SAIt - Società Astronomica Italiana - INAF - Istituto Nazionale di Astrofisica
LVIII Congresso SAIt - MILANO - 13-16 maggio 2014 - Palazzo Cusani via Brera 15
"Strutture cosmiche: dal Sistema Solare ai confini dell'Universo"

stelle e galassie primordiali

Raffaella Schneider
INAF/Osservatorio Astronomico di Roma

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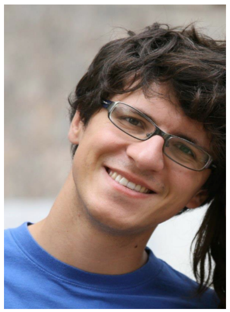
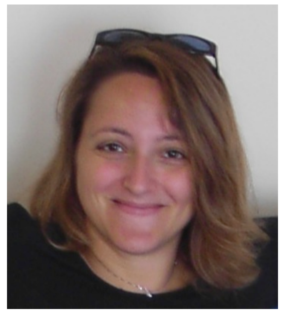
FIRST
THE FIRST STARS AND GALAXIES



Matteo de Bennassuti, PhD
INAF/OAR



Stefania Marassi, Pdoc
INAF/OAR

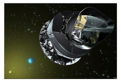
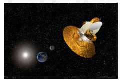
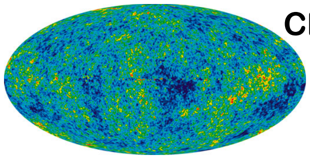
Luca Graziani, Pdoc
INAF/OAR

Rosa Valiante, Pdoc
INAF/OAR

Stefania Salvadori, Kapteyn, Groningen
Marco Limongi, INAF/OARoma
Alessandro Chieffi, INAF/IAPS
Kazuyuki Omukai, Tohoku University

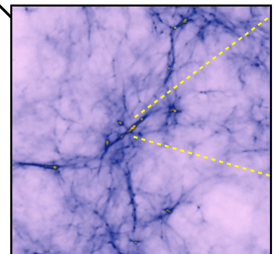
Gen Chiaki, Tokyo University
Takaya Nozawa, NAOJ
Naoki Yoshida, Tokyo University
Daisuke Kawata, University College, UK

FIRST – Scientific background

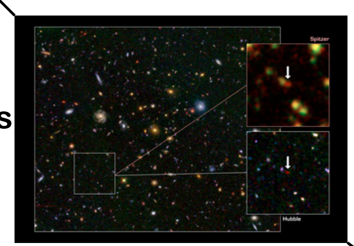




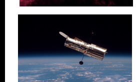
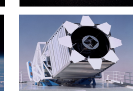
CMB radiation
z = 1100
370 000 yr

theoretical studies:
numerical simulations
semi-analytical models



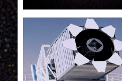
most distant
galaxies & quasars
z ≈ 7 - 10
600-700 Myr



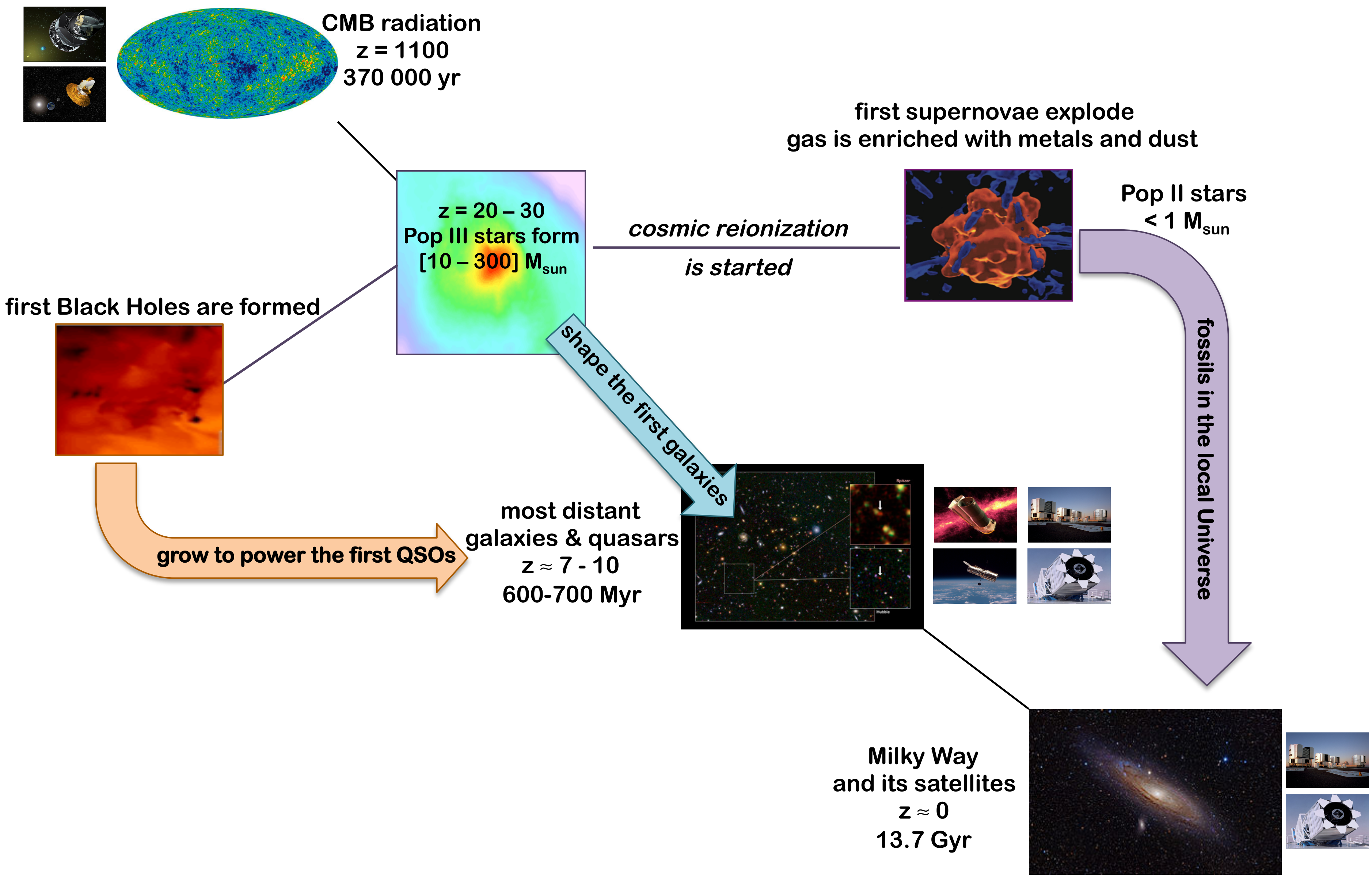




Milky Way
and its satellites
z ≈ 0
13.7 Gyr

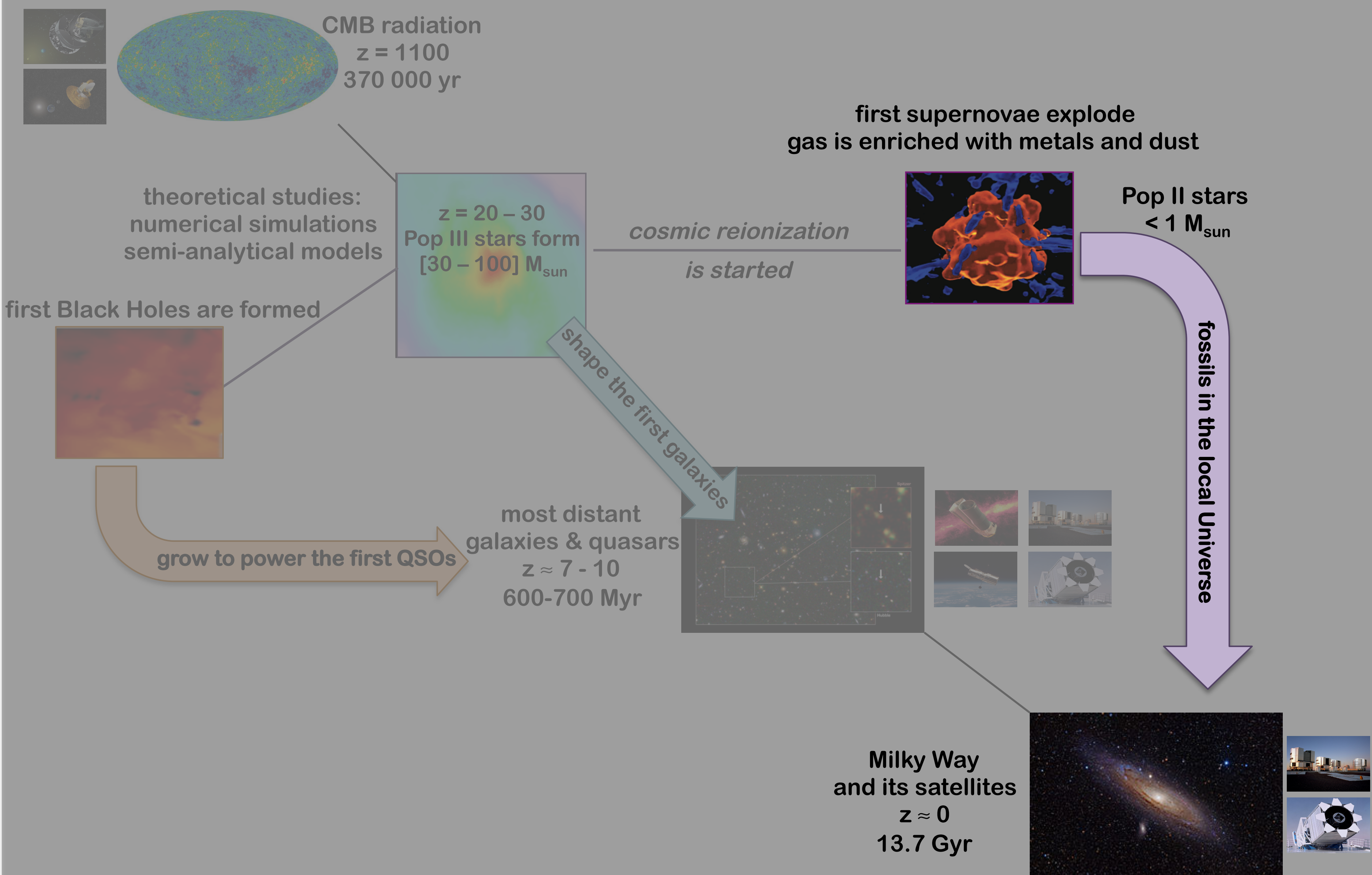




FIRST – Scientific background



from the first stars to the local universe



stellar archaeology with the most metal poor stars

			[Fe/H] < -3	[Fe/H] < -5	
Survey	Effective sky coverage	Effective mag limit	$N < -3.0$ (EMP)	$N < -5.0$ (HMP)	People
HES	6,400 deg^2	$B < 16.5$	200	2	Christlieb et al.
SEGUE	1,000 deg^2	$B < 19$	(1,000)	(10)	Beers et al.; Caffau et al.
LAMOST	12,200 deg^2	$B < 18.0$	(3,000)	(30)	Zhao et al.
SSS	20,000 deg^2	$B < 17.5$	(2,500)	(25)	Keller et al.

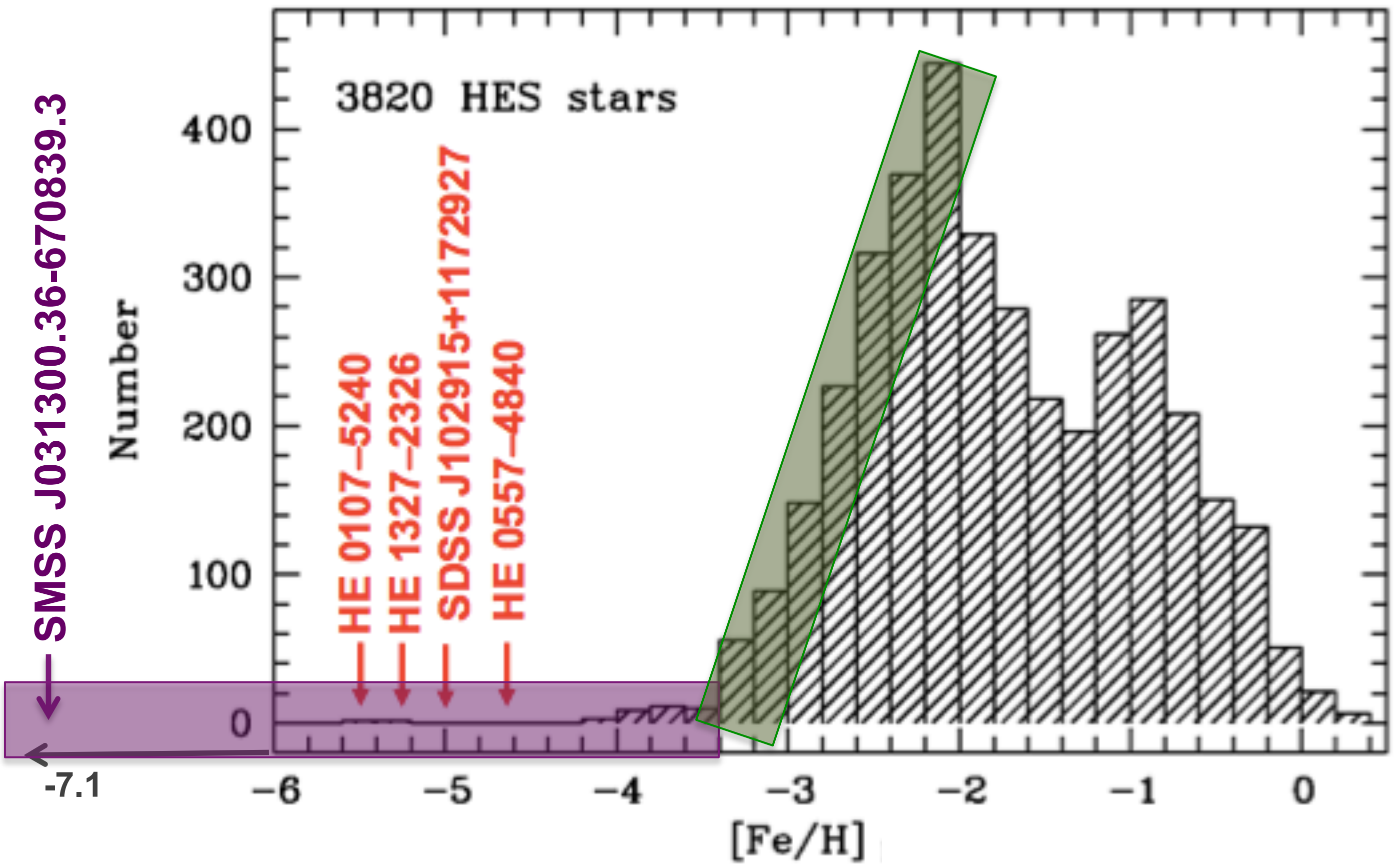
2014 Nature, 506, 463

A single low-energy, iron-poor supernova as the source of metals in the star SMSS J031300.36-670839.3

S. C. Keller, M. S. Bessell, A. Frebel*, A. R. Casey, M. Asplund, H. R. Jacobson*, K. Lind*, J. E. Norris, D. Yong, A. Heger+, Z. Magic△, G. S. Da Costa, B. P. Schmidt, & P. Tisserand

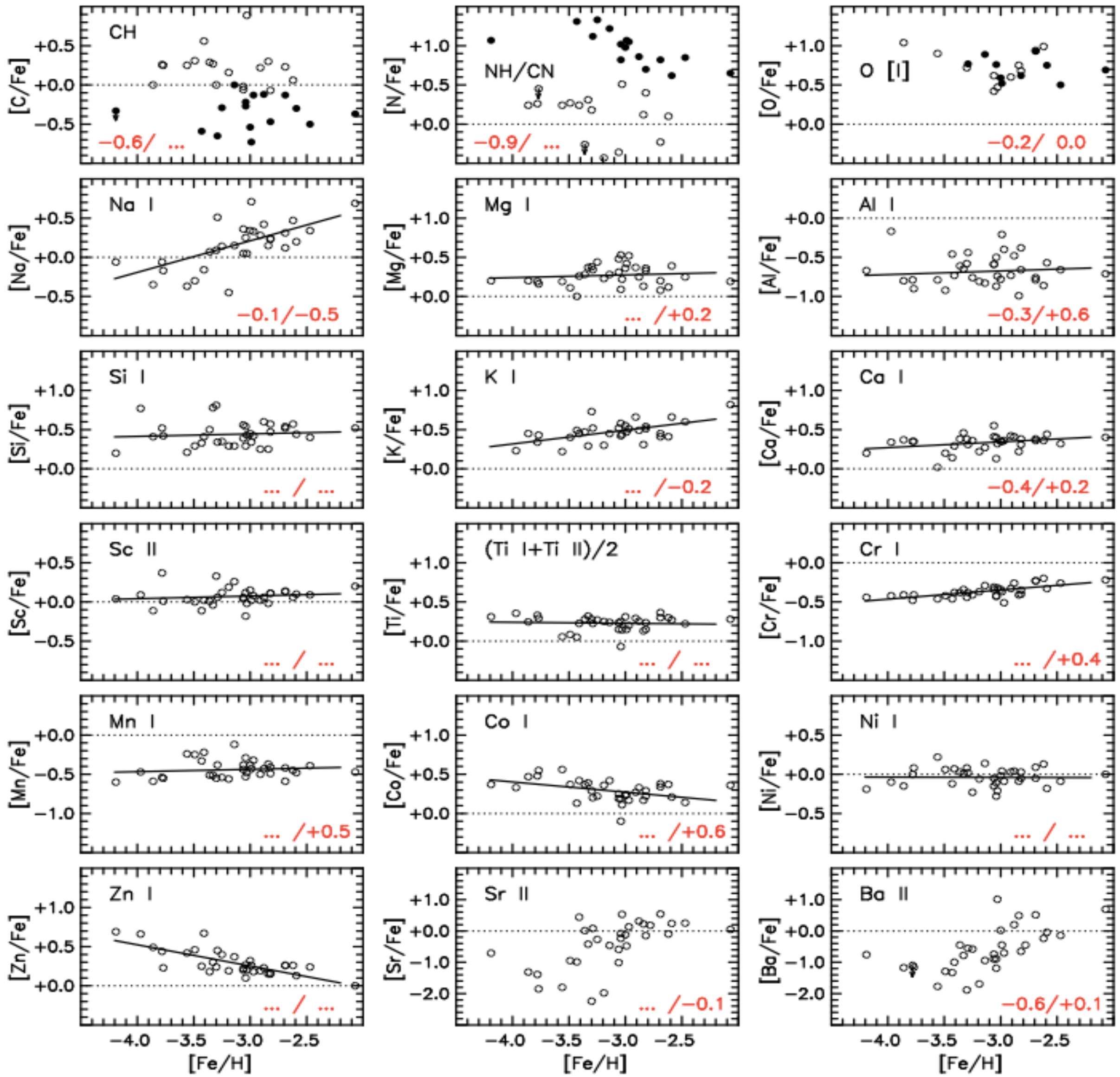
[Fe/H] < -7.1

the metallicity distribution function of the Galactic halo



Schörck et al. 2009
Christlieb 2013

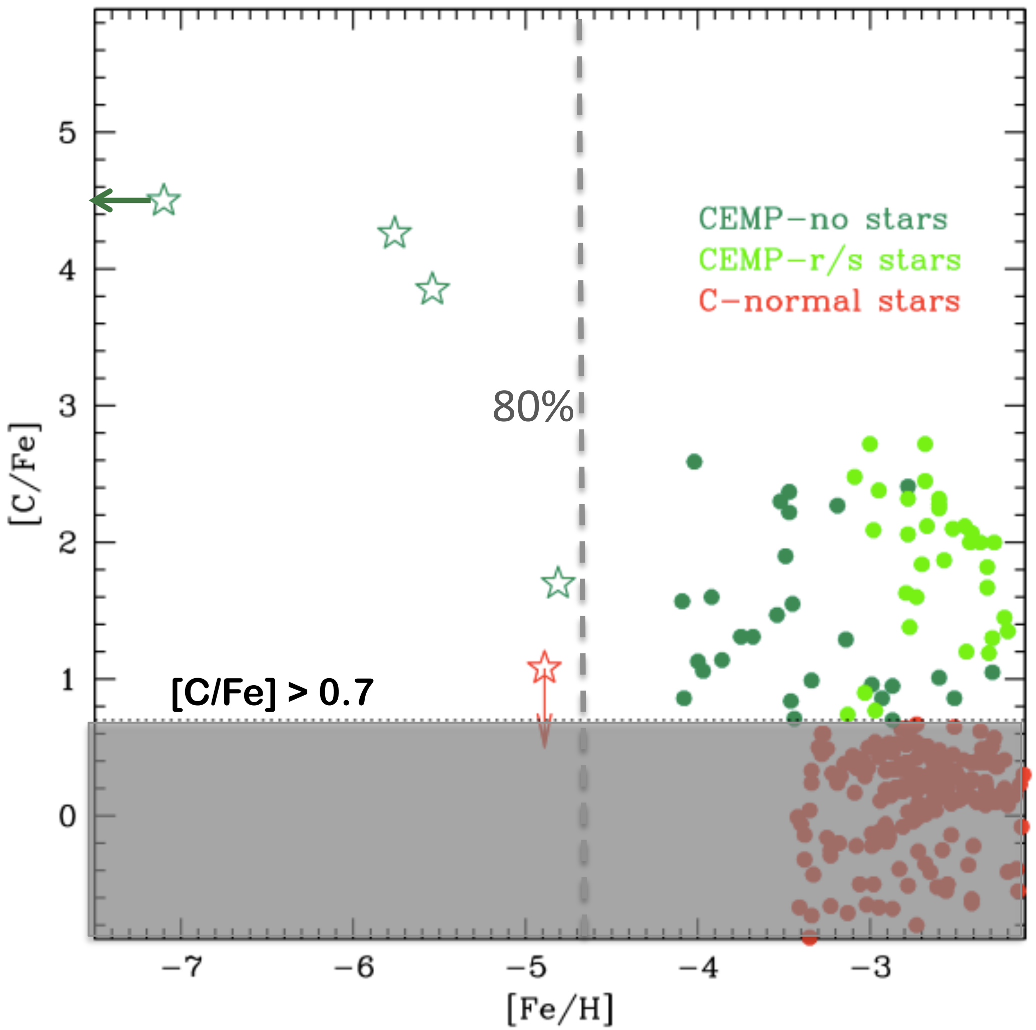
the C to Zn abundances of metal poor stars



Cayrel et al. 2004; Spite et al. 2005; François et al. 2007

carbon-enhanced metal poor stars

~ 20 % of stars with [Fe/H] < -2 are C-enhanced: [C/Fe] > 0.7



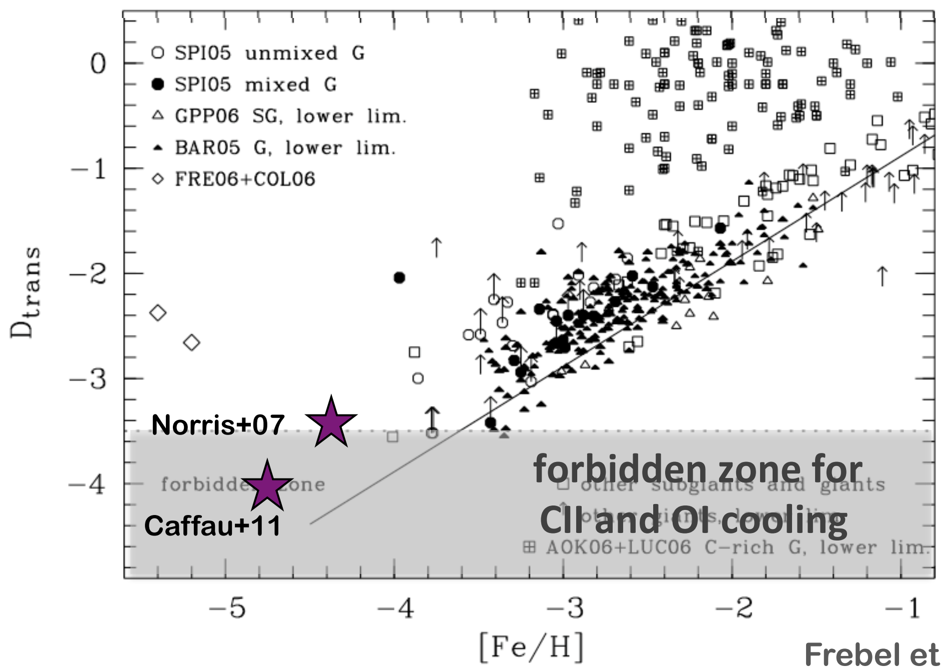
CEMP – r/s
mass transfer from an AGB companion in binary systems

CEMP – no
metal yields from faint SNe with mixing/fallback

Yong et al. 2013; Norris et al. 2013

C-normal and C-rich stars: different formation patways?

$$D_{trans} = \text{Log}(10^{[C/H]} + 0.3\ 10^{[O/H]})$$



Frebel et al. (2009)

C-normal stars with [Fe/H] < -3.5 can not form through metal line-cooling

Dust-driven fragmentation if the $\mathcal{D} > \mathcal{D}_{cr} = (4.4 \pm 2.0) \times 10^{-9}$

$$S\mathcal{D} > 1.4 \times 10^{-3} \text{cm}^2/\text{gr} \left[\frac{T}{10^3 \text{K}}\right]^{-1/2} \left[\frac{n_{\rm H}}{10^{12} \text{cm}^{-3}}\right]^{-1/2}$$

Schneider & Omukai (2010)
Schneider et al. (2012)

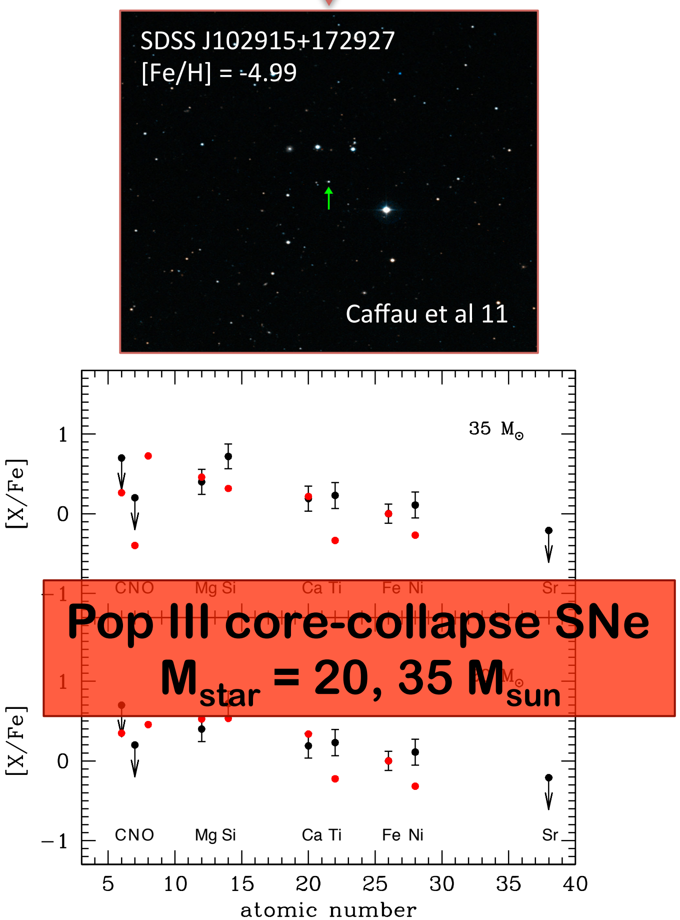
Questions that we want to address:

What are the formation pathways of C-normal and C-rich stars?

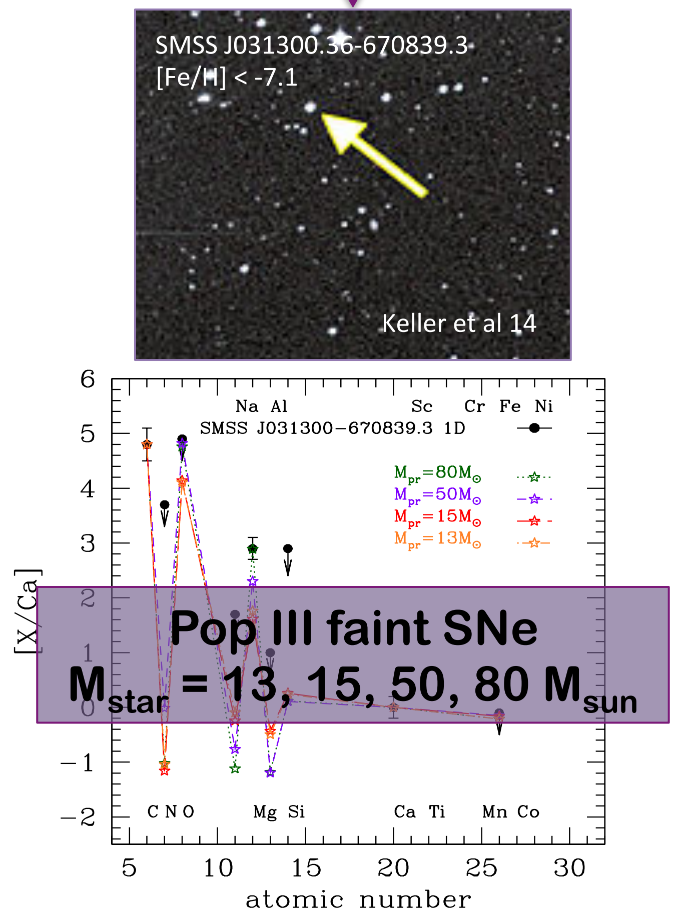
What are the physical processes that shape the low-[Fe/H] tail of the MDF ?

Why is the relative fraction of C-normal and C-rich stars varying with [Fe/H] ?

simulating the birth environment of C-normal and C-rich stars

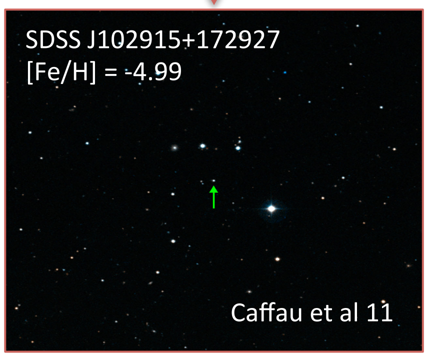


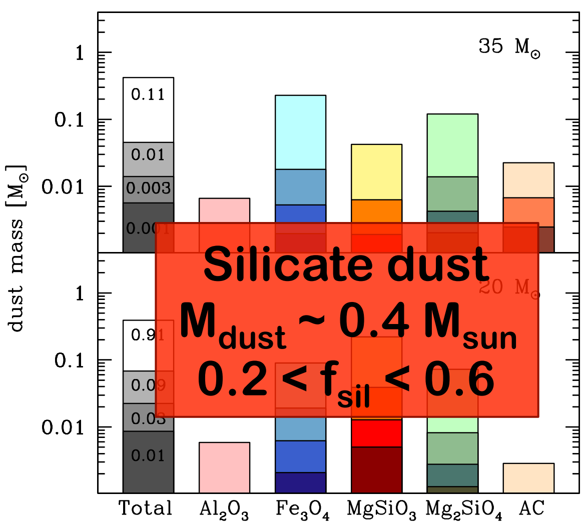
Schneider et al. 2012



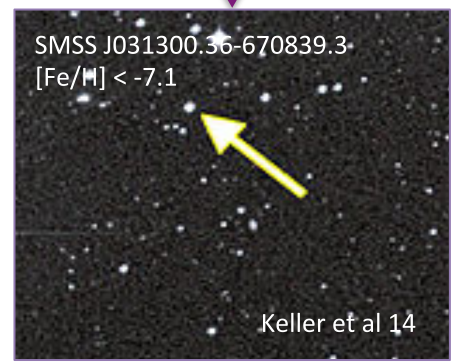
Marassi et al. 2014

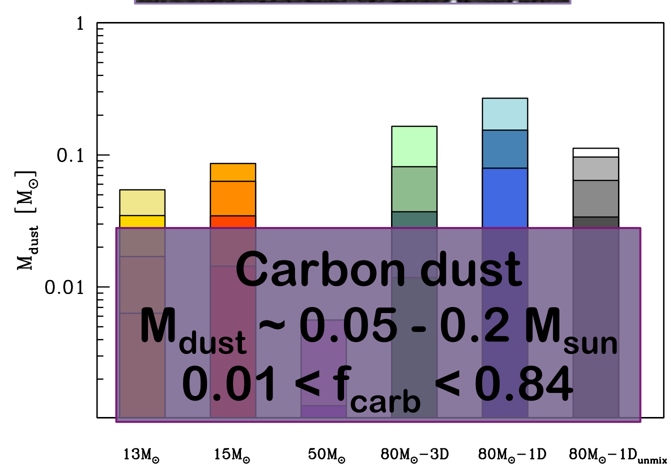
simulating the birth environment of C-normal and C-rich stars





Schneider et al. 2012

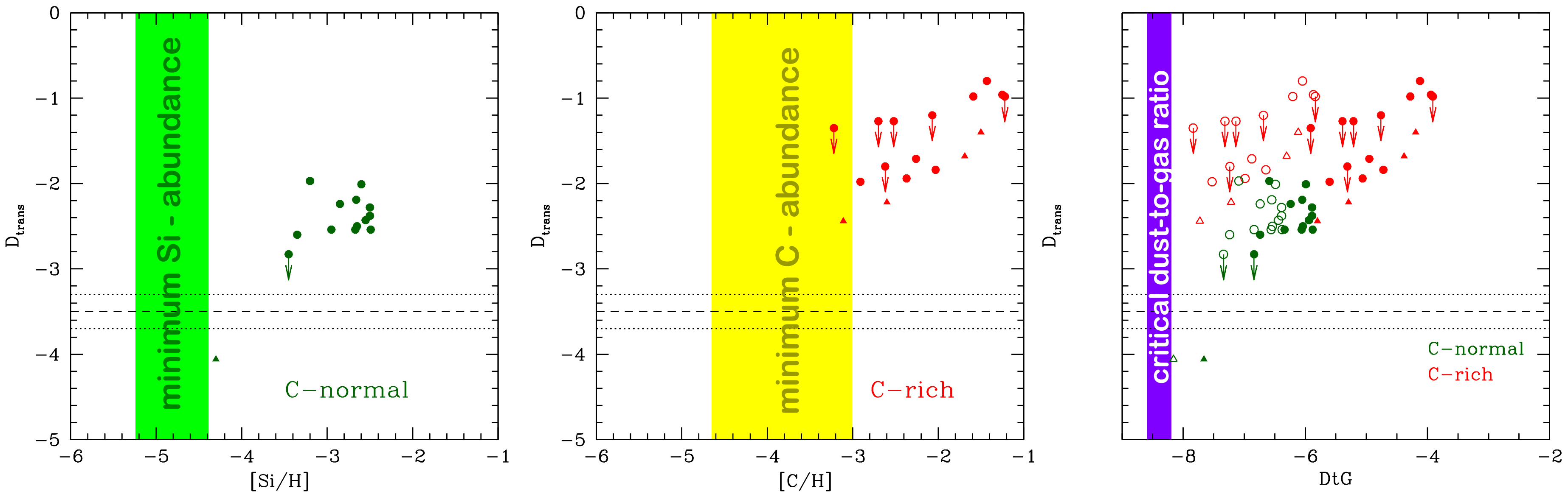




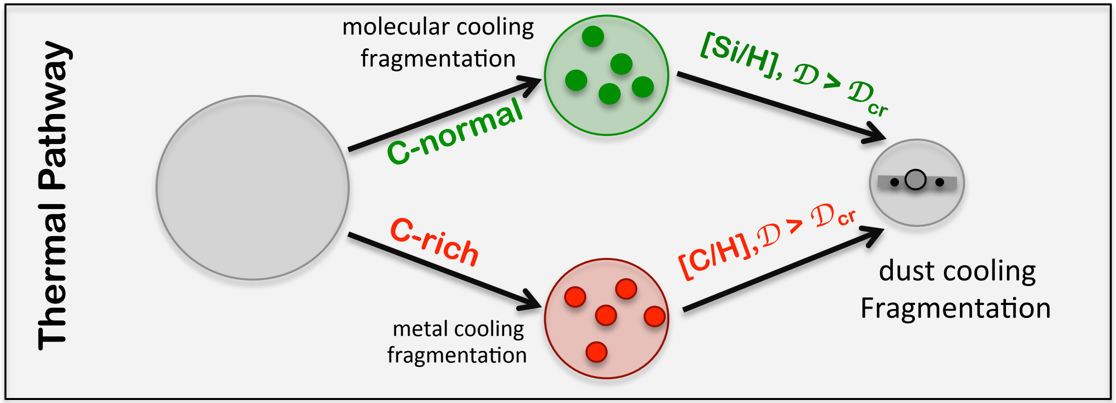
Marassi et al. 2014

simulating the birth environment of C-normal and C-rich stars

Marassi et al. 2014



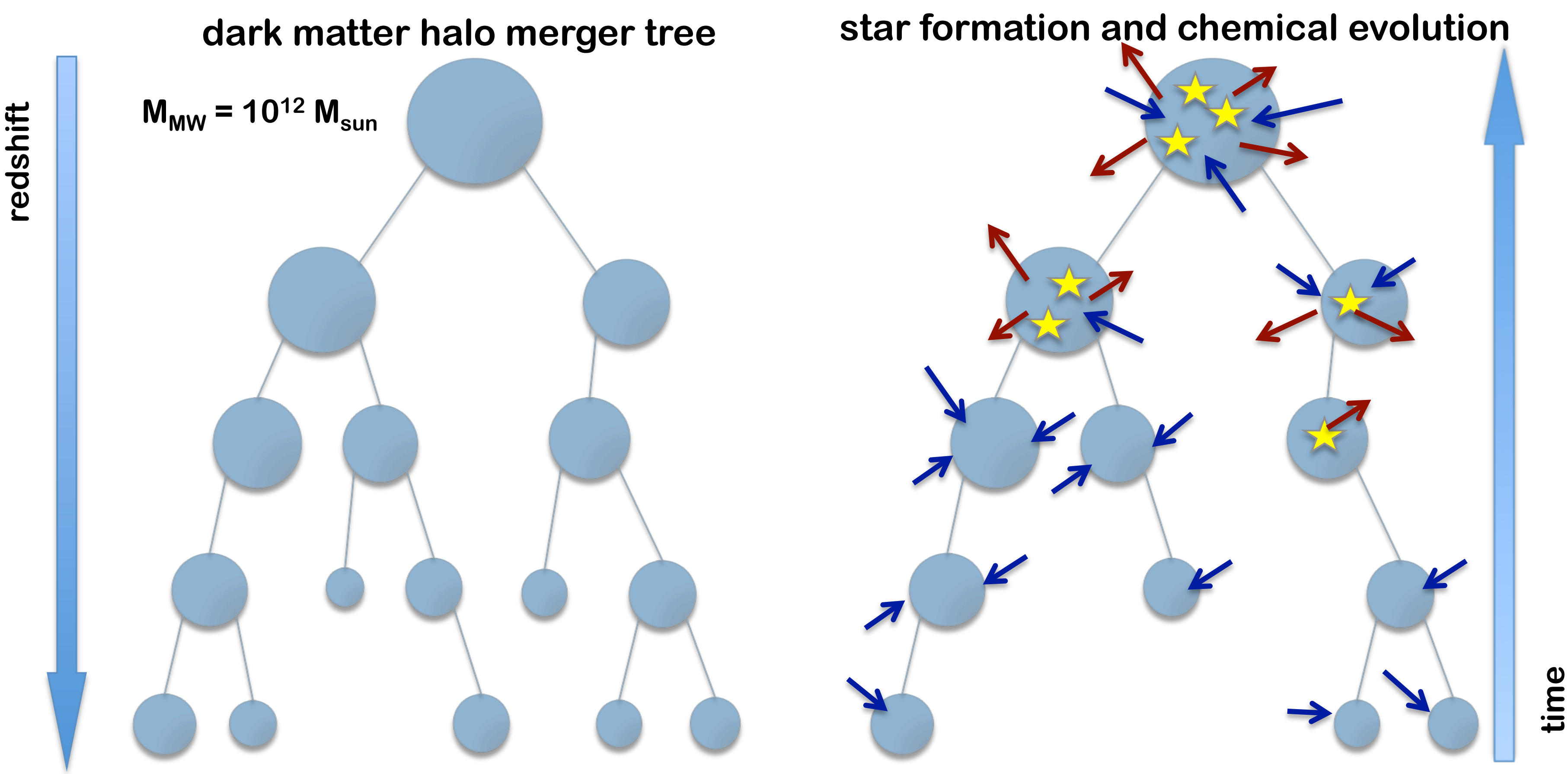
a single formation pathway based on dust-driven fragmentation



GAMETE

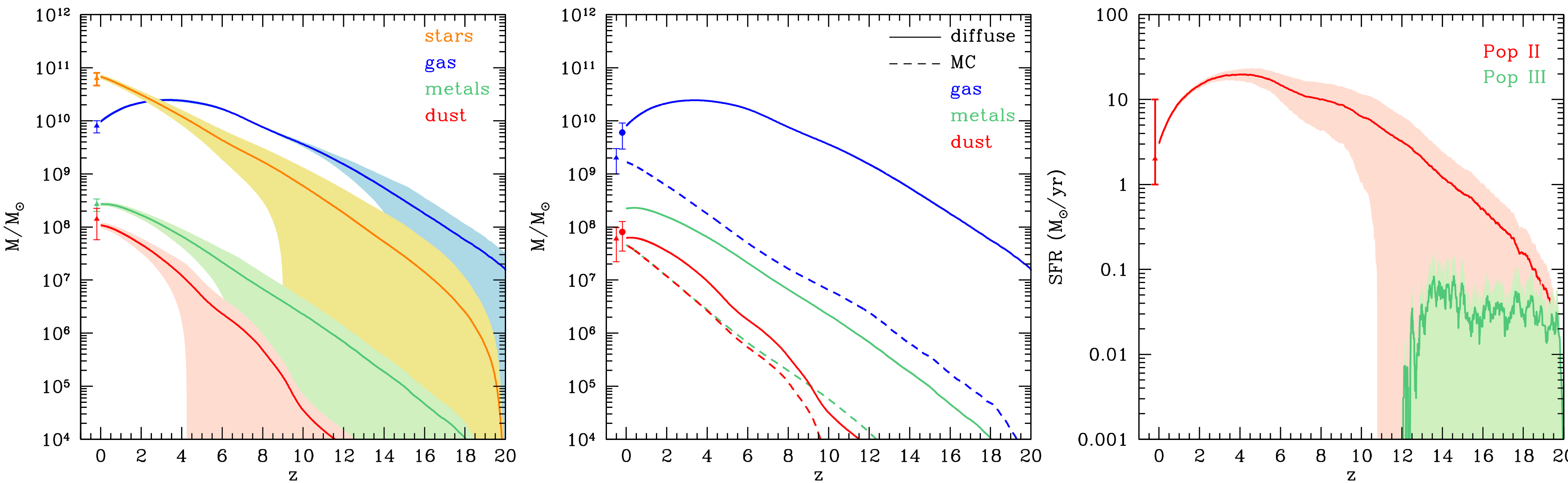
GAlaxy MErger Tree and Evolution

Salvadori et al. 2007, 2008, 2009; Valiante et al. 2011, 2014; de Bennassuti et al. 2014



The MW and its dusty progenitors

global properties of the MW | **2-phase structure of the ISM** | **Pop III and Pop II SFRs**



average over 50 independent merger trees

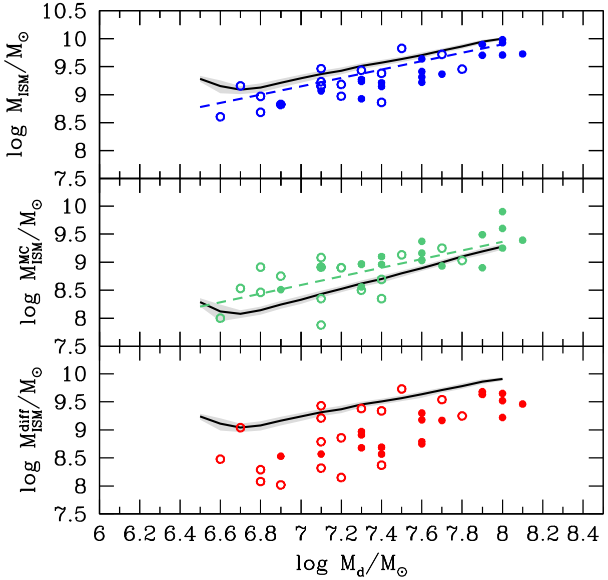
1 – σ

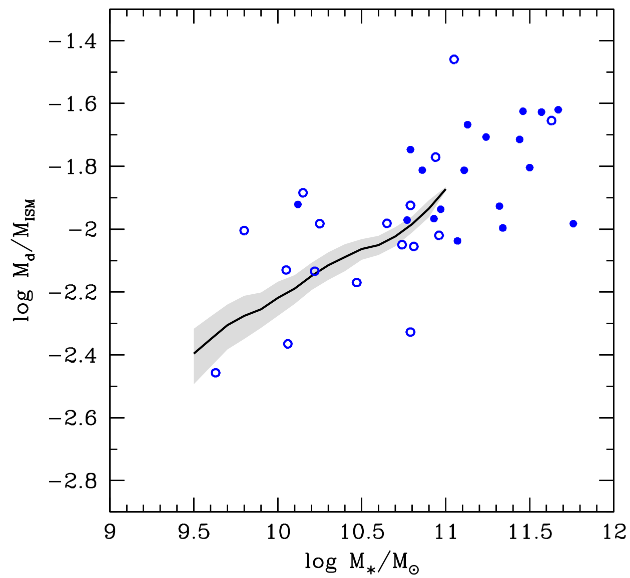
de Bennassuti et al 2014

The MW and its dusty progenitors

de Bennassuti et al 2014

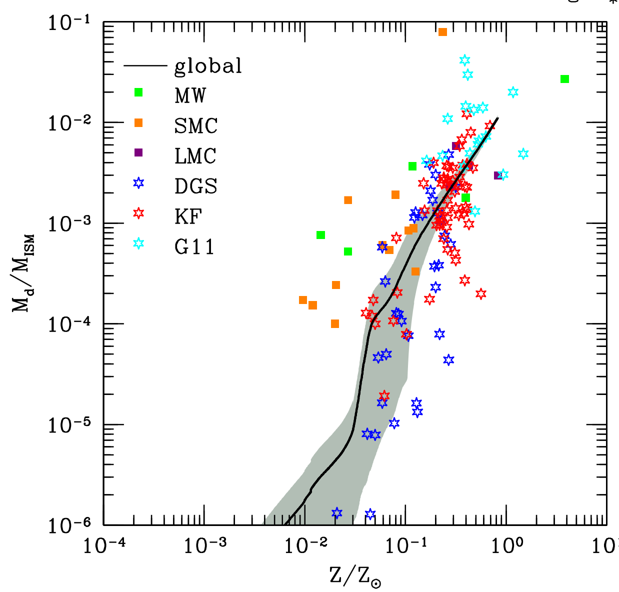
gas and dust scaling relations





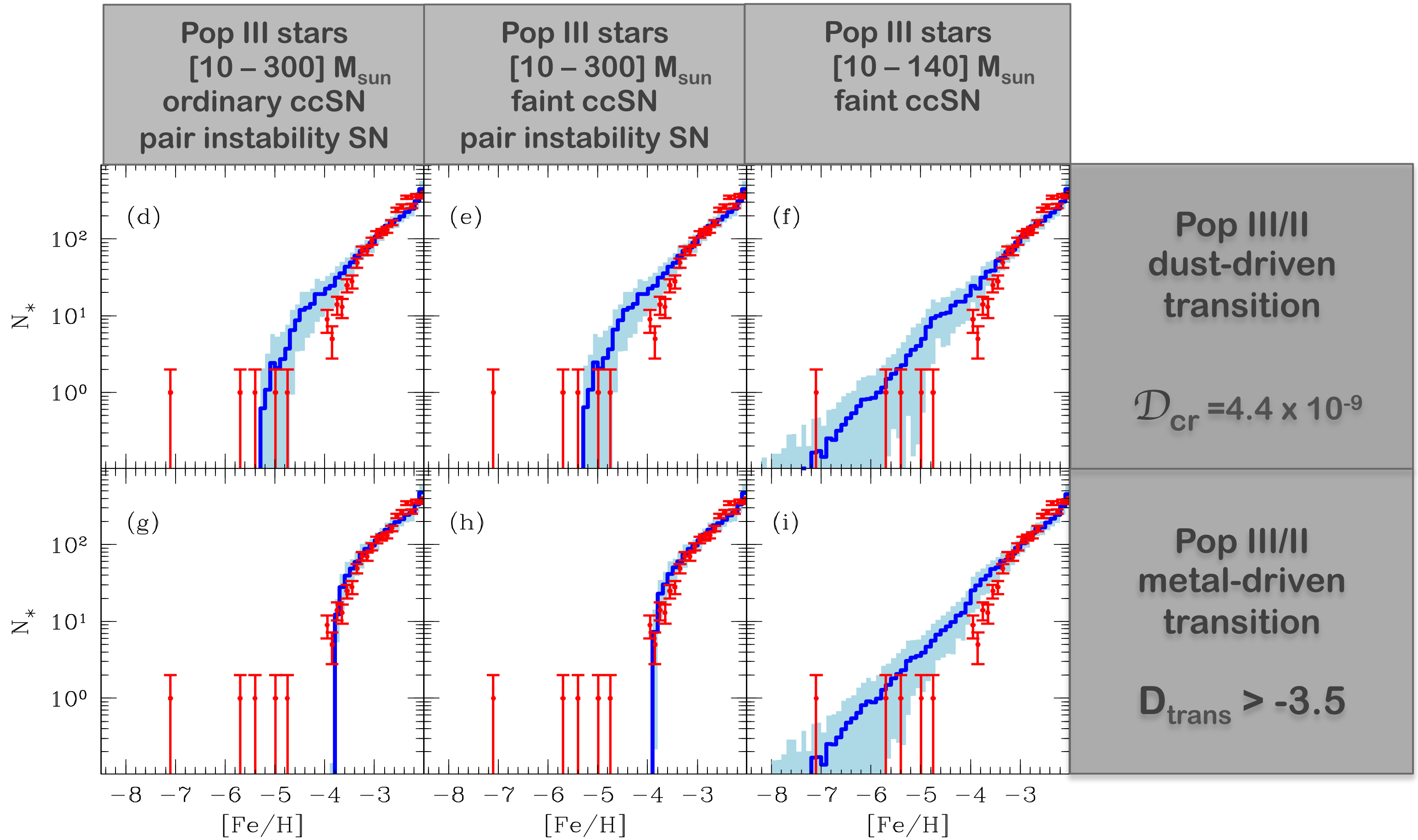
data points:
sample of local
Virgo galaxies
Corbelli et al. (2012)

dust-to-gas ratio
vs metallicity



data points:
sample of GRB hosts
0.1 < z < 6.3 Zafar & Watson (2013)
Local dwarfs Galametz et al. (2011)
Madden et al. (2013),
Remy-Ruyer et al. (2014)

The low-[Fe/H] tail of the MDF



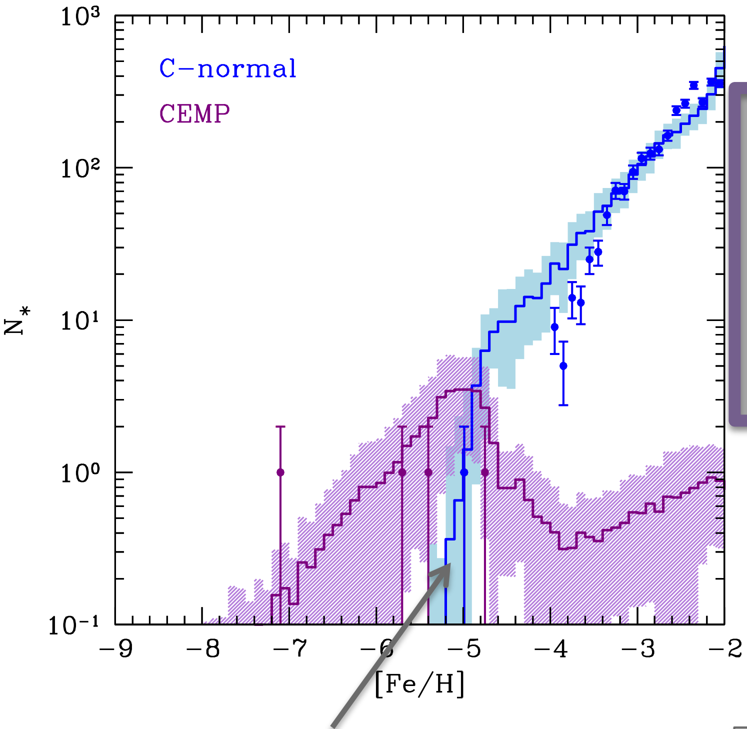
Pop III stars IMF → [10-140] M_{sun} and explode as faint ccSN

Pop III/II transition criterium → degenerate with the Pop III IMF

Change of slope in the low-[Fe/H] tail → radiative feedback effects?

de Bennassuti et al 2014

Metallicity distribution of C-rich stars

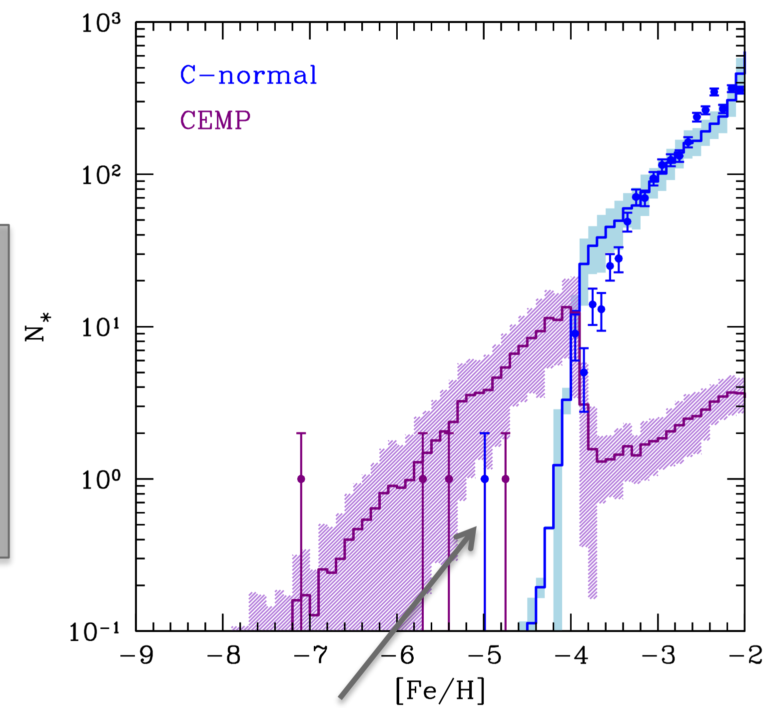


Pop III/II dust-driven transition

$\mathcal{D}_{cr} = 4.4 \times 10^{-9}$

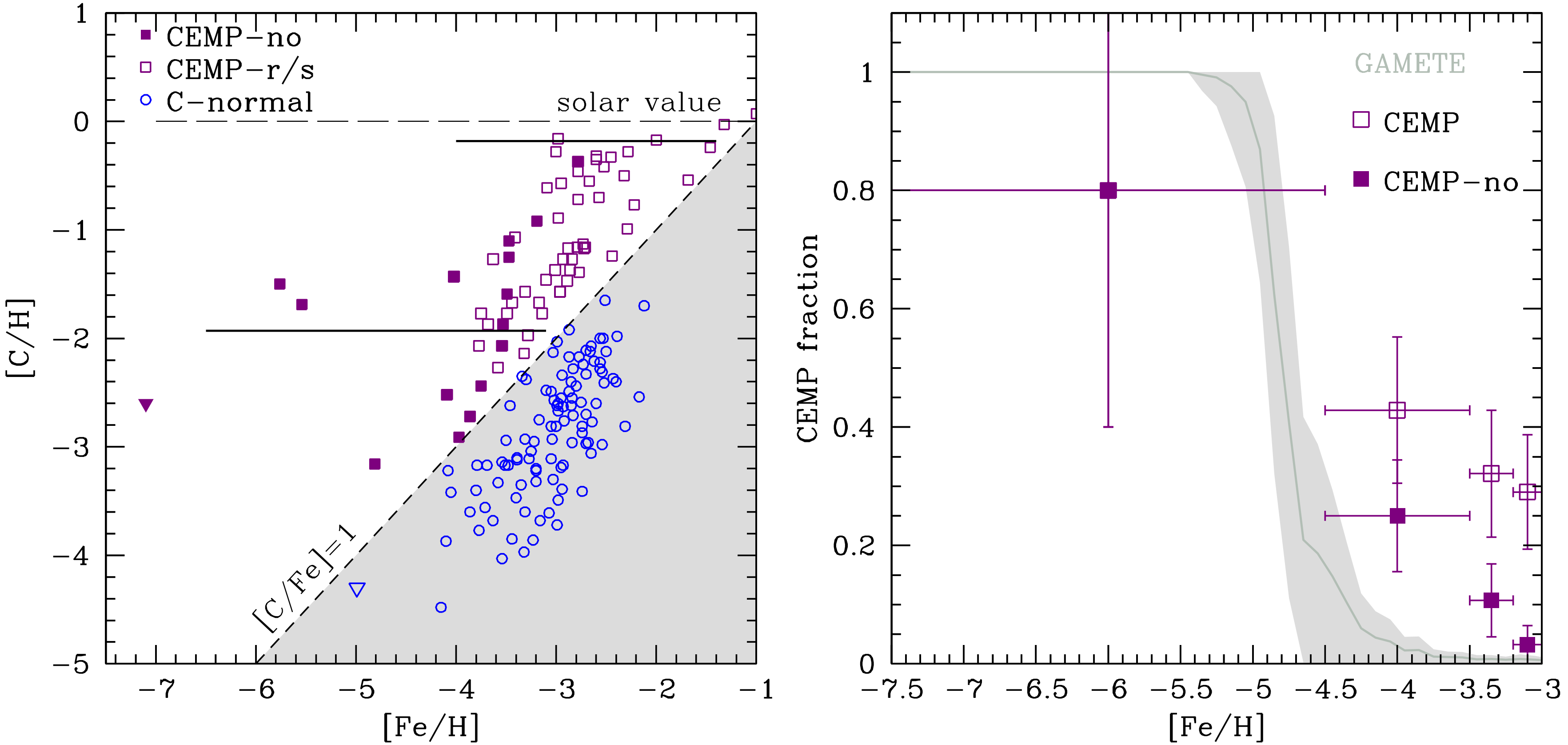
Pop III/II metal-driven transition

$D_{trans} > -3.5$



de Bennassuti et al 2014

Relative fraction of C-rich and C-normal stars



data points from Yong et al. (2013)

de Bennassuti et al 2014

Conclusions:

Stellar Archaeology of the most metal-poor stars is a powerful way to constrain the first stellar generations

What are the formation pathways of C-normal and C-rich stars?

Ordinary vs faint SN: a single thermal pathway with dust-driven fragmentation

What are the physical processes that shape the low-[Fe/H] tail of the MDF ?

very sensitive to the adopted Pop III IMF and SN yields
interplay between chemical and radiative feedback effects

Why is the relative fraction of C-normal and C-rich stars varying with [Fe/H] ?

sensitive to the Pop III/II transition
observed CEMP fraction at [Fe/H] > -4 may require that a fraction of Pop II SN is faint