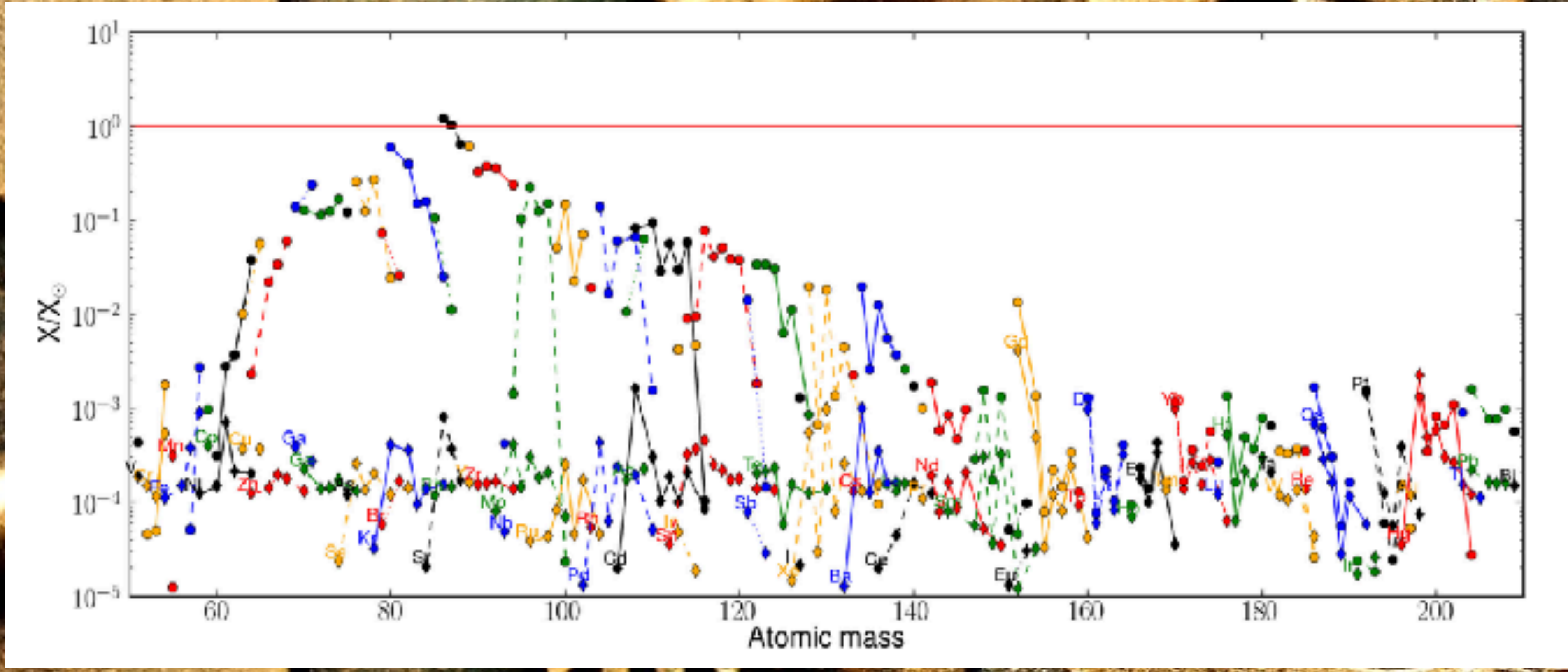
Roma, 23 October 2018

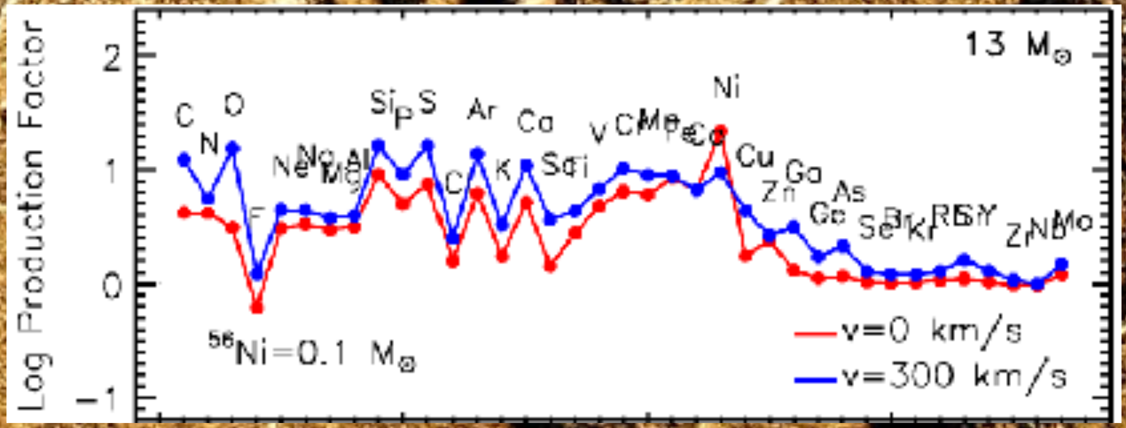
Stellar evolution model with nucleosynthesis



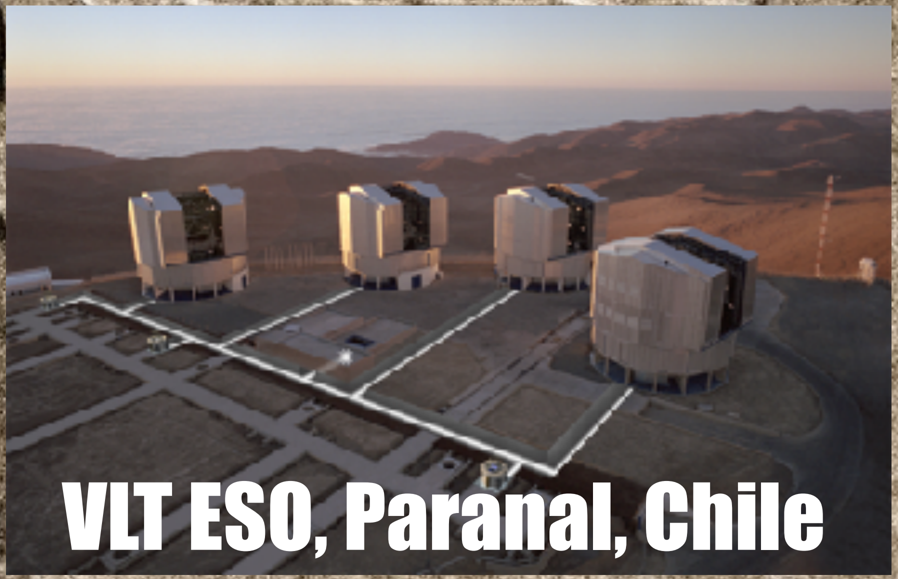


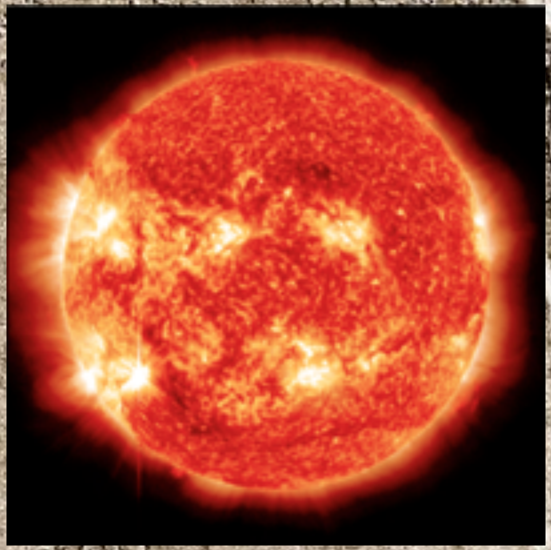
Frischknecht+16

Limongi+12



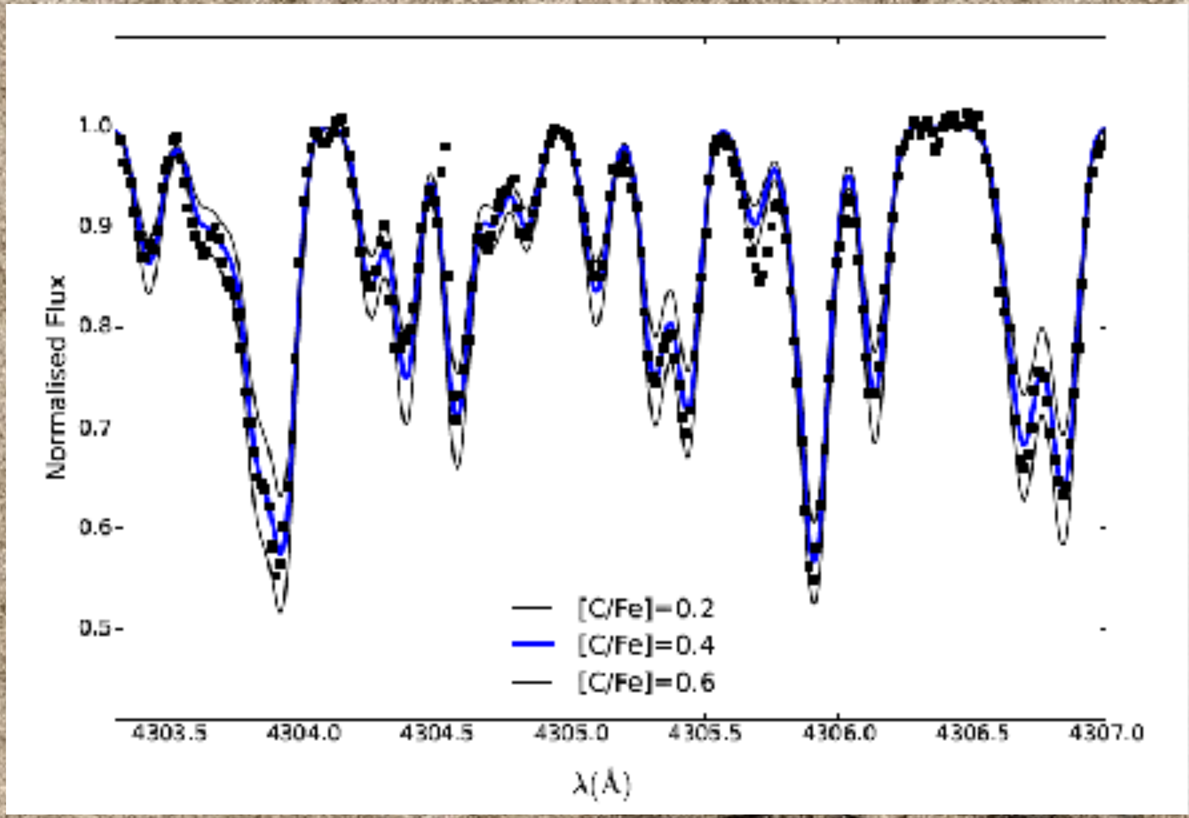
Chemical abundances in stars





High resolution spectra of stars

Abundances of chemical elements

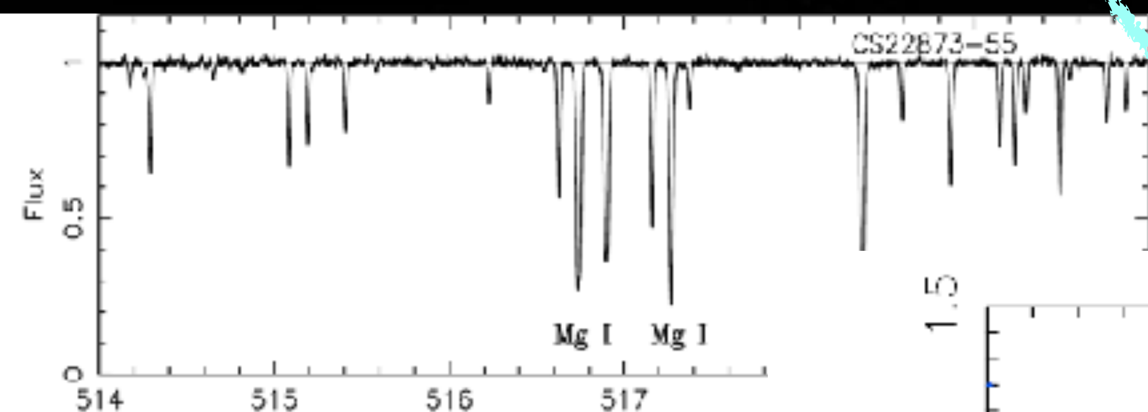


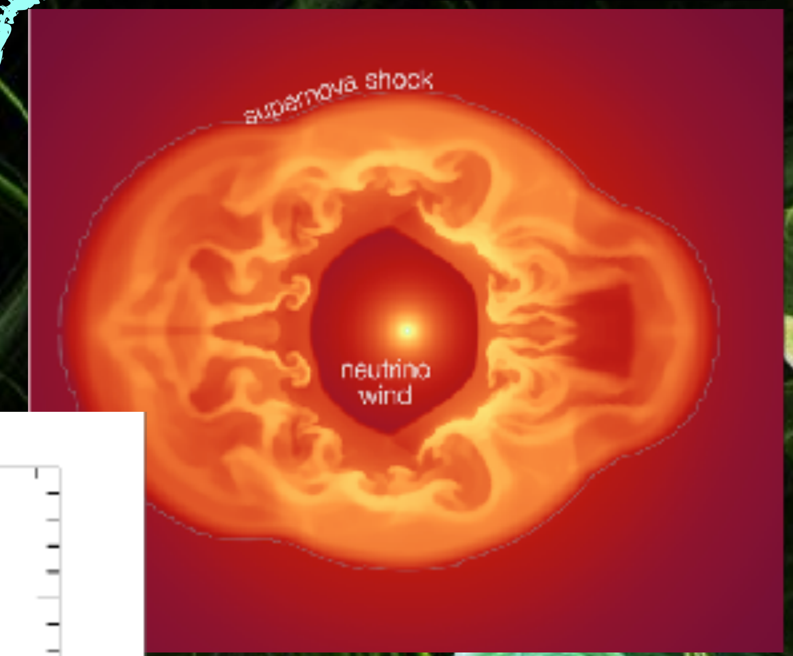
Chemical evolution models

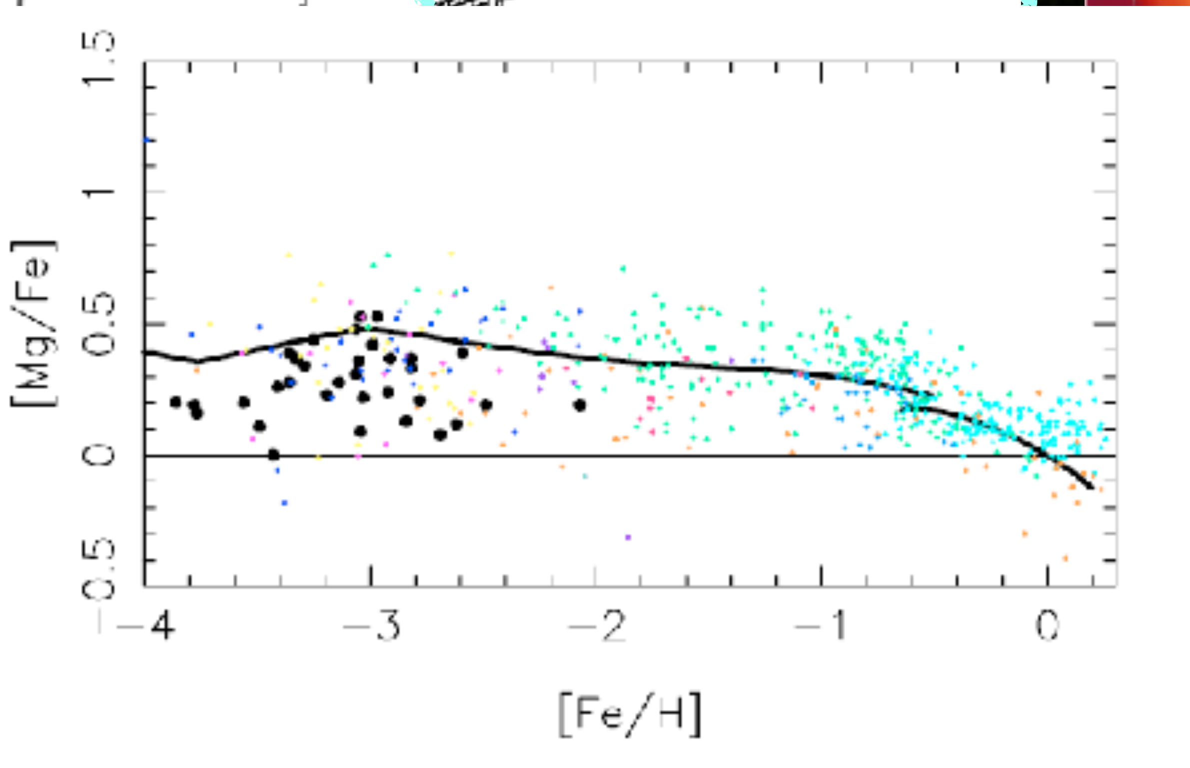
Stellar evolution

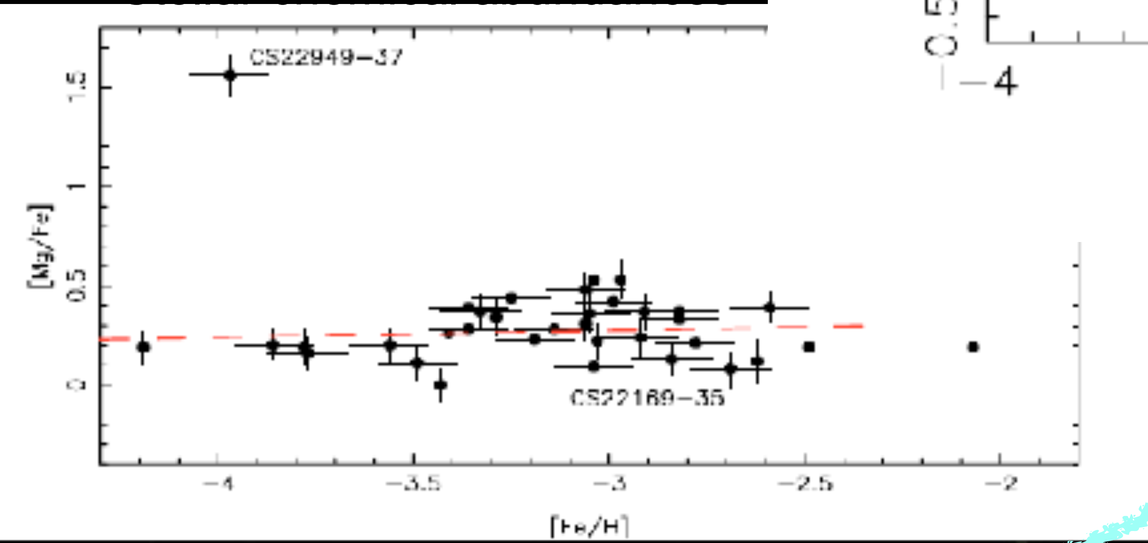
?

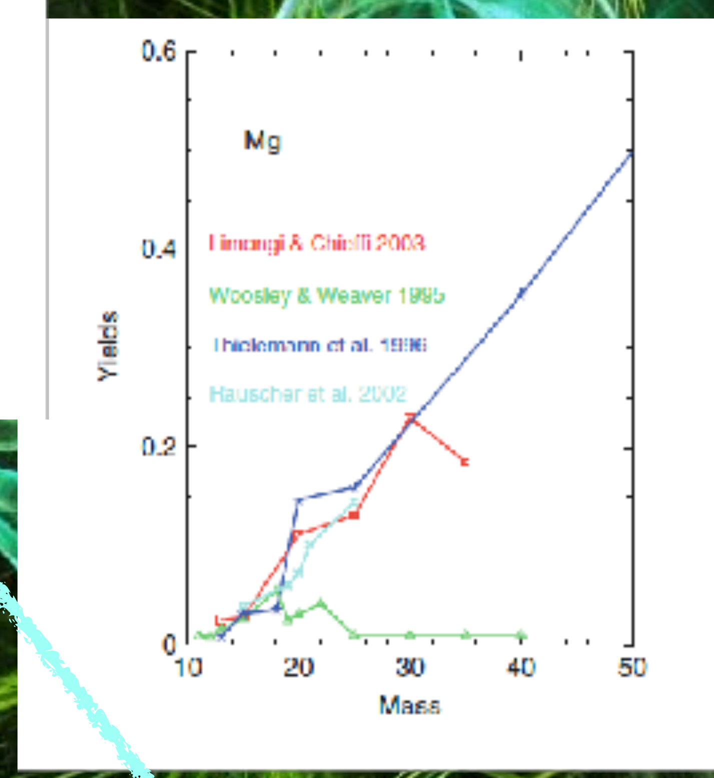
Stellar spectra











Chemical abundances

Nucleosynthesis

Roma, 23 October 2018

Second year plan:

- Implement in the models nucleosynthesis for the First Stars Hypernovae and Keele group
- Test the statistical code with the results in the halo and its observational data
- Publish first results using the statistical code of multiple stellar nucleosynthesis in the Galactic halo
- Develop a generic code for satellite dwarf galaxies and adapt the code for a selection of galaxies

Invited to AAS in Denver for the Meeting in the meeting:
Abundance in dwarf spheroidal galaxies

Università degli Studi di Trieste

Dipartimento di Fisica

Corso di Laurea Triennale in Fisica

Nucleosynthesis of Heavy Elements and Chemical Evolution of the Galaxy

Tesi di Laurea Triennale

Anno Accademico 2017/2018

The oldest stars of the bulge: new information on the ancient Galaxy

Gabriele Cescutti[1], Cristina Chiappini[2] and Raphael Hirschi[3,4]

Manganese spread in Ursa Minor as a proof of sub-classes of type Ia supernovae

G. Cescutti and C. Kobayashi

Astronomy & Astrophysics

Uncertainties in s-process nucleosynthesis in low-mass stars determined from Monte Carlo variations

G. Cescutti, R. Hirschi, N. Nishimura, J. W. den Hartogh, T. Rauscher, A. St. J. Murphy and S. Cristallo

Project on nucleosynthesis

^{7}Li evolution in the thin and thick disks of the Milky Way

G. Cescutti[1] * and P. Molaro [1],

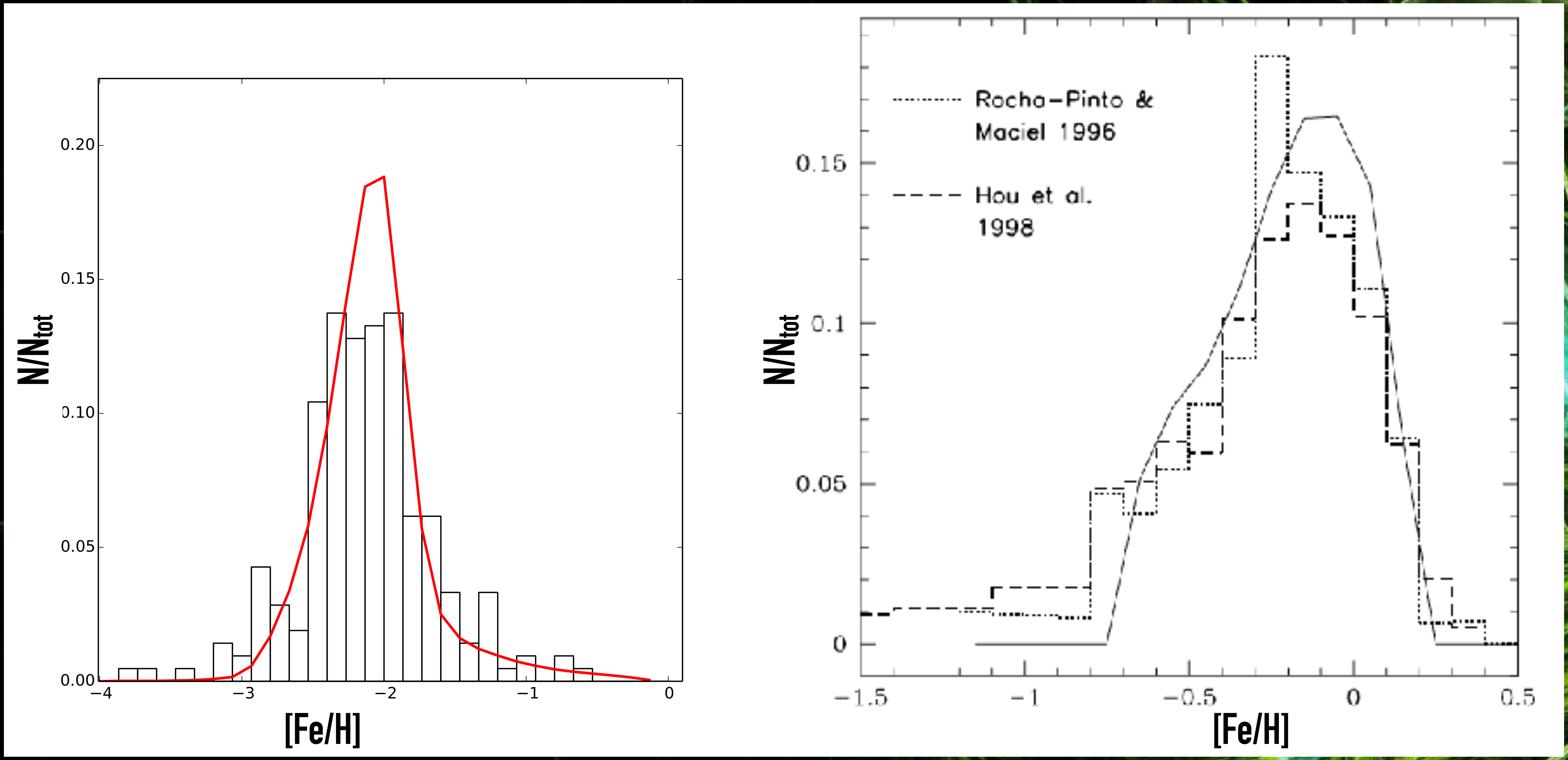
[1] INAF Osservatorio Astronomico di Trieste, Via G.B. Tiepolo 11, I 34143 Trieste, Italy

Personal chemical evolution models

Different galaxies have different chemical evolution, typical constrain is the metallicity distribution function.
More massive systems have higher efficiency; dSph models present outflows.

Ursa minor MDF

MW solar vicinity MDF

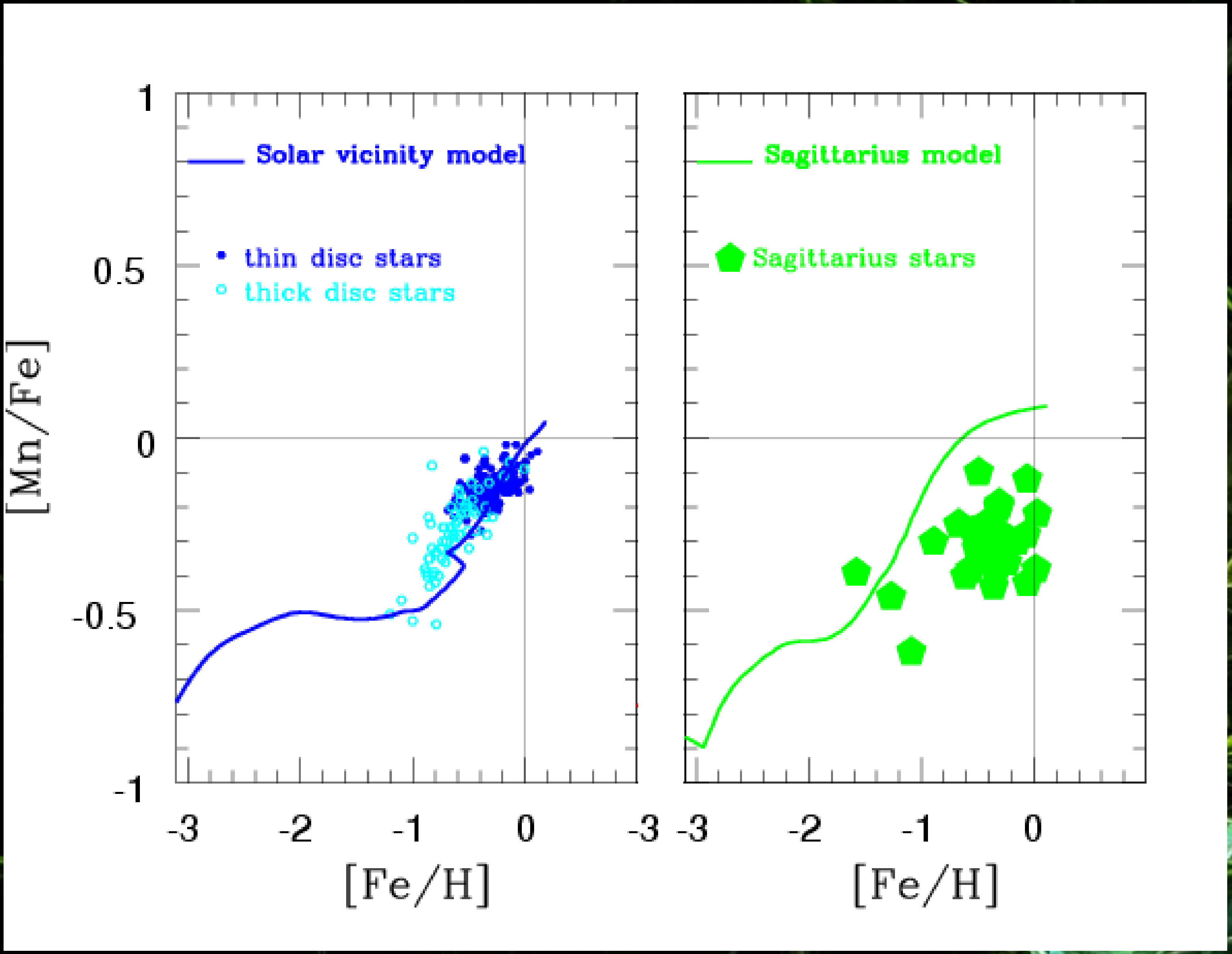


model Ural, GC+15
data Kirby+11

model Chiappini+01

The first issue with Manganese...

Iron peak element and its evolution is driven by SNII and SNIa



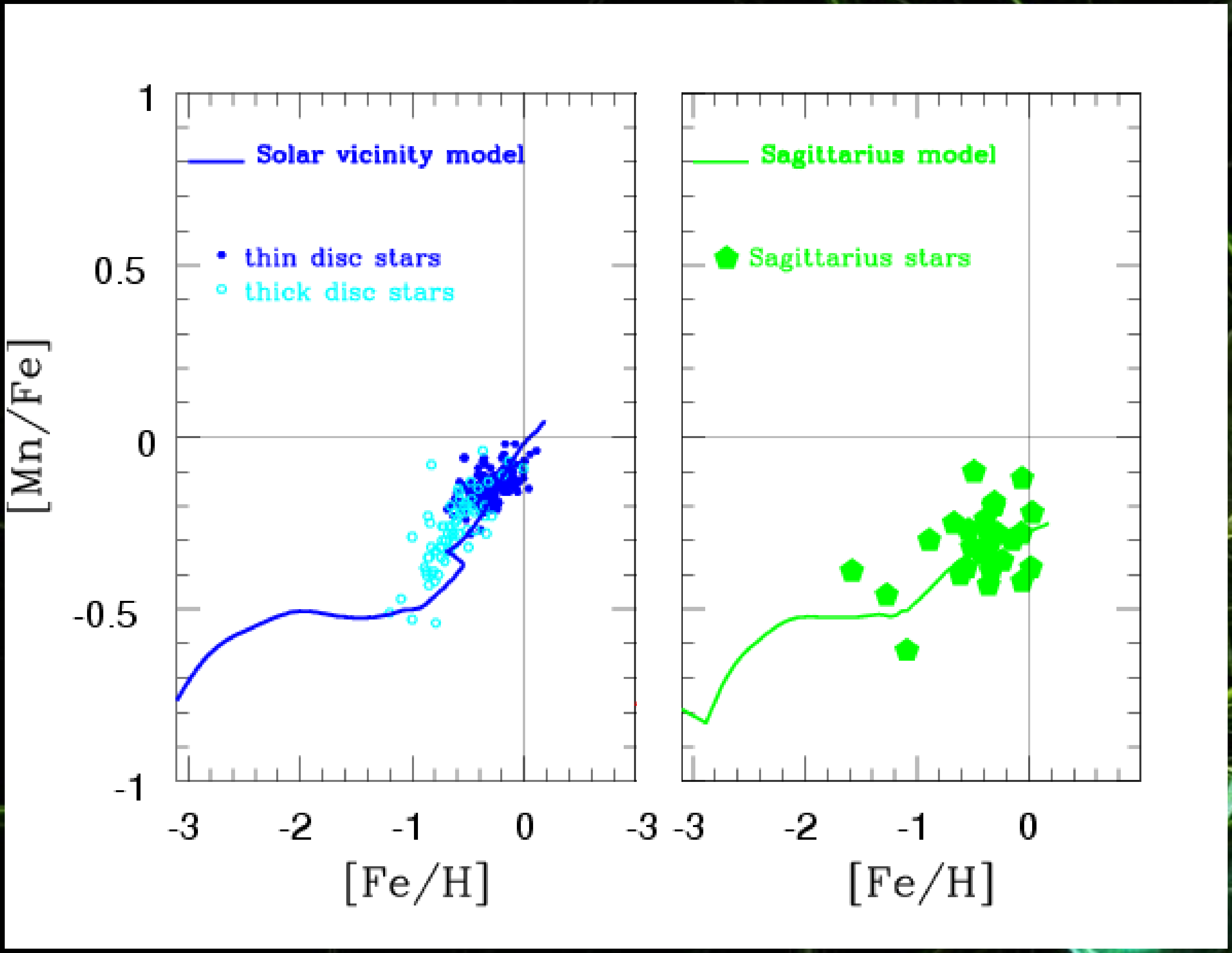
Cescutti et al. (2008)

MW:
Reddy et al 2003
Sagittarius:
McWilliam 2003
Sbordone 2007

Results obtained using standard nucleosynthesis for SNe II and SNe Ia with a Ch-mass deflagration (W7 model)

First solution: SNIa yields metal dependent?

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



Cescutti et al. (2008)

MW:
Reddy et al 2003
Sagittarius:
McWilliam 2003
Sbordone 2007

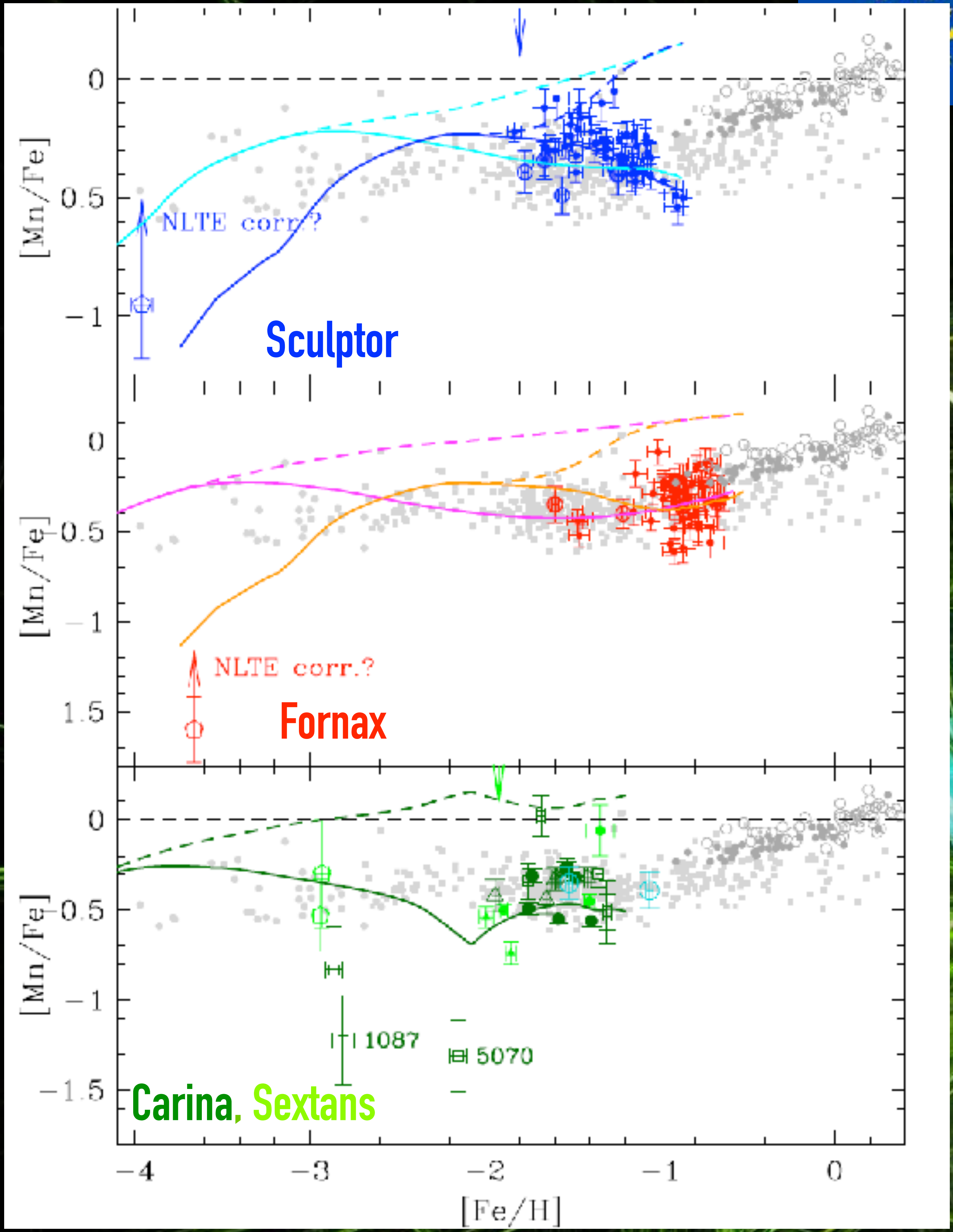
This solution to the Mn problem in Sagittarius was suggested by McWilliam et al. (2003)

North, GC+ (2012)

Same prescriptions give excellent results for
Sculptor, Fornax, Carina and Sextans

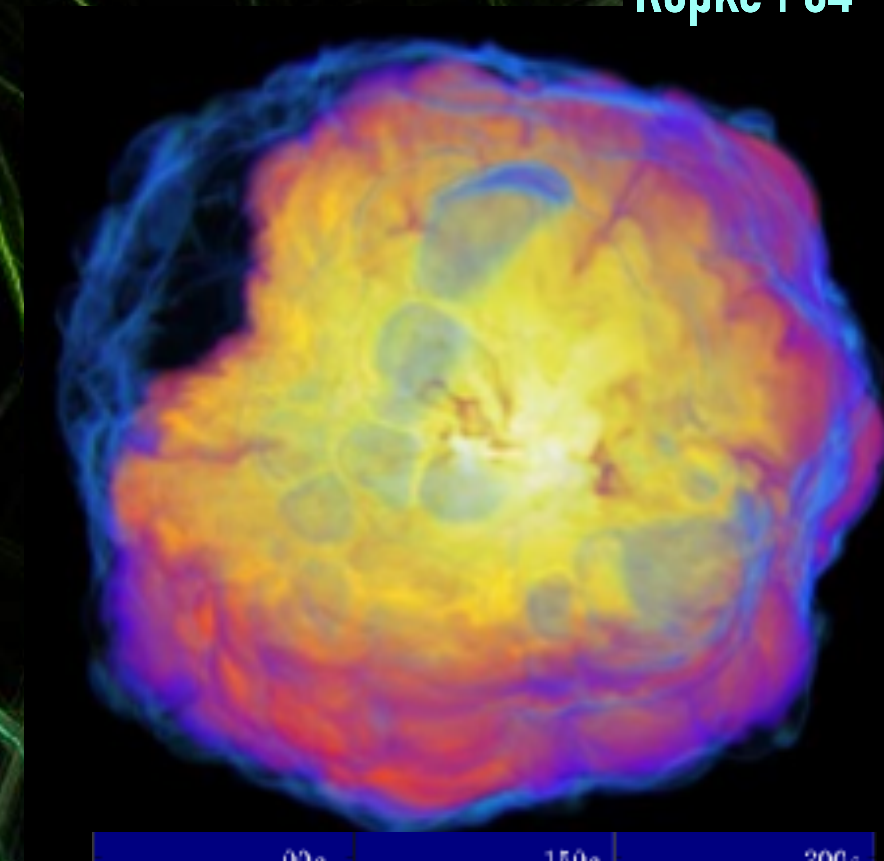
Issues :

- Ch-mass deflagration or delayed-detonation, do not produce Mn with a strong metal dependency
- spread of the measured abundances of Mn in this dSph?



Mn nucleosynthesis in different SNIa explosions/progenitors

Röpke+04

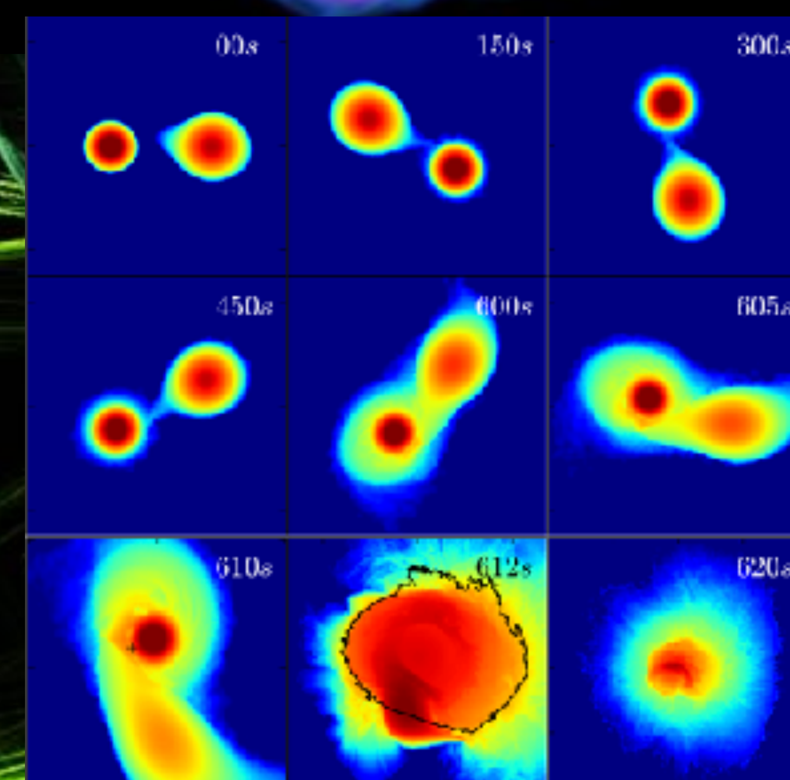


Delayed-detonation models near-CH mass

[Mn/Fe]~0.3 dex
Theoretically, they do not explode at low metallicity!

Sub-CH mass violent mergers (double detonation)

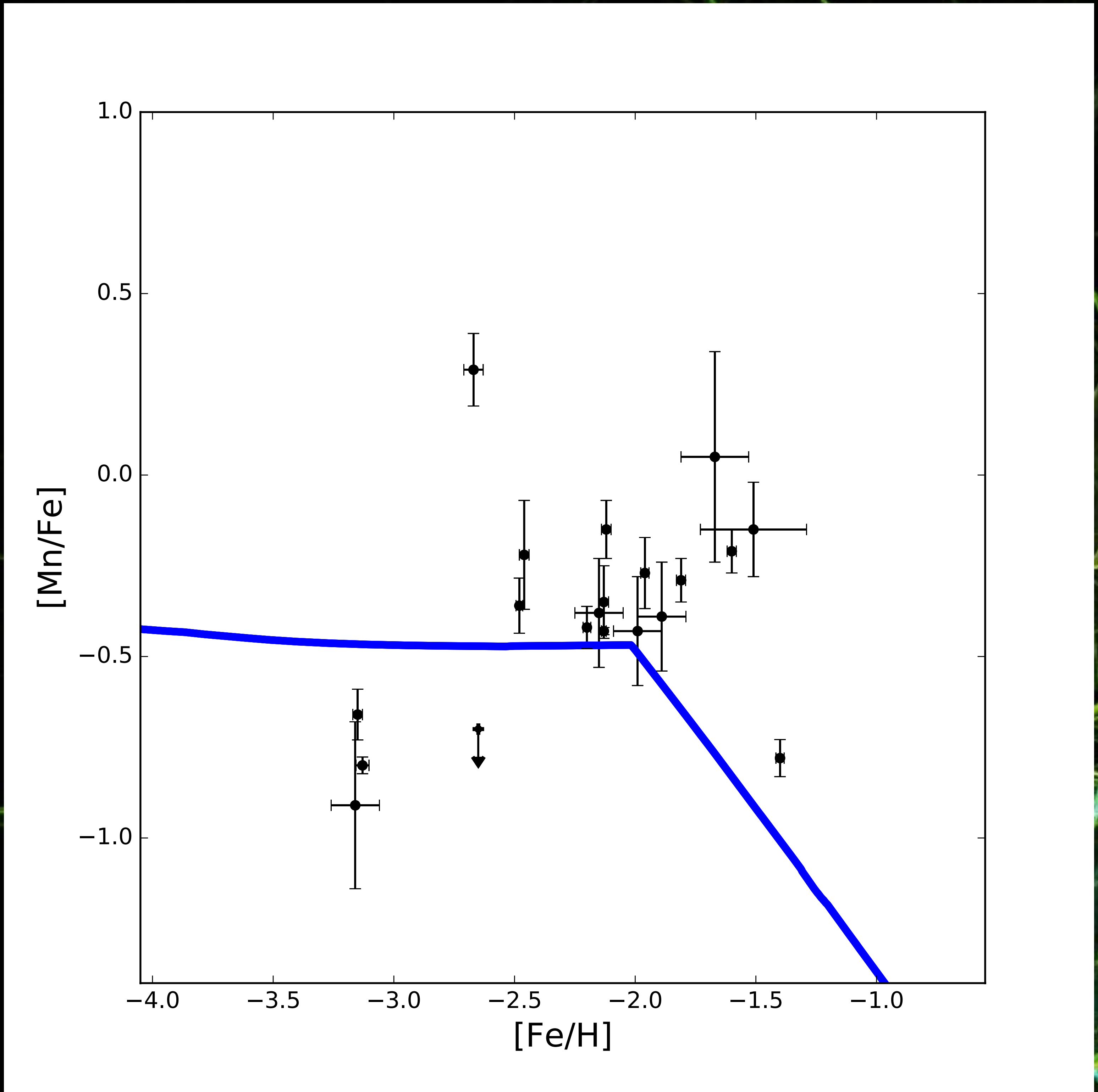
[Mn/Fe]~-0.2dex



Pakmor+12

Delayed-detonation models involve higher densities and they will have an enhanced production of Mn from the contribution of "normal" freeze-out from NSE (as opposed to "alpha-rich"). This is not the case for violent merger or double detonation models.

Results for Ursa minor only with sub-Ch SNe



data from Ural, GC+15

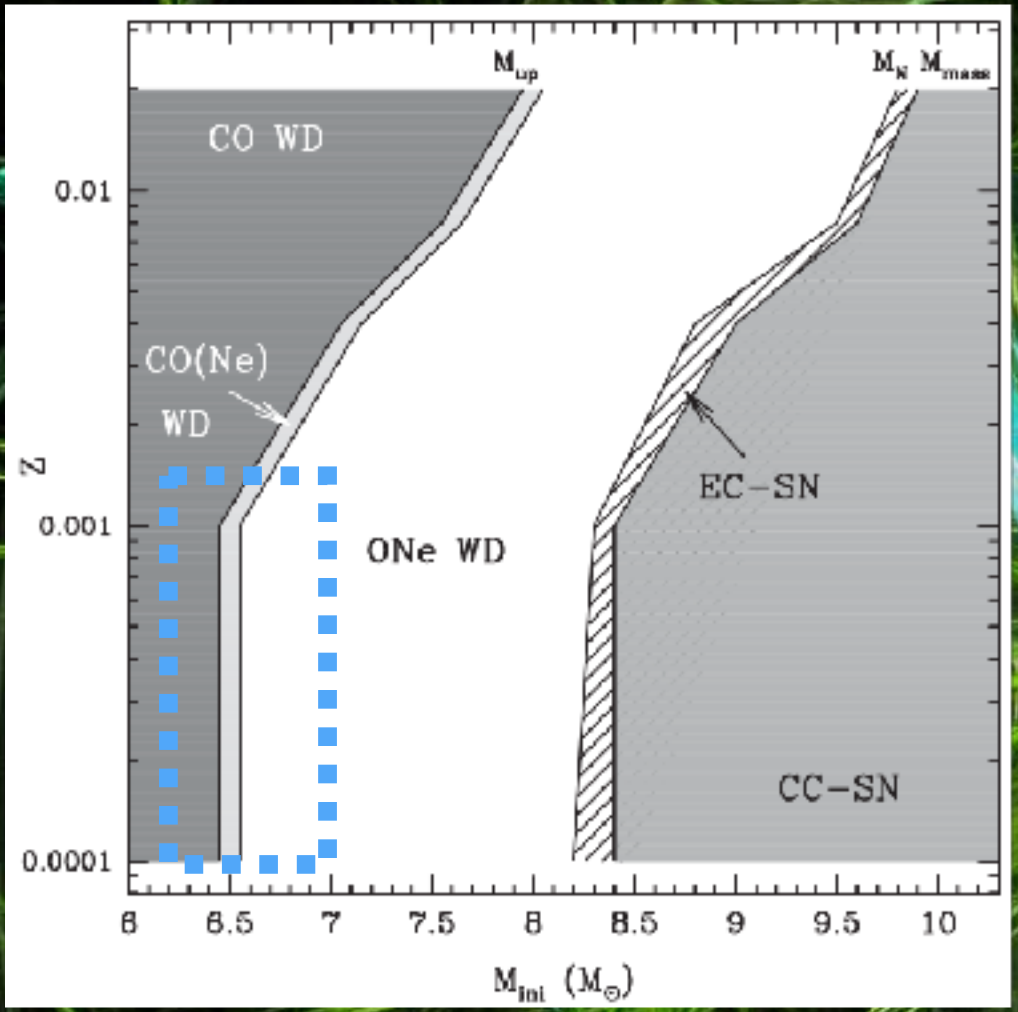
CEM with only
sub-Ch mass SNe Ia
cannot reproduce the
observed abundance in
Ursa minor
(same applies to others
dSph galaxies)

More SN Ia channels:
SNe I ax

A near CH CO-WD or hybrid CO(Ne) WD (Denissenkov+13) undergoes central carbon deflagration similar to the one of a normal SNe Ia but the carbon deflagration is quenched when it reaches the outer O+Ne layer.

The progenitor WD is only partially burnt and ejected. The SN Ia produce less Ni and it has a fainter luminosity
(yields from N5def, Kromer+13, Fink+14)

SNe Iax

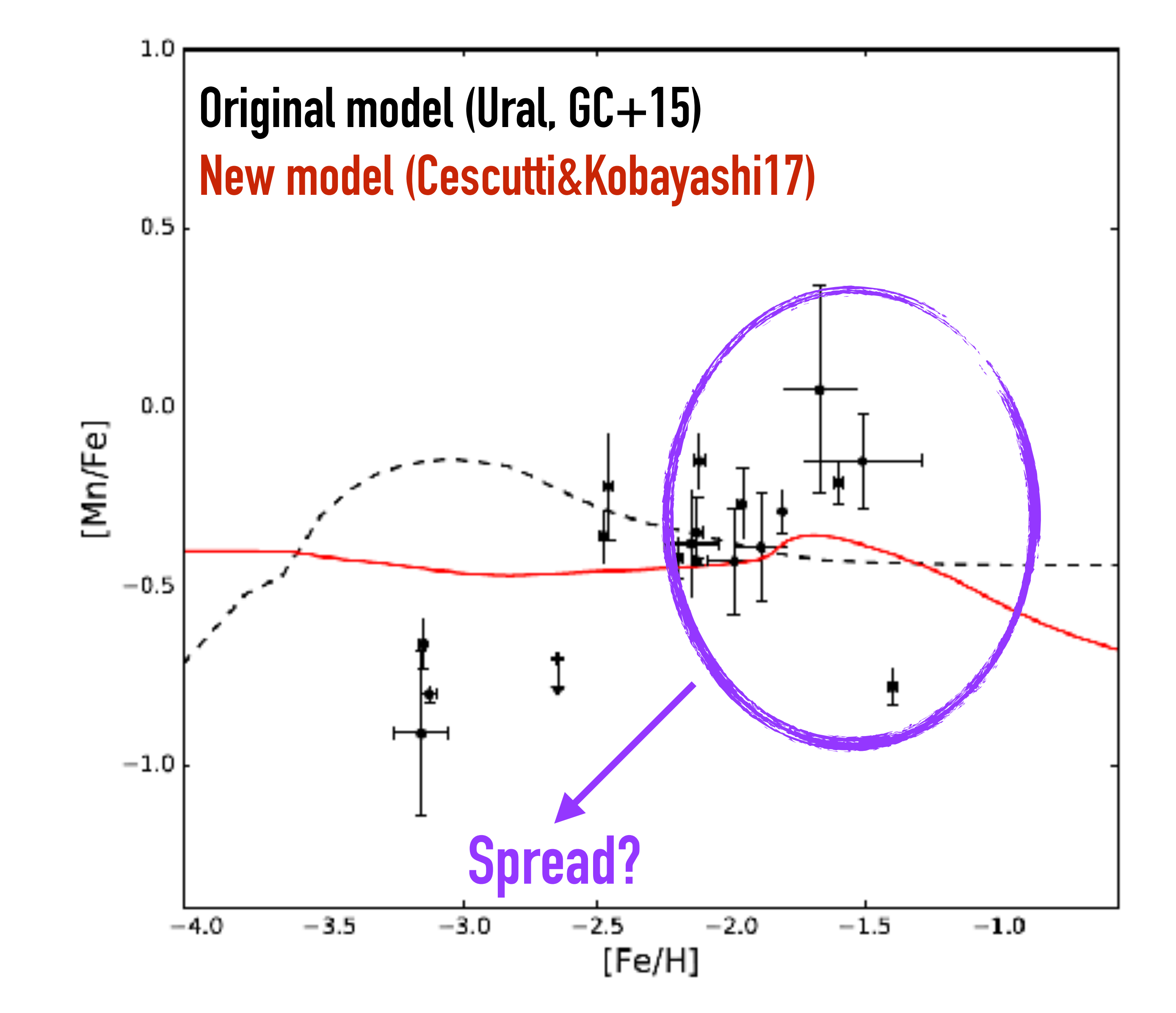


Doherty +15

Meng & Podsiadlowski 14, Kobayashi+15, Kromer+13 +15

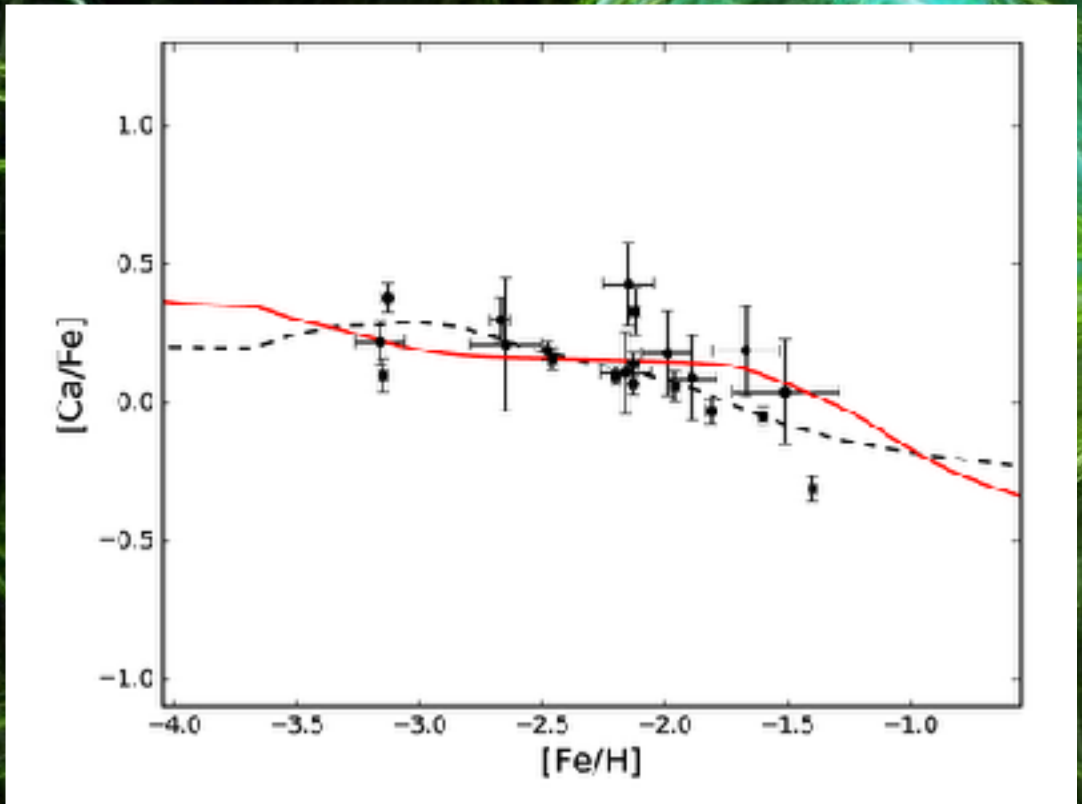
New channels of SNe Ia in Ursa minor model

Cescutti & Kobayashi (2017)



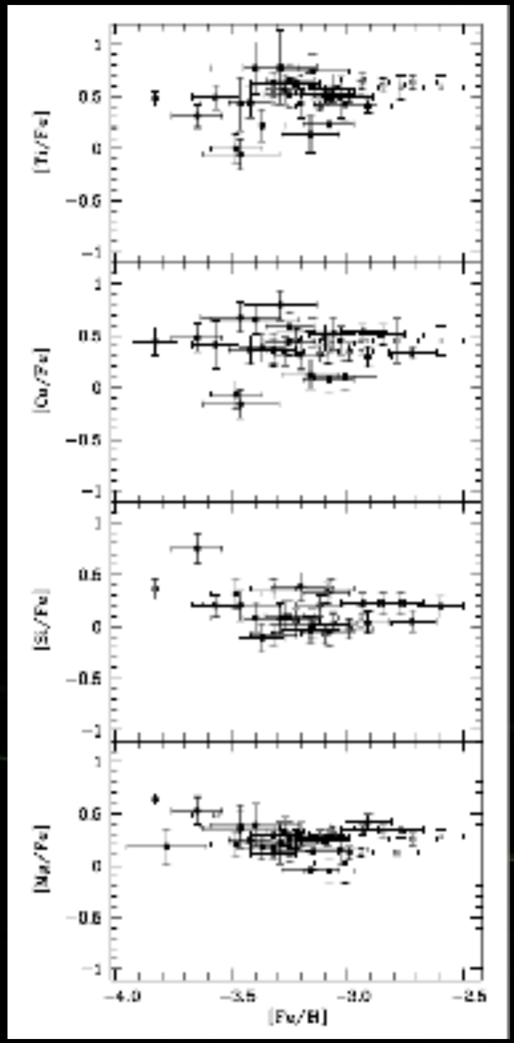
Metal dependent deflagration channel reproduces the data of Mn, but also the new model with both SNe I ax and sub-Ch

Both are able to reproduce the knee in alpha elements



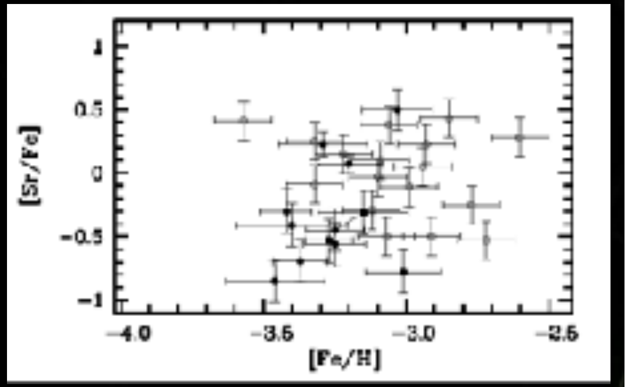
data from Ural,GC+15

Stochastic chemical evolution models

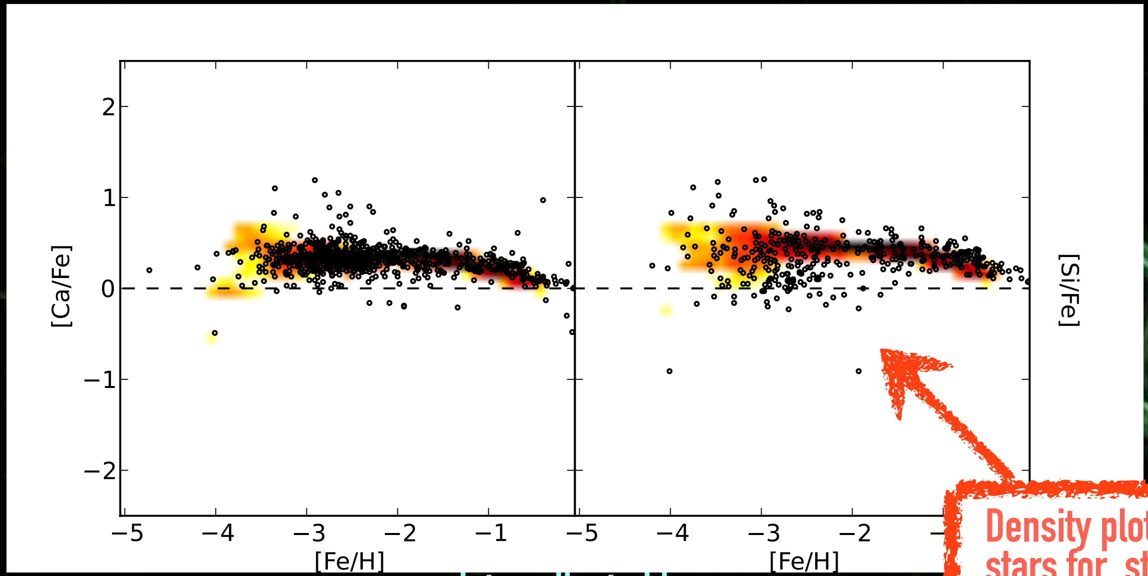


Bonifacio+09

Problem:
Neutron capture elements present a spread alpha elements do not

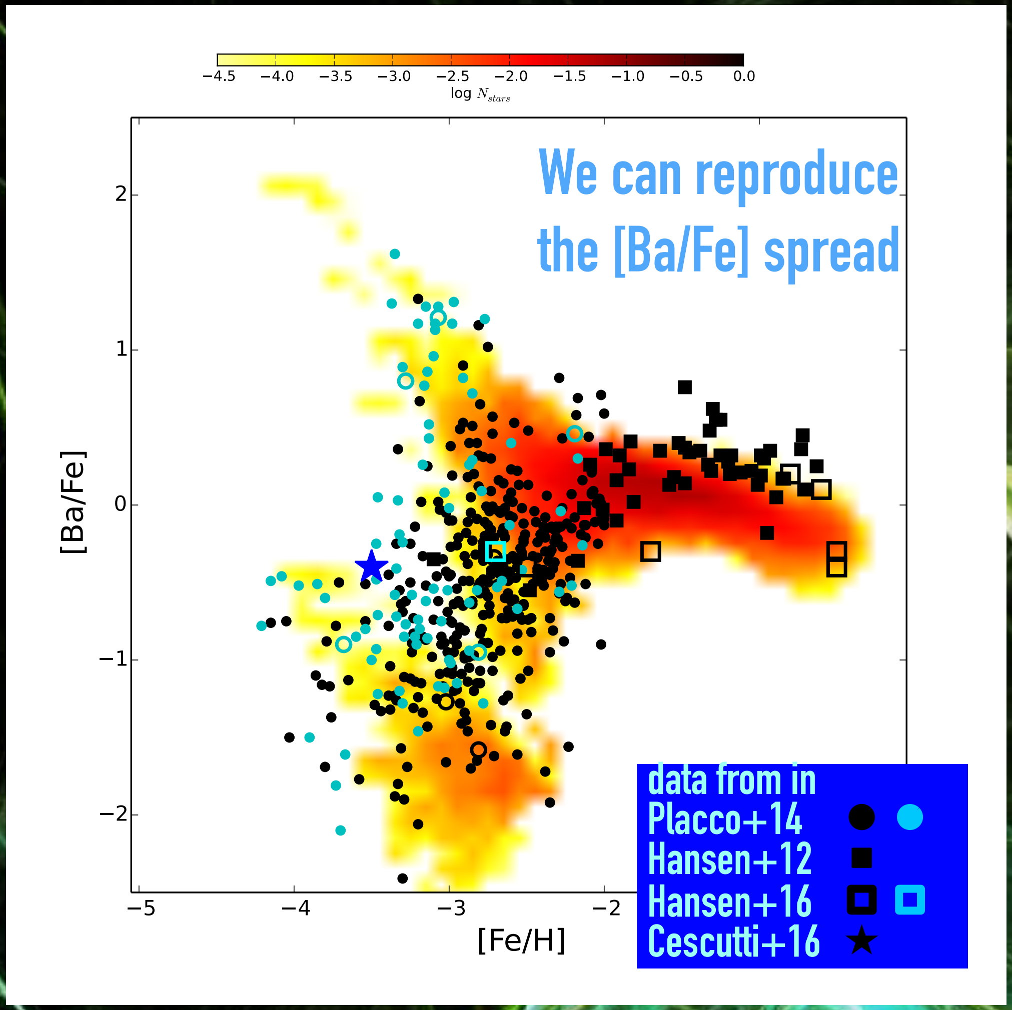


Solution:
The volumes in which the ISM is well mixed are discrete. Assuming a SNe bubble as typical volume with a low regime of star formation the IMF is not fully sampled.
This promotes spread among different volumes if nucleosynthesis of the element is is different among different SNe.



Density plot of long living stars for stochastic model

data collected in Frebel 2010



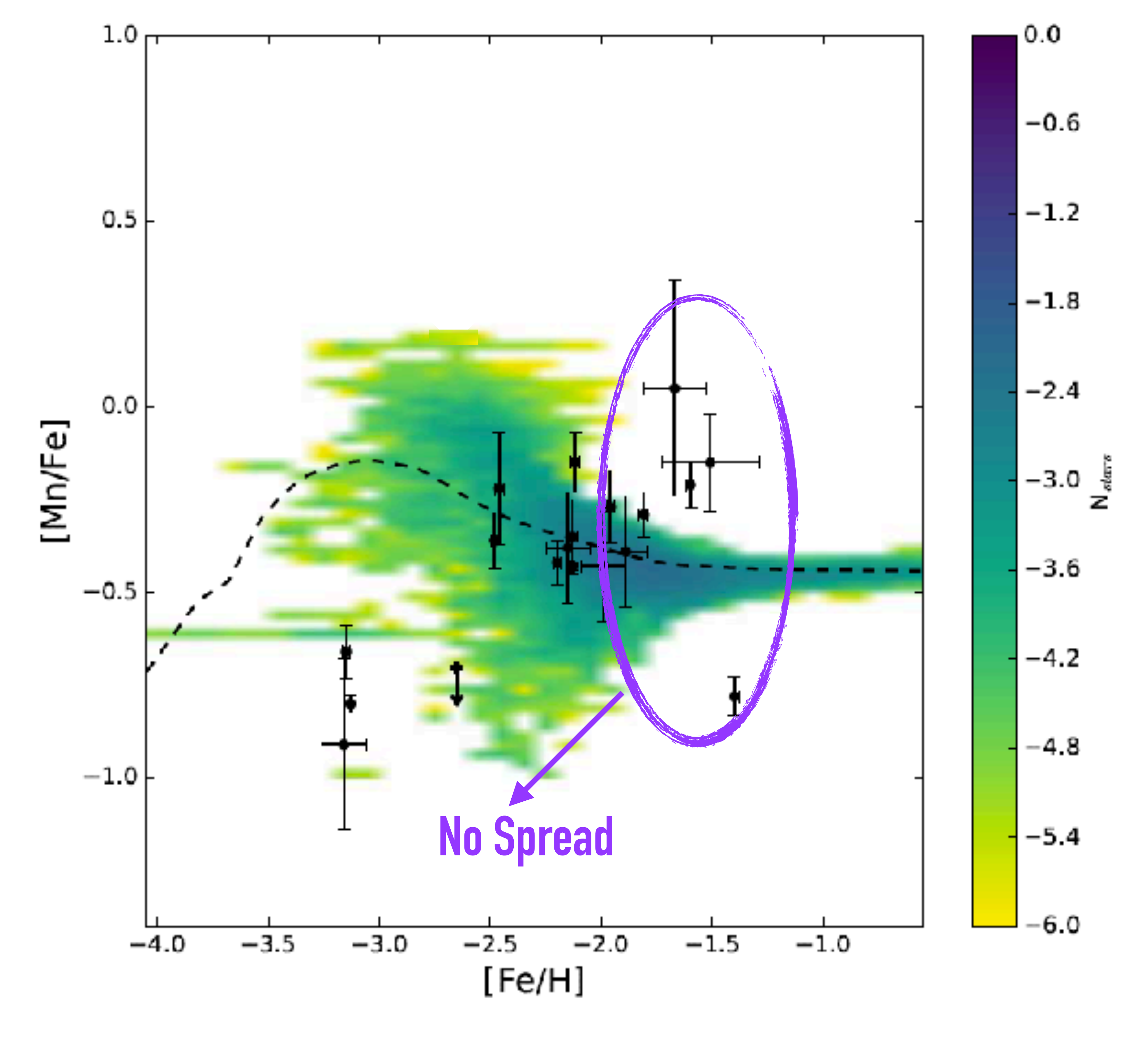
Cescutti 08 +13,+16

Same concept applied to Ursa minor model

Roma, 23 October 2018

Stochastic model for Ursa minor 1

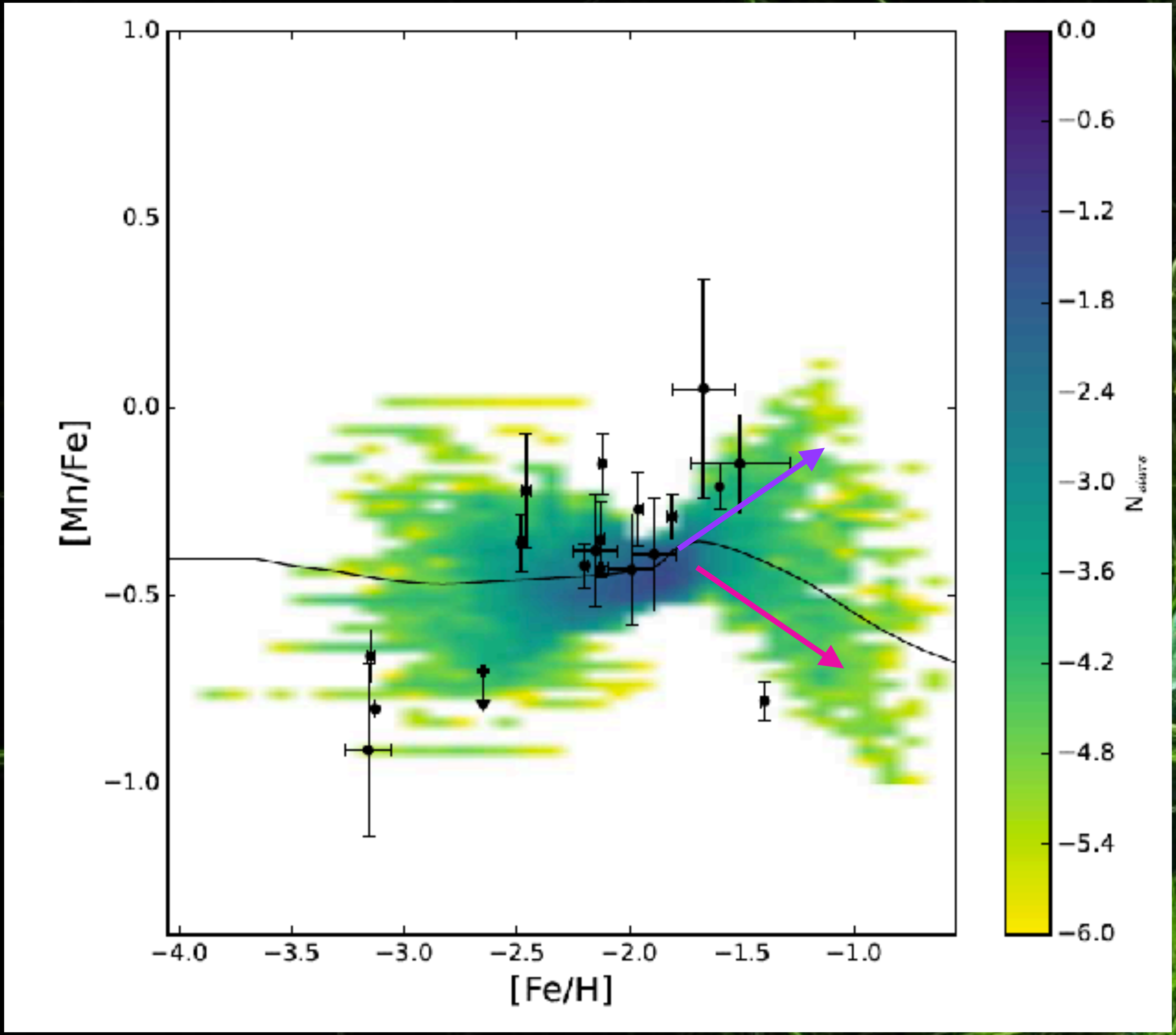
Mn metal dependent from a single degenerate Ch-mass SNe Ia



Cescutti & Kobayashi (2017)

Stochastic model for Ursa minor 2

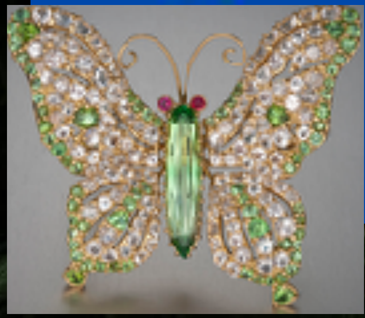
New model with Ch-mass (SNe Iax) & sub-CH mass



The manganese butterfly

Cescutti & Kobayashi (2017)

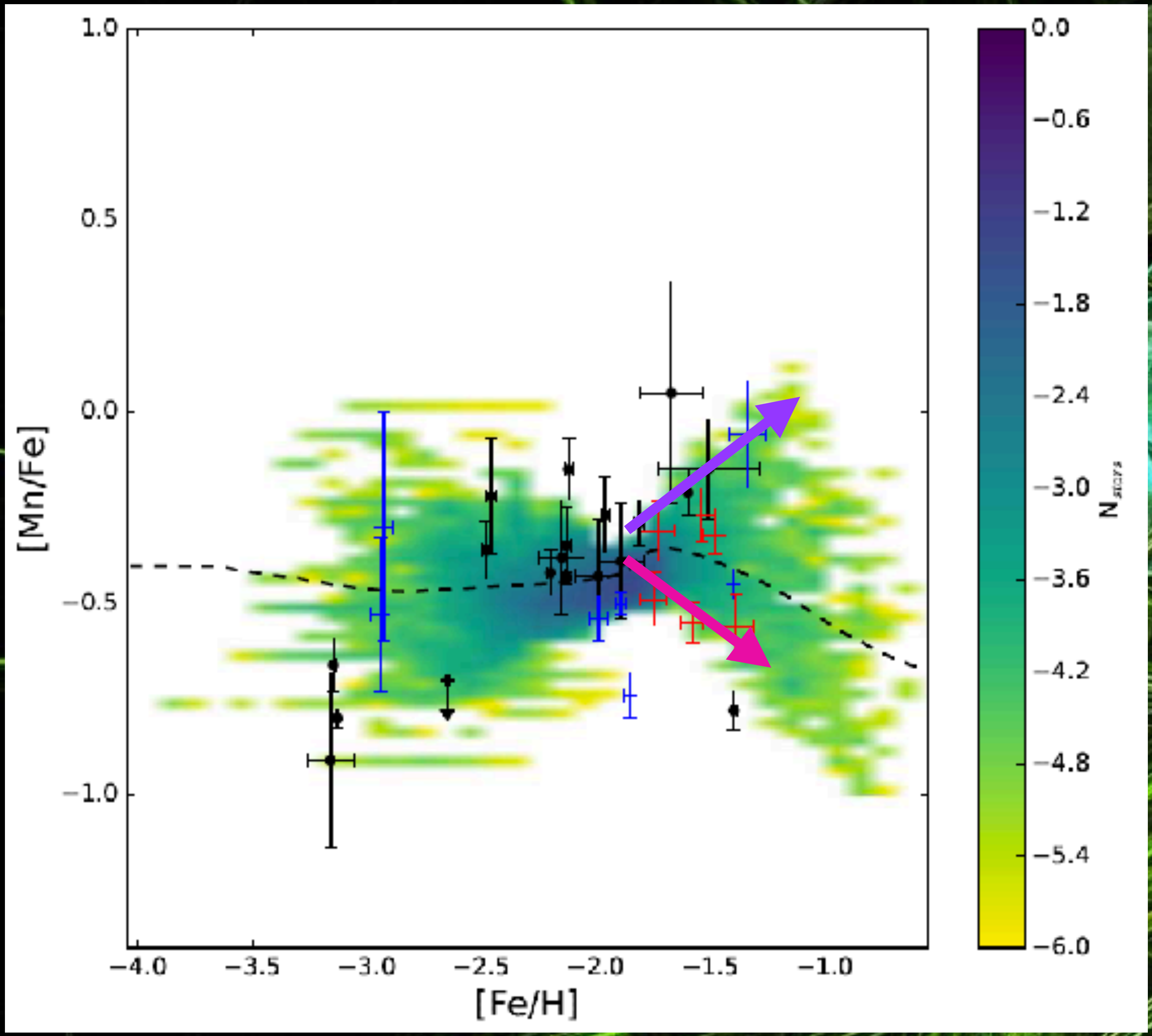
Stochastic chemical evolution models



More data from Carina and Sextans, dSph with similar mass compared to Ursa minor

We can study the origin of the spread in chemical abundance space.
In this case it is originated by two possible SNe Ia progenitors:

Chandrasekhar-mass &
sub-Chandrasekhar mass



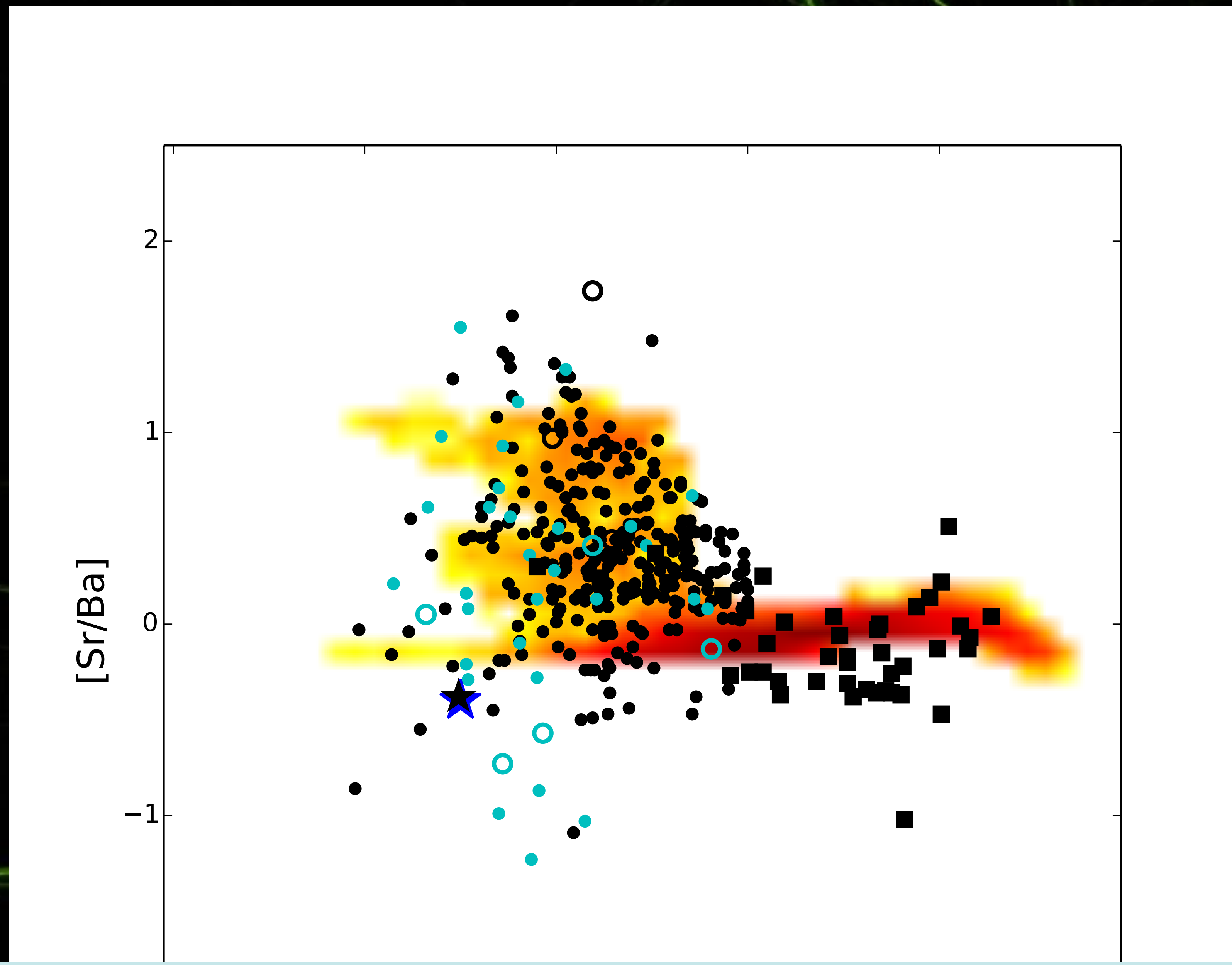
Neutron capture elements

GALACTIC HALO

	s-process		r-process
site	Low-(intermediate) mass stars	fast 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+ 2016	....
	Cristallo+ 2011 Karakas+ 2012	Chieffi & Limongi yields available	

s-process from fast rotating massive stars

+ an r-process site (the 2 productions are not coupled!)



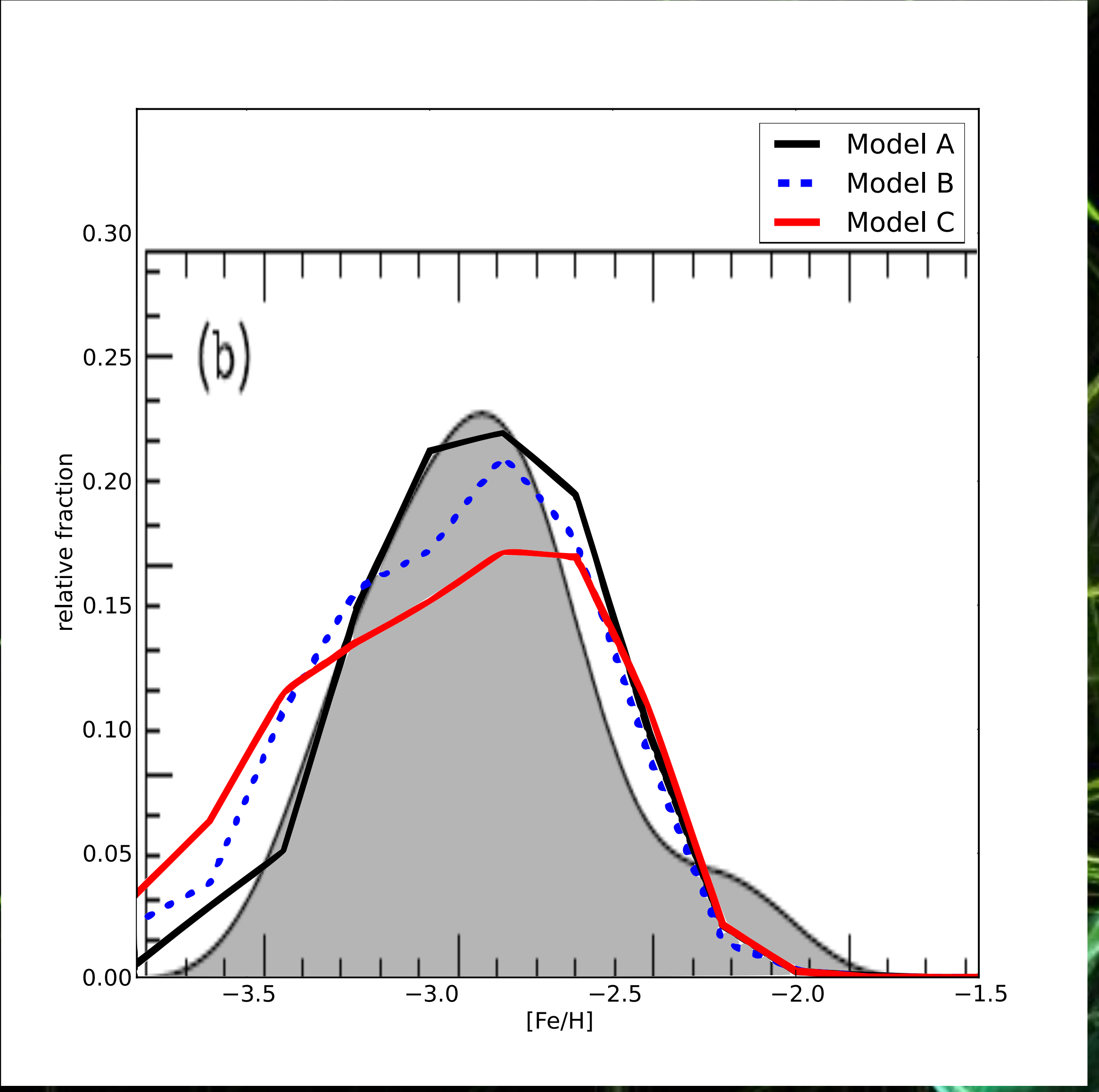
Cescutti et al. (2013)
Cescutti & Chiappini (2014)

A s-process (from fast rotating massive stars)
and an r-process (from rare events)
can reproduce the neutron capture elements in the Early Universe

The model for an ultra faint galaxies: Hercules

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

Aden+11



We constrain the model to match the MDF (and the total stellar mass)

The nucleosynthesis is exactly the same as the halo.

Tested three different (initial) total mass of gas.

A :1 10^5 Msun

B: 2 10^5 Msun

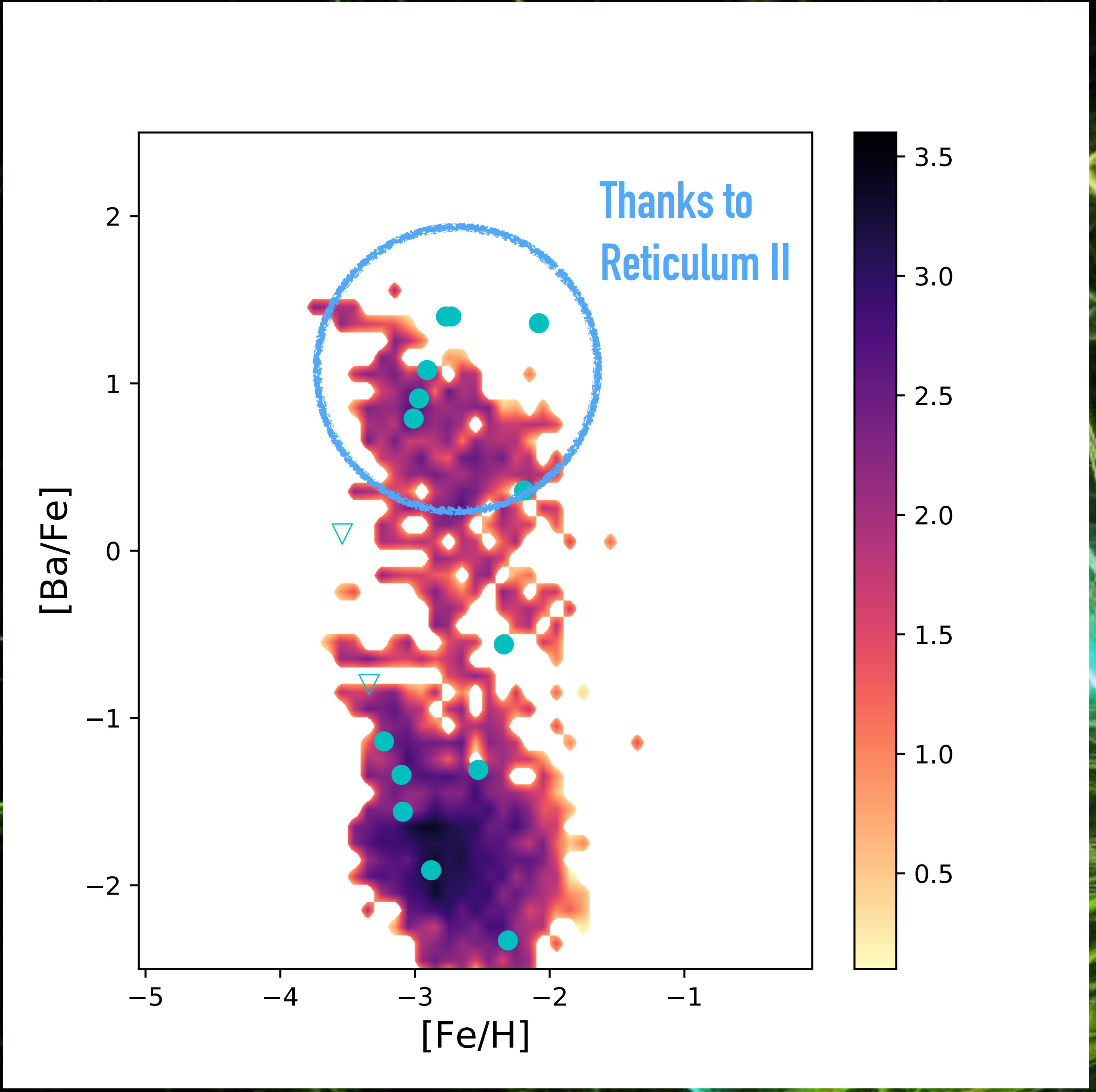
(C : 5 10^5 Msun)

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

Results in Ultra Faint Galaxies: Ba

Data support the model: some UF galaxies are indeed enriched by r-process elements…



Ji+16
Frebel+10
Roederer+16
upper limits

Results in Ultra Faint Galaxies: Eu

All the stars with low Ba do not show any Eu.

It is connected to problem in measuring Eu, but possibly also in a pristine environment, such as in a UF galaxy, maybe we can find Eu-free stars(?)