Chemical Evolution of r-process elements

30.09.2016

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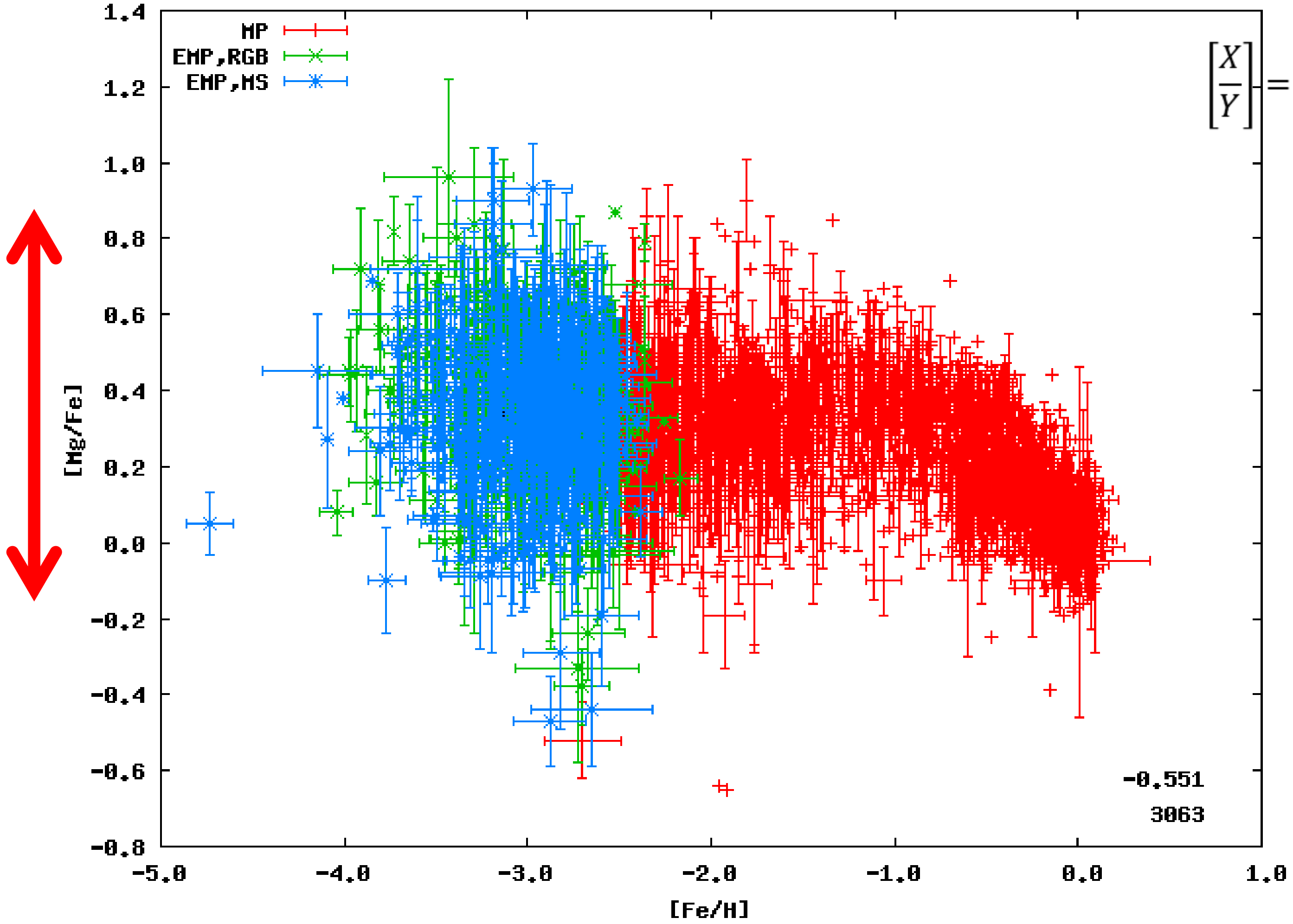
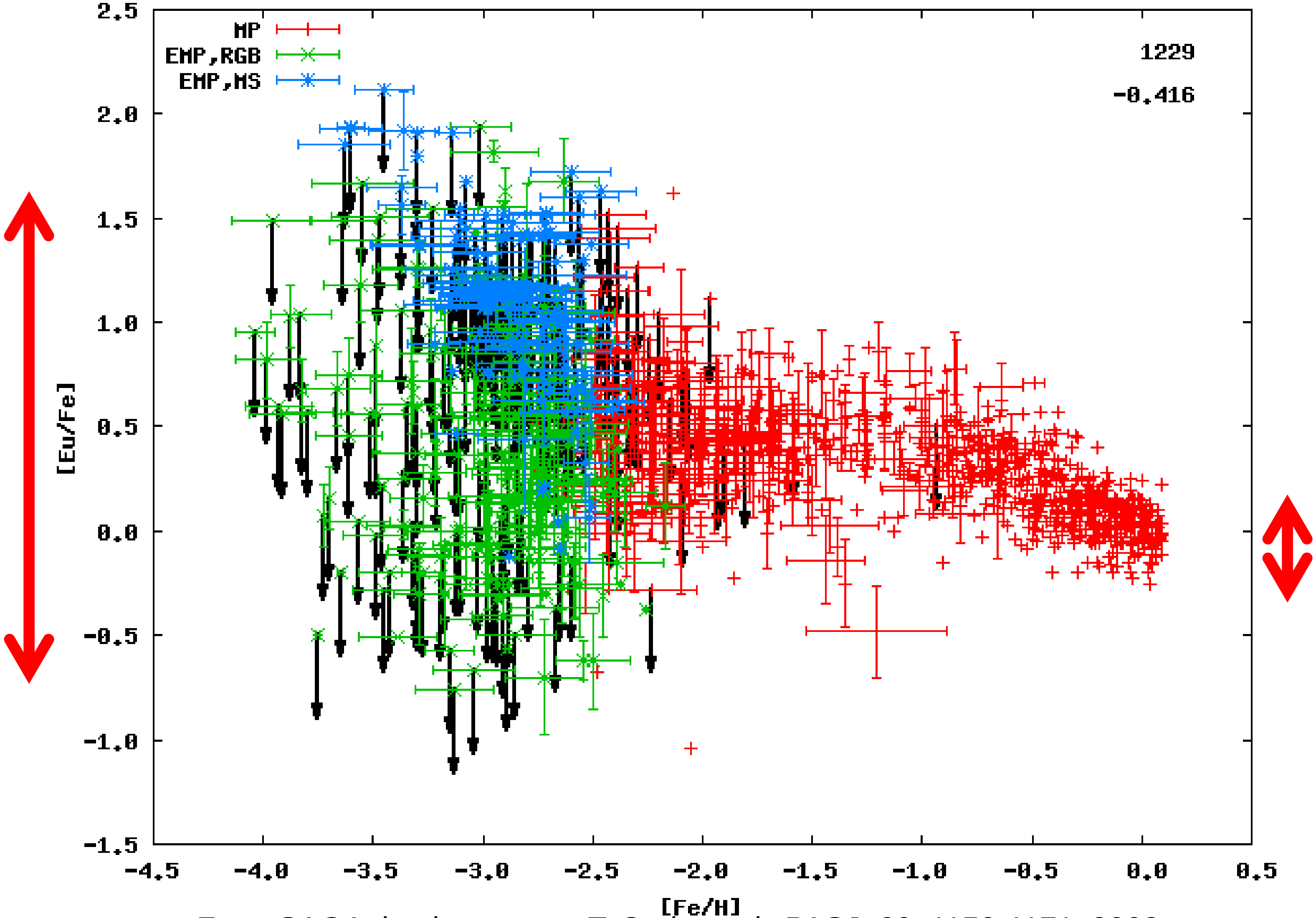
Abundances of alpha elements



$$\left[\frac{X}{Y}\right] = \log \frac{X_{Star}/Y_{Star}}{X_{Sol}/Y_{Sol}}$$

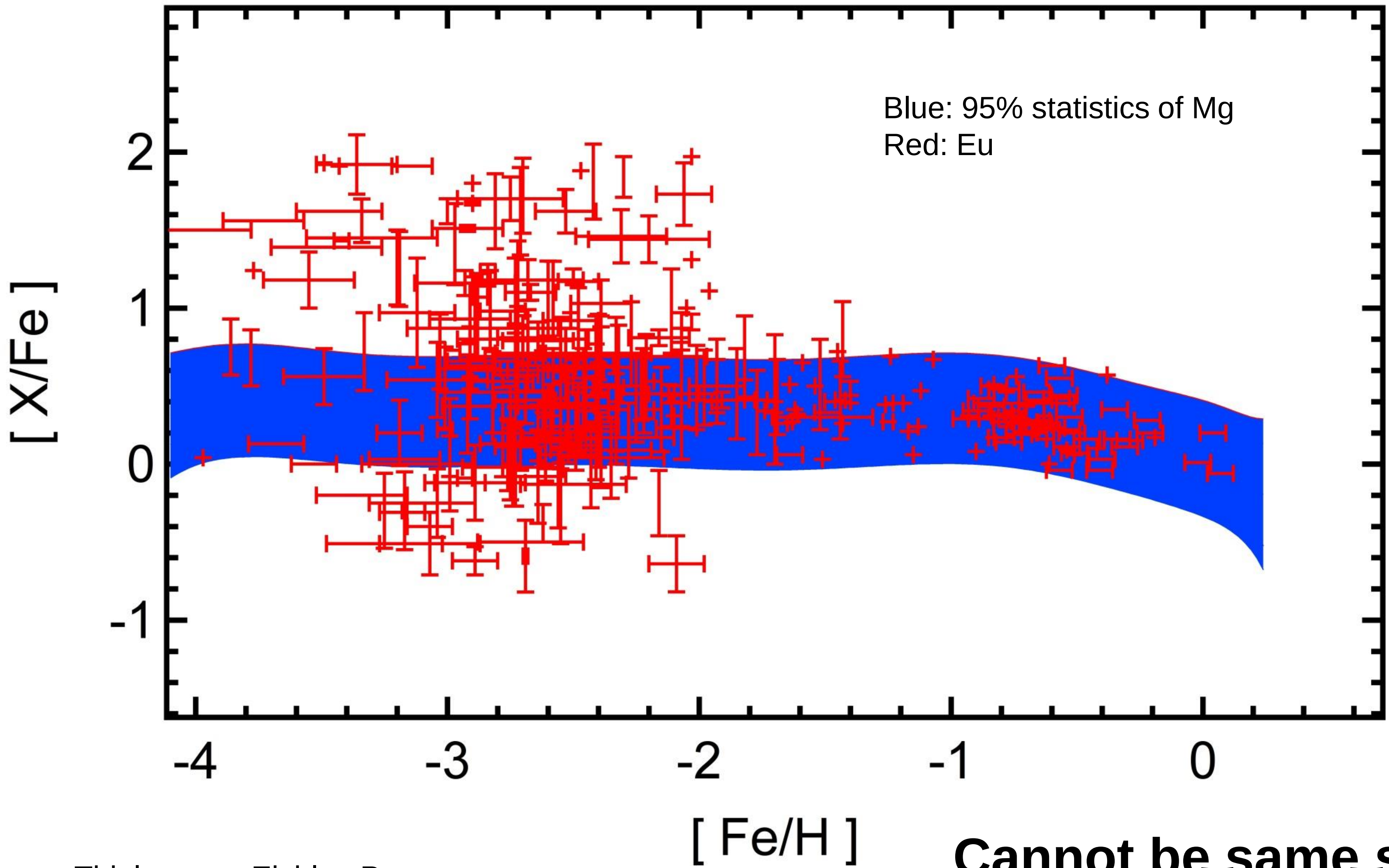
From SAGA database, e.g., *T. Suda et al.*, PASJ, 60, 1159-1171, 2008.

But what about r-process elements?



From SAGA database, e.g., *T. Suda et al.*, PASJ, 60, 1159-1171, 2008.

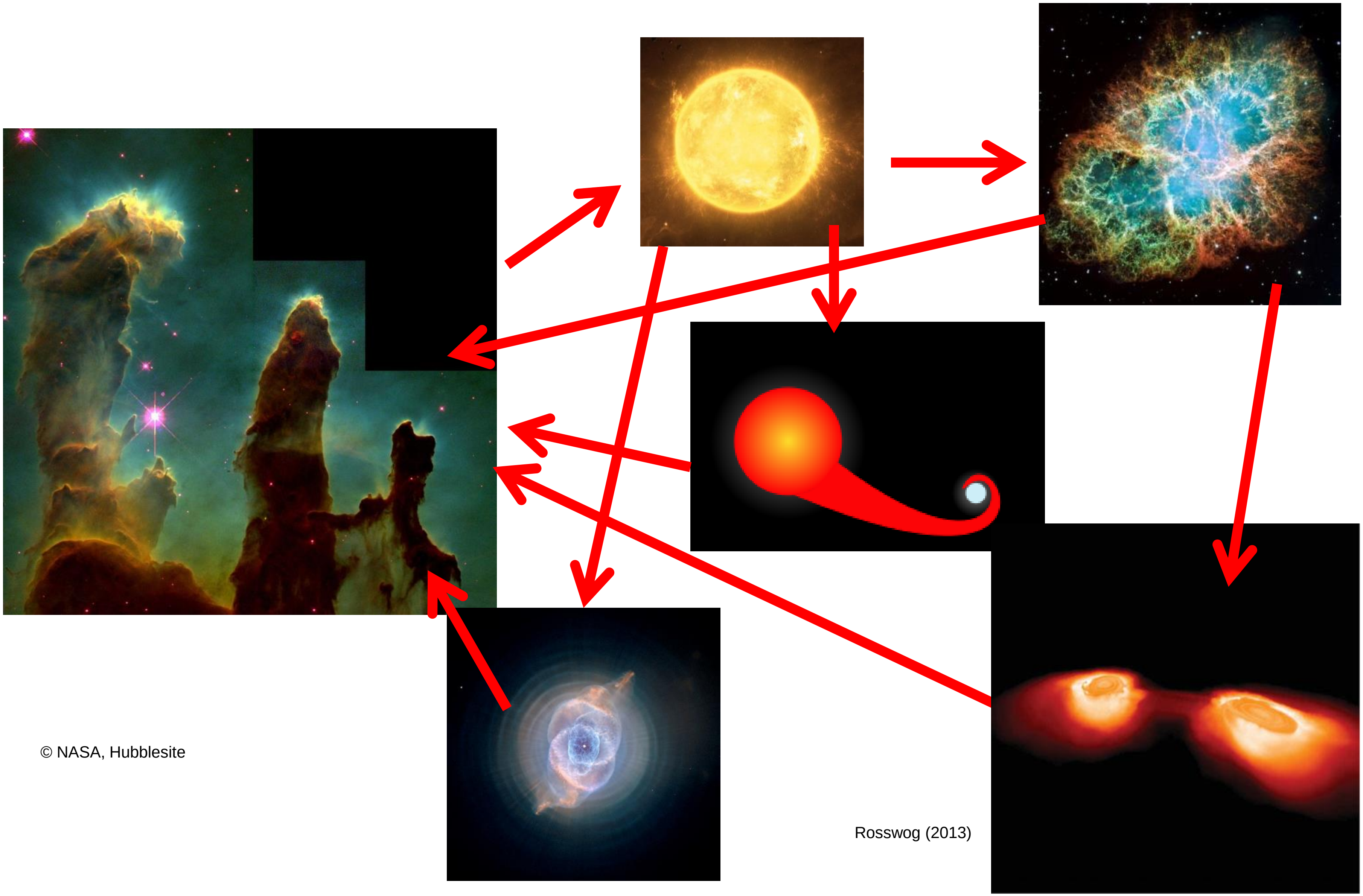
Both together



Cannot be same site!

Thielemann, Eichler, Panov, Pignatari, BW, 2016

The cosmic life cycle



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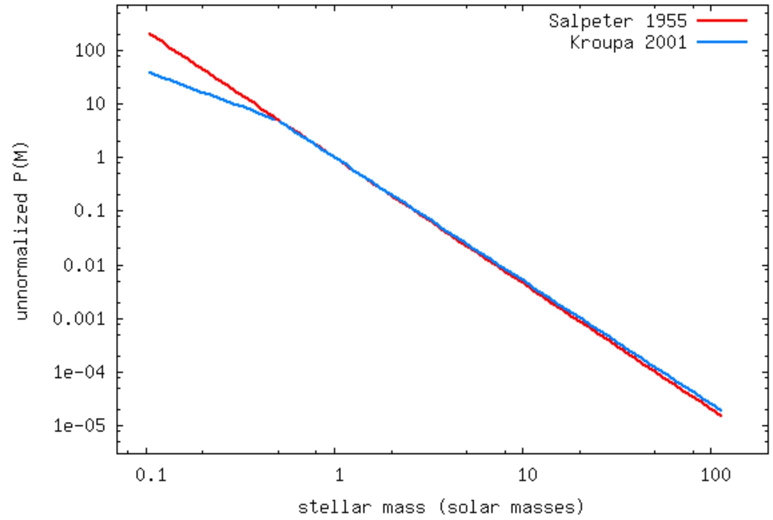
Rosswog (2013)

Let‘s set up our galaxy!

- Infall
- Read local density
- SF (coupled to density) with IMF
- Add local ISM enrichment to stars
- star reached end of life time? =>Simulate explosion
- Double star NS system reached end of life time? =>simulate explosion



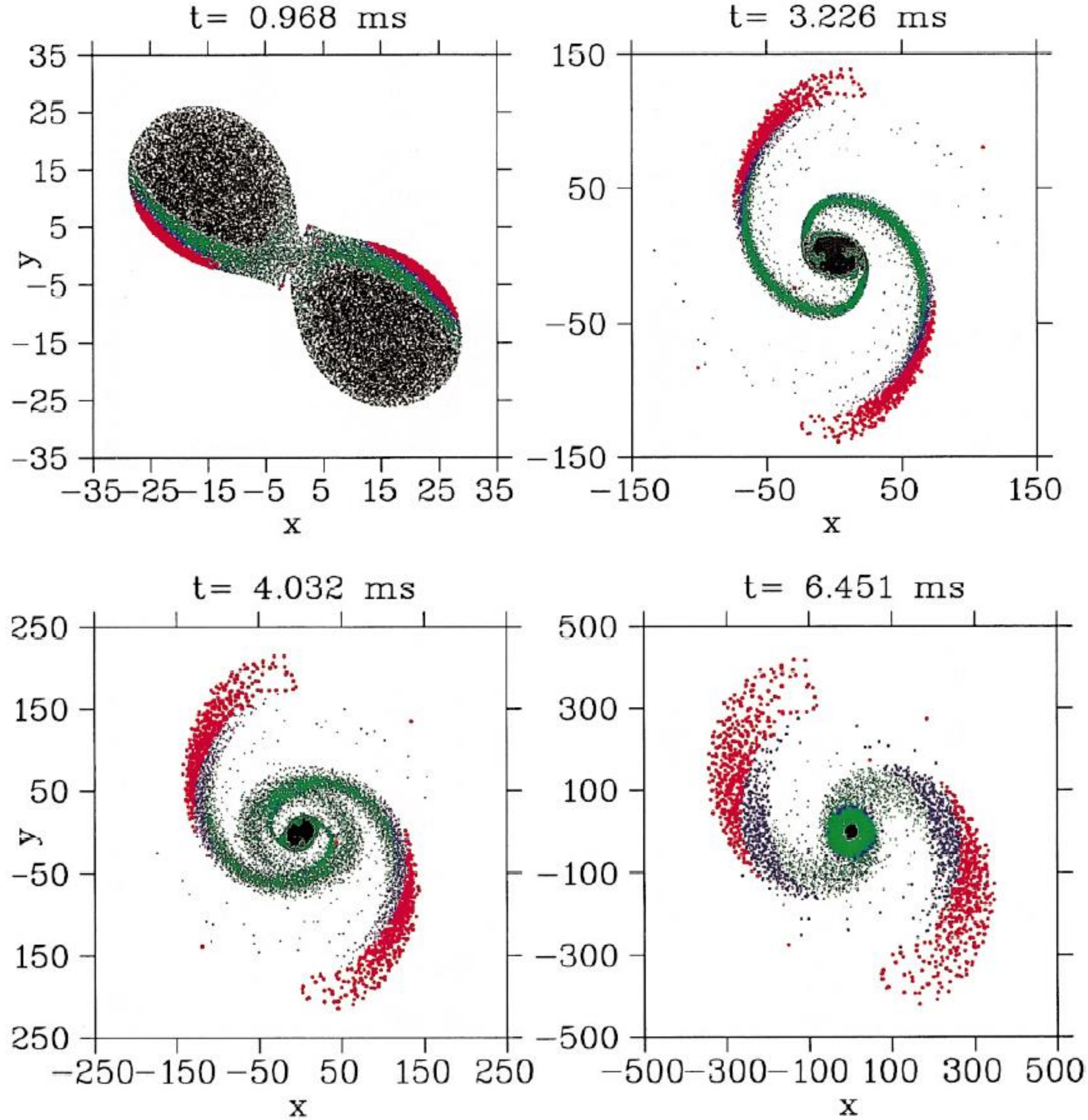
Log(T)= (3,79+0,24Z)
-(3,10+0,35Z) * log (M)
+(0,74+0,11Z) * log (M)^2

Geneva stellar evolution group, e.g., Schaller+, Meynet+

Stars

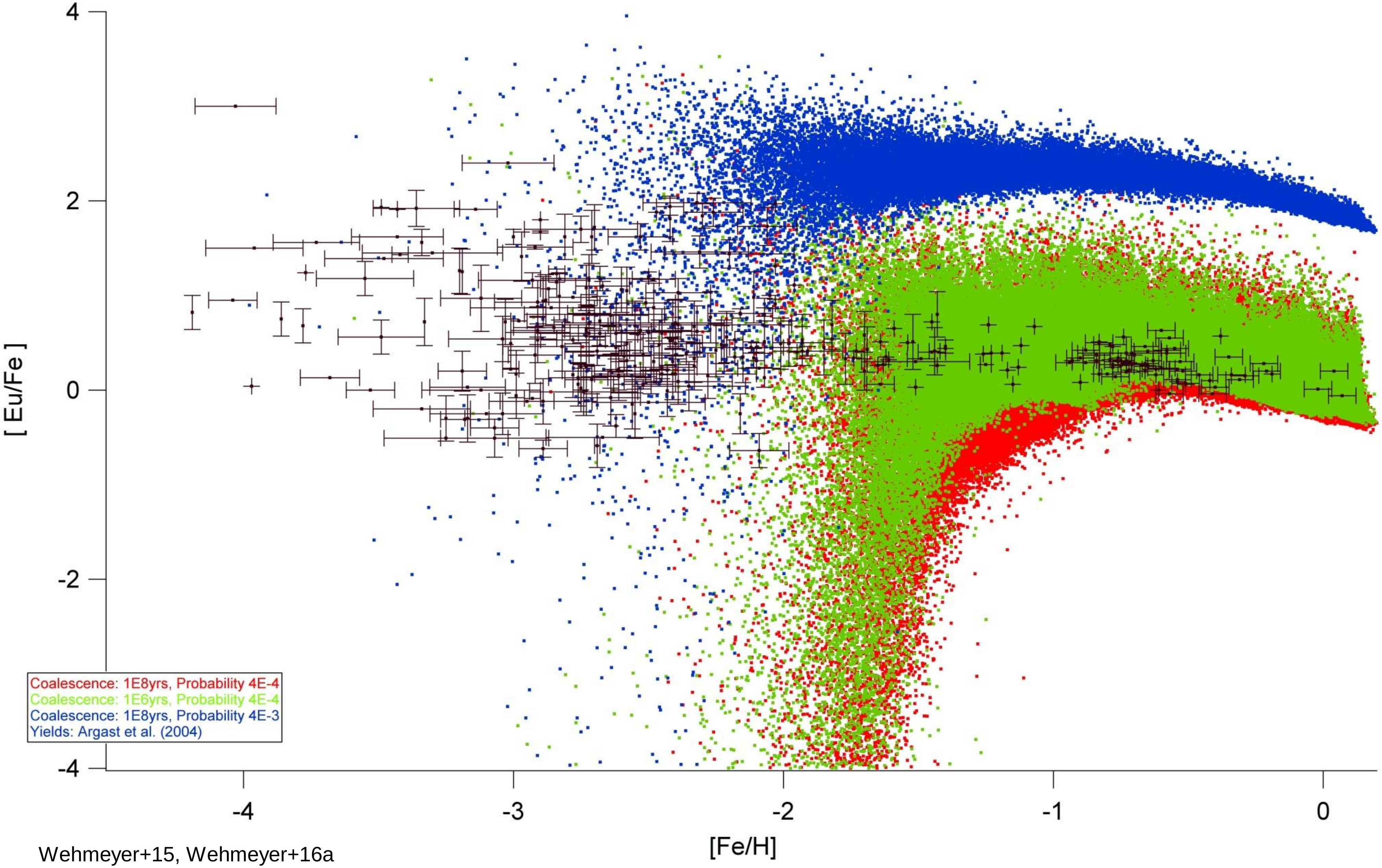
- $M<8\text{-}10M_{Sol}$: Not producing SN elements, but lock up ISM for the duration of their life time
- $M>8\text{-}10M_{Sol}$: Star is doing ccSN
- NSM: Possibility P_{NSM} for a double star (HMS) system to also do NSM-Event
- Ia: Possibility P_{SNIa} for a double star system (IMS) to do SNIa event

„Classical“ r-process site: NSM



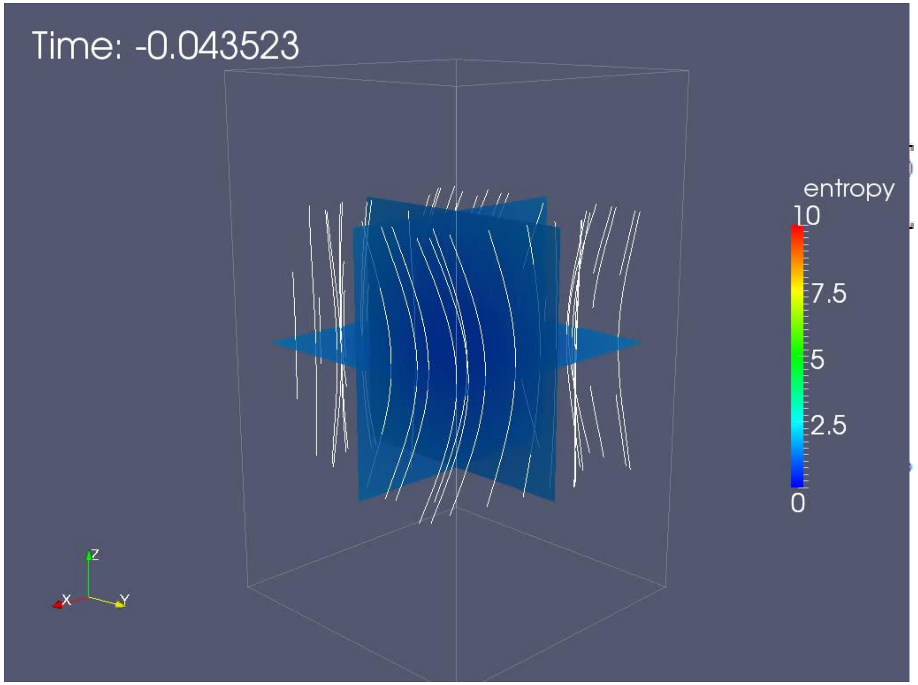
Rosswog et al.
A&A 341 (1999)
499

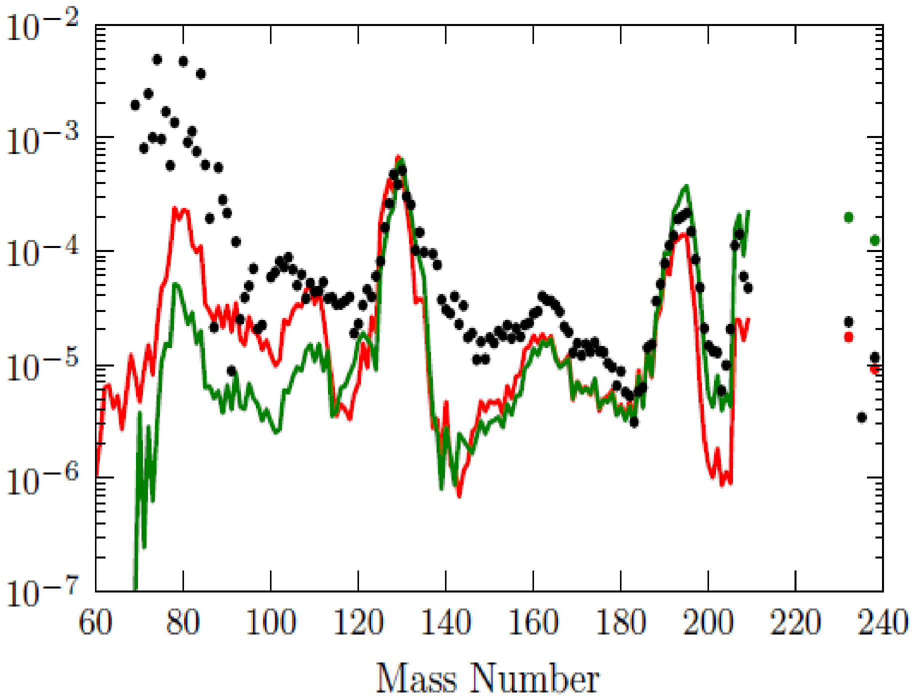
Short reminder from 2 (or 12) years ago



Wehmeyer+15, Wehmeyer+16a

Let‘s consider a second r-process site: MHD-SNe!

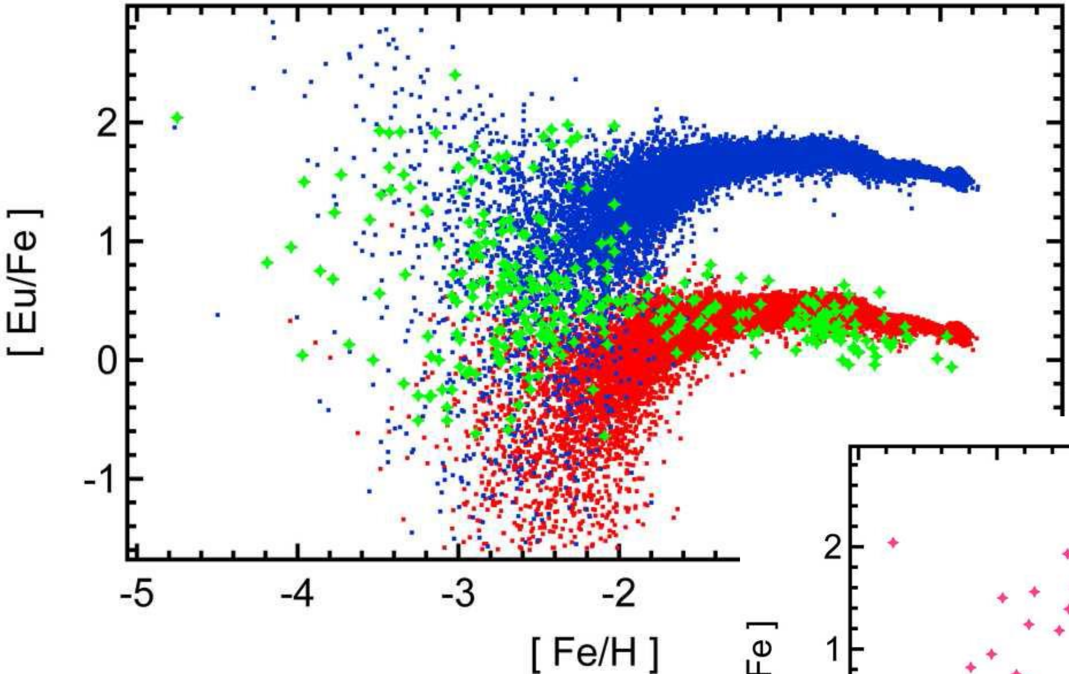




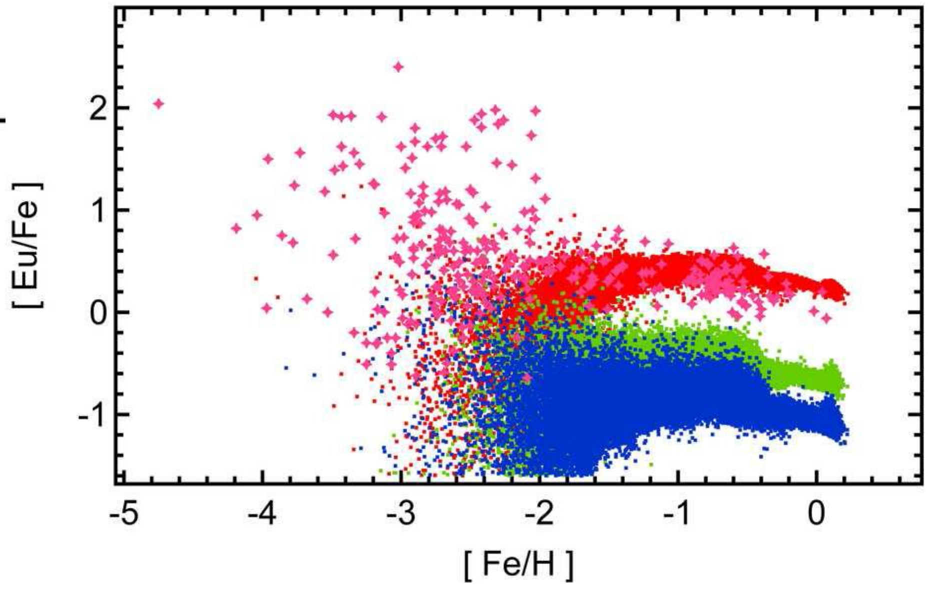
Winteler+12, but also see new calculations, e.g., Nishimura+15

May provide r-process Nucleosynthesis at low(est) metallicities!

Compare GCE model predictions with observations: MHD-SNe as exlusive r-process site

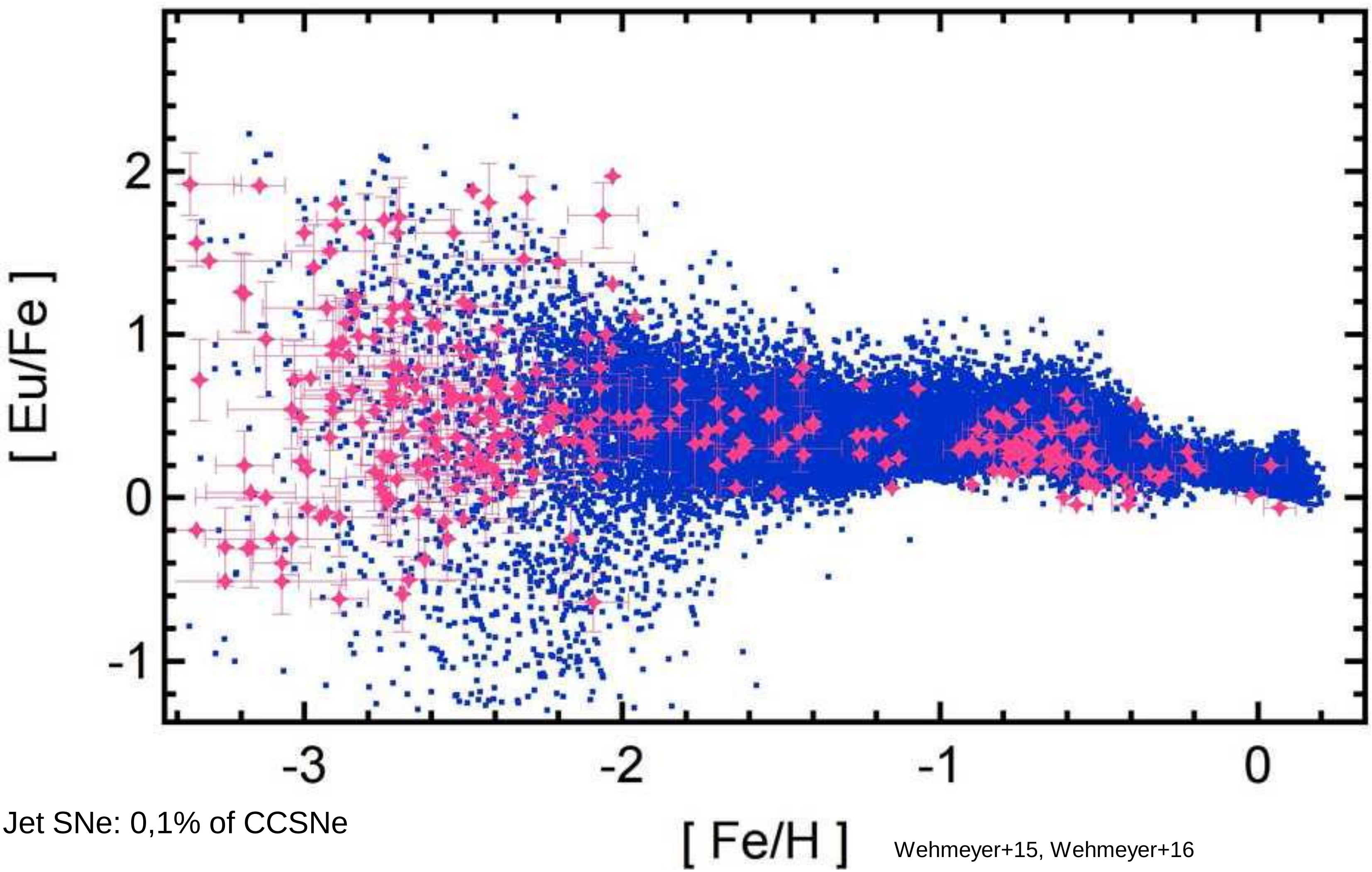


Wehmeyer+15



Combined environment with

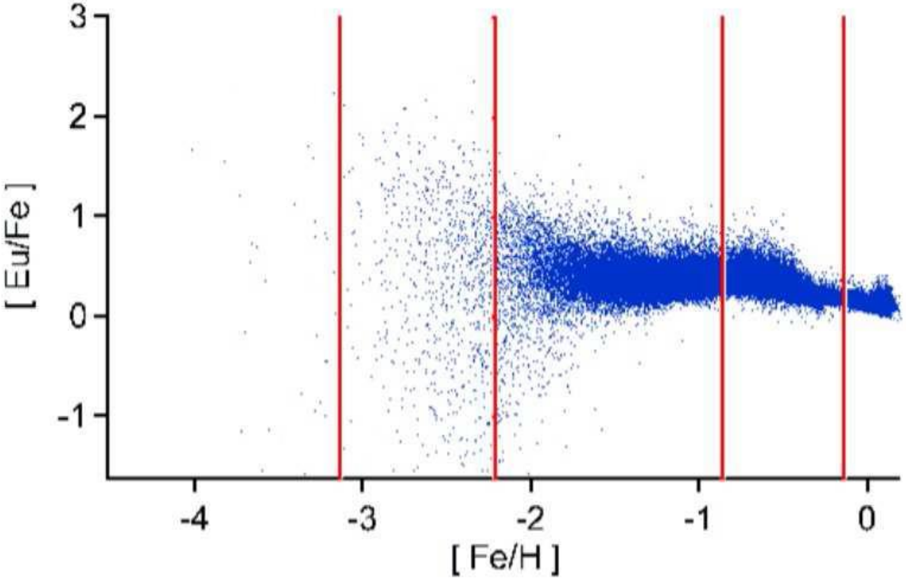
<u>both</u> NSMs <u>and</u> MHD-SNe!

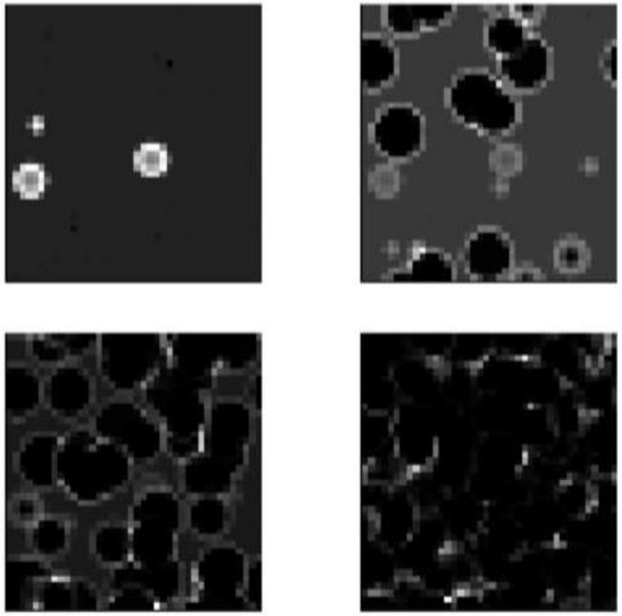


Jet SNe: 0,1% of CCSNe

Wehmeyer+15, Wehmeyer+16

The role of inhomogenieties

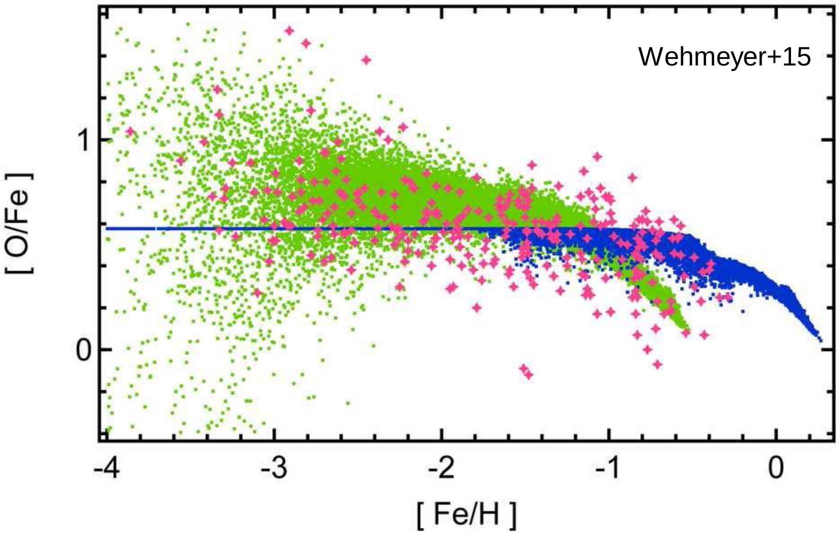


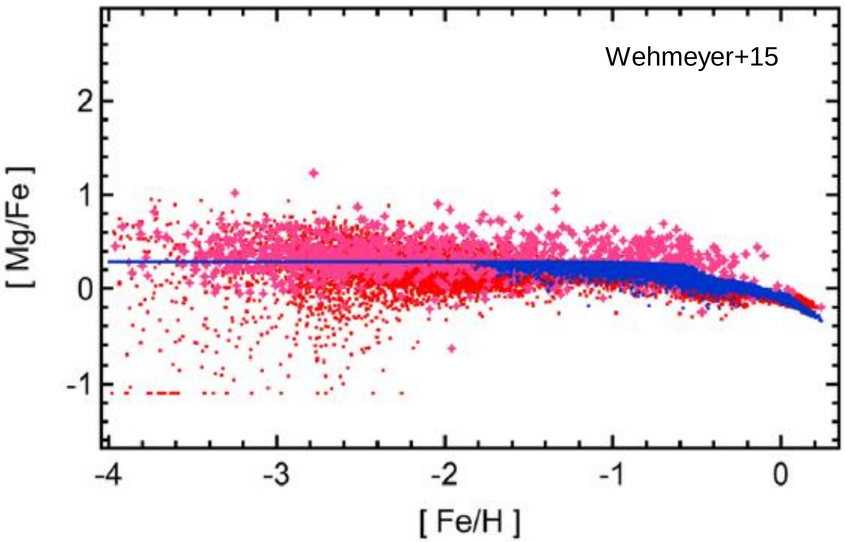


Extreme inhomogenieties together with the rare site(s) in the early Galaxy explain the scatter…

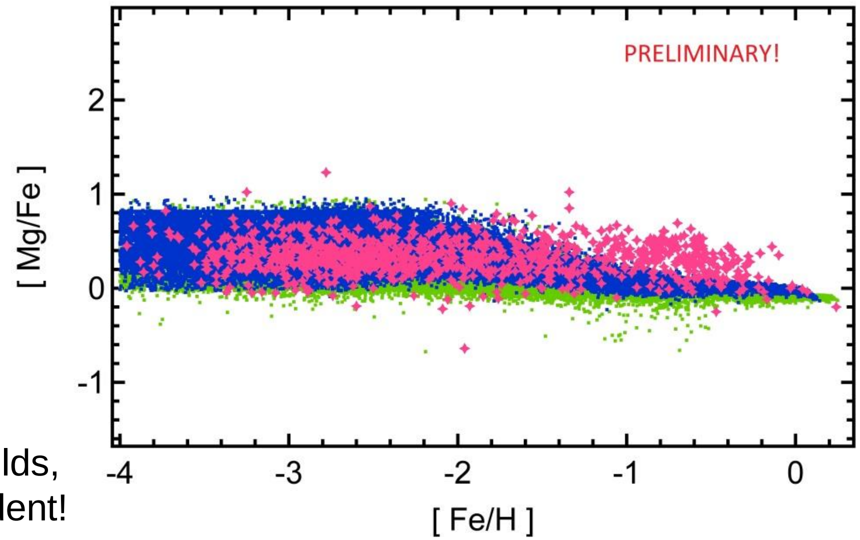
Wehmeyer+15

Problem(?) with ccSN Yields



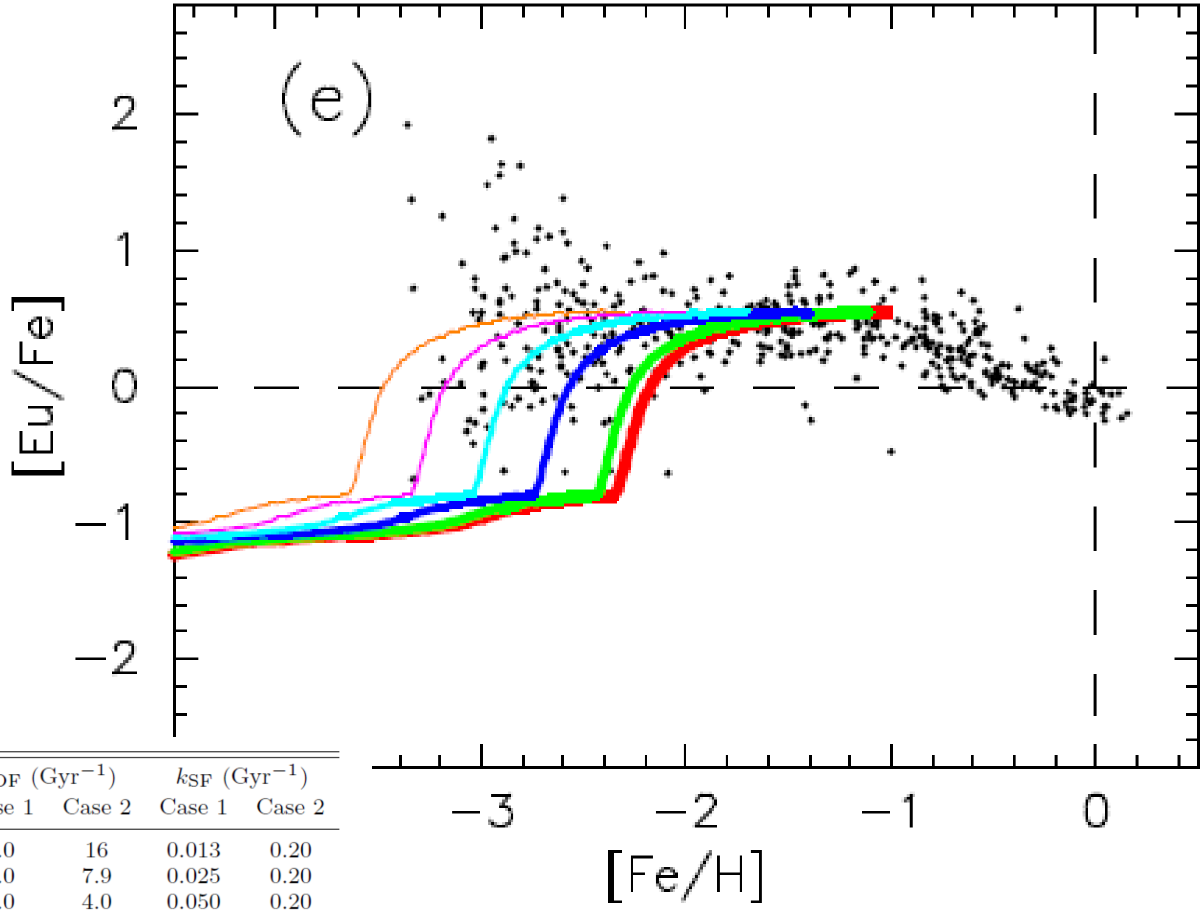


Green and red dots from Thielemann+96
or Nomoto+97 CCSN yields,
Blue dots represent
ad-hoc yields, e.g., Y(Fe)=0.5 Y(alpha)



Kobayashi+06 /
Kobayashi+12 yields,
Metallicity dependent!

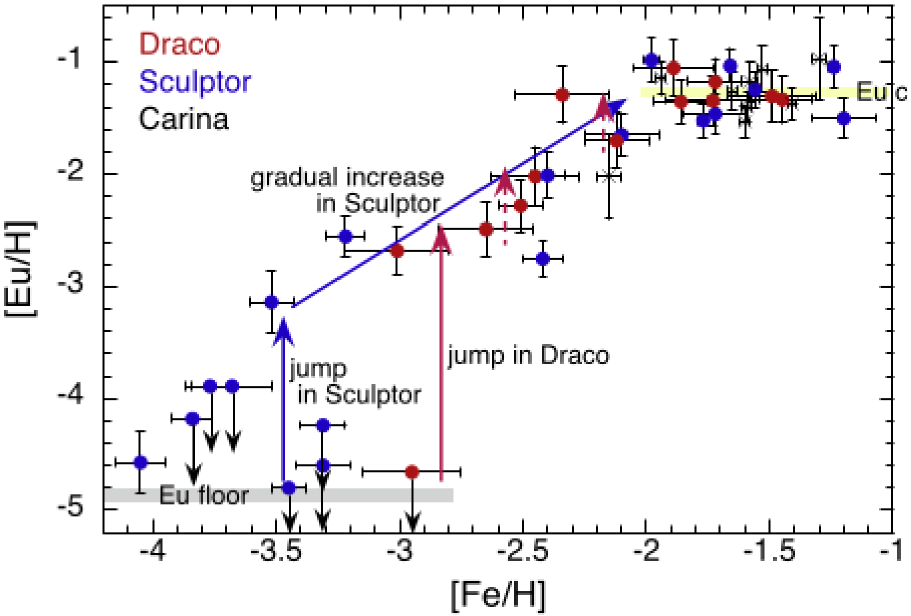
The role of Sub-Halos

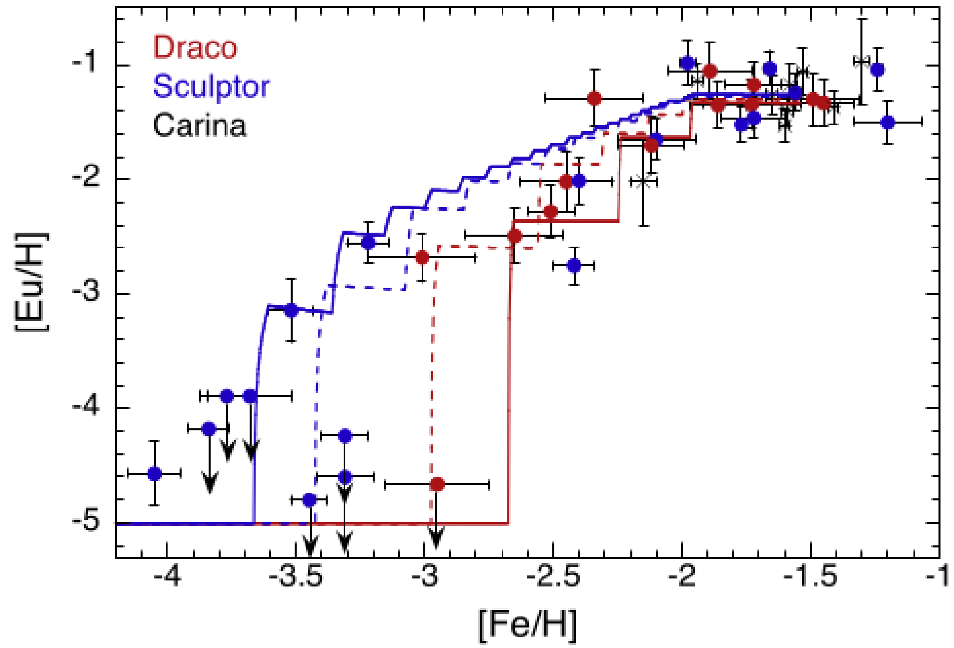


M_* ($M_\odot$)	η	$k_{\rm OF}$ (Gyr^{-1})		$k_{\rm SF}$ (Gyr^{-1})	
		Case 1	Case 2	Case 1	Case 2
10^4	79	1.0	16	0.013	0.20
10^5	40	1.0	7.9	0.025	0.20
10^6	20	1.0	4.0	0.050	0.20
10^7	10	1.0	2.0	0.10	0.20
10^8	5.0	1.0	1.0	0.20	0.20
2×10^8	4.1	1.0	0.81	0.25	0.20

Ishimaru, Wanajo, Prantzos (2015)

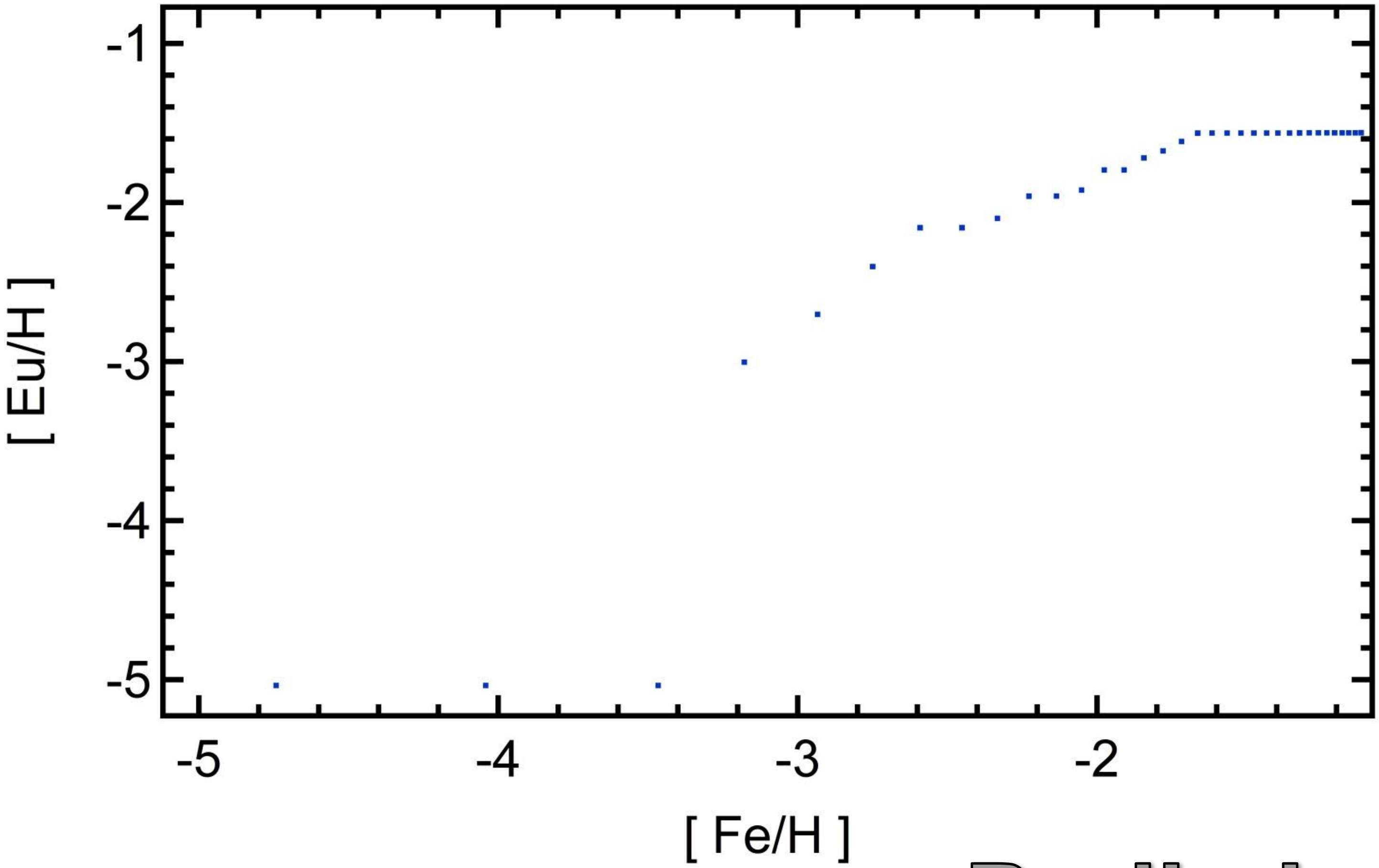
So let‘s (also) consider dwarfs!





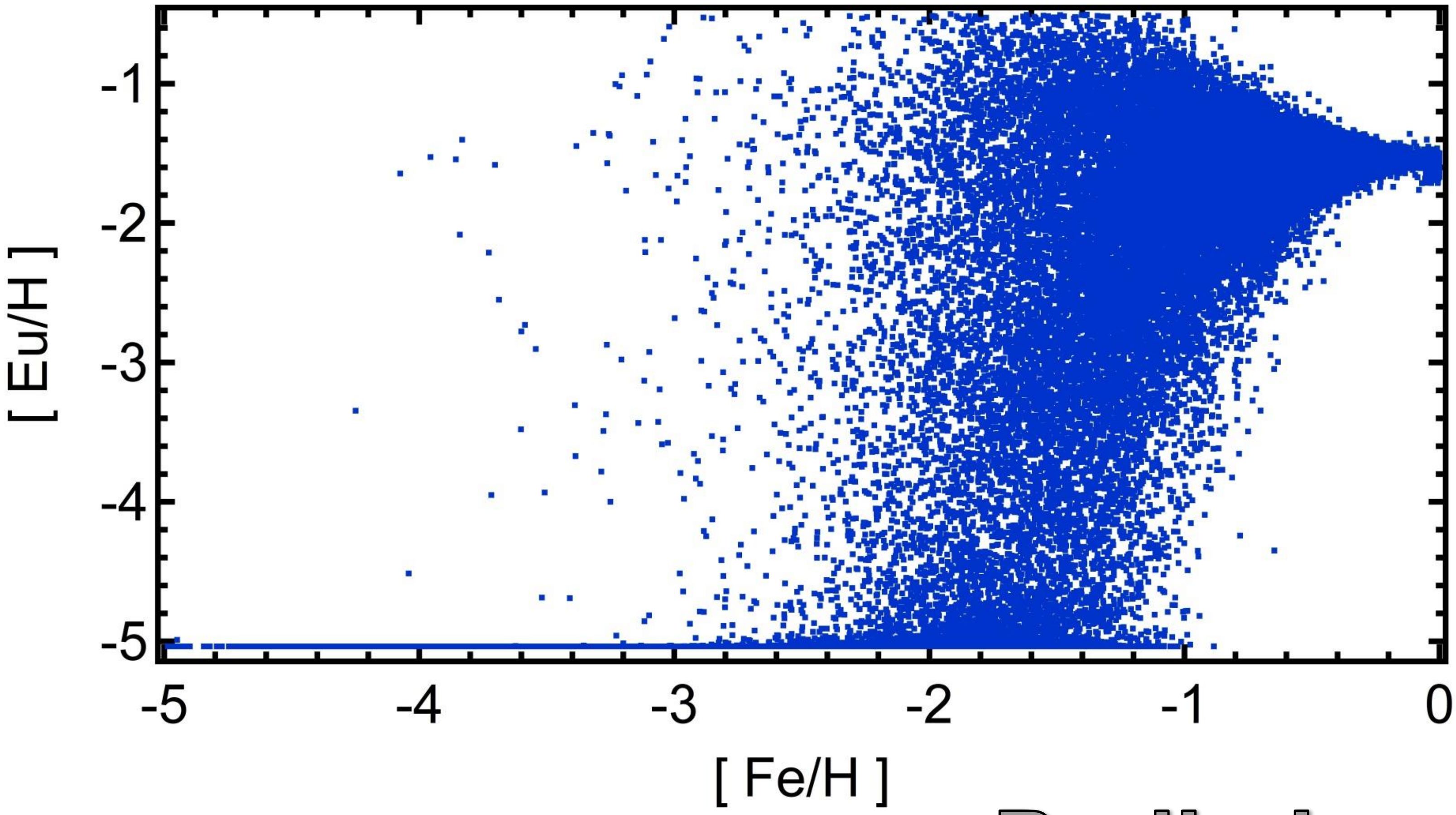
Tsujimoto & Nishimura (2015)

This works in the homogeneous case…



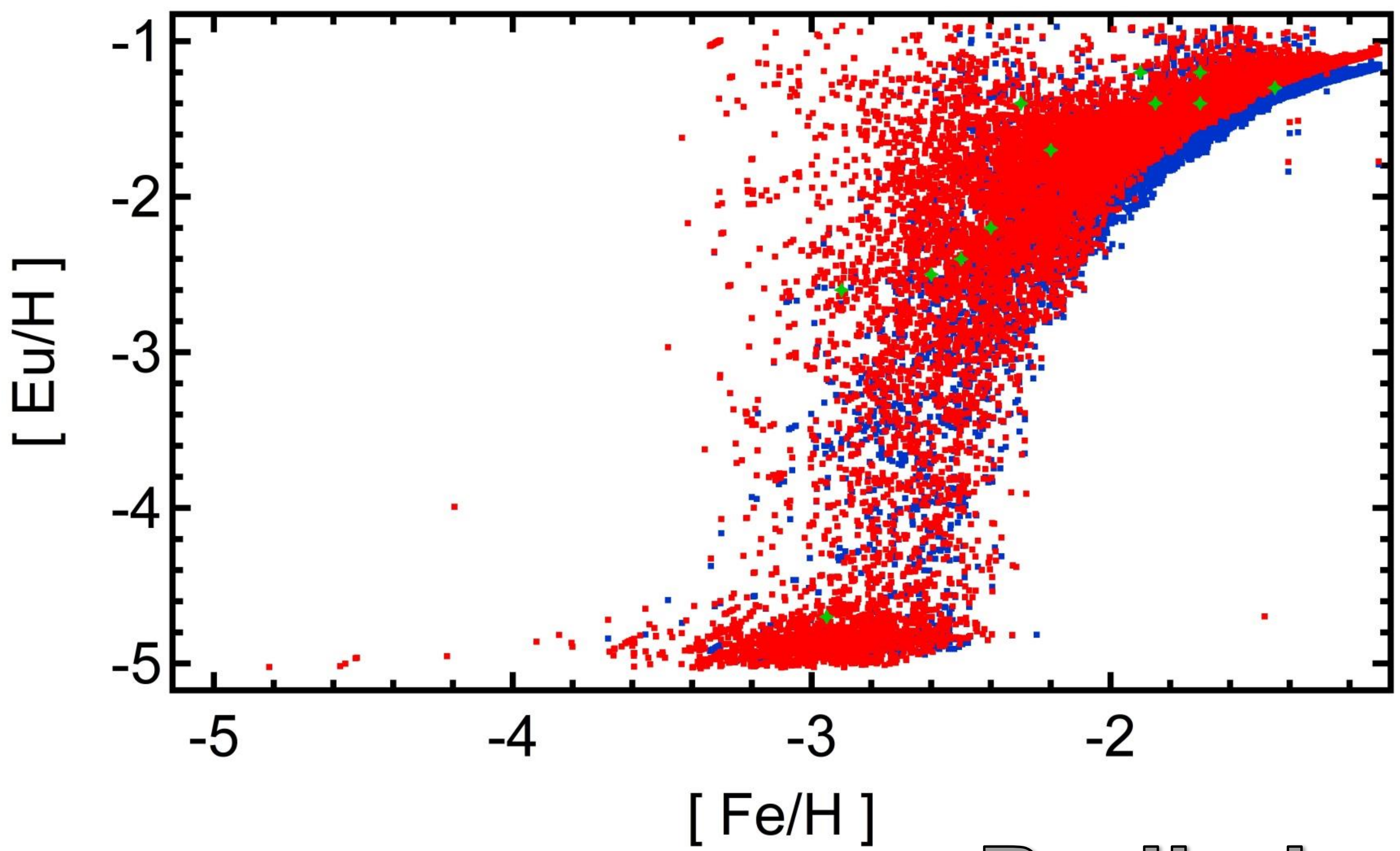
Preliminary!

But not easy in the inhomogeneous case!



Preliminary!

Unless one goes to highly aspherical SN bubbles in dwarfs



Preliminary!

Conclusions

- NSM alone have difficulties to explain abundances at low metallicities =>earlier site cures this (e.g., MHD-SNe)
- The spread in r-process elements at low-metallicities can be explained by inhomogenieties
- Yields from SNe still have to be improved (=>have huge impact on GCE)
- Mixing dynamics benchmarks are highly desired, especially in dwarfs!

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