Barium in UFDs

Yuta Tarumi

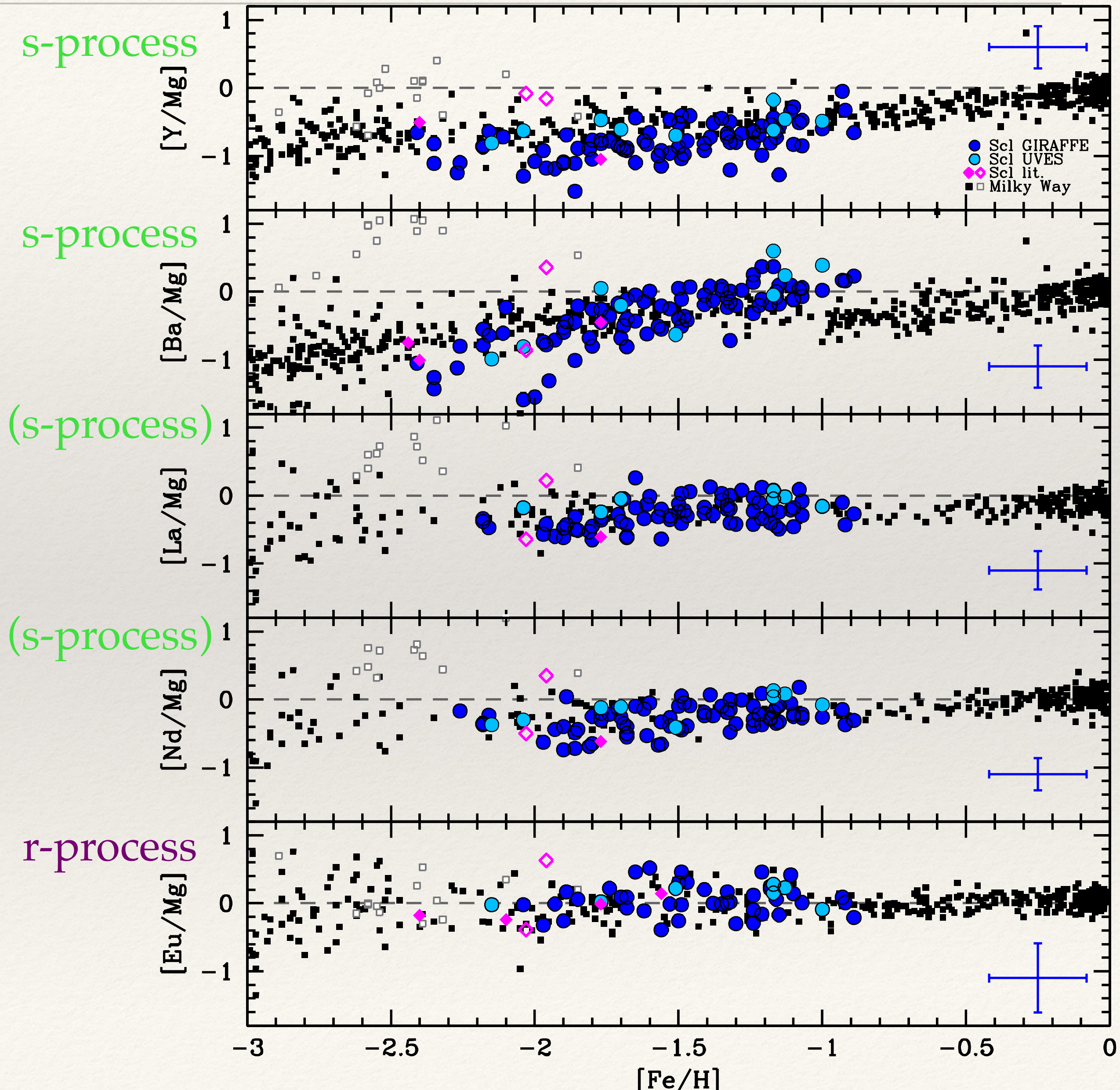
Recent observations

- 1. n-capture elements in Sculptor
  - ESO's VLT, FLAMES/GIRAFFE, FLAMES/UVES
  - 2.3×10^6 Msun
- 2. n-capture elements in Milky-Way
  - GALAH survey, APOGEE survey
- 3. Eu detection in Grus II (3rd UFD with Eu)
  - LCO's Magellan-Clay telescope, MIKE spectrograph
  - 3.4×10^3 Msun

1. n-capture in Sculptor

- 2.3×10^6 Msun
- s-process elements are delayed compared to α-elements
- r-process elements are not delayed compared to α-elements

Skuladottir+19



1. n-capture in Sculptor

Skuladottir+19

- SFH is different from MW
- s-process elements are delayed compared to Fe
- r-process elements are similar to α-elements
- **weak-s and main-s seems to be different.**

α-element

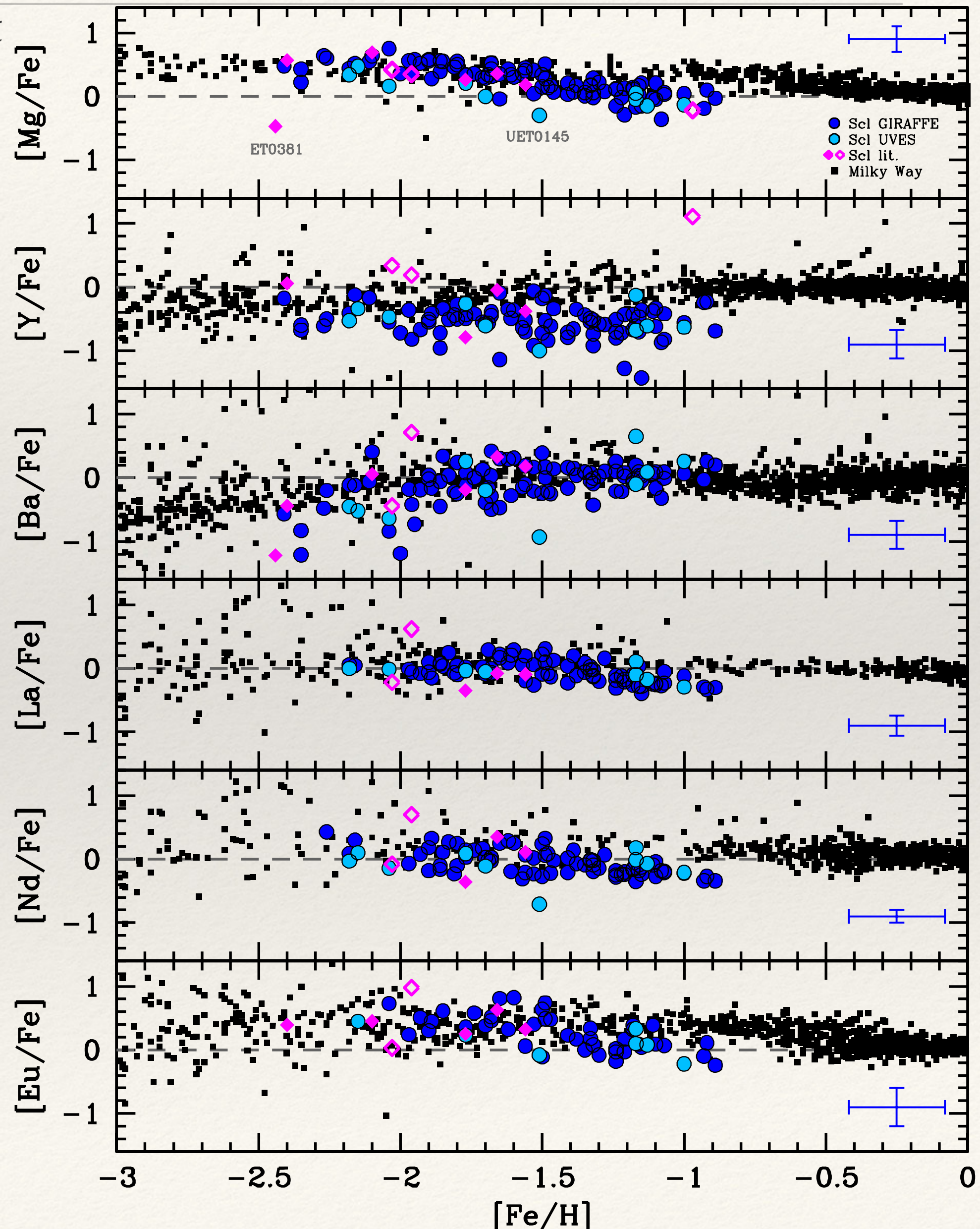
weak-s

main-s
(main-r)

main-s
main-r

main-s
main-r

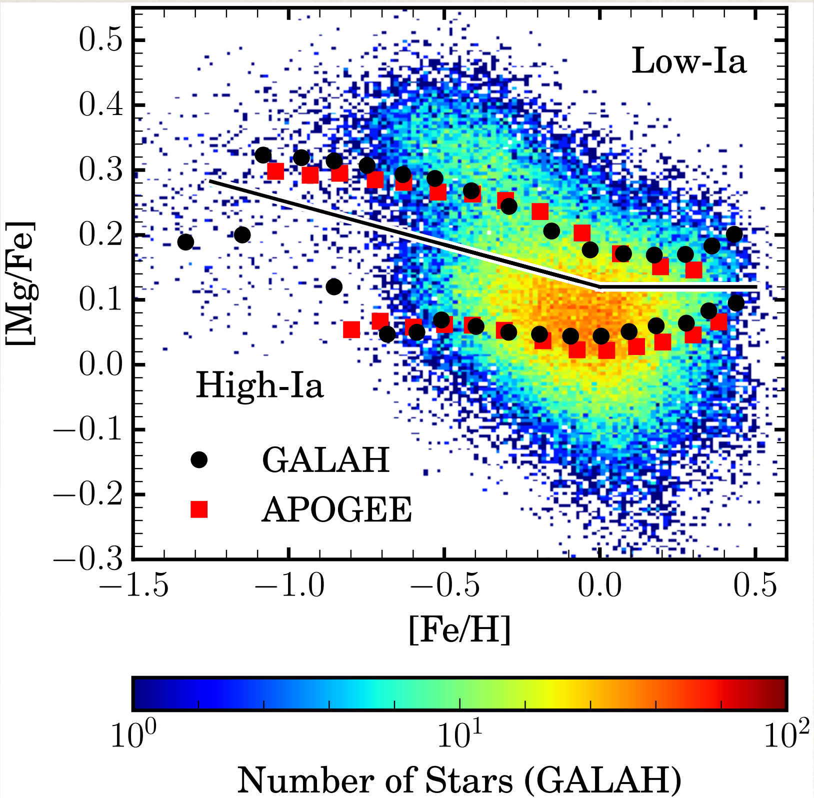
main-r

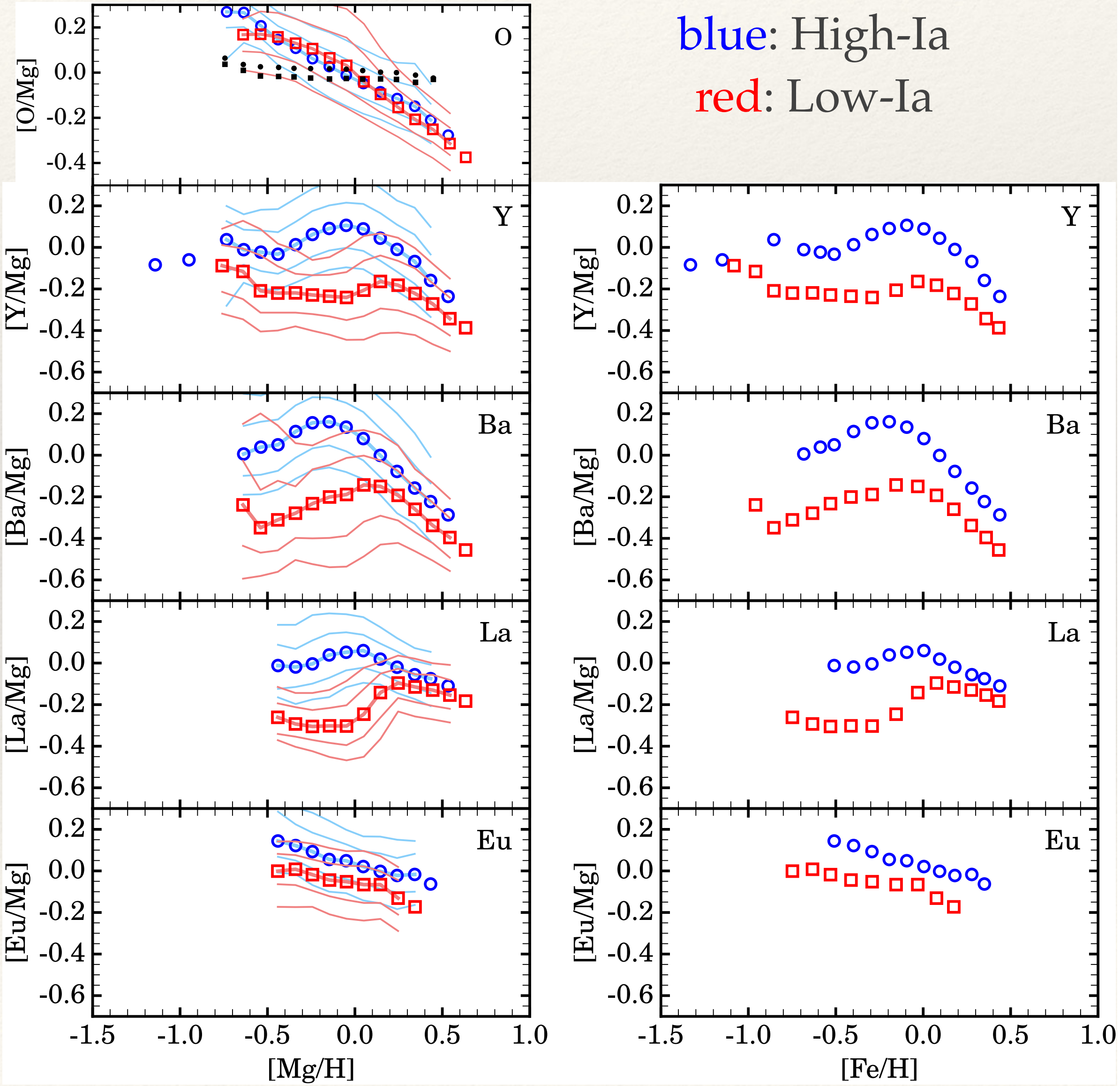


2. n-capture in Milky Way

Griffith+20

- high-Ia and low-Ia behave differently: **all the n-capture elements have delay, including Eu**.



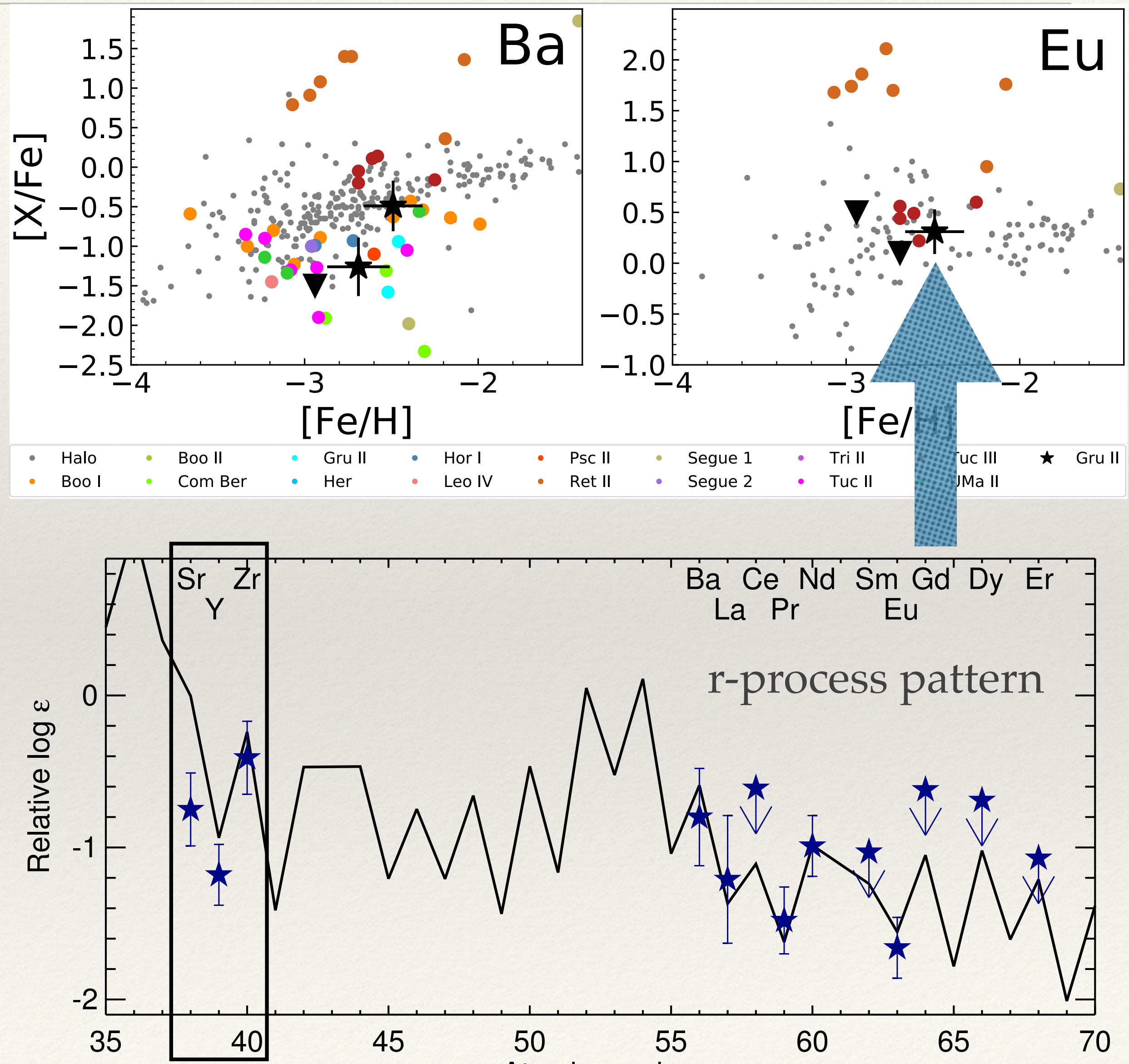


blue: High-Ia
red: Low-Ia

3. Eu detection in Grus II

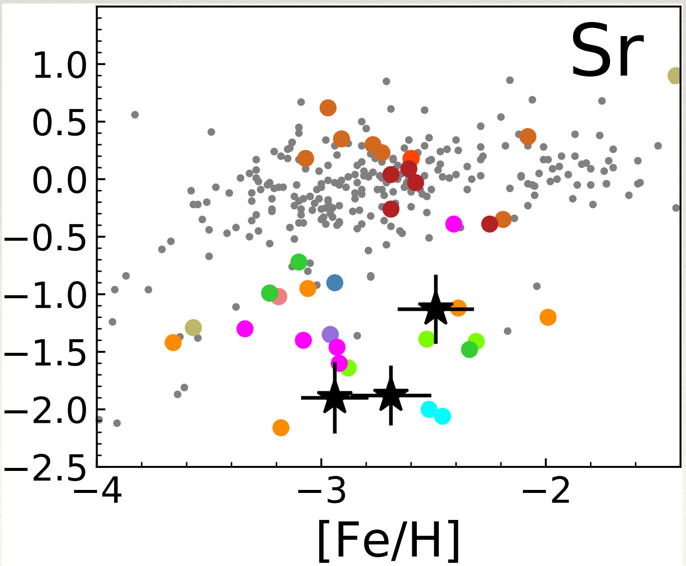
Hansen+20

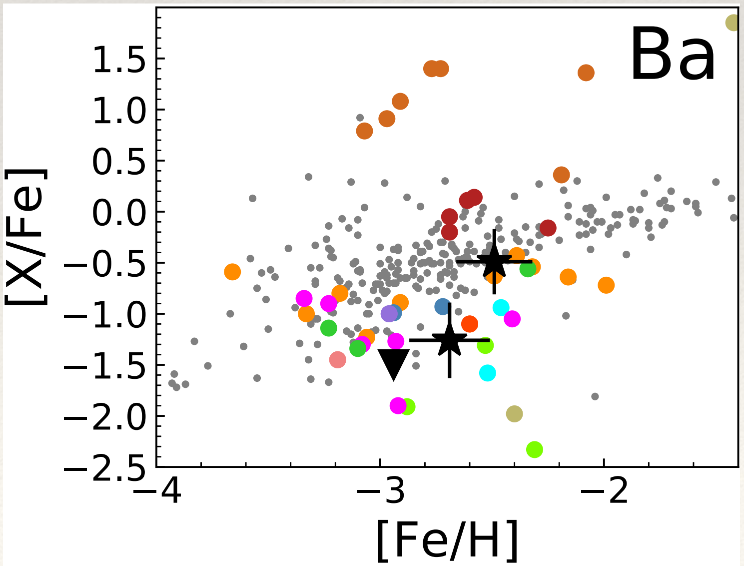
- Third UFD with Eu
- Consistent with r-process pattern
- [Ba/Fe] jump from ~ -1.5 to -0.5
- Consistent with one prolific r-process
- X_{La} = -1.2 > -2.2 (GW170817 value)



Motivation

- **What can we learn from recent UFD observations?**
  - Ba, Sr abundances of UFDs are lower than MW stars.
- Theoretically, UFDs are different from MW.
  - UFDs are small, **"0 or 1 r-process"**.
  - UFDs quench within first 1 Gyr, **weaker AGB contribution**.

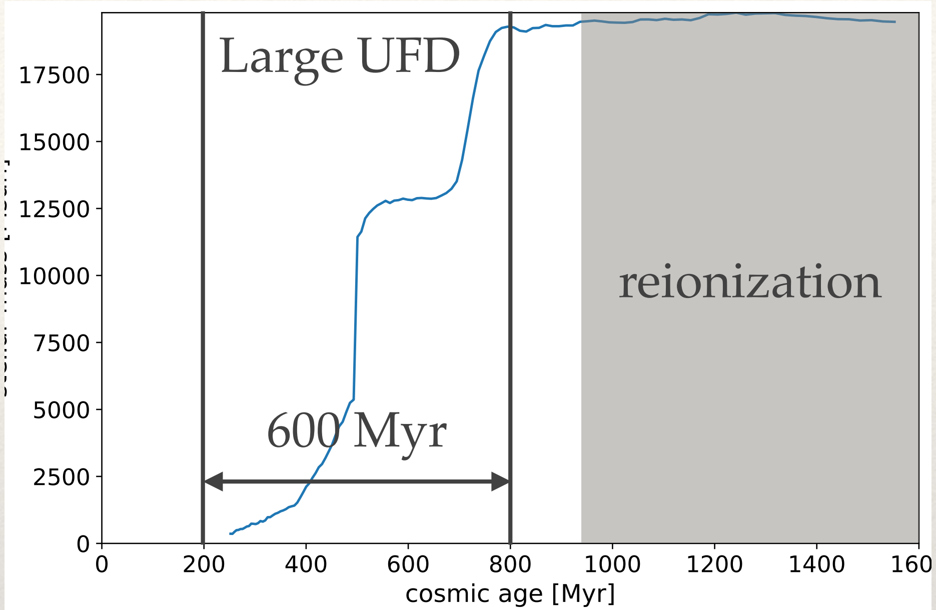


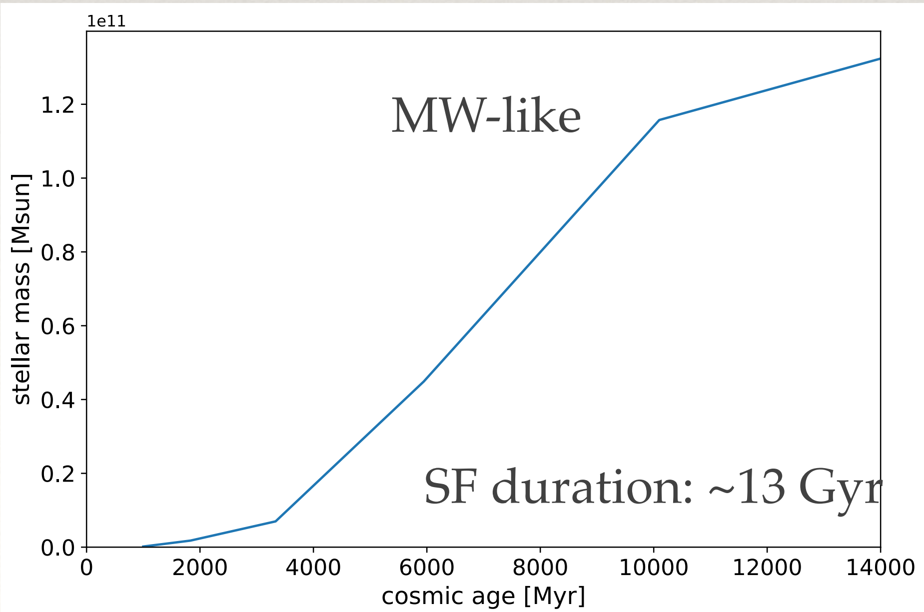


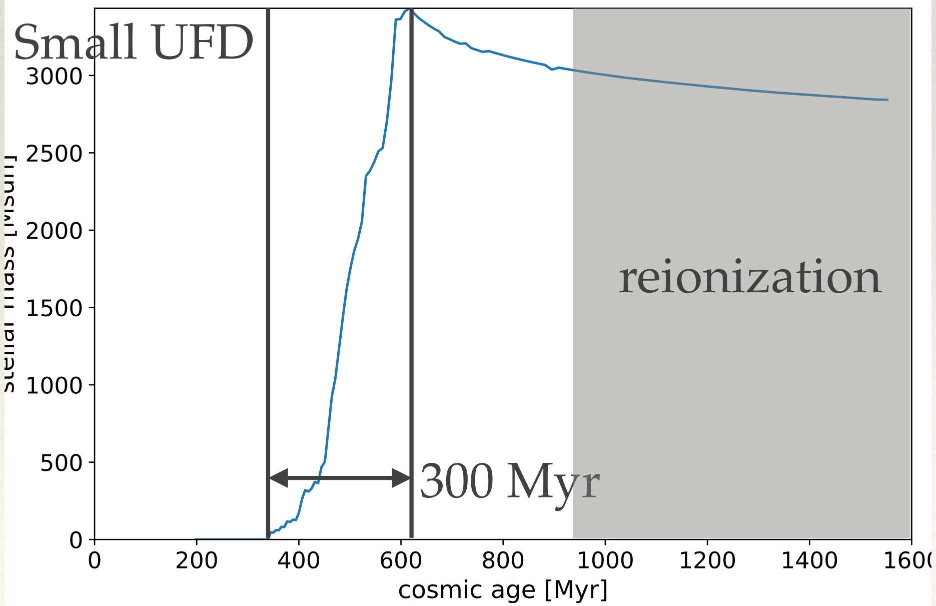
Hansen+20

Simulation settings

- Yield table: Karakas+10 (?)
- Auriga galaxy formation model
- 3 galaxies: large UFD, small UFD, MW-like

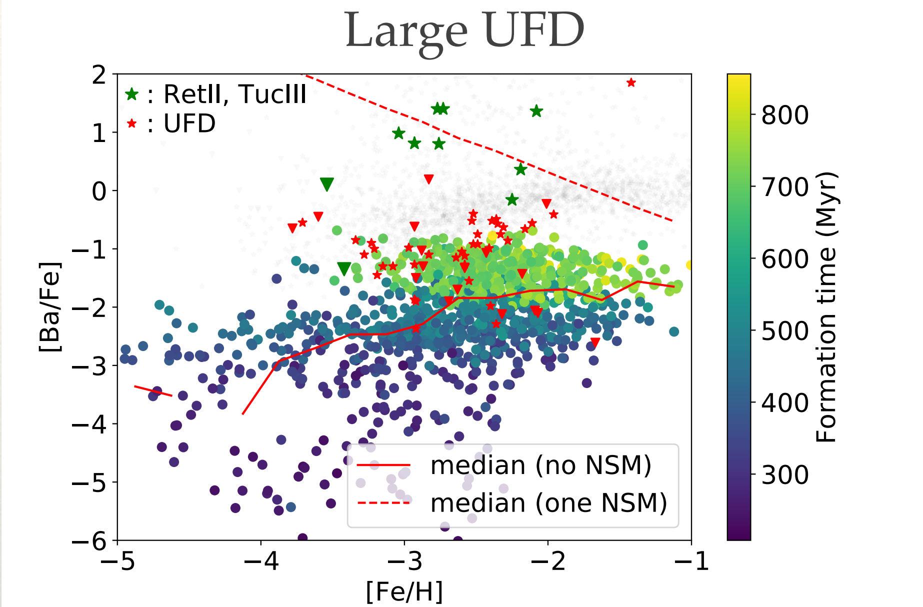


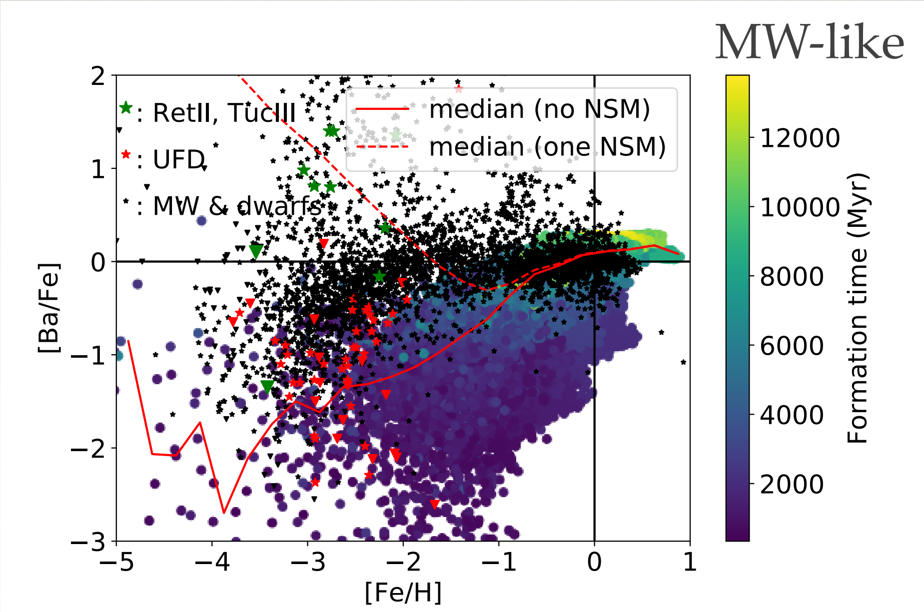


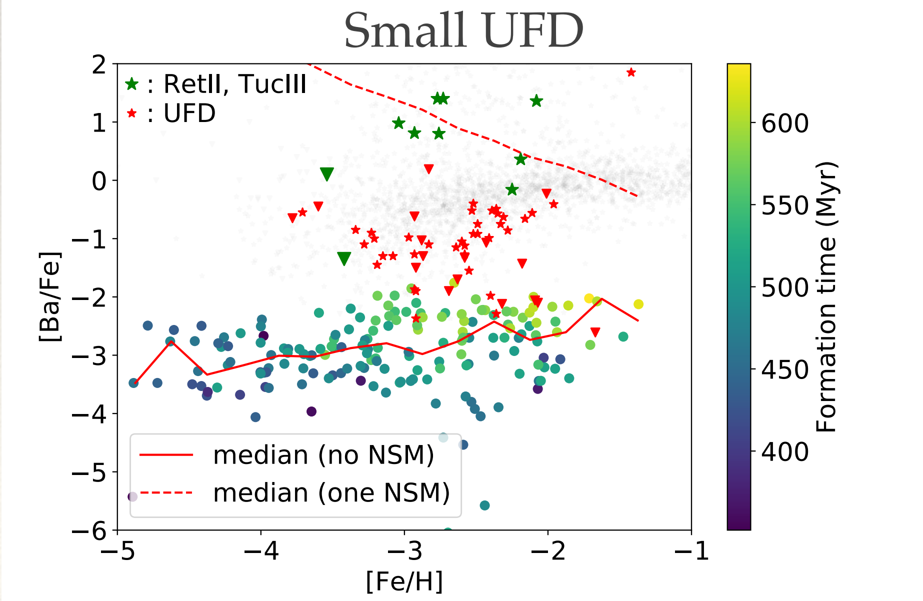


Results

- **We need more Ba** to explain [Ba/Fe] of UFDs.
- Extended SFH galaxies have higher [Ba/Fe].
- It catches up at z=0 or [Fe/H] = 0.

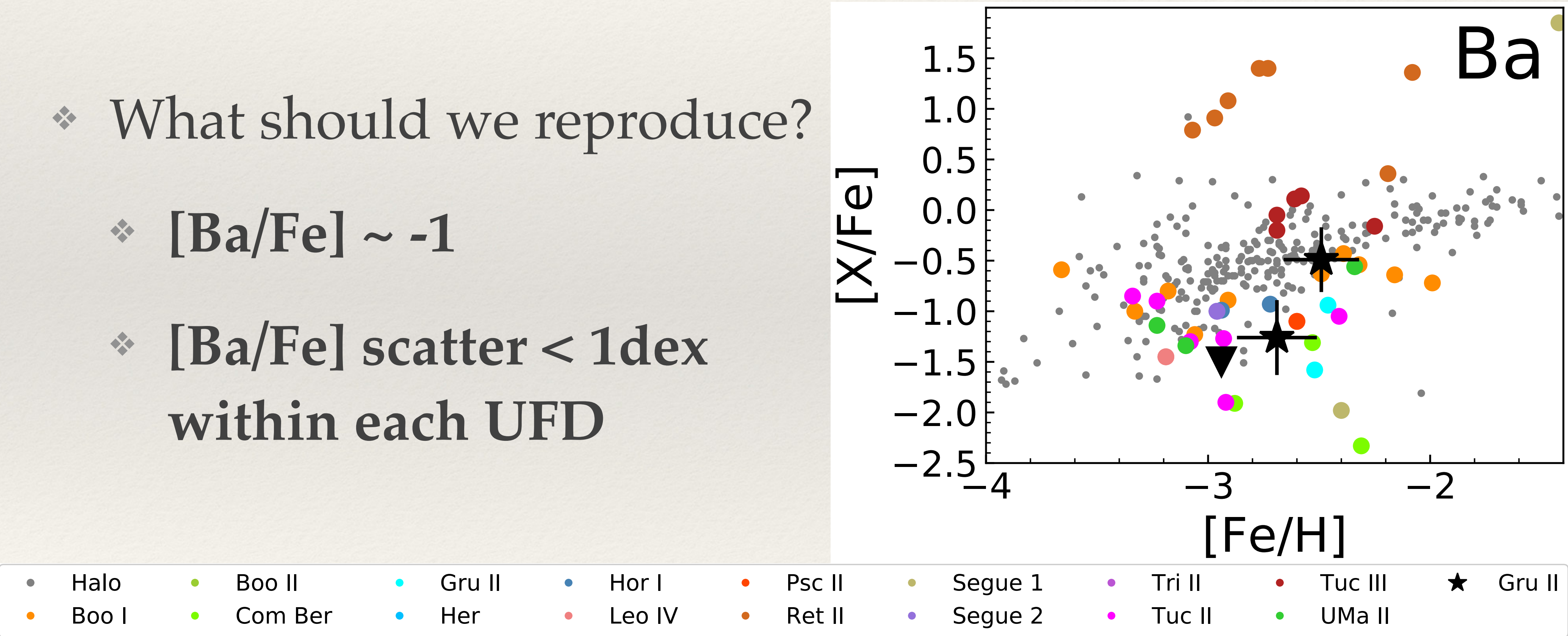






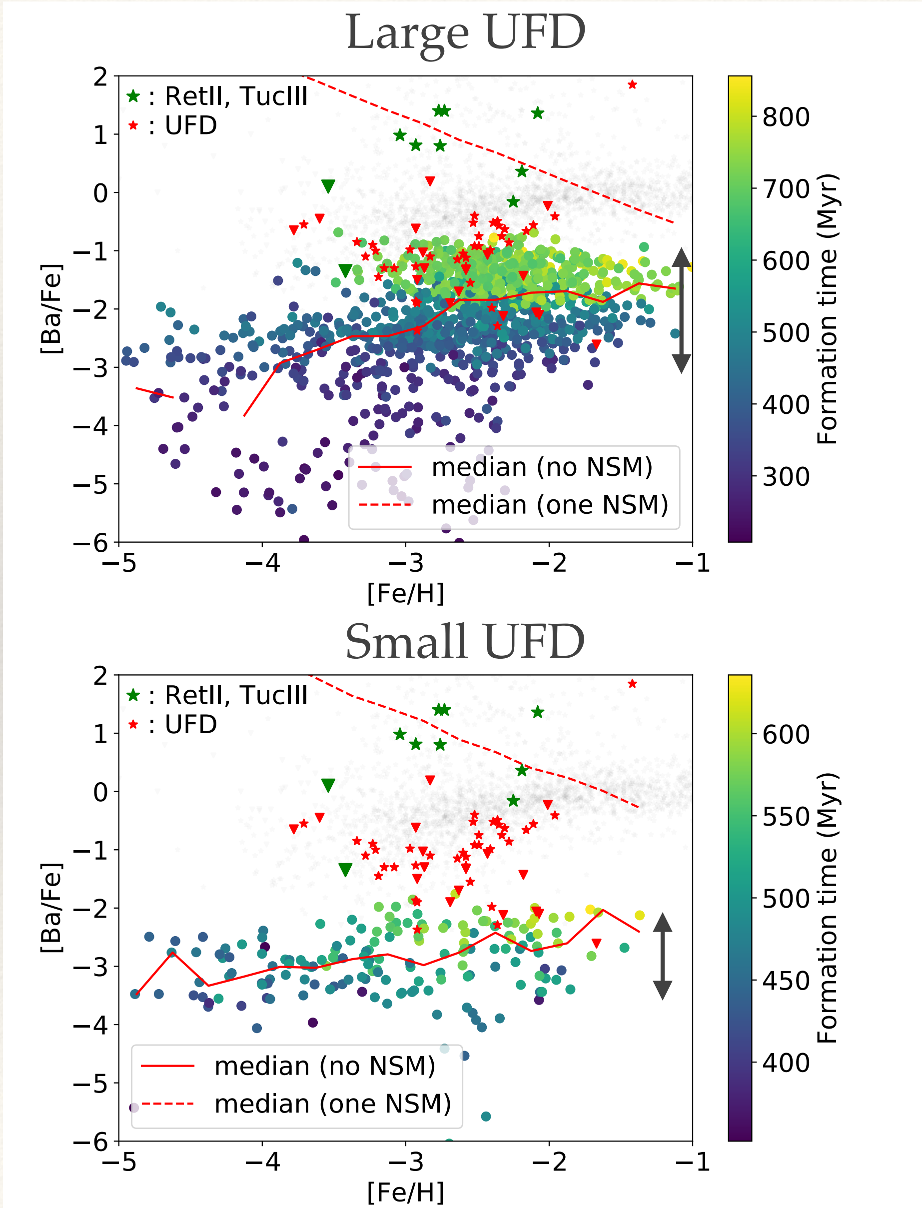
How can we reconcile?

- What should we reproduce?
  - **[Ba/Fe] ~ -1**
  - **[Ba/Fe] scatter < 1dex within each UFD**



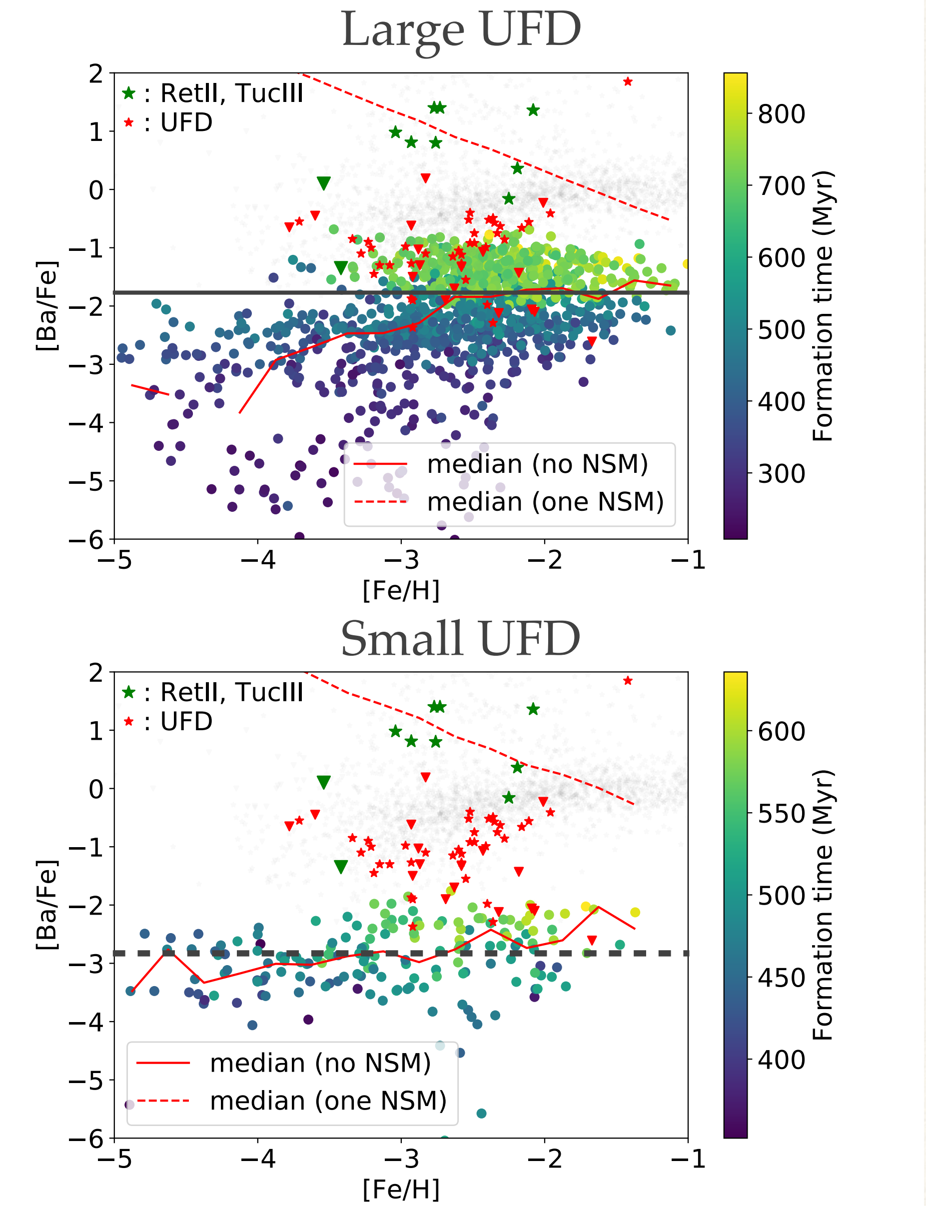
[Ba/Fe] scatter

- If star formation duration is long (> ~500Myr), [Ba/Fe] scatter would be too large.
- Possible solutions are…
  - Quickly quench.
  - Enhance Ba production in (relatively) massive stars.



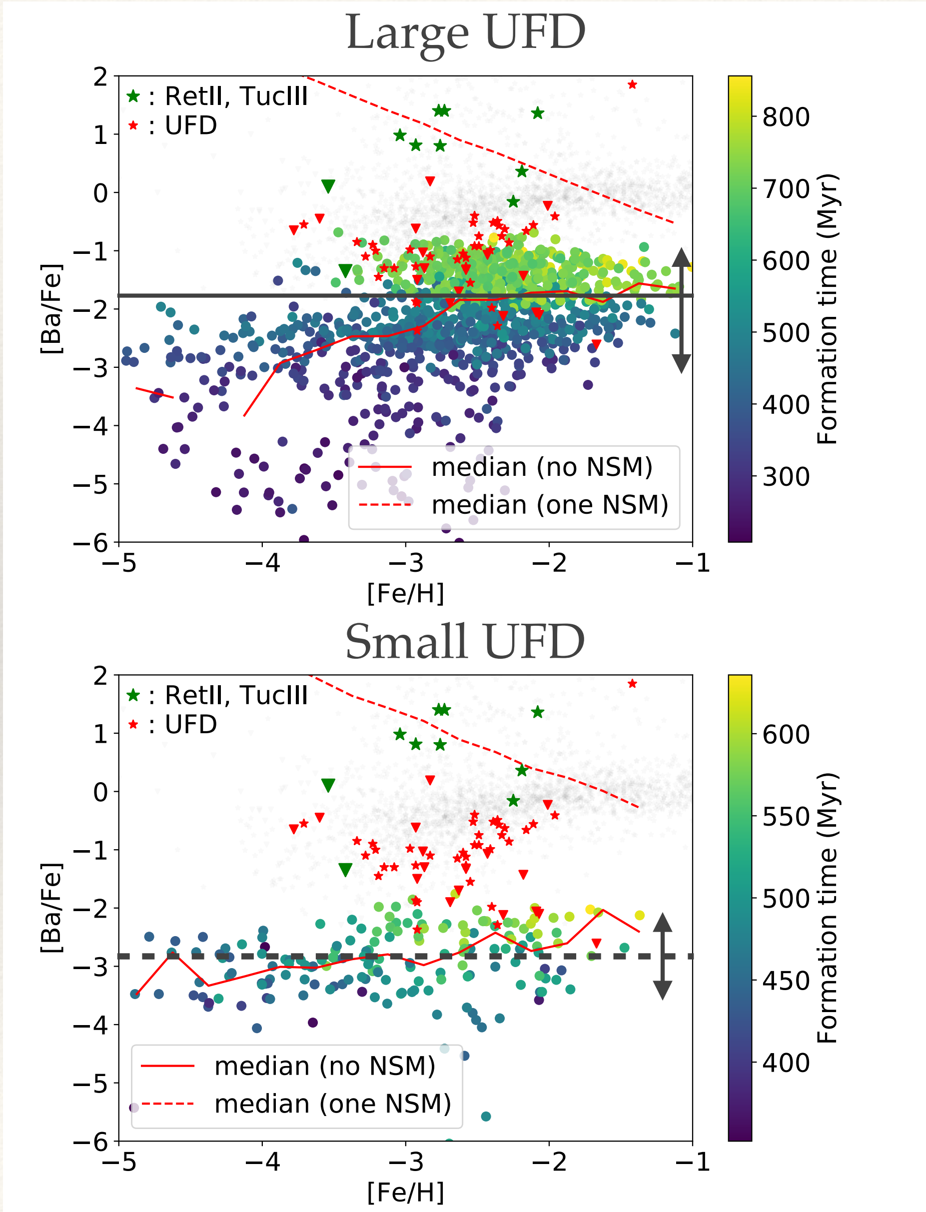
[Ba/Fe] value

- If star formation duration is short (< ~500Myr), [Ba/Fe] is too low.
- Possible solutions are…
    - Keep forming stars for a long time.
    - Modify yield.



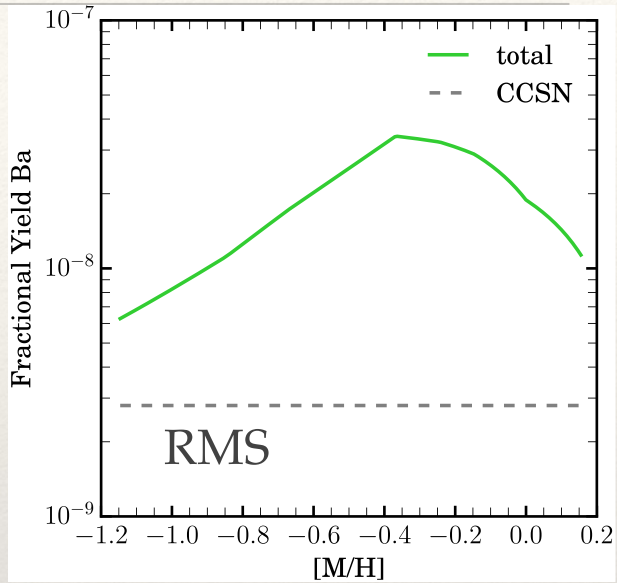
Constraints

- In terms of [Ba/Fe] scatter, short star formation is favored.
- In terms of [Ba/Fe] values, long star formation is favored.
- **It seems difficult to reconcile the simulation with observation only by modifying star formation history.**

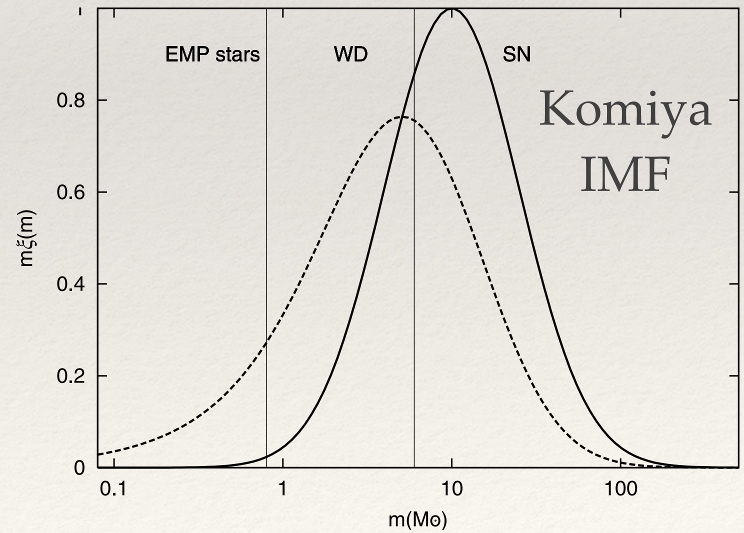


Enhance Ba production

Griffith+20



- **Other Ba sources?**
  - Rotating massive stars.
  - super-AGB stars.
  - Some r-process events.
- **Modify IMF?**

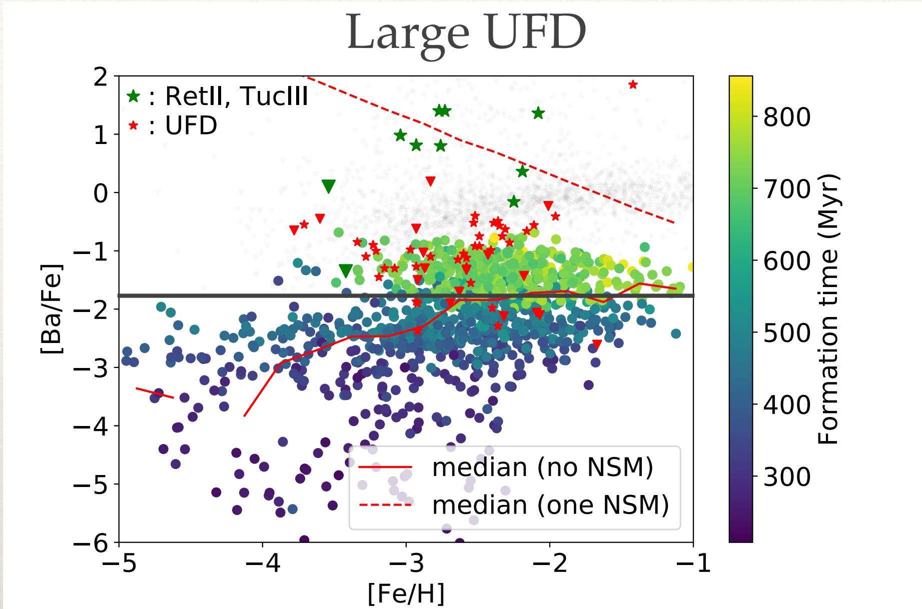


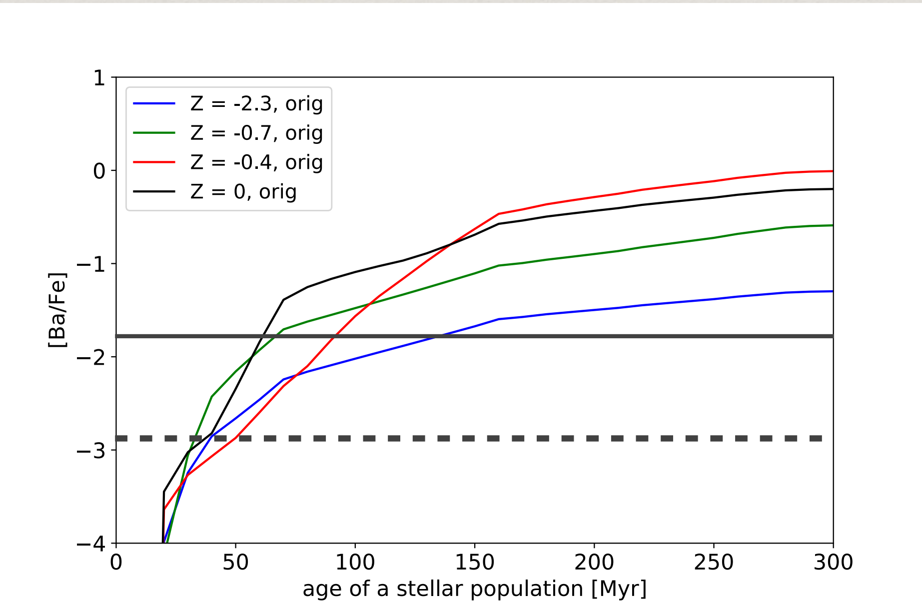
Komiya+07

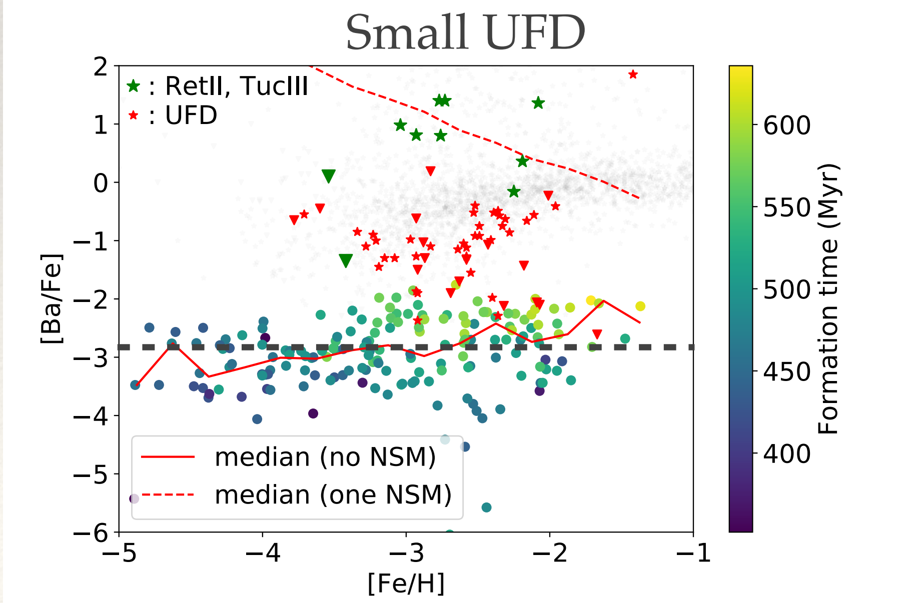
FIG. 12.—Relative distributions, $m\xi(m)$, of stellar masses for the derived IMF of EMP stars with $M_{md} = 10\,M_\odot$ and $\Delta_M = 0.4$; solid and dashed curves denote the mass distributions of primary and secondary components, respectively.

Ba production

- Large UFD: [Ba/Fe] at ~130Myr
- Small UFD: [Ba/Fe] at ~50Myr
- **→Ba should be produced within ~100Myr.**

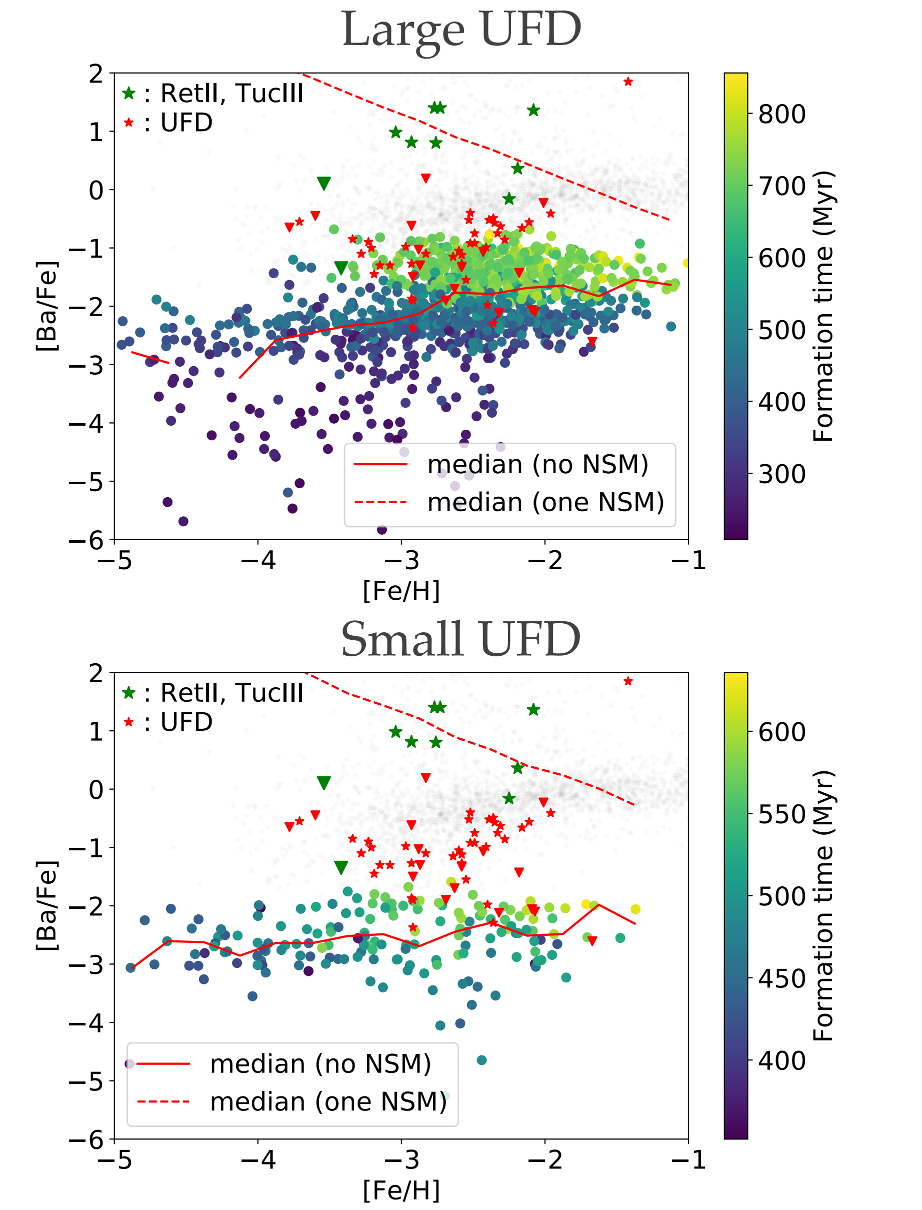


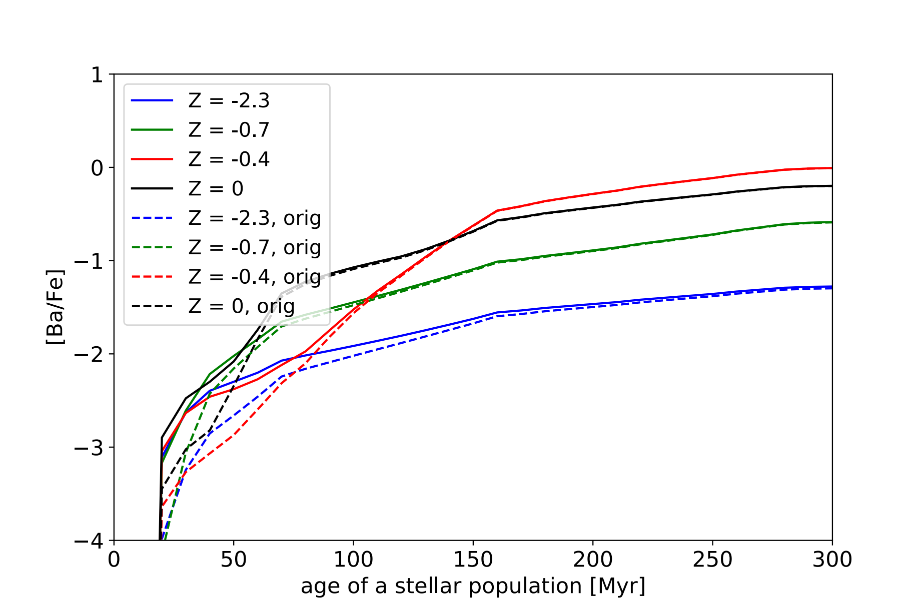




super-AGB stars

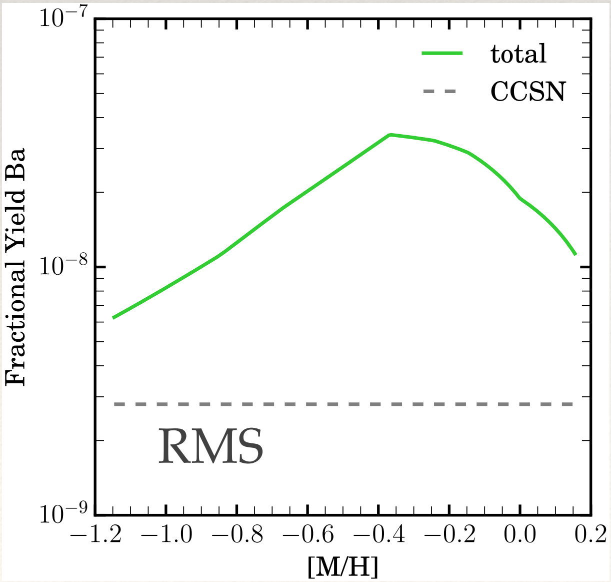
- Assuming 5Msun < M* < 7.5Msun experience super-AGB phase, yield is from Doherty+17, Z = -0.7 model
- [Ba/Fe] is enhanced, but not enough
- If sAGB were 10times more efficient, [Ba/Fe] seems consistent



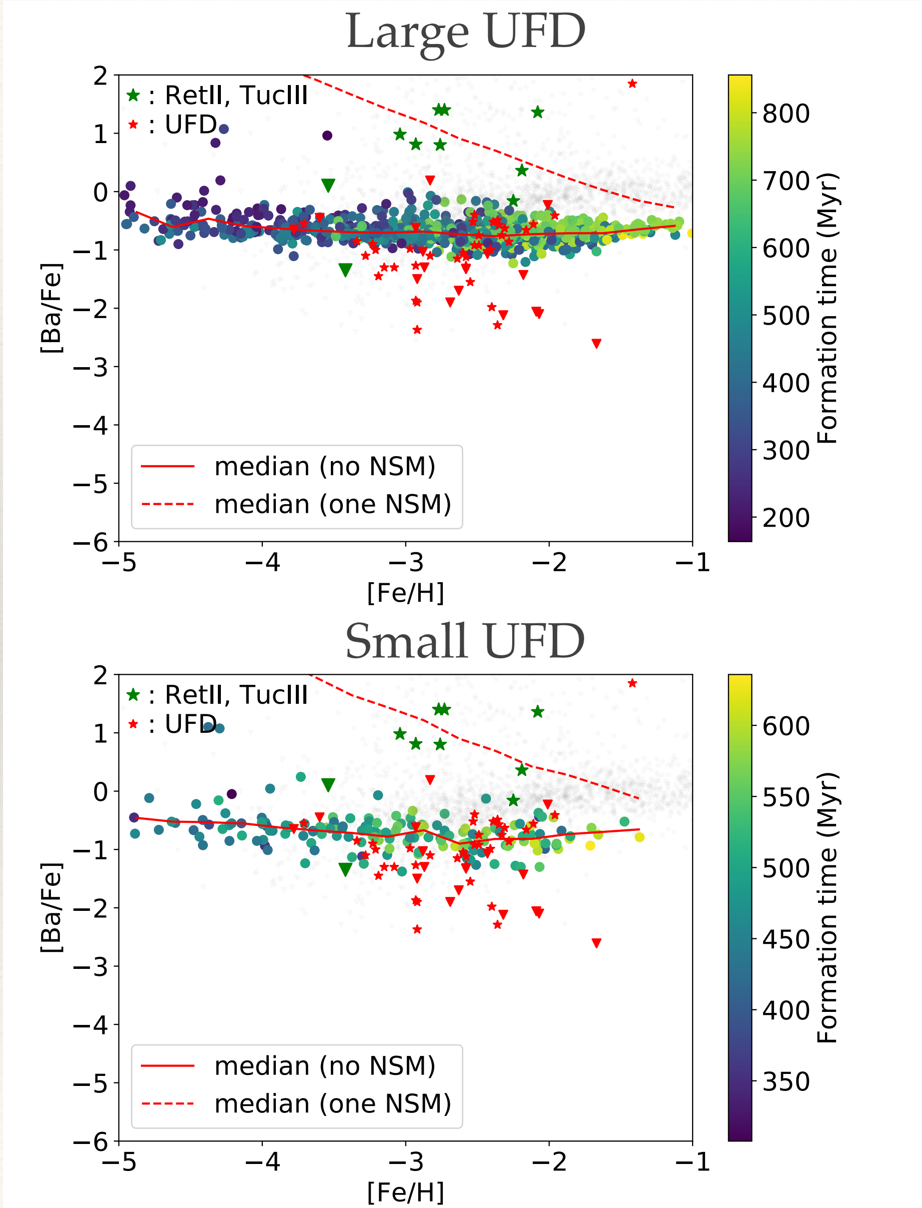


Rotating massive stars

- Assuming 3×10^{-9} Msun of Ba is formed per 1Msun (following Griffith+20, originally Limongi&Chieffi18)
- Too many Ba.

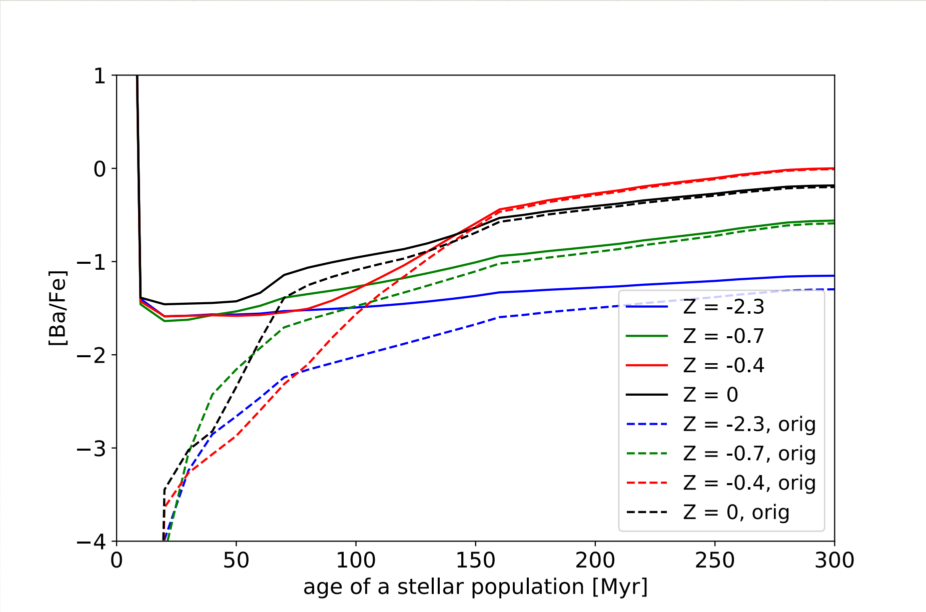


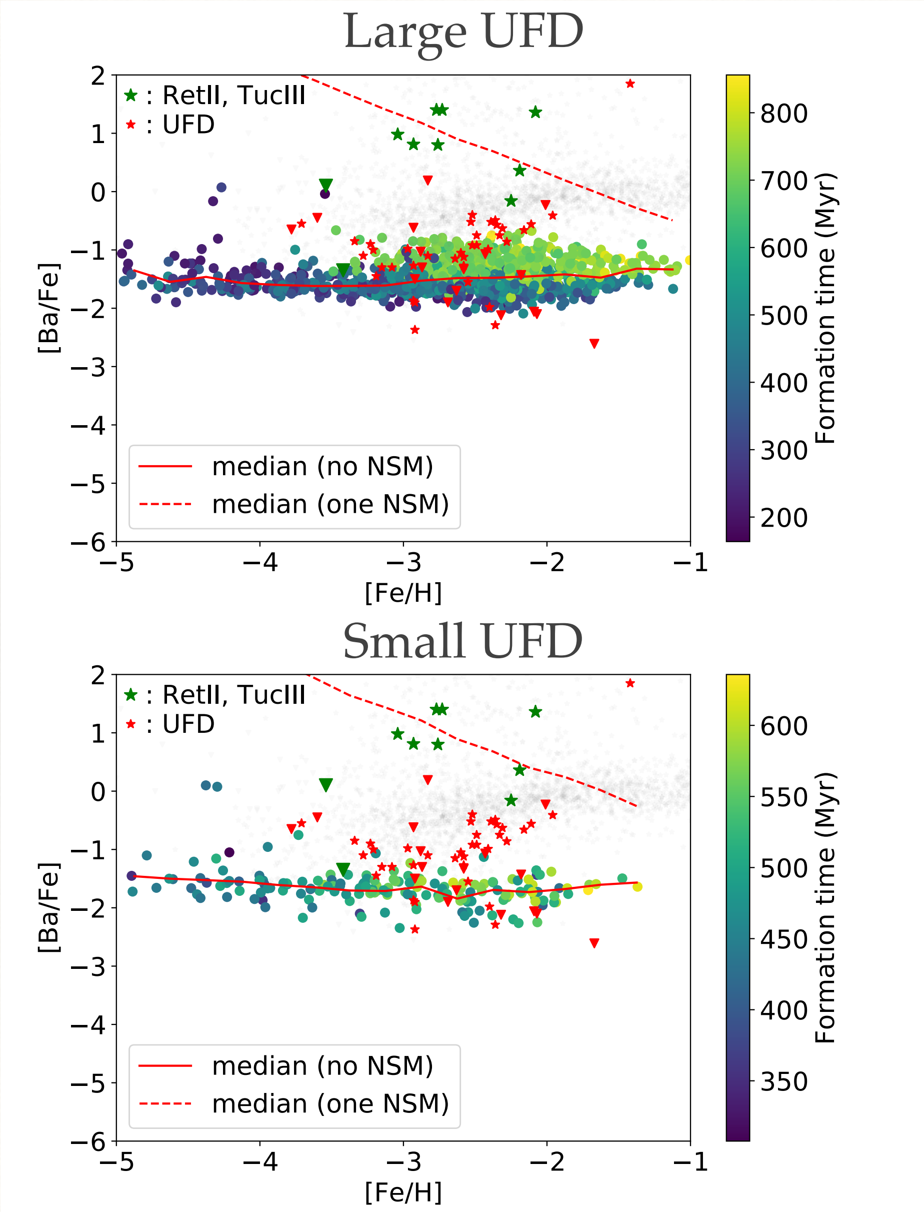
Griffith+20



Rotating massive stars

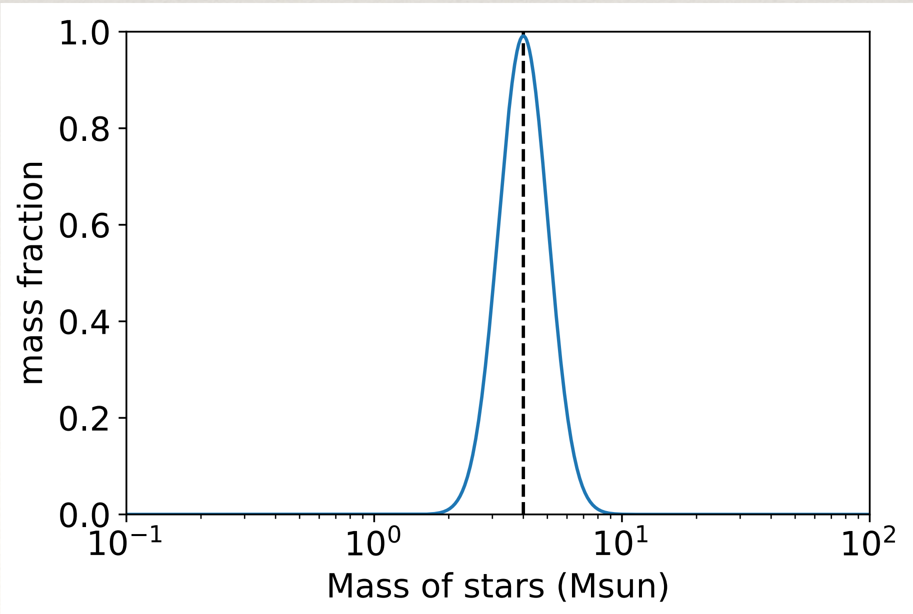
- Assuming 10 times less, [Ba/Fe] seems consistent with observation.
- However, with this yield we cannot form [Ba/Fe] < -2… contradiction to Segue I?

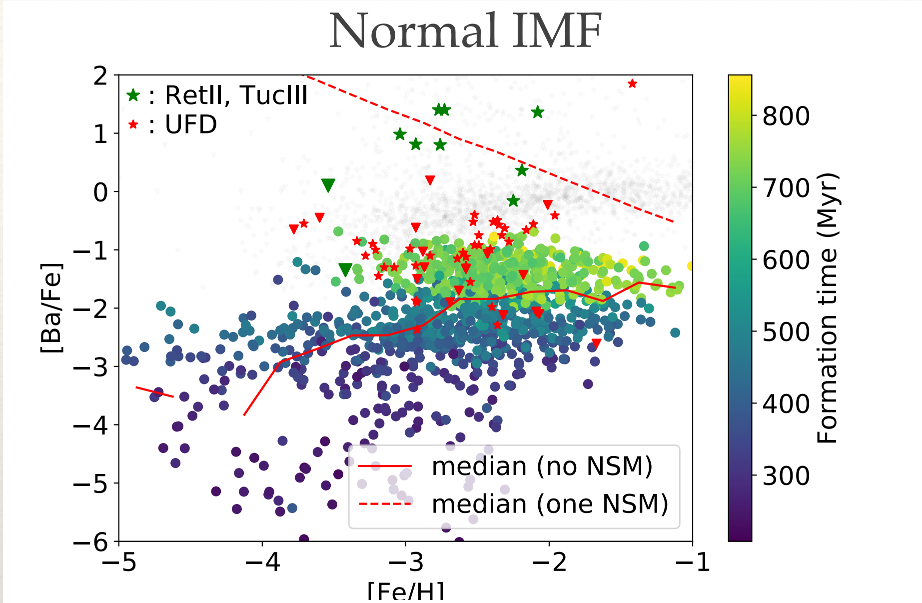


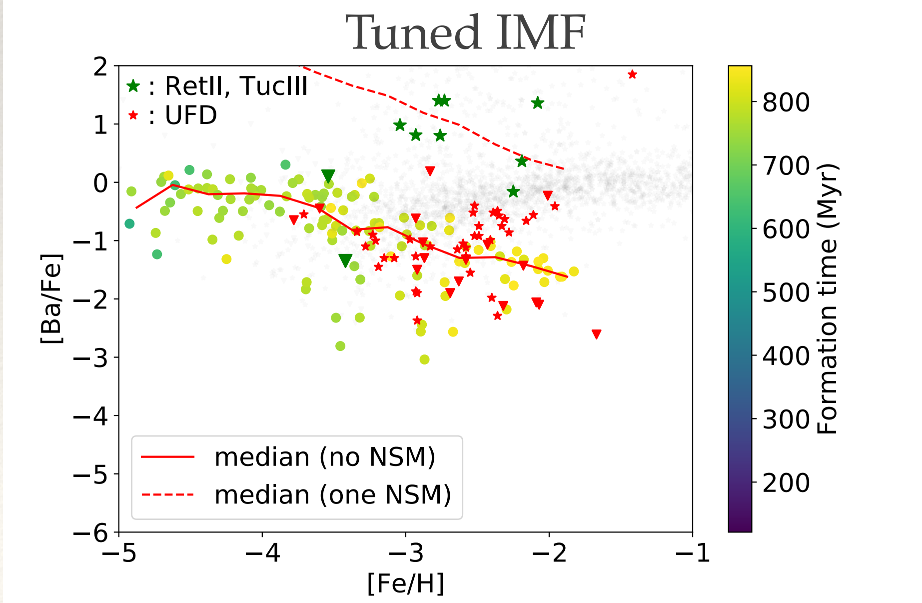


Modify IMF

- Choosing IMF with smaller number of massive stars, [Ba/Fe] can be adjusted
- [Ba/Fe] **decreases** as [Fe/H] increases, as type-Ia is not negligible







Discussions

- On the contribution of r-process to Ba
- On the diversity of Ba abundance among UFDs

Discussion 1: r-process?

- UFDs: $L^* < 10^5$ Lsun
- r-process: **rare** and **prolific**.
  - To explain high abundances in Ret-II
  - To explain large scatter among halo stars
  - Roughly consistent with $1/10^5$ Msun of stars formed
- → High [Eu/Fe] in Ret II, Tuc III and Gru II can be understood as “0 or 1” event of a prolific r-process.

Discussion 1: r-process?

- Cescutti+06
  - At [Fe/H] < -2 r-process is important.
  - Roughly explains [Ba/Fe] - [Fe/H].
  - r-process is from massive stars. **Not rare nor prolific.**

Mod	s-process Ba	r-process Ba	s-process Eu	r-process Eu
1	$1. - 3M_{\odot}$ Busso et al.(2001)ext.	$12 - 30M_{\odot}$ yields table 3	none	$12 - 30M_{\odot}$ yields table 3
2	$1. - 3M_{\odot}$ Busso et al.(2001)ext.	$10 - 25M_{\odot}$ yields table 4	none	$10 - 25M_{\odot}$ yields table 4
3	$1.5 - 3M_{\odot}$ Busso et al.(2001)	$8 - 10M_{\odot}$ $X^{new}_{Ba} = 5.7 \cdot 10^{-6}/M_{*}$ (Travaglio et al. 2001)	none	$12 - 30M_{\odot}$ yields table 3
4	$1.5 - 3M_{\odot}$ Busso et al.(2001)	$10 - 30M_{\odot}$ yields table 3	none	$8 - 10M_{\odot}$ $X^{new}_{Eu} = 3.1 \cdot 10^{-7}/M_{*}$ (Ishimaru et al.2004 Mod.A)
5	$1.5 - 3M_{\odot}$ Busso et al.(2001)	$10 - 30M_{\odot}$ yields table 3	none	$20 - 25M_{\odot}$ $X^{new}_{Eu} = 1.1 \cdot 10^{-6}/M_{*}$ (Ishimaru et al.2004 Mod.B)
6	$1.5 - 3M_{\odot}$ Busso et al.(2001)	$10 - 30M_{\odot}$ yields table 3	none	$> 30M_{\odot}$ $X^{new}_{Eu} = 7.8 \cdot 10^{-7}/M_{*}$ (Ishimaru et al.2004 Mod.C)

Cescutti+06

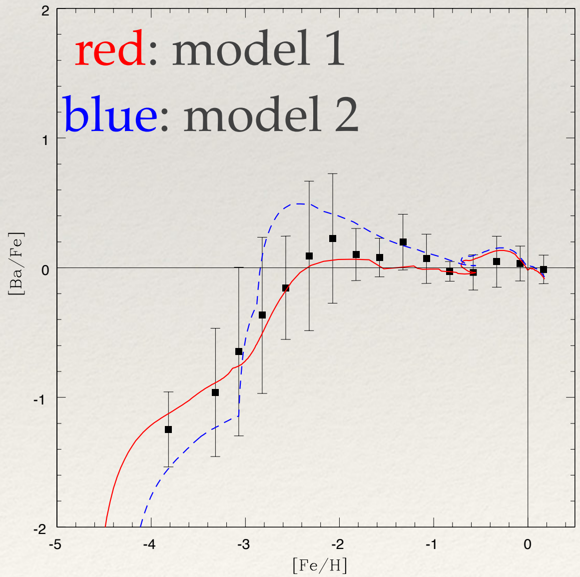


Fig. 6. The data are the same as in Fig. 5. In this Fig. we show in solid line the model 1 and in dashed line the model 2 (models are described in table 2) predictions.

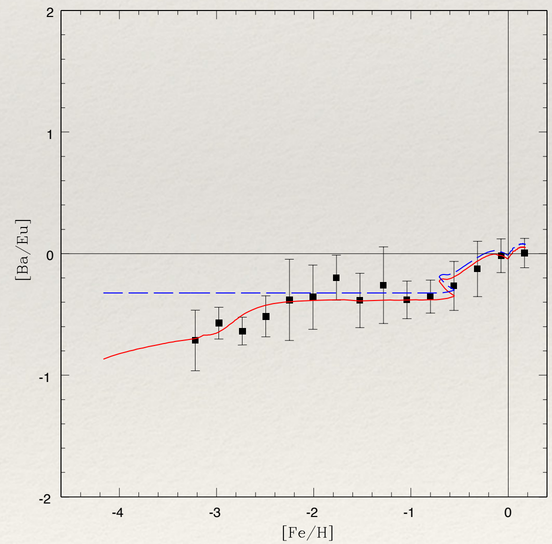
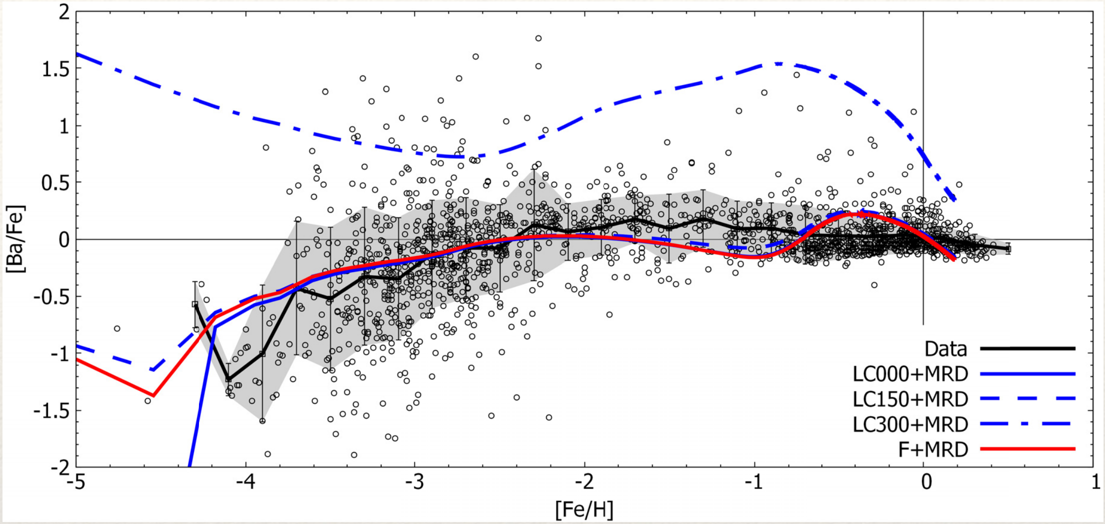
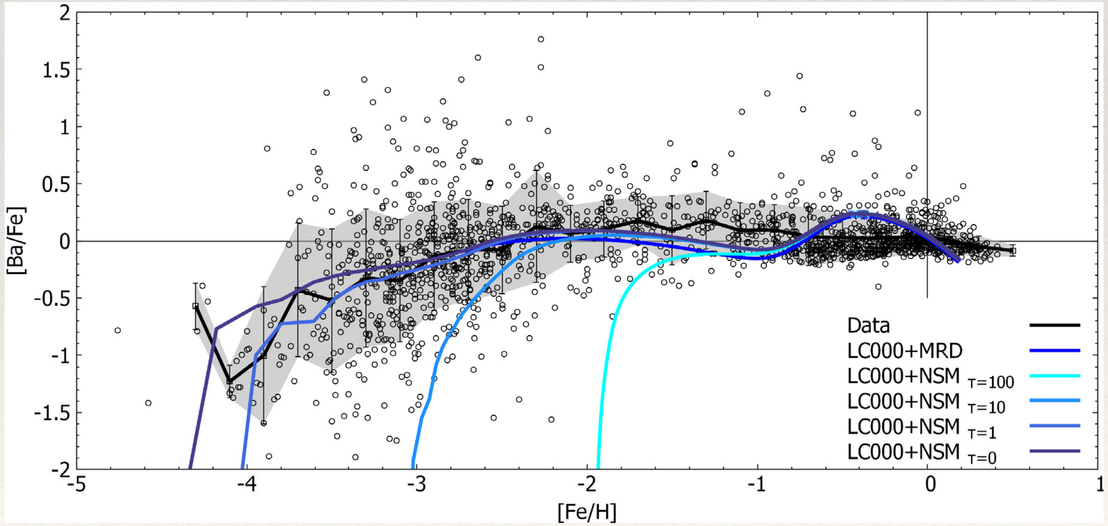


Fig. 9. In this Fig. we show the ratio of [Ba/Eu] versus [Fe/H]. The squares are the mean values of the data bins described in the table 6. As error bars we consider the standard deviation (see table 6). The results of model 1 are rappresented in solid line, the results of model 2 in long dashed line (models are described in table 2).

Discussion 1: r-process?

- Rizutti+18: Rotating Massive stars (RMS)
  - r-process from NSM or Magneto-Rotationally Driven (MRD) SNe
  - The origin of Ba at [Fe/H] < -2 is mostly r-process.

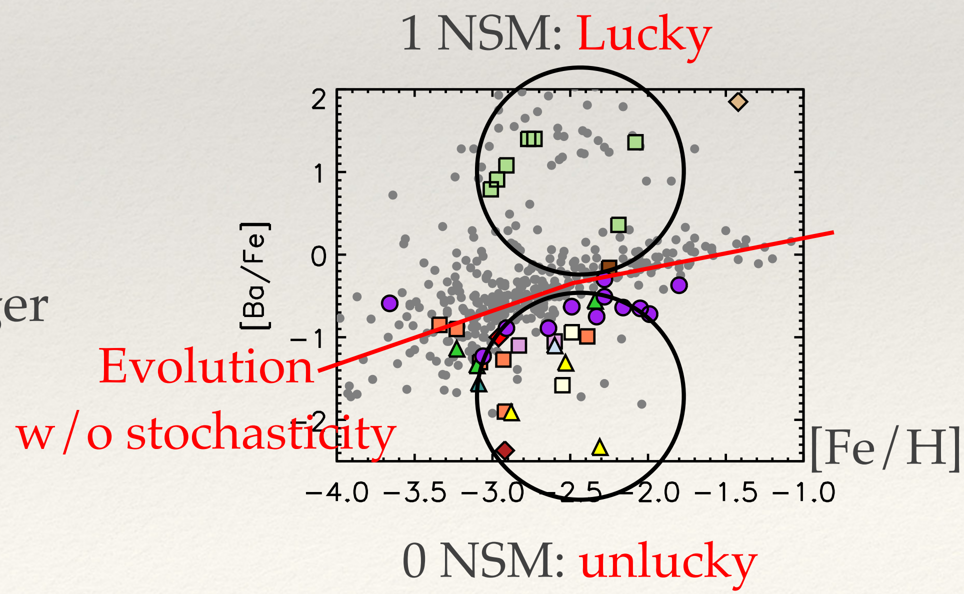




Rizutti+18

Discussion 1: r-process?

- The origin of Ba is "main" r-process and "main" s-process.
  - → (NSM or some other r-process) and (low-mass) AGB stars.
- **The stochasticity of r-process diversifies [Ba/Fe]: MW should be somewhere between Ret II (, Tuc III) and other UFDs.**
- If we fix [Fe/H]:
  - MW is at higher density peak.
  - MW is larger than UFDs because of larger mixing mass.
  - → **Stochasticity ("0 or 1"-ness) is more important in UFDs than in MW.**



Discussion 2: difference among UFDs

- If we assume that IMF depends only on metallicity, IMF should be similar in any UFDs.
- How can we make UFDs with diverse [Ba/Fe] (-0.5 ~ -2.5), except for Ret II, Tuc III and Gru II?
  - SFH: Galaxies with long star formation duration has higher [Ba/Fe] than lower ones. **However, it enhances scatter within each UFD**.
  - The r-process: All the UFDs with [Ba/Fe] ~ -0.5 actually have Eu from the stochastic r-process, but below the detection limit.
  - Another stochastic event: It can be r- or s- process. Roughly $1/10^4$ Msun of stars formed
- Or, IMF depends on other conditions?

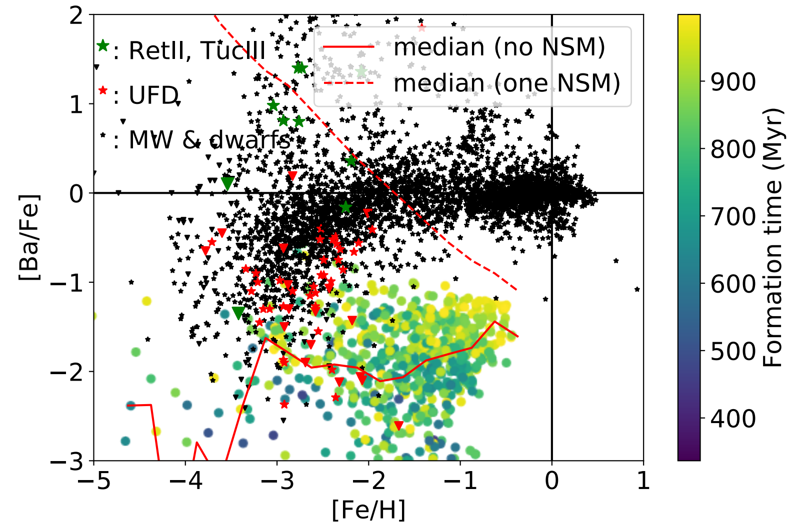
Conclusion

- Low [Ba/Fe] of UFDs (than MW) can be attributed to two facts:
  - Short star formation duration.
  - No r-process contribution.
- We need to enhance Ba production.
  - Only super-AGB seems not enough.
  - Top-heavy IMF seems to have an opposite effect. However, we can tune the IMF to reproduce Ba abundance.
  - Rotating massive stars seems too much (?)

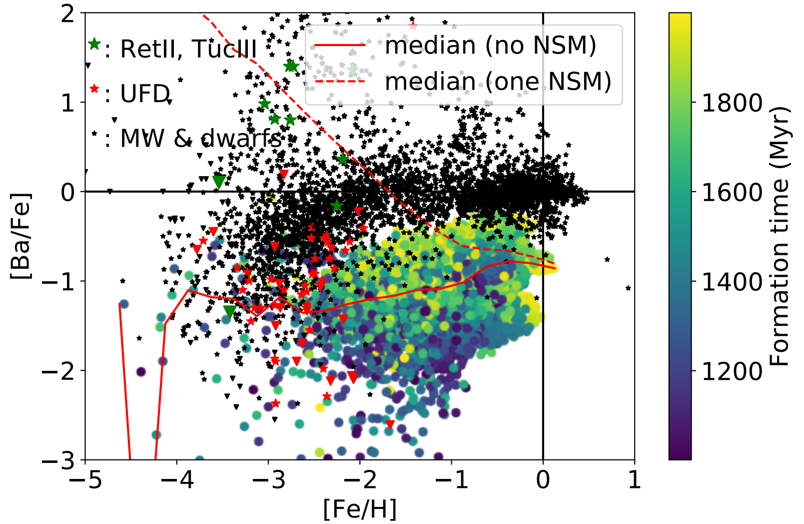
Results, MW-like

- Formation epochs are important for [Ba/Fe].
- [Ba/Fe] increases as it ages, even if [Fe/H] are the same.

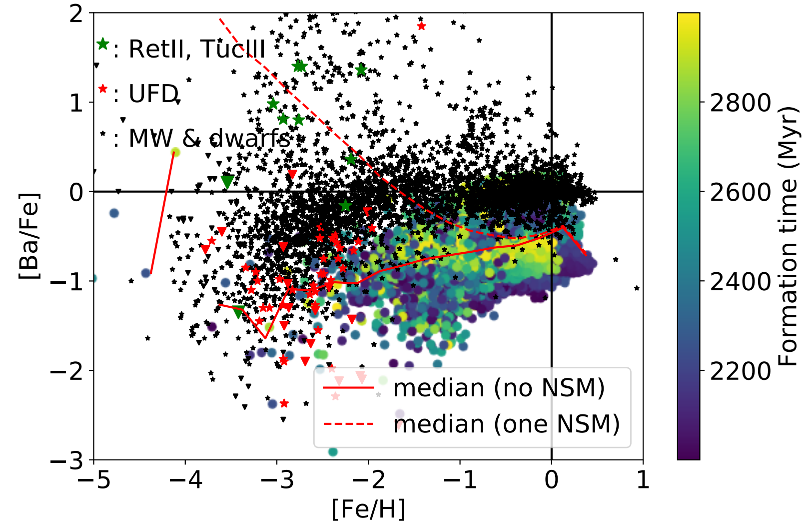
First 1Gyr



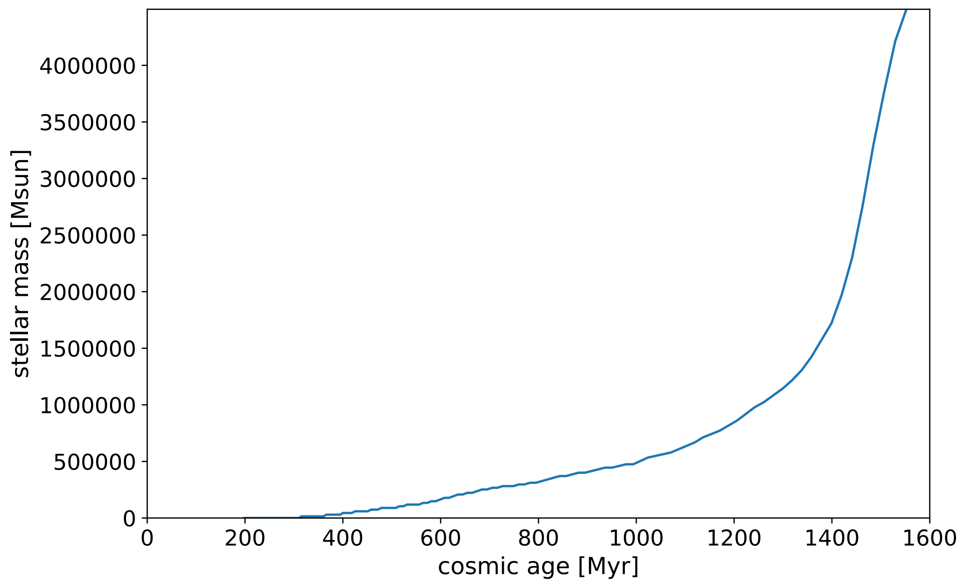
1Gyr < M_{form} < 2Gyr

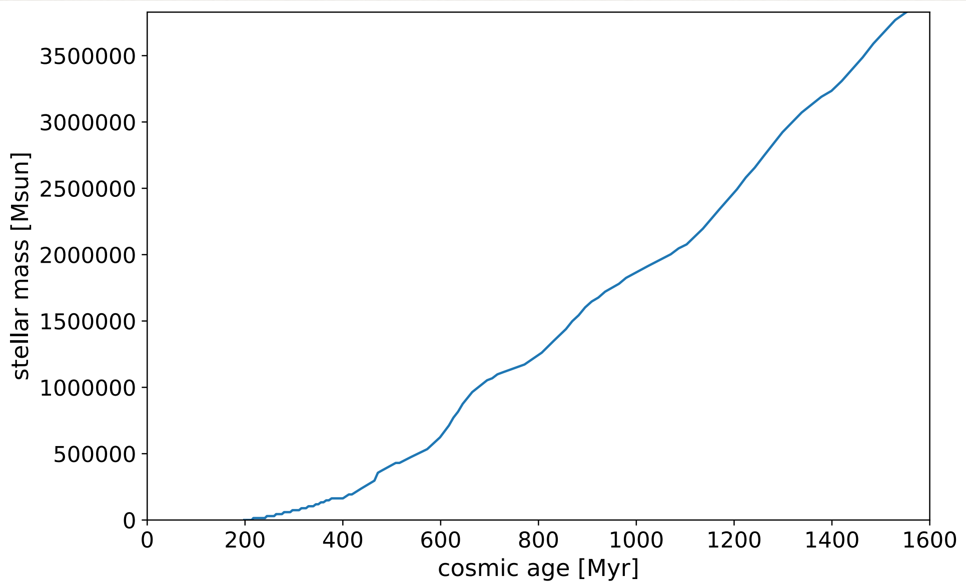


2Gyr < M_{form} < 3Gyr

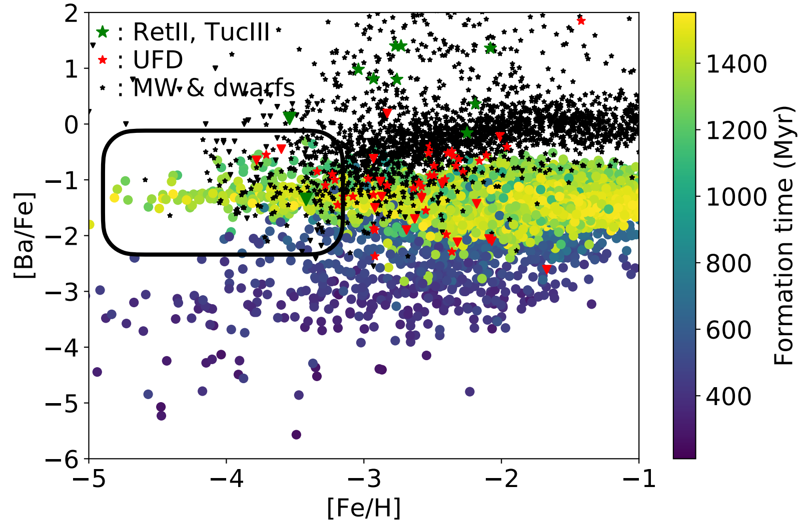


Results, dwarf

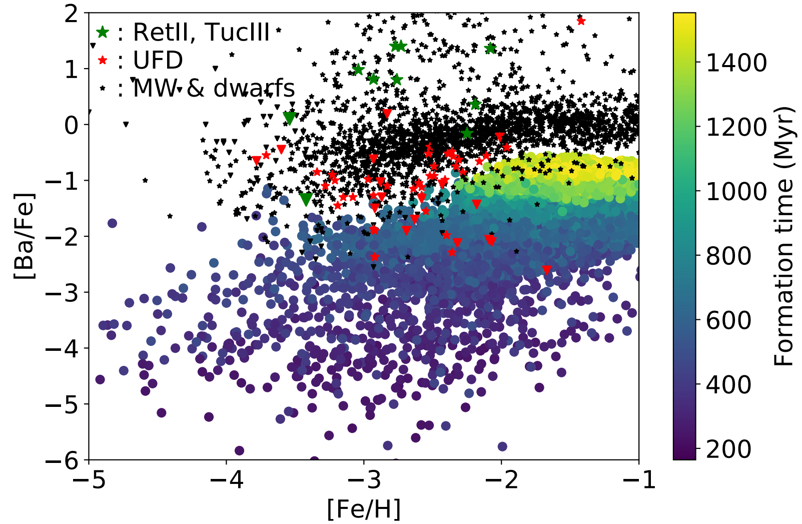




First 1Gyr



2Gyr < M_{form} < 3Gyr



dwarf & UFD list

Simon+19

Dwarf	M_V	$R_{1/2}$ (pc)	Distance (kpc)	v_{hel} (km s^{-1})	σ (km s^{-1})	[Fe/H]	$\sigma_{[Fe/H]}$
Tucana IV	$-3.50^{+0.28}_{-0.28}$	127^{+26}_{-22}	$48.0^{+4.0}_{-4.0}$				
Sculptor	$-10.82^{+0.14}_{-0.14}$	279^{+16}_{-16}	$86.0^{+5.0}_{-5.0}$	$111.4^{+0.1}_{-0.1}$	$9.2^{+1.1}_{-1.1}$	$-1.73^{+0.03}_{-0.02}$	$0.44^{+0.02}_{-0.02}$
Cetus II	$0.00^{+0.68}_{-0.68}$	17^{+9}_{-5}	$30.0^{+3.0}_{-3.0}$				
Cetus III	$-2.45^{+0.57}_{-0.56}$	90^{+32}_{-14}	$251.0^{+24.0}_{-11.0}$				
Triangulum II	$-1.60^{+0.76}_{-0.76}$	16^{+4}_{-4}	$28.4^{+1.6}_{-1.6}$	$-381.7^{+1.1}_{-1.1}$	< 3.4[c]	$-2.24^{+0.05}_{-0.05}$	$0.53^{+0.12}_{-0.38}$
Segue 2	$-1.98^{+0.88}_{-0.88}$	40^{+4}_{-4}	$37.0^{+3.0}_{-3.0}$	$-40.2^{+0.9}_{-0.9}$	< 2.2[c]	$-2.14^{+0.16}_{-0.15}$	$0.39^{+0.12}_{-0.13}$
DESJ0225+0304	$-1.10^{+0.50}_{-0.30}$	19^{+9}_{-5}	$23.8^{+0.7}_{-0.5}$				
Hydrus I	$-4.71^{+0.08}_{-0.08}$	53^{+4}_{-4}	$27.6^{+0.5}_{-0.5}$	$80.4^{+0.6}_{-0.6}$	$2.7^{+0.5}_{-0.4}$	$-2.52^{+0.09}_{-0.09}$	$0.41^{+0.08}_{-0.08}$
Fornax	$-13.34^{+0.14}_{-0.14}$	792^{+18}_{-18}	$139.0^{+3.0}_{-3.0}$	$55.2^{+0.1}_{-0.1}$	$11.7^{+0.9}_{-0.9}$	$-1.07^{+0.02}_{-0.01}$	$0.27^{+0.01}_{-0.01}$
Horologium I	$-3.76^{+0.56}_{-0.56}$	40^{+10}_{-9}	$87.0^{+13.0}_{-11.0}$	$112.8^{+2.5}_{-2.6}$	$4.9^{+2.8}_{-0.9}$	$-2.76^{+0.10}_{-0.10}$	$0.17^{+0.20}_{-0.03}$
Horologium II	$-1.56^{+1.02}_{-1.02}$	44^{+15}_{-14}	$78.0^{+8.0}_{-7.0}$				
Reticulum II	$-3.99^{+0.38}_{-0.38}$	51^{+3}_{-3}	$31.6^{+1.5}_{-1.4}$	$62.8^{+0.5}_{-0.5}$	$3.3^{+0.7}_{-0.7}$	$-2.65^{+0.07}_{-0.07}$	$0.28^{+0.09}_{-0.09}$
Eridanus II	$-7.10^{+0.30}_{-0.30}$	246^{+17}_{-17}	$366.0^{+17.0}_{-17.0}$	$75.6^{+1.3}_{-1.3}$	$6.9^{+1.2}_{-0.9}$	$-2.38^{+0.13}_{-0.13}$	$0.47^{+0.12}_{-0.09}$
Reticulum III	$-3.30^{+0.29}_{-0.29}$	64^{+26}_{-23}	$92.0^{+13.0}_{-13.0}$				
Pictor I	$-3.67^{+0.60}_{-0.60}$	32^{+15}_{-15}	$126.0^{+19.0}_{-16.0}$				
Columba I	$-4.20^{+0.20}_{-0.20}$	117^{+12}_{-12}	$183.0^{+10.0}_{-10.0}$				
Carina	$-9.45^{+0.05}_{-0.05}$	311^{+15}_{-15}	$106.0^{+5.0}_{-5.0}$	$222.9^{+0.1}_{-0.1}$	$6.6^{+1.2}_{-1.2}$	$-1.80^{+0.02}_{-0.02}$	0.24[d]
Pictor II	$-3.20^{+0.40}_{-0.50}$	47^{+20}_{-13}	$45.0^{+5.0}_{-4.0}$				
Carina II	$-4.50^{+0.10}_{-0.10}$	92^{+8}_{-8}	$36.2^{+0.6}_{-0.6}$	$477.2^{+1.2}_{-1.2}$	$3.4^{+1.2}_{-0.8}$	$-2.44^{+0.09}_{-0.09}$	$0.22^{+0.10}_{-0.07}$
Carina III	$-2.40^{+0.20}_{-0.20}$	30^{+8}_{-8}	$27.8^{+0.6}_{-0.6}$	$284.6^{+3.4}_{-3.1}$	$5.6^{+4.3}_{-2.1}$		
Ursa Major II	$-4.43^{+0.26}_{-0.26}$	139^{+9}_{-9}	$34.7^{+2.0}_{-1.9}$	$-116.5^{+1.9}_{-1.9}$	$5.6^{+1.4}_{-1.4}$	$-2.23^{+0.21}_{-0.24}$	$0.67^{+0.20}_{-0.15}$
Leo T	-8.00[e]	118^{+11}_{-11}	$409.0^{+29.0}_{-27.0}$	$38.1^{+2.0}_{-2.0}$	$7.5^{+1.6}_{-1.6}$	$-1.91^{+0.12}_{-0.14}$	$0.43^{+0.13}_{-0.09}$
Segue 1	$-1.30^{+0.73}_{-0.73}$	24^{+4}_{-4}	$23.0^{+2.0}_{-2.0}$	$208.5^{+0.9}_{-0.9}$	$3.7^{+1.4}_{-1.1}$	$-2.71^{+0.45}_{-0.39}$	$0.95^{+0.42}_{-0.26}$

Dwarf	M_V	$R_{1/2}$ (pc)	Distance (kpc)	v_{hel} (km s^{-1})	σ (km s^{-1})	[Fe/H]	$\sigma_{[Fe/H]}$
Leo I	$-11.78^{+0.28}_{-0.28}$	270^{+17}_{-16}	$254.0^{+16.0}_{-15.0}$	$282.9^{+0.5}_{-0.5}$	$9.2^{+0.4}_{-0.4}$	$-1.48^{+0.02}_{-0.01}$	$0.26^{+0.01}_{-0.01}$
Sextans	$-8.94^{+0.06}_{-0.06}$	456^{+15}_{-15}	$95.0^{+3.0}_{-3.0}$	$224.3^{+0.1}_{-0.1}$	$7.9^{+1.3}_{-1.3}$	$-1.97^{+0.04}_{-0.04}$	$0.38^{+0.03}_{-0.03}$
Ursa Major I	$-5.13^{+0.38}_{-0.38}$	295^{+28}_{-28}	$97.3^{+6.0}_{-5.7}$	$-55.3^{+1.4}_{-1.4}$	$7.0^{+1.0}_{-1.0}$	$-2.16^{+0.11}_{-0.13}$	$0.62^{+0.10}_{-0.08}$
Willman 1	$-2.90^{+0.74}_{-0.74}$	33^{+8}_{-8}	$45.0^{+10.0}_{-10.0}$	$-14.1^{+1.0}_{-1.0}$	$4.0^{+0.8}_{-0.8}$	$-2.19^{+0.08}_{-0.08}$	
Leo II	$-9.74^{+0.04}_{-0.04}$	171^{+10}_{-10}	$233.0^{+14.0}_{-14.0}$	$78.3^{+0.6}_{-0.6}$	$7.4^{+0.4}_{-0.4}$	$-1.68^{+0.02}_{-0.03}$	$0.34^{+0.02}_{-0.02}$
Leo V	$-4.29^{+0.36}_{-0.36}$	49^{+16}_{-16}	$169.0^{+4.0}_{-4.0}$	$170.9^{+2.1}_{-1.9}$	$2.3^{+3.2}_{-1.6}$	$-2.48^{+0.21}_{-0.21}$	$0.47^{+0.23}_{-0.13}$
Leo IV	$-4.99^{+0.26}_{-0.26}$	114^{+13}_{-13}	$154.0^{+5.0}_{-5.0}$	$132.3^{+1.4}_{-1.4}$	$3.3^{+1.7}_{-1.7}$	$-2.29^{+0.19}_{-0.22}$	$0.56^{+0.19}_{-0.14}$
Crater II	$-8.20^{+0.10}_{-0.10}$	1066^{+86}_{-86}	$117.5^{+1.1}_{-1.1}$	$87.5^{+0.4}_{-0.4}$	$2.7^{+0.3}_{-0.3}$	$-1.98^{+0.10}_{-0.10}$	$0.22^{+0.04}_{-0.03}$
Virgo I	$-0.80^{+0.90}_{-0.90}$	38^{+12}_{-11}	$87.0^{+13.0}_{-8.0}$				
Hydra II	$-4.86^{+0.37}_{-0.37}$	67^{+13}_{-13}	$151.0^{+8.0}_{-7.0}$	$303.1^{+1.4}_{-1.4}$	< 3.6[c]	$-2.02^{+0.08}_{-0.08}$	$0.40^{+0.48}_{-0.26}$
Coma Berenices	$-4.28^{+0.25}_{-0.25}$	69^{+5}_{-4}	$42.0^{+1.6}_{-1.5}$	$98.1^{+0.9}_{-0.9}$	$4.6^{+0.8}_{-0.8}$	$-2.43^{+0.11}_{-0.11}$	$0.46^{+0.09}_{-0.08}$
Canes Venatici II	$-5.17^{+0.32}_{-0.32}$	71^{+11}_{-11}	$160.0^{+4.0}_{-4.0}$	$-128.9^{+1.2}_{-1.2}$	$4.6^{+1.0}_{-1.0}$	$-2.35^{+0.16}_{-0.19}$	$0.57^{+0.15}_{-0.12}$
Canes Venatici I	$-8.73^{+0.06}_{-0.06}$	437^{+18}_{-18}	$211.0^{+6.0}_{-6.0}$	$30.9^{+0.6}_{-0.6}$	$7.6^{+0.4}_{-0.4}$	$-1.91^{+0.04}_{-0.04}$	$0.39^{+0.03}_{-0.02}$
Boötes II	$-2.94^{+0.74}_{-0.75}$	39^{+5}_{-5}	$42.0^{+1.0}_{-1.0}$	$-117.0^{+5.2}_{-5.2}$	$10.5^{+7.4}_{-7.4}$	$-2.79^{+0.06}_{-0.10}$	< 0.35[c]
Boötes I	$-6.02^{+0.25}_{-0.25}$	191^{+8}_{-8}	$66.0^{+2.0}_{-2.0}$	$101.8^{+0.7}_{-0.7}$	$4.6^{+0.8}_{-0.6}$	$-2.35^{+0.09}_{-0.08}$	$0.44^{+0.07}_{-0.06}$
Ursa Minor	$-9.03^{+0.05}_{-0.05}$	405^{+21}_{-21}	$76.0^{+4.0}_{-4.0}$	$-247.2^{+0.8}_{-0.8}$	$9.5^{+1.2}_{-1.2}$	$-2.12^{+0.03}_{-0.02}$	$0.33^{+0.02}_{-0.03}$
Draco II	$-0.80^{+0.40}_{-1.00}$	19^{+4}_{-3}	$21.5^{+0.4}_{-0.4}$	$-342.5^{+1.1}_{-1.2}$	< 5.9[c]	$-2.70^{+0.10}_{-0.10}$	< 0.24[c]
Hercules	$-5.83^{+0.17}_{-0.17}$	216^{+20}_{-20}	$132.0^{+6.0}_{-6.0}$	$45.0^{+1.1}_{-1.1}$	$5.1^{+0.9}_{-0.9}$	$-2.47^{+0.13}_{-0.12}$	$0.47^{+0.11}_{-0.08}$
Draco	$-8.88^{+0.05}_{-0.05}$	231^{+17}_{-17}	$82.0^{+6.0}_{-6.0}$	$-290.7^{+0.7}_{-0.8}$	$9.1^{+1.2}_{-1.2}$	$-2.00^{+0.02}_{-0.02}$	$0.34^{+0.02}_{-0.02}$
Sagittarius	$-13.50^{+0.15}_{-0.15}$	2662^{+193}_{-193}	$26.7^{+1.3}_{-1.3}$	$139.4^{+0.6}_{-0.6}$	$9.6^{+0.4}_{-0.4}$	$-0.53^{+0.03}_{-0.02}$	$0.17^{+0.02}_{-0.02}$
Sagittarius II	$-5.20^{+0.10}_{-0.10}$	33^{+2}_{-2}	$70.1^{+2.3}_{-2.3}$				
Indus II	$-4.30^{+0.19}_{-0.19}$	181^{+70}_{-64}	$214.0^{+16.0}_{-16.0}$				
Grus II	$-3.90^{+0.22}_{-0.22}$	93^{+16}_{-12}	$53.0^{+5.0}_{-5.0}$				

Sun: Mv = 4.8

100 Lsun = -0.2

10^4 Lsun = -5.2

10^5 Lsun = -7.7

Dwarf	M_V	$R_{1/2}$ (pc)	Distance (kpc)	v_{hel} (km s^{-1})	σ (km s^{-1})	[Fe/H]	$\sigma_{[Fe/H]}$
Pegasus III	$-4.10^{+0.50}_{-0.50}$	78^{+31}_{-25}	$205.0^{+20.0}_{-20.0}$	$-222.9^{+2.6}_{-2.6}$	$5.4^{+3.0}_{-2.5}$	$-2.40^{+0.15}_{-0.15}$	
Aquarius II	$-4.36^{+0.14}_{-0.14}$	160^{+26}_{-26}	$107.9^{+3.3}_{-3.3}$	$-71.1^{+2.5}_{-2.5}$	$5.4^{+3.4}_{-0.9}$	$-2.30^{+0.50}_{-0.50}$	
Tucana II	$-3.90^{+0.20}_{-0.20}$	121^{+35}_{-35}	$58.0^{+8.0}_{-8.0}$	$-129.1^{+3.5}_{-3.5}$	$8.6^{+4.4}_{-2.7}$	$-2.90^{+0.15}_{-0.16}$	$0.29^{+0.15}_{-0.12}$
Grus I	$-3.47^{+0.59}_{-0.59}$	28^{+23}_{-23}	$120.0^{+12.0}_{-11.0}$	$-140.5^{+2.4}_{-1.6}$	$2.9^{+2.1}_{-1.0}$	$-1.42^{+0.55}_{-0.42}$	$0.41^{+0.49}_{-0.23}$
Pisces II	$-4.23^{+0.38}_{-0.38}$	60^{+10}_{-10}	$183.0^{+15.0}_{-15.0}$	$-226.5^{+2.7}_{-2.7}$	$5.4^{+3.6}_{-2.4}$	$-2.45^{+0.07}_{-0.07}$	$0.48^{+0.70}_{-0.29}$
Tucana V	$-1.60^{+0.49}_{-0.49}$	16^{+5}_{-5}	$55.0^{+9.0}_{-9.0}$				
Phoenix II	$-2.70^{+0.40}_{-0.40}$	37^{+8}_{-8}	$84.3^{+4.0}_{-4.0}$				
Tucana III	$-1.49^{+0.20}_{-0.20}$	37^{+9}_{-9}	$25.0^{+2.0}_{-2.0}$	$-102.3^{+0.4}_{-0.4}$	< 1.2[c]	$-2.42^{+0.07}_{-0.08}$	< 0.19[c]