Simulating Neutron Star Mergers as *r*-process Sources in Ultra Faint Dwarf Galaxies

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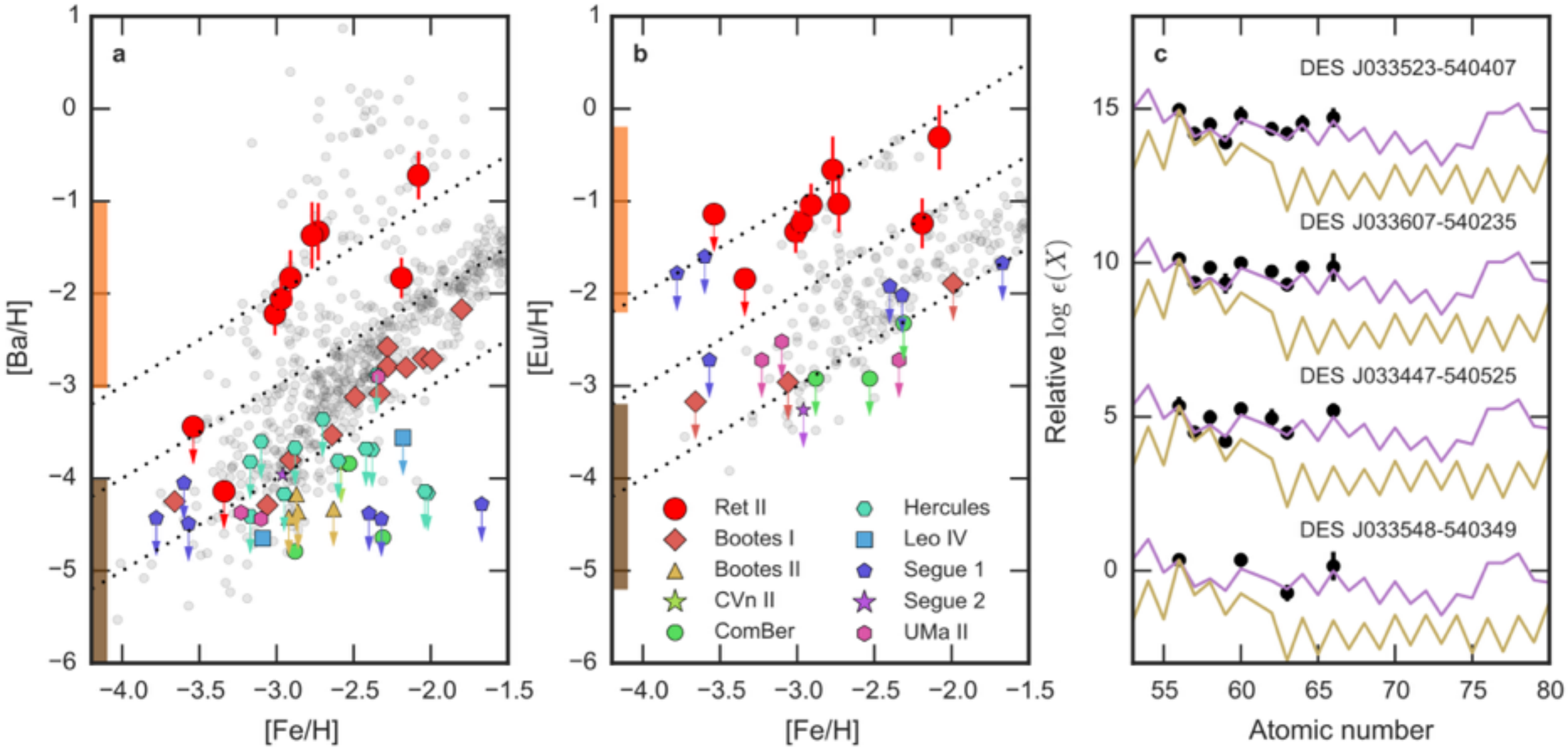
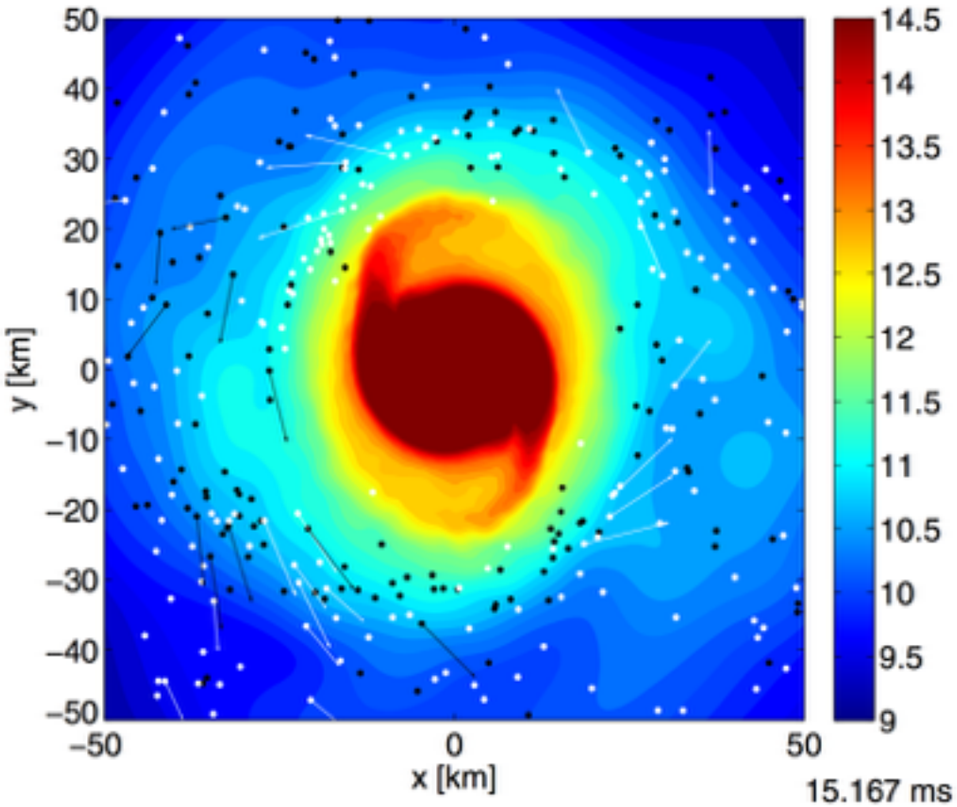
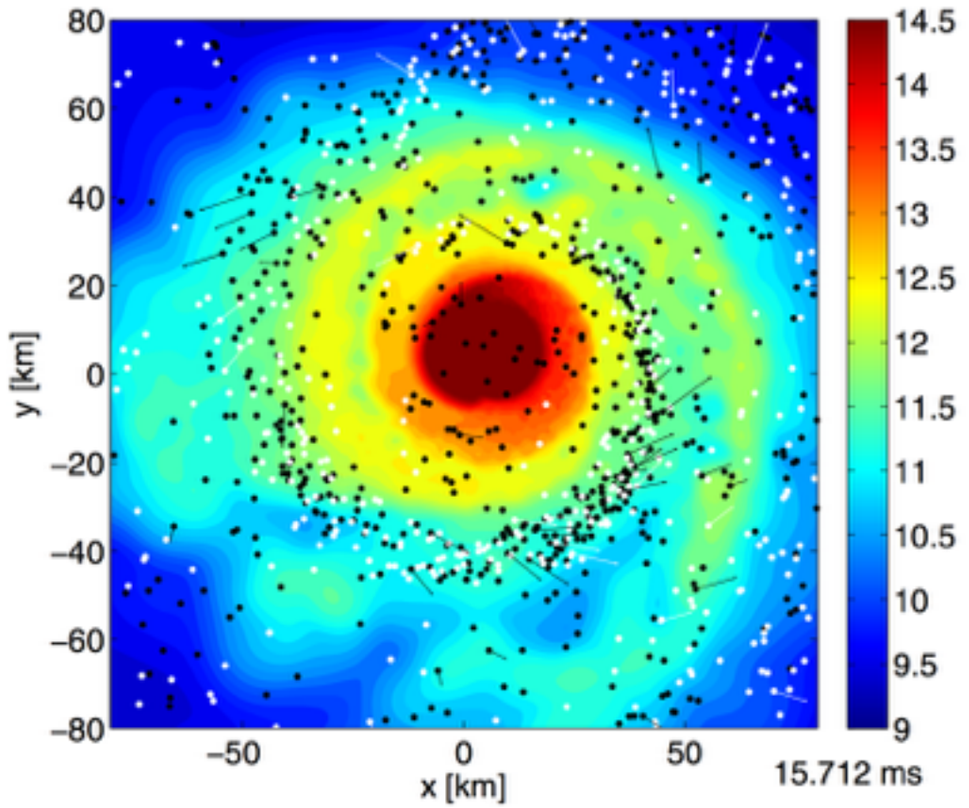
Arizona State University

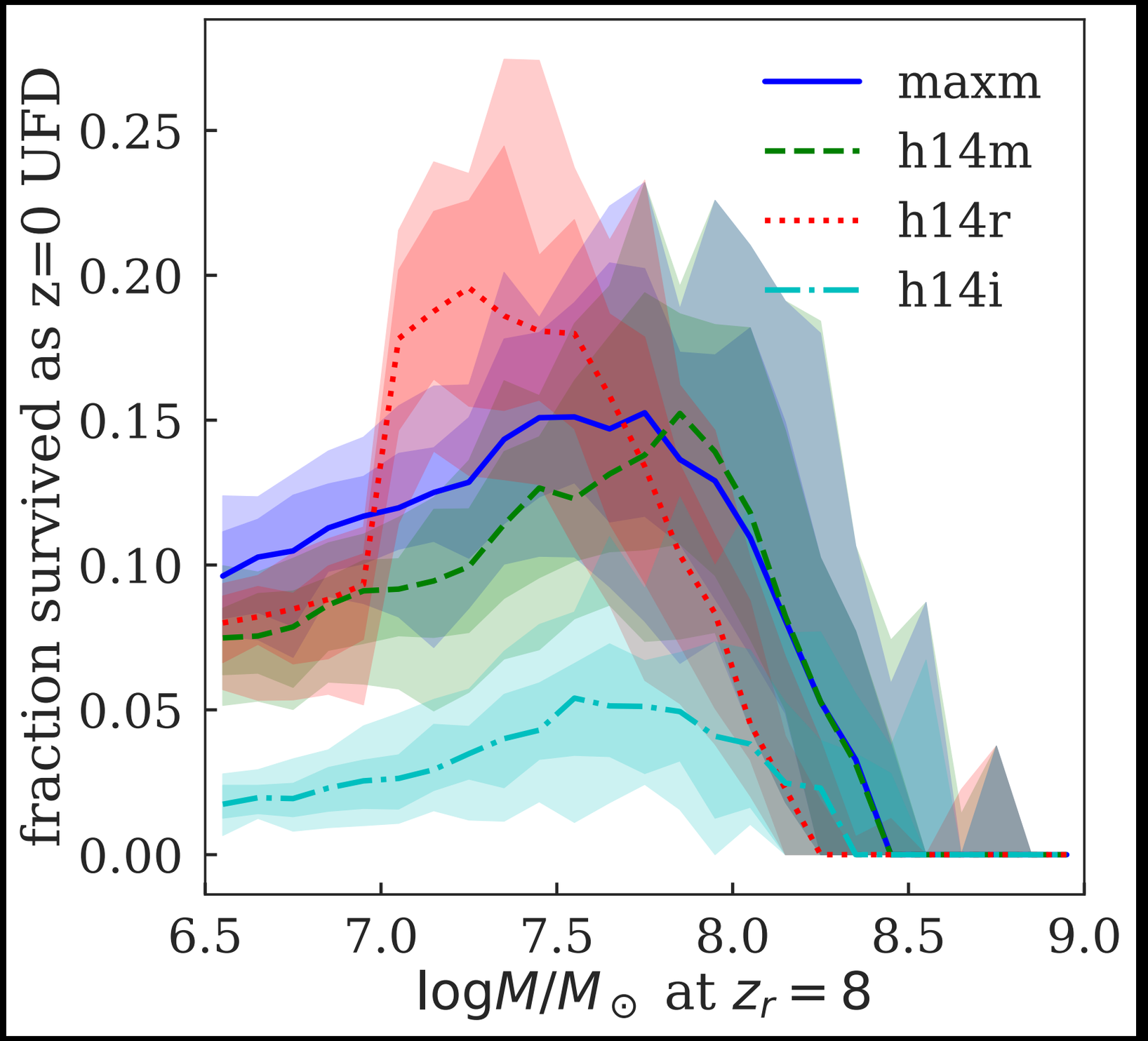
Frontiers 2017, Lansing, MI


a
b
c
[Ba/H]
[Eu/H]
Relative log $\epsilon(X)$
[Fe/H]
[Fe/H]
Atomic number
DES J033523-540407
DES J033607-540235
DES J033447-540525
DES J033548-540349
Ret II
Bootes I
Bootes II
CVn II
ComBer
Hercules
Leo IV
Segue 1
Segue 2
UMa II


50
40
30
20
10
0
−10
−20
−30
−40
−50
y [km]
−50
0
50
x [km]
14.5
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
15.167 ms

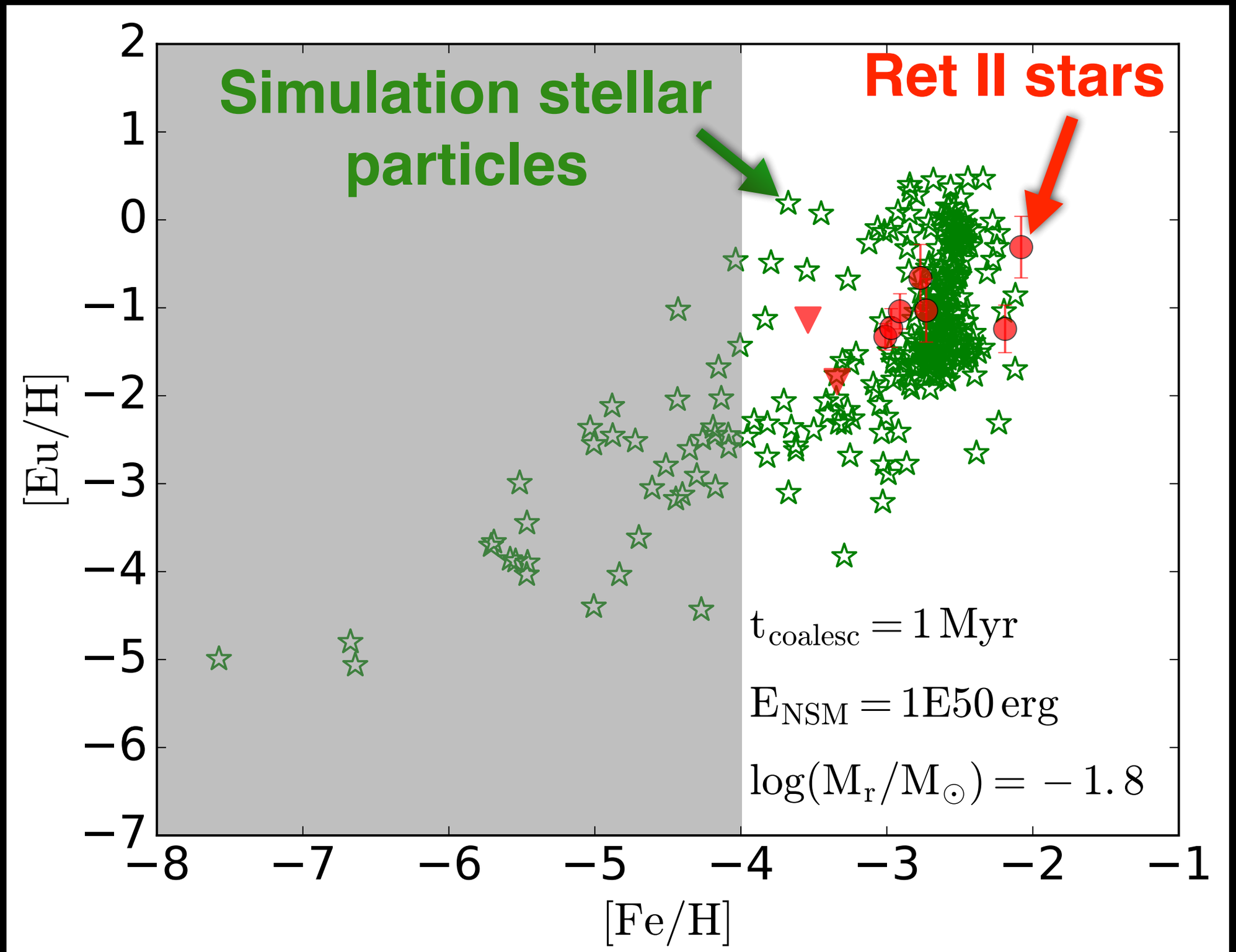

80
60
40
20
0
−20
−40
−60
−80
y [km]
−50
0
50
x [km]
14.5
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
15.712 ms

What are the chances that a halo survives intact?

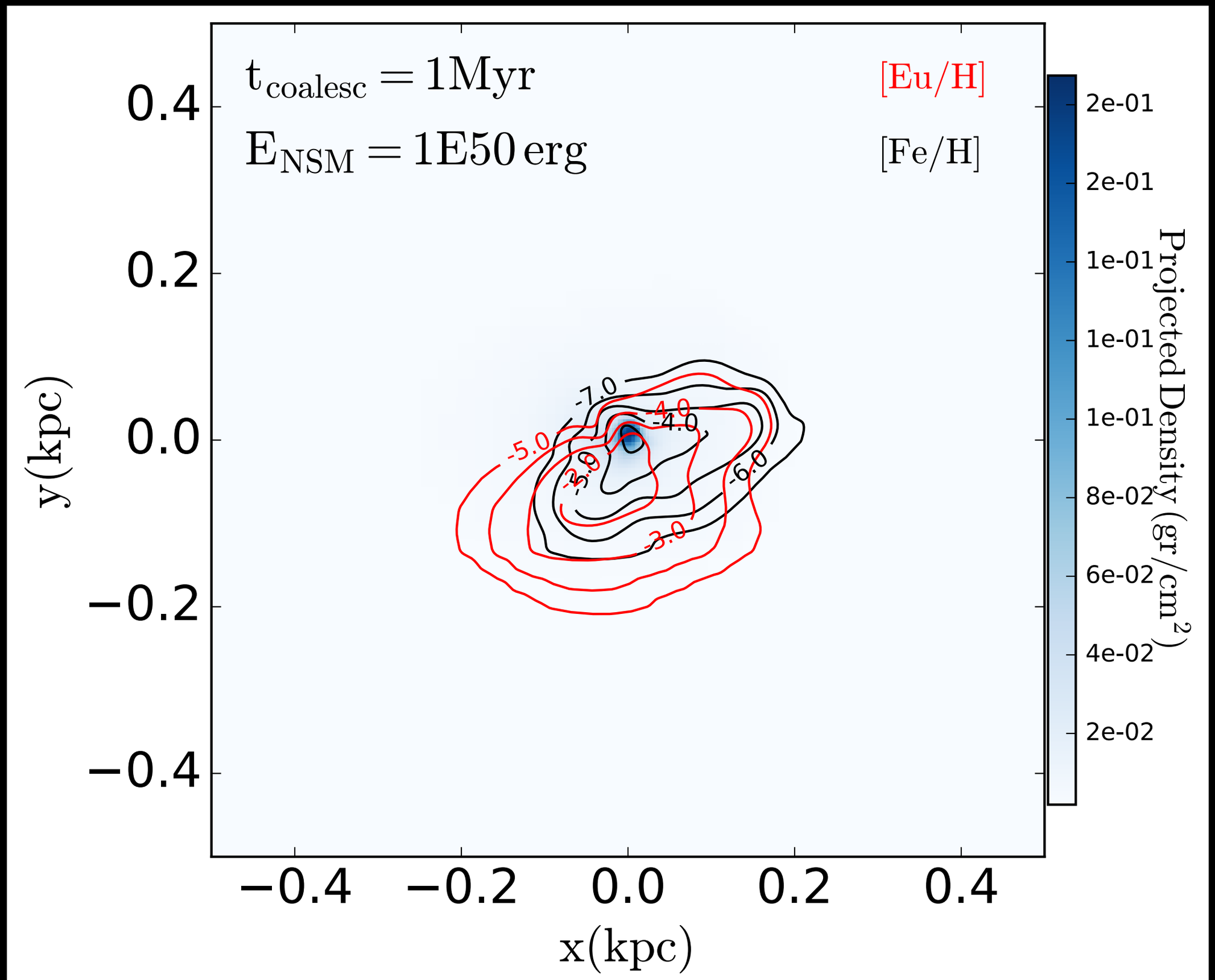


Safarzadeh & Ji (in prep)

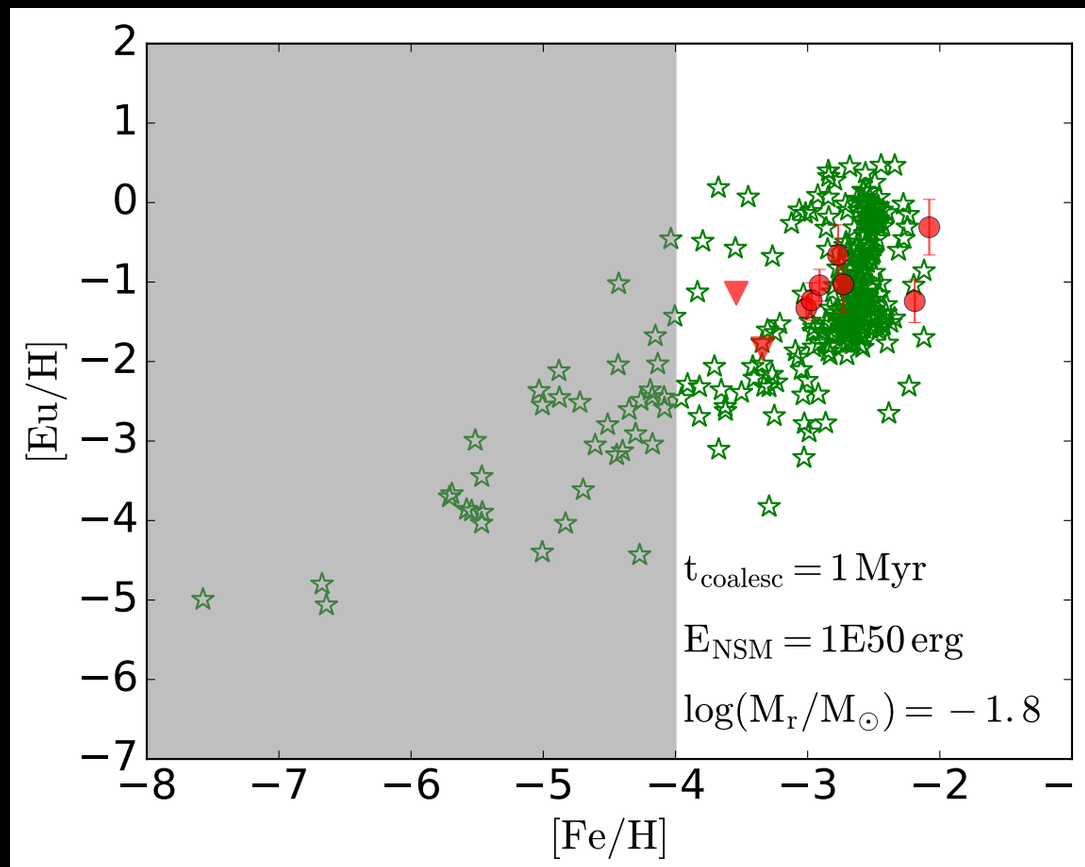
Comparing the results to Ret II

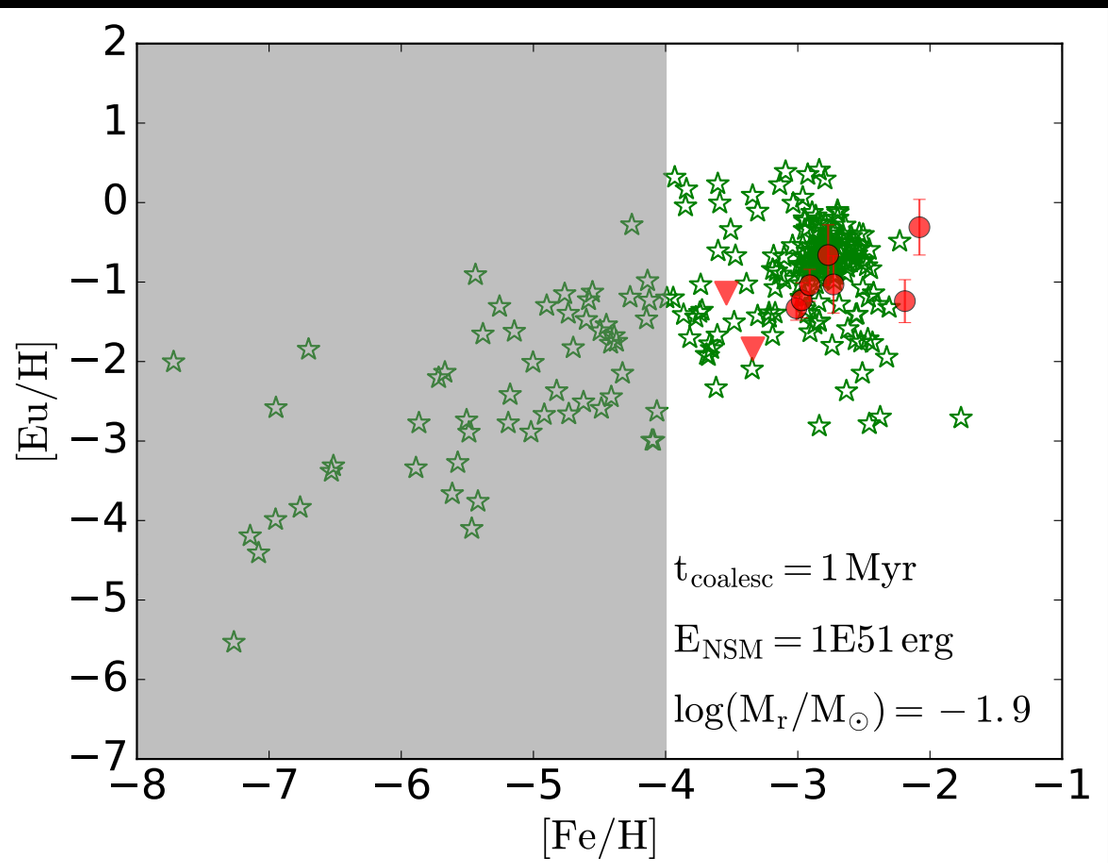


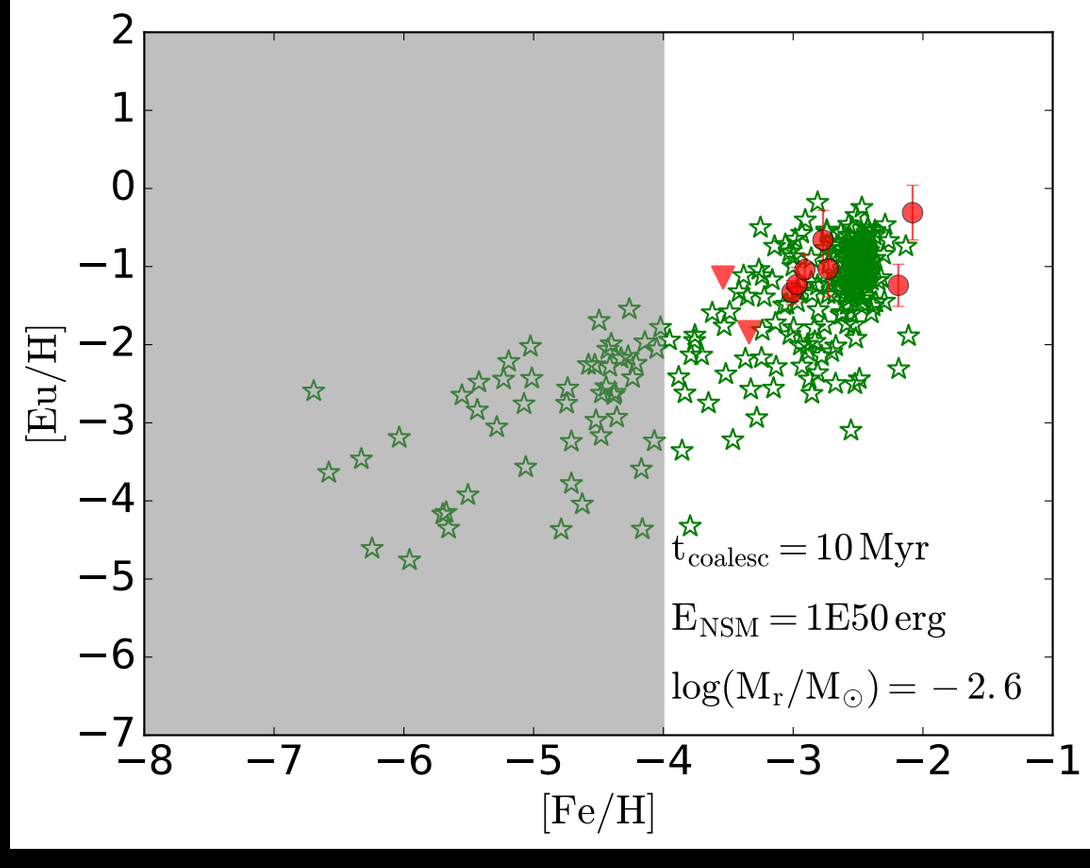
Projected [Eu/H] vs. [Fe/H] for the gas

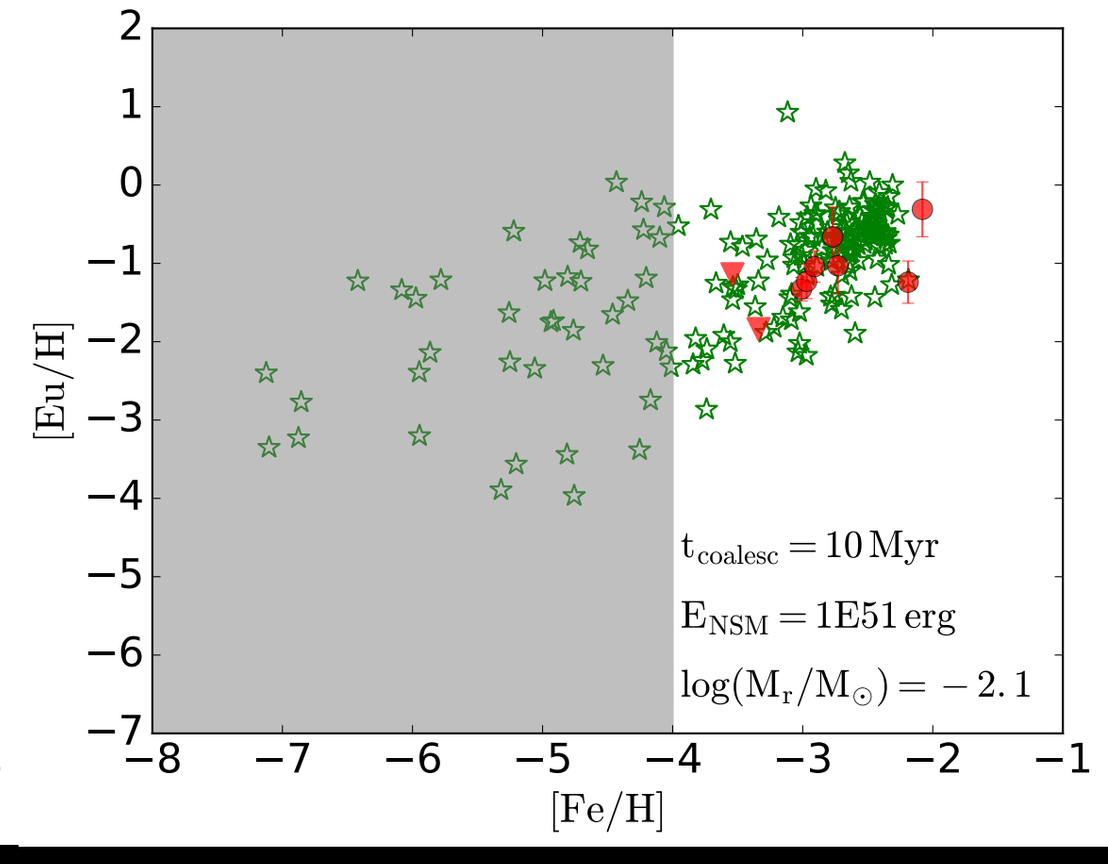


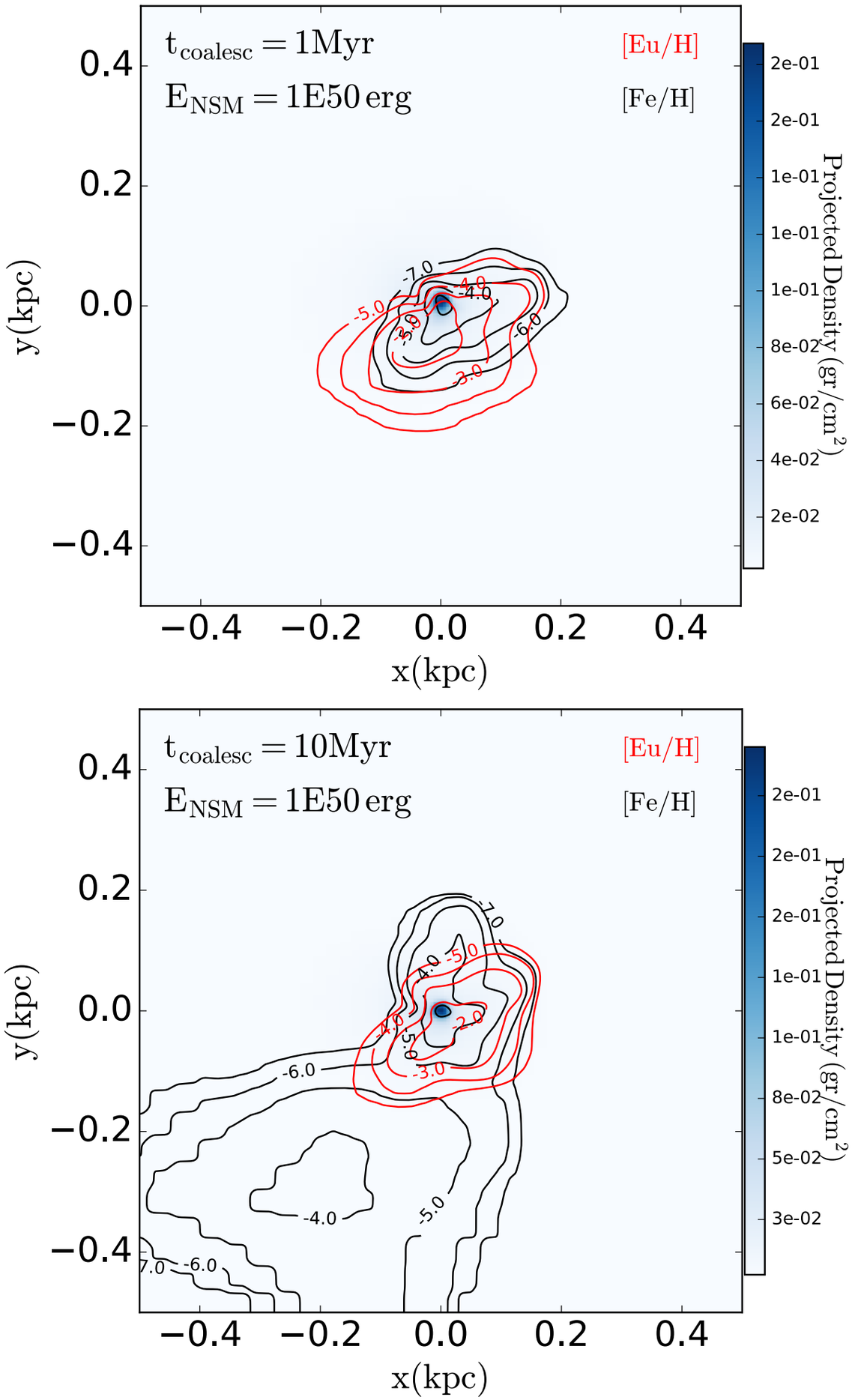
varying coalescence time scale and Explosion energy

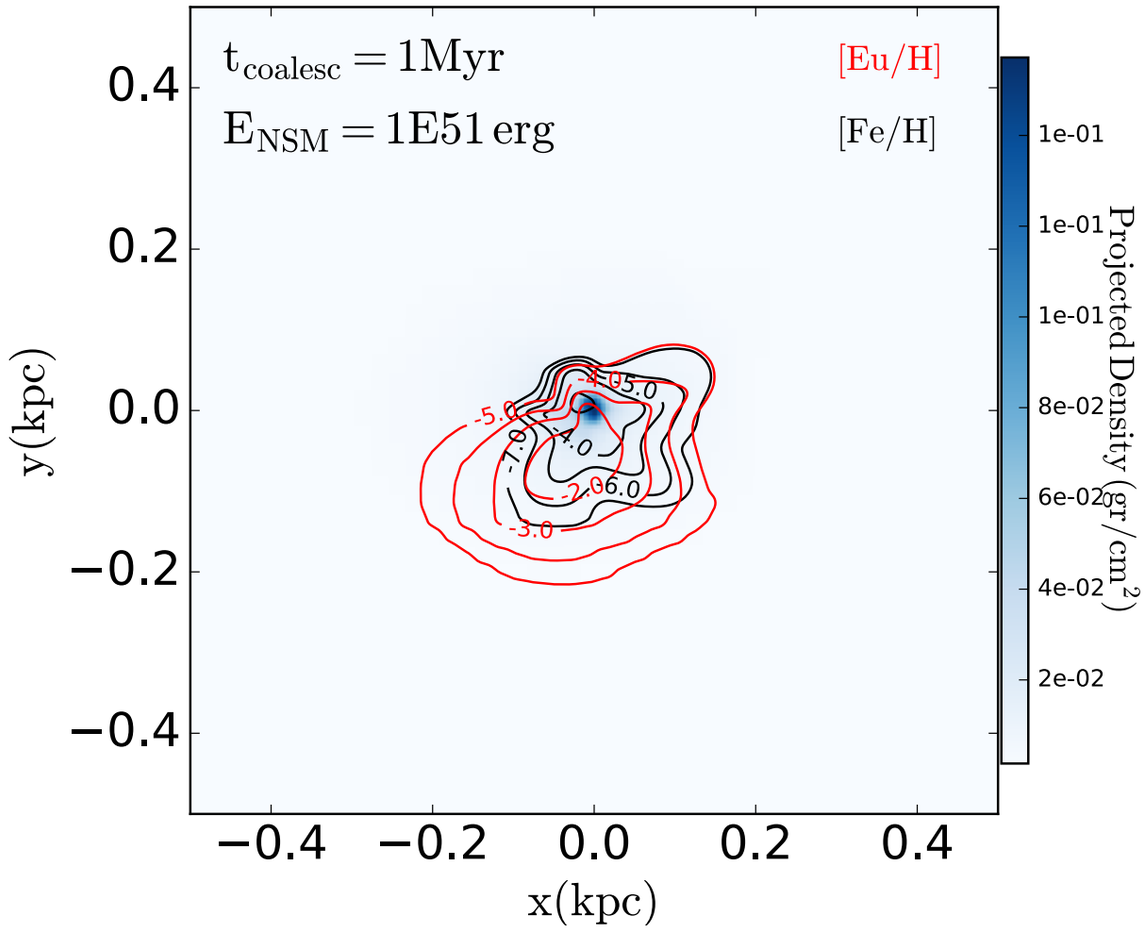




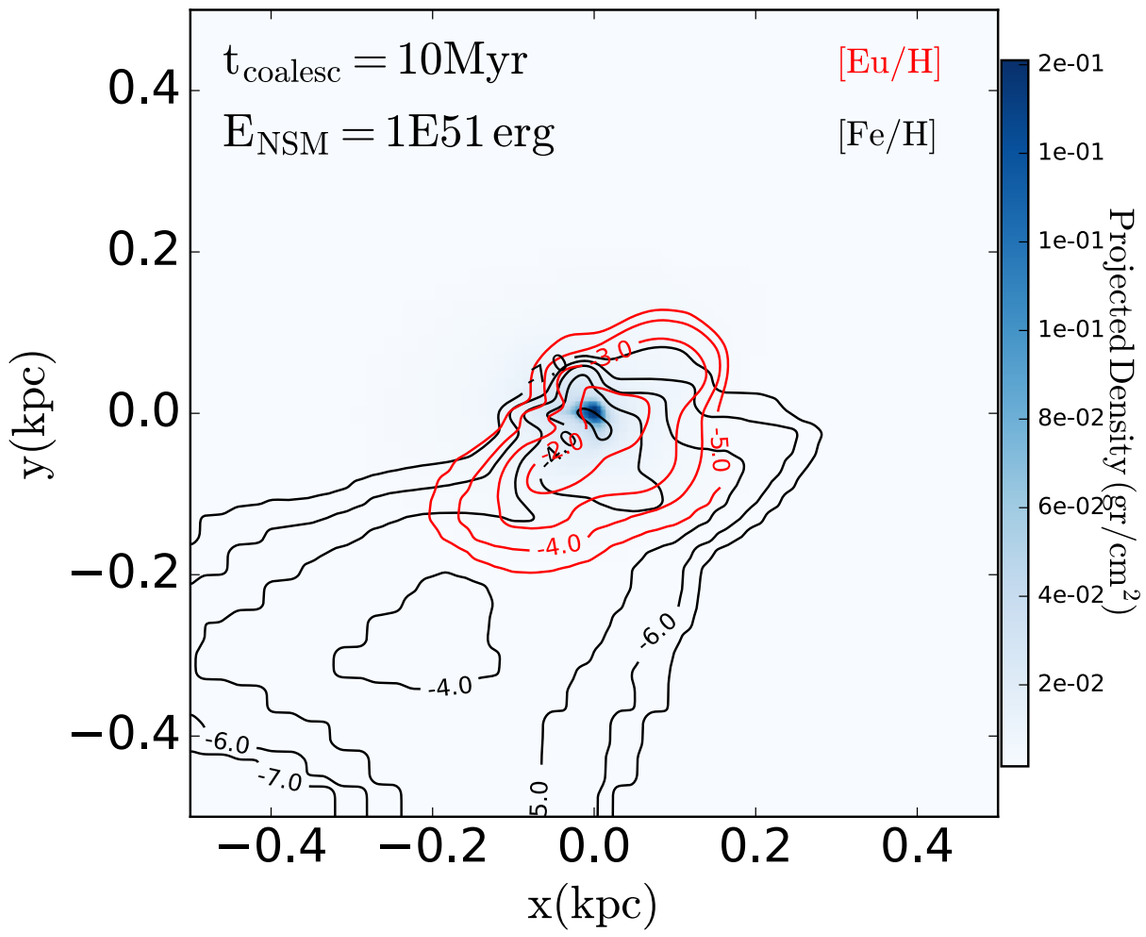




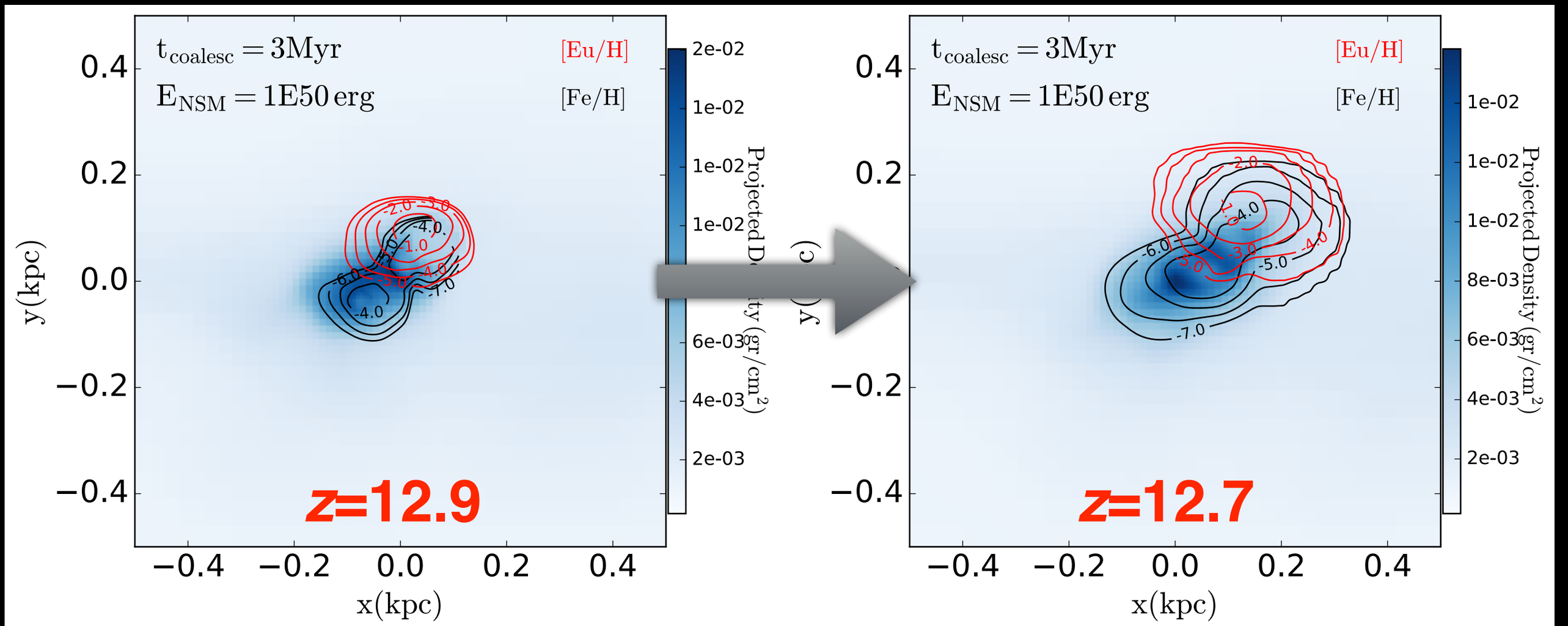

$t_{coalesc} = 1Myr$
$E_{NSM} = 1E50\,erg$
[Eu/H]
[Fe/H]
y(kpc)
x(kpc)
Projected Density (gr/cm^2)


$t_{coalesc} = 1Myr$
$E_{NSM} = 1E51\,erg$
[Eu/H]
[Fe/H]
y(kpc)
x(kpc)
Projected Density (gr/cm^2)

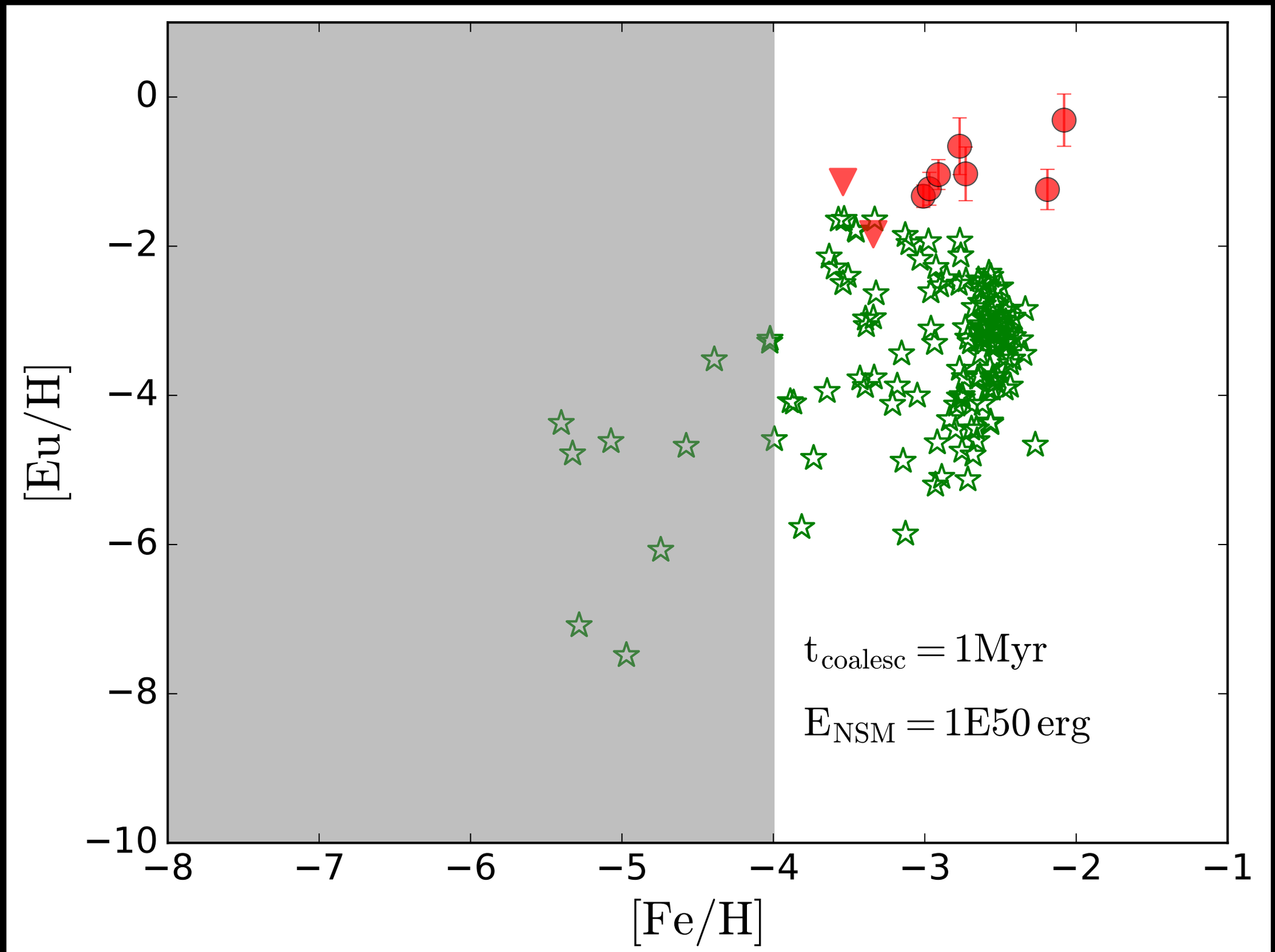
$t_{coalesc} = 10Myr$
$E_{NSM} = 1E50\,erg$
[Eu/H]
[Fe/H]
y(kpc)
x(kpc)
Projected Density (gr/cm^2)


$t_{coalesc} = 10Myr$
$E_{NSM} = 1E51\,erg$
[Eu/H]
[Fe/H]
y(kpc)
x(kpc)
Projected Density (gr/cm^2)

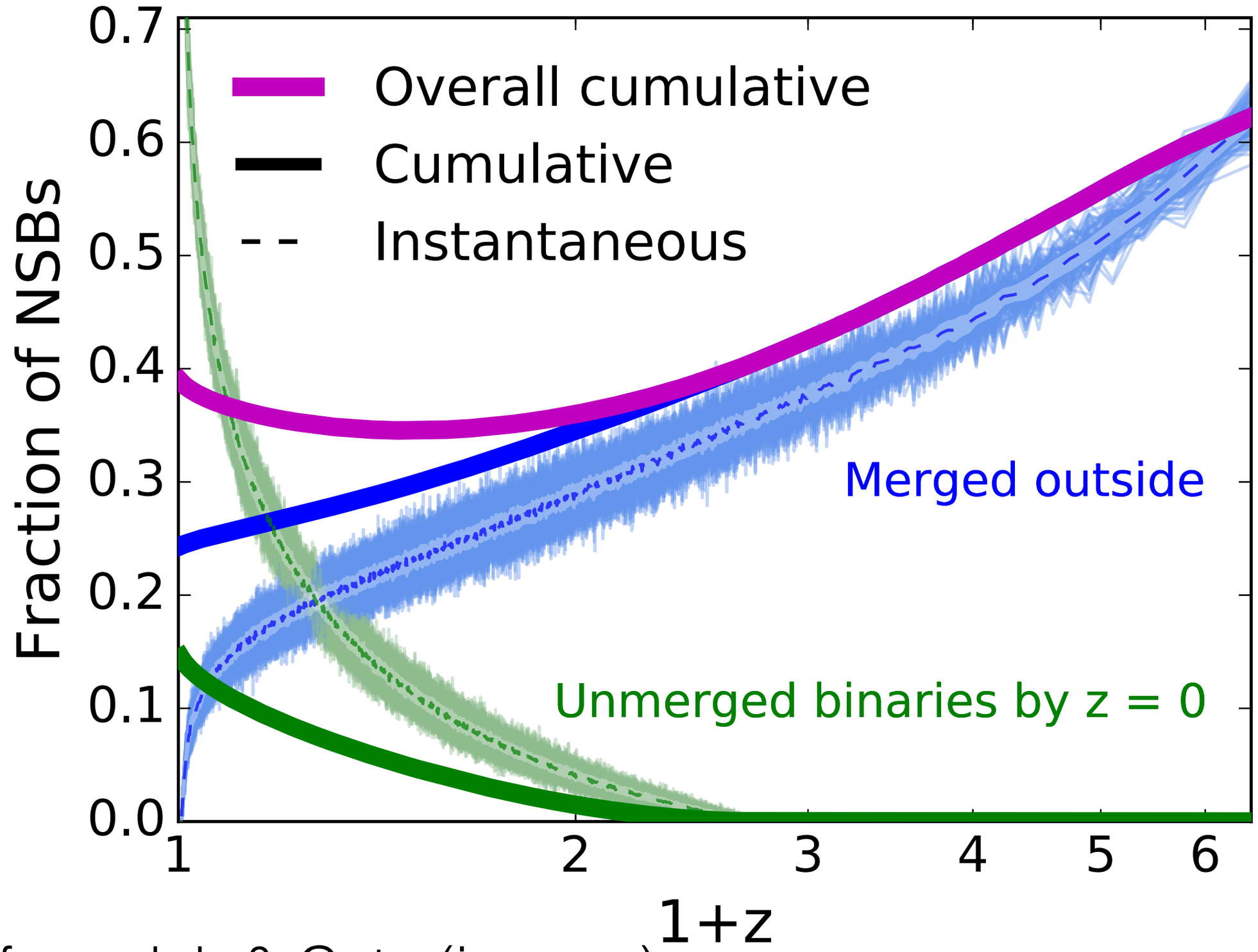
Off-center explosion



leads to low enrichment by r-process elements



Impact of natal kicks on galactic *r*-process enrichment

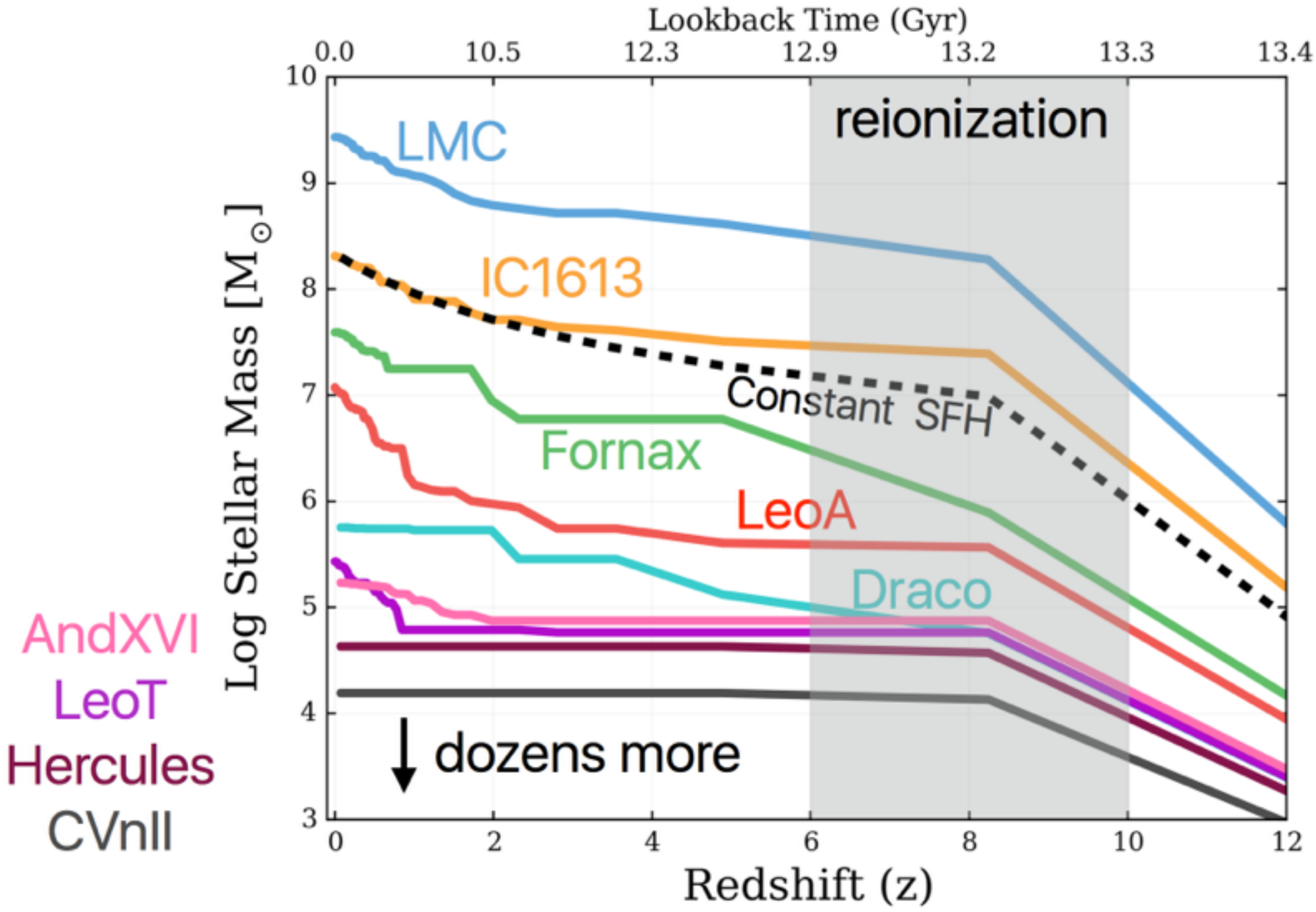


Safarzadeh & Cote (in prep)

Summary

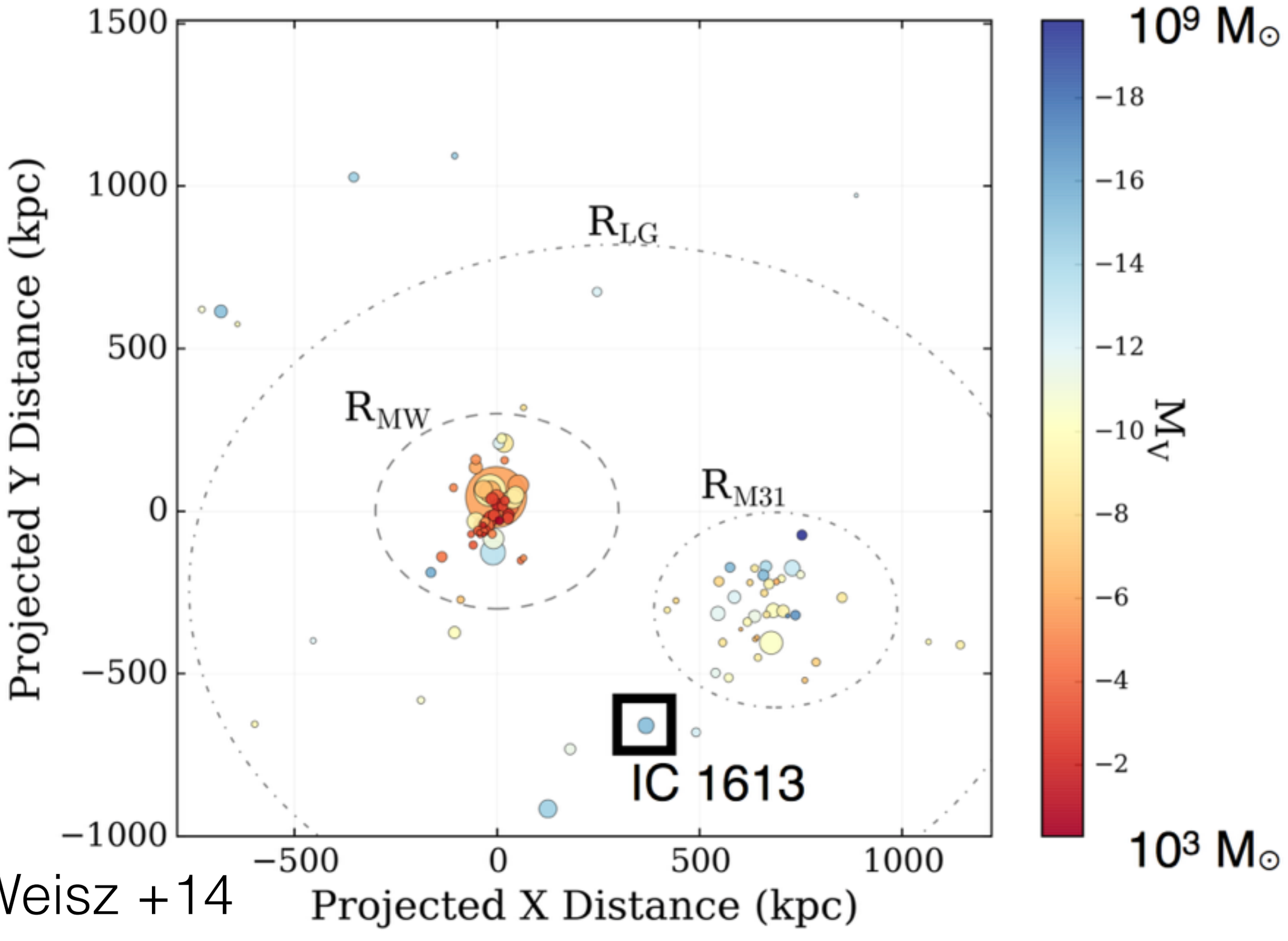
- **A single NSM event in star formation history of a UFD is compatible with Ret II observations.**
- **Ejection energy and coalescence time scale have minor impacts on the enrichment level.**
- ***r*-process enrichment efficiency is highly dependent on the location of NSM event.**

Low-Mass Galaxies Across Cosmic Time

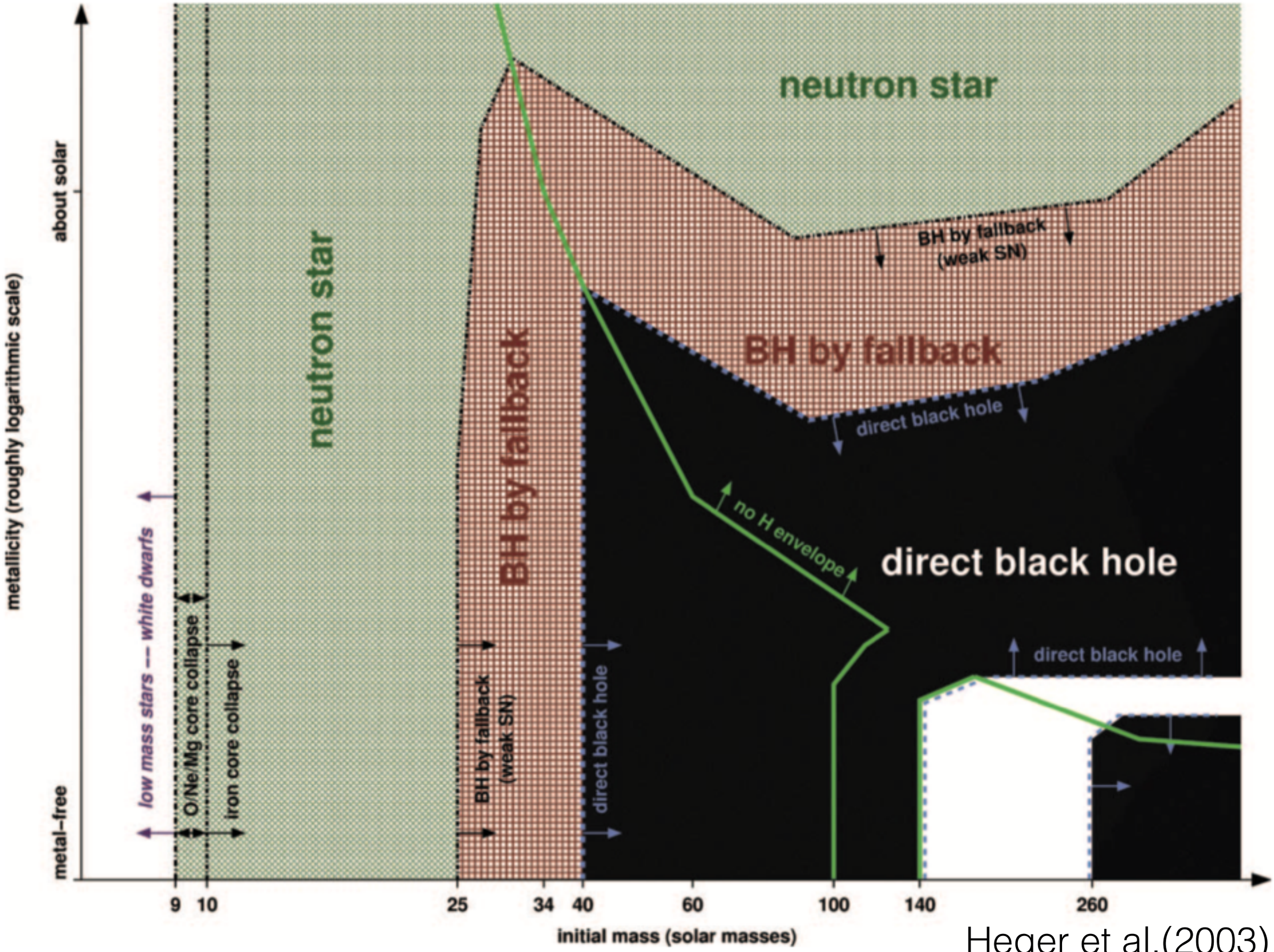


e.g., Weisz+ 2012, 2014a; Brown+ 2014; Skillman+ 2014

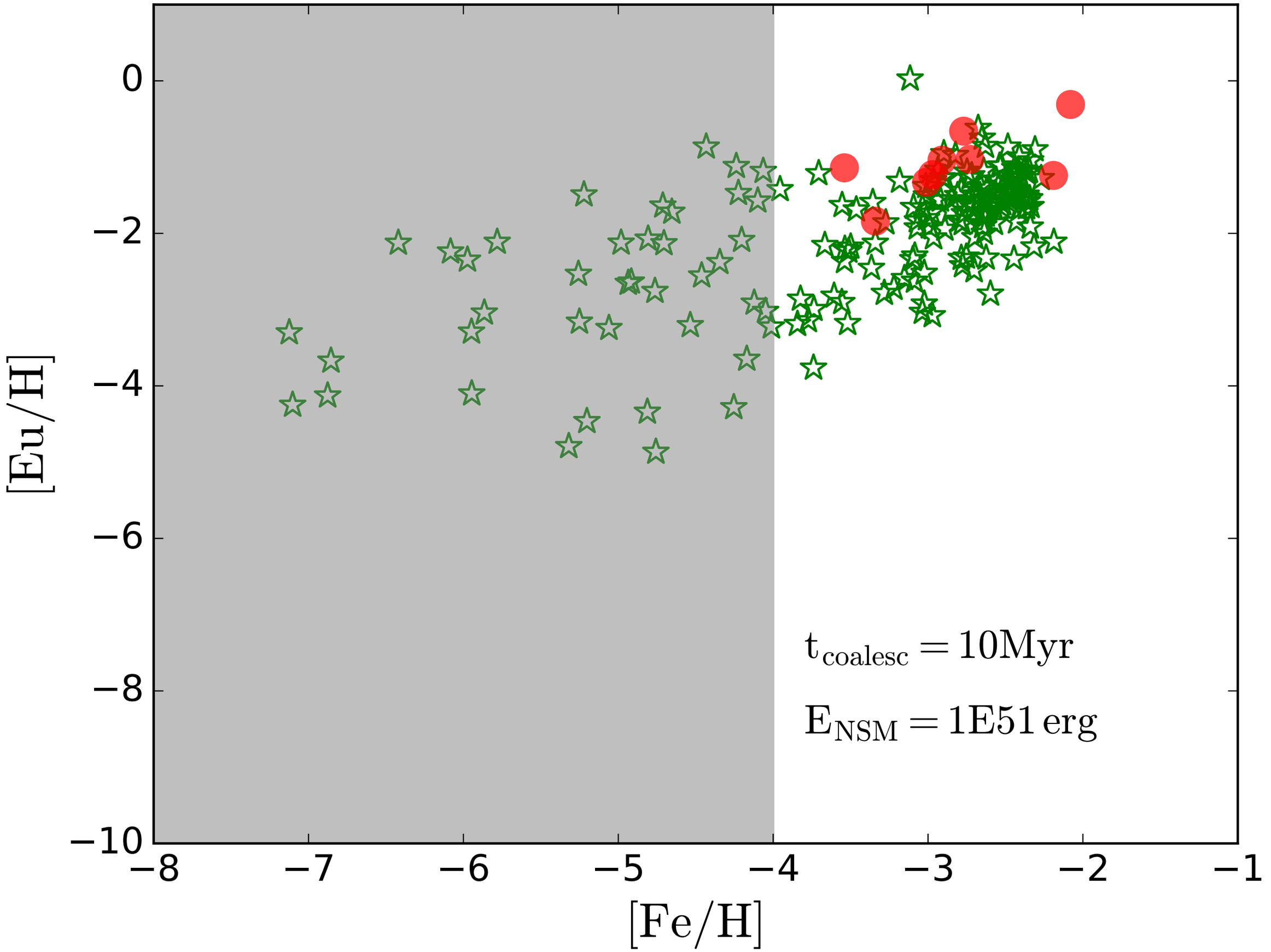
Local Group Dwarf Galaxy Demographics

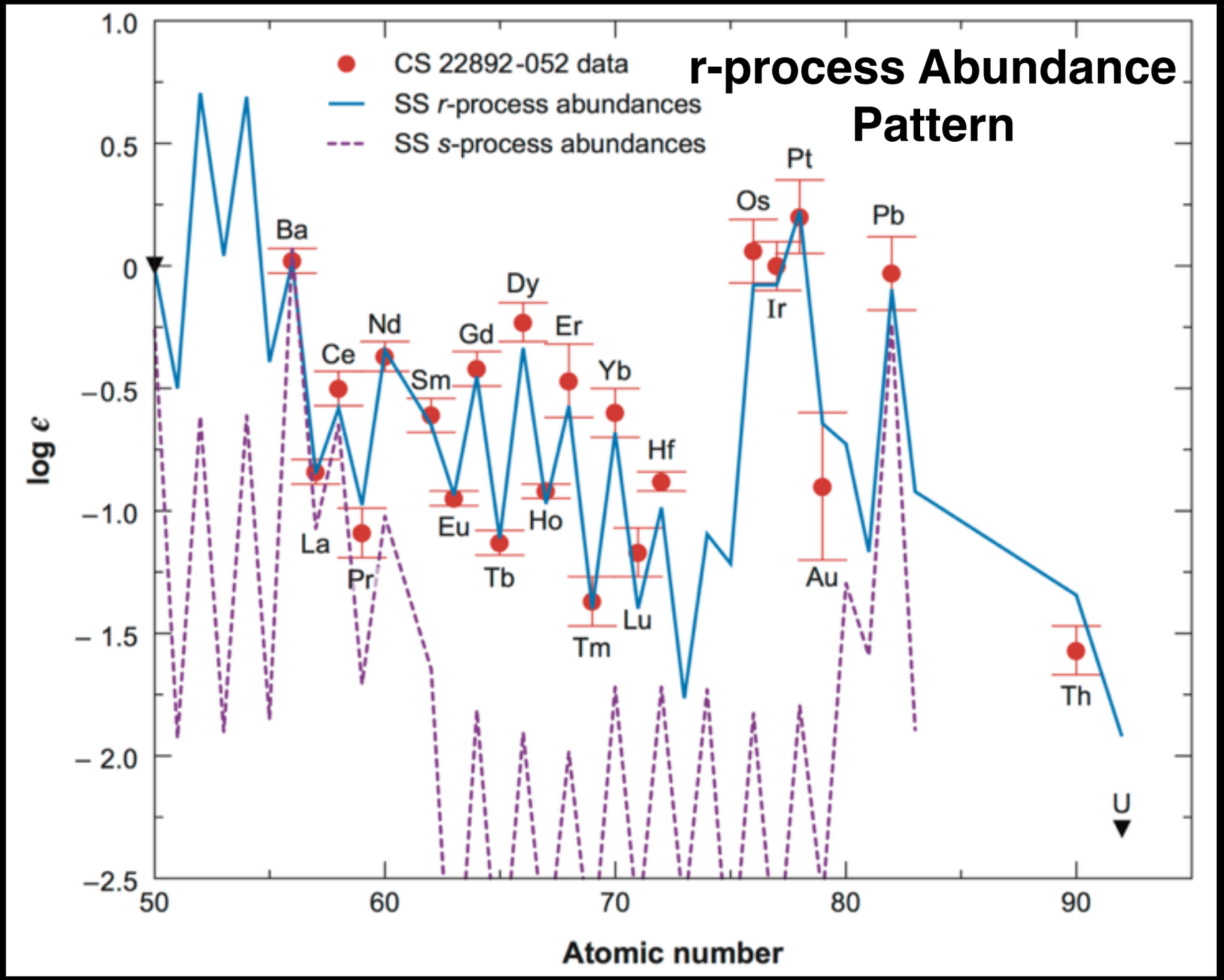


Weisz +14



Heger et al.(2003)


0
−2
−4
−6
−8
−10
−8
−7
−6
−5
−4
−3
−2
−1
[Eu/H]
[Fe/H]
$t_{coalesc} = 10 Myr$
$E_{NSM} = 1E51\,erg$

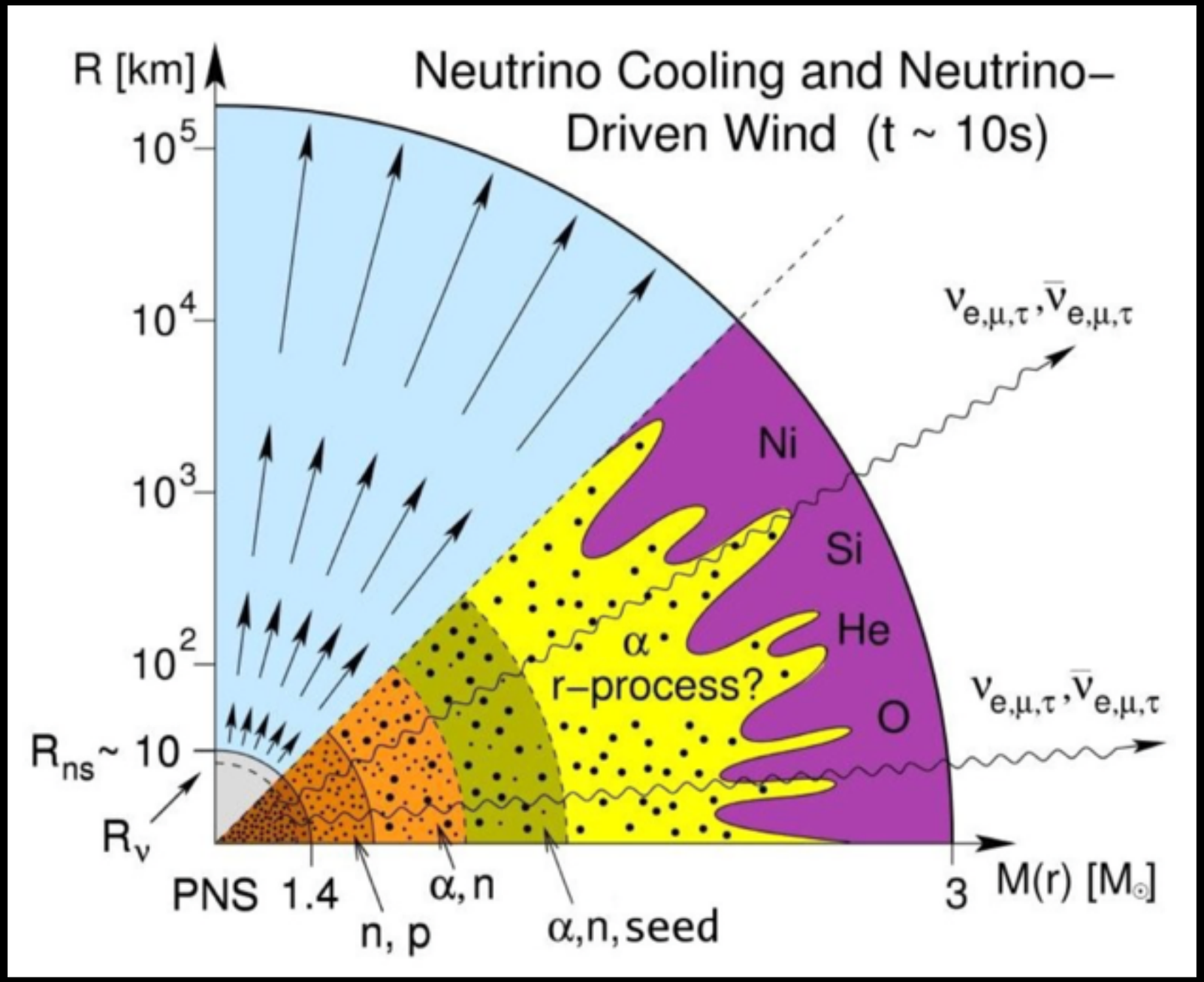


Sneden et al. (2008)

Core-collapse SN

$$\nu_e + n \rightarrow p + e^-$$
$$\bar{\nu}_e + p \rightarrow n + e^+$$

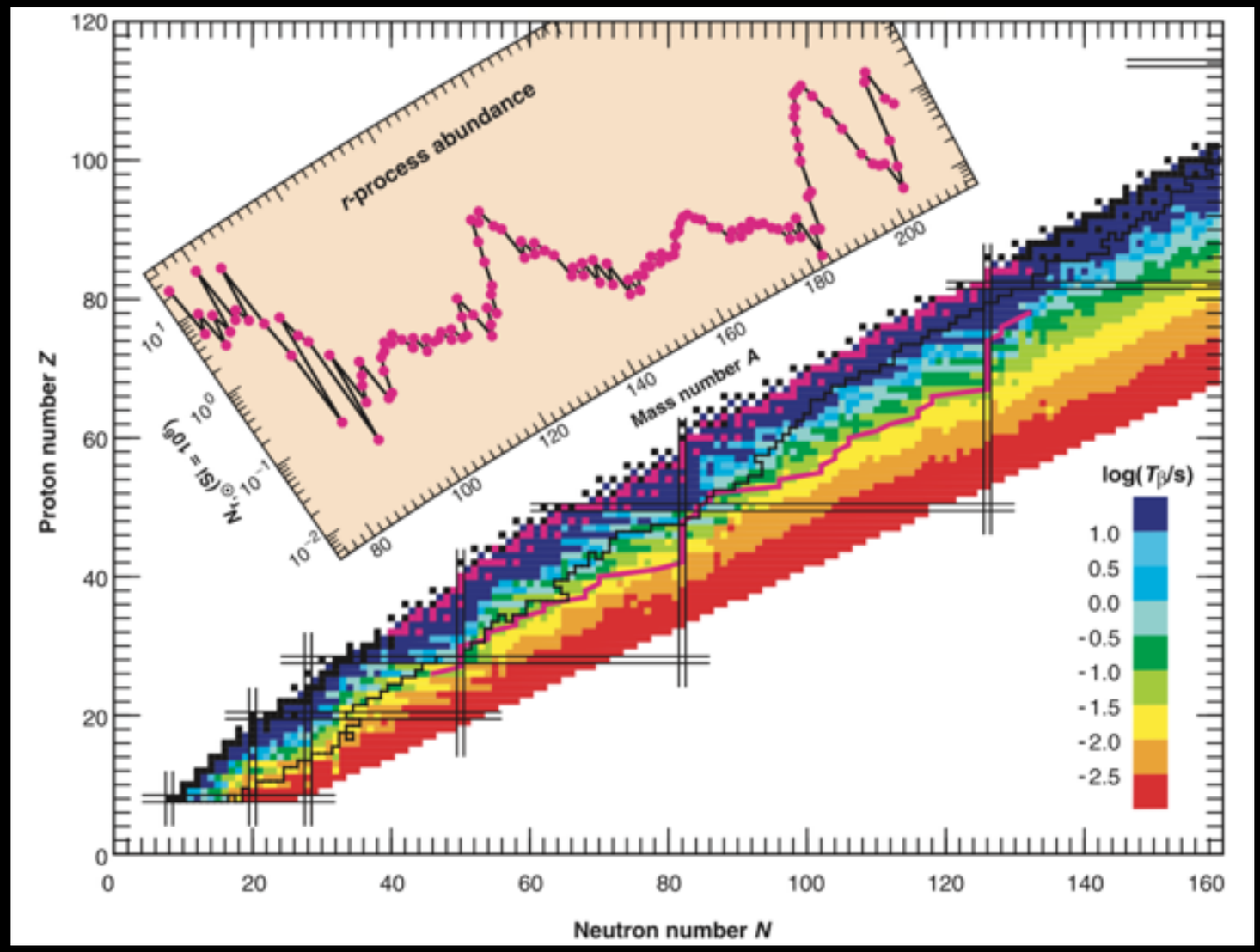
- **Neutrino winds expels material from the surface of the NS**
- **Small r-process yield (<$10^{-7.5}$ M_{sun} Eu per SN)**
- **Produced after any episode of star formation**



Woosley & Janka (2005)

r-process elements

- **All Z>30 elements are formed by capture of free neutron by a Fe-peak nuclei with a subsequent beta decay. All these elements are called n-capture elements.**
- **If there is enough time for a beta-decay between successive neutron capture events, the moving up of the ladder in Z is slow and therefore it is called slow(s-)process elements. (nearly half of the isotopes are formed through this channel.**
- **SNe II and neutron star mergers are plausible candidates**



Sneden & Conway (2004)

$t_{coalesc} = 10 Myr$

$E_{NSM} = 1E51\,erg$

[Eu/H]

[Fe/H]

-1.0
-3.0
-2.0
-5.0
-4.0
-6.0
-4.0
-6.0
-7.0
-5.0

0.4
0.2
0.0
−0.2
−0.4

y(kpc)

−0.4 −0.2 0.0 0.2 0.4

x(kpc)

2e-01
1e-01
1e-01
1e-01
8e-02
6e-02
4e-02
2e-02

Projected Density (gr/cm^2)

$t_{coalesc} = 1 Myr$

$E_{NSM} = 1E50\,erg$

[Eu/H]

[Fe/H]

-4.0

-3.0

-2.0

-6.0

-7.0

-4.0

-5.0

0.4

0.2

0.0

−0.2

−0.4

y(kpc)

−0.4 −0.2 0.0 0.2 0.4

x(kpc)

8e-02

7e-02

6e-02

5e-02

4e-02

3e-02

2e-02

1e-02

Projected Density (gr/cm^2)