



Universal properties of the high- and low-a disk: small intrinsic abundance scatter and migrating stars

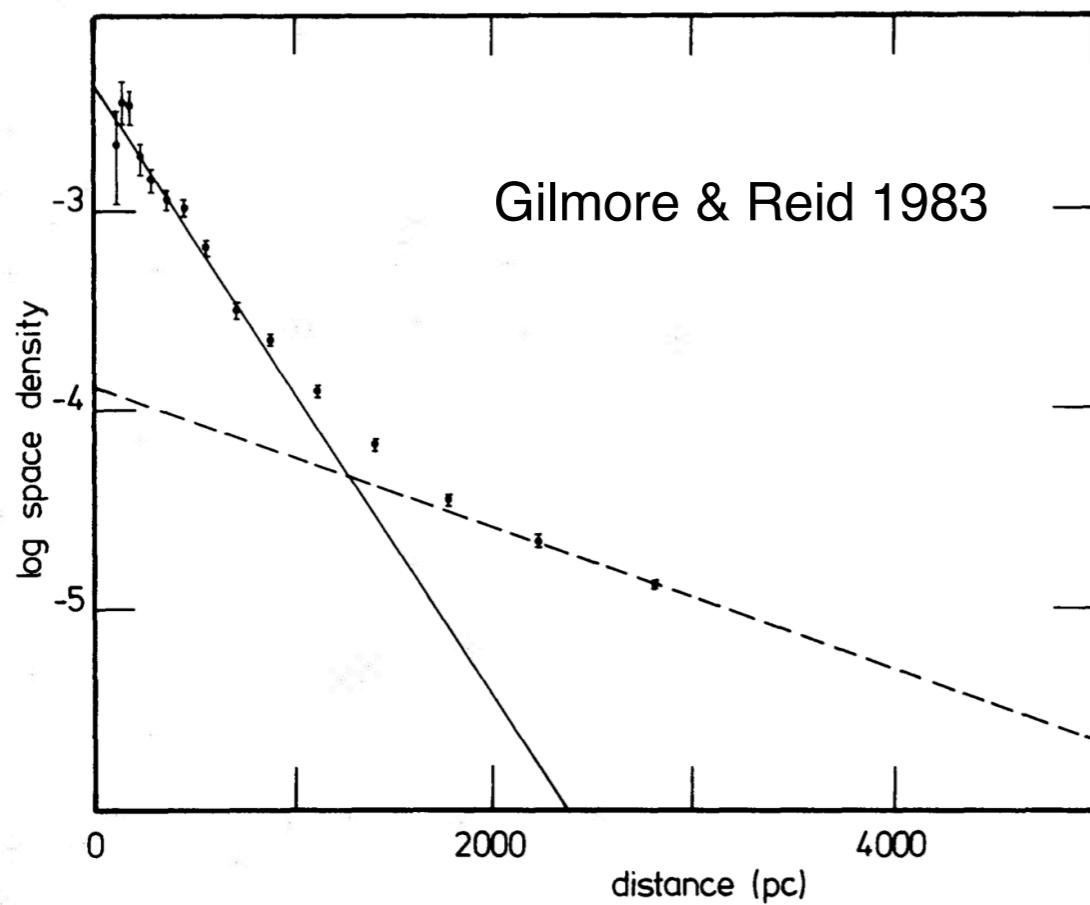
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2. American Museum of Natural History, Central Park West, Manhattan, NY, USA
3. Leibniz Institute for Astrophysics Potsdam, An der Sternwarte 16, 14482 Potsdam, Germany

Outline

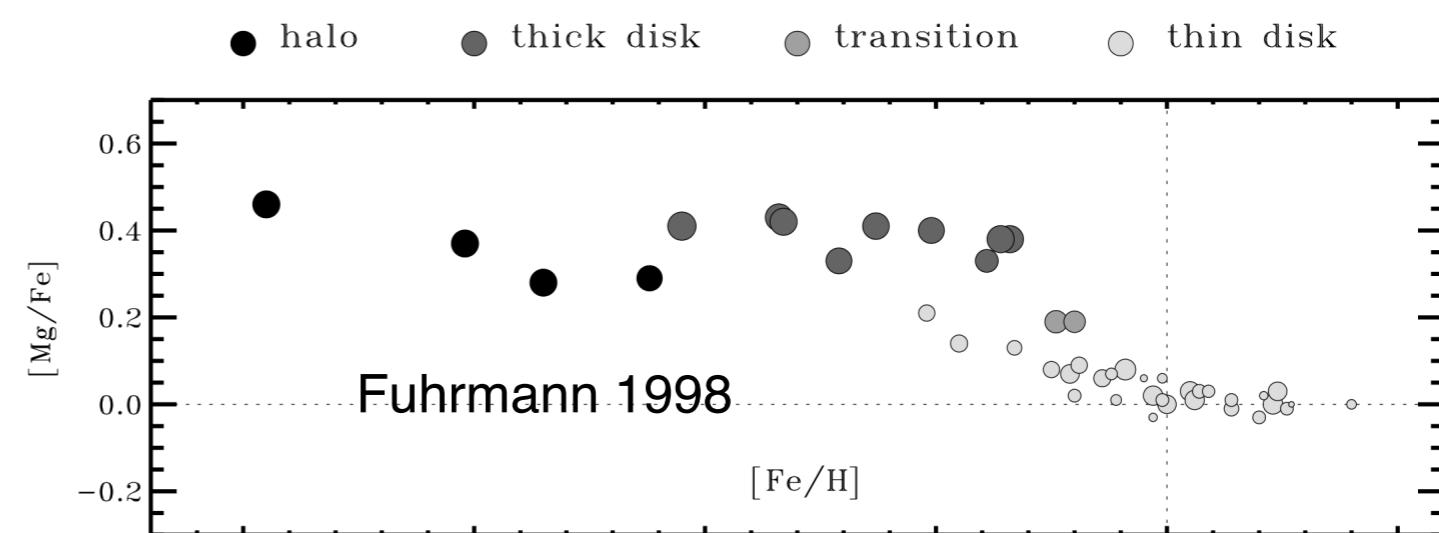
- Motivation: History of high- and low- a disk
- Data/Method
- Results:
 - Global age distribution
 - Age distribution in mono-spatial/chemical bins
 - Age-metallicity relation
 - Detailed age-element abundance relation
- If we have time:
 - Stellar ages for all stars with spectra?

Motivation: History of high- and low-a disk



Gilmore & Reid 1983

2 different scale
heights ->
kinematic “thin”
and “thick” disk



Fuhrmann 1998

[Fe/H]

Bi-modality ->
chemical high- and
low-a disk

Two disks has different formation history.
- Understand the similarities and differences
- Provide clues for models from data

Data/Method: APOGEE DR16 & The Cannon

2,616 stars with asteroseismic ages, temperature, logg, metallicity (APOKASC), period spacing (ΔP) and frequency spacing (Δv) (Vrard+2016)

Training
stars

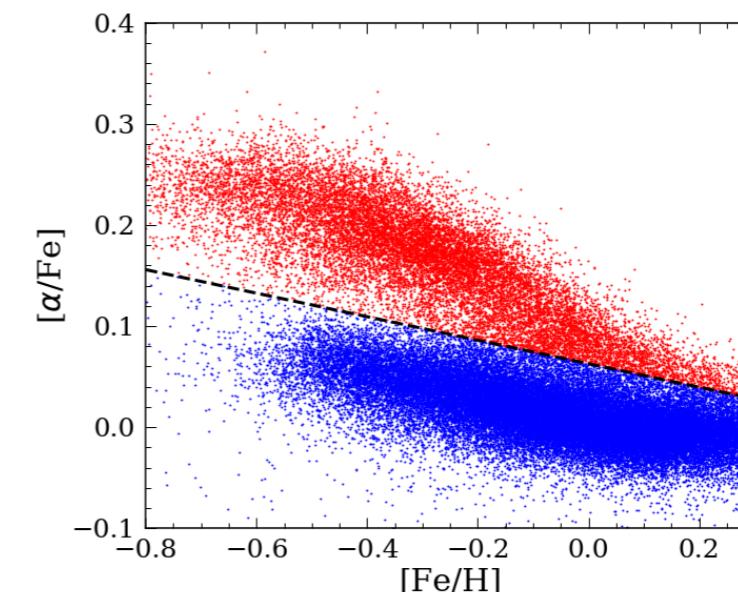
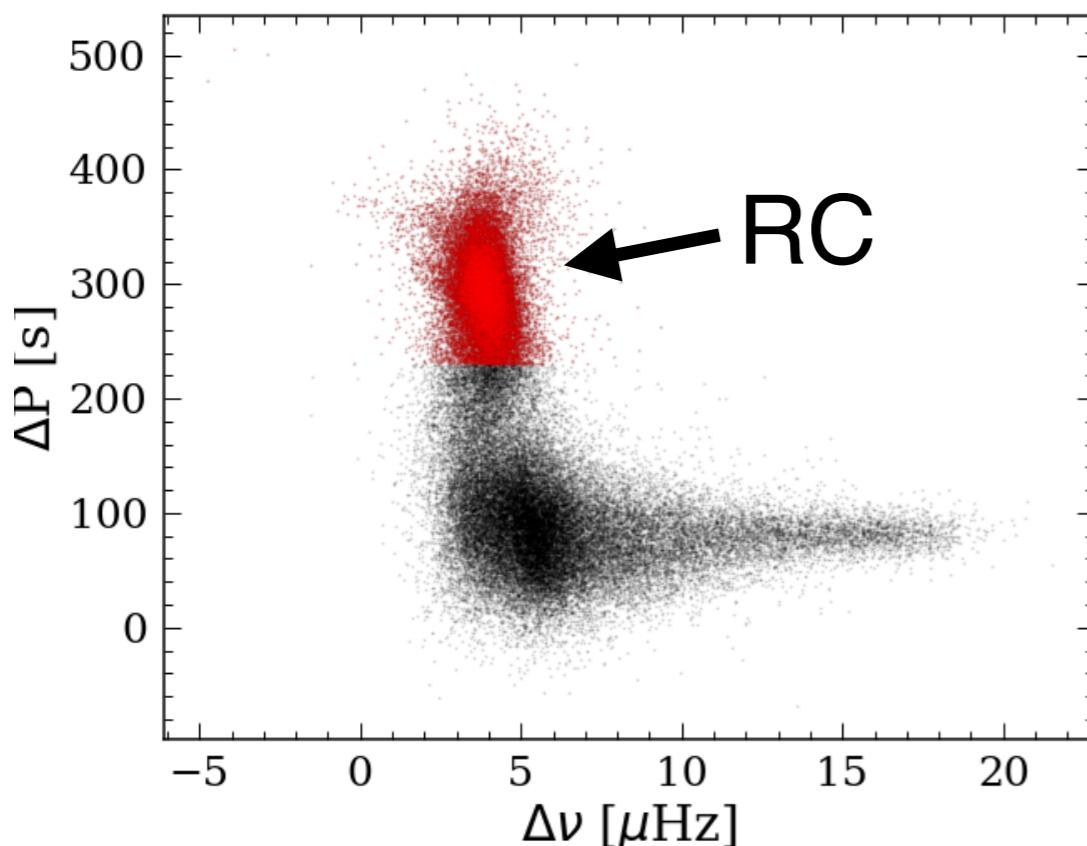


The Cannon

Tool

64,399 Giant stars, 22,074 Red clump stars (age error 1.9 Gyr, contamination rate for RC 2.7%)

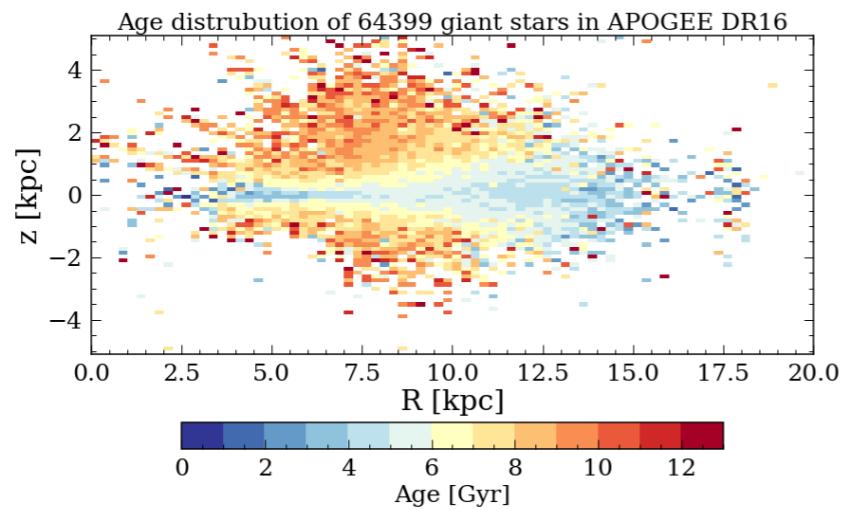
Result



Separating **high- α** and **low- α**
disk with a line

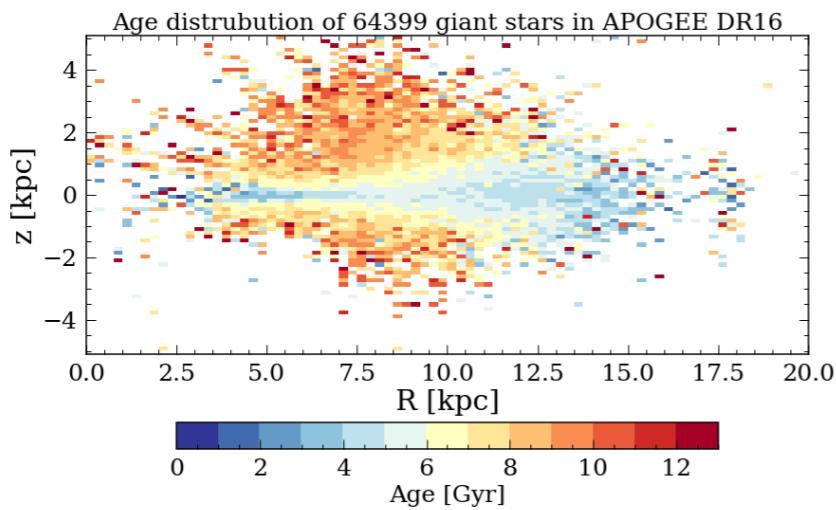
Results: Global age distribution

All

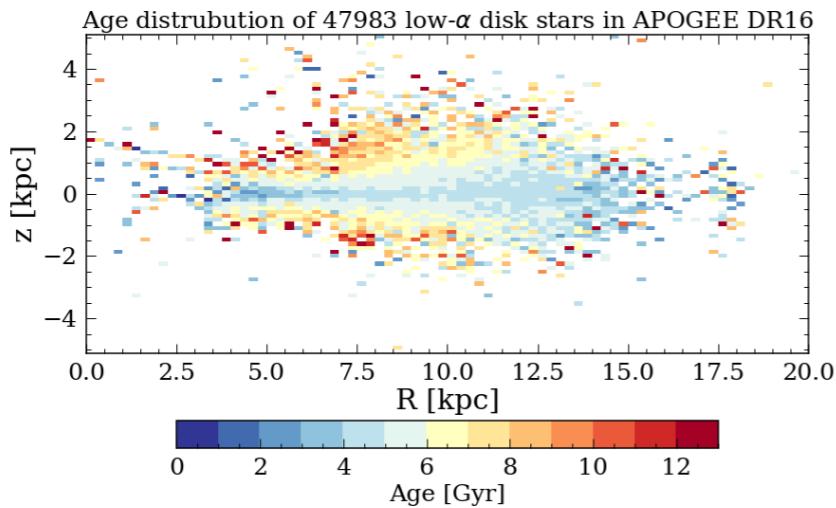


Results: Global age distribution

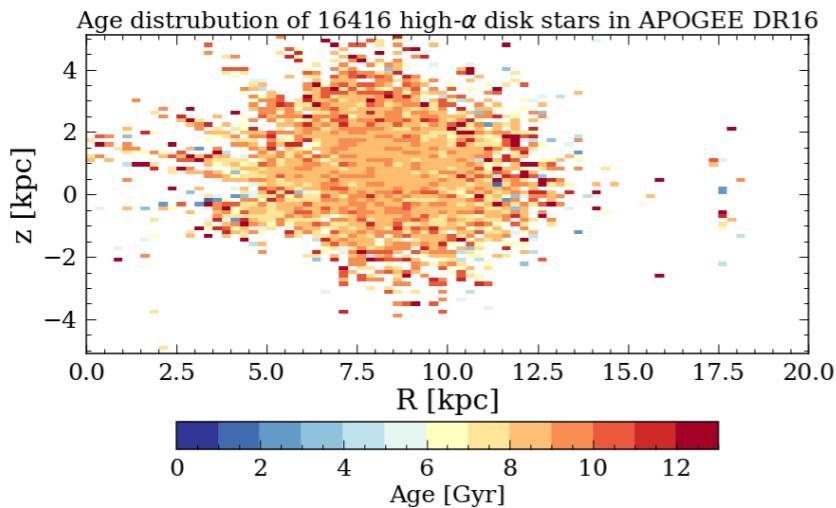
All



low- α

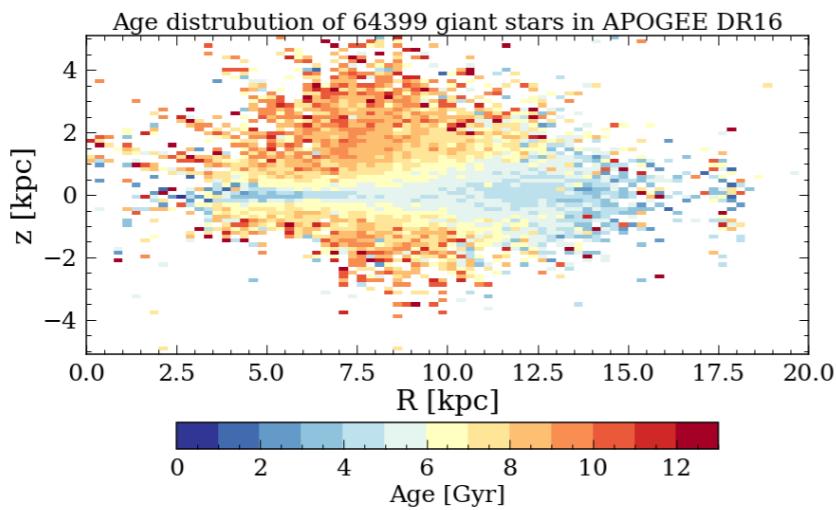


high- α

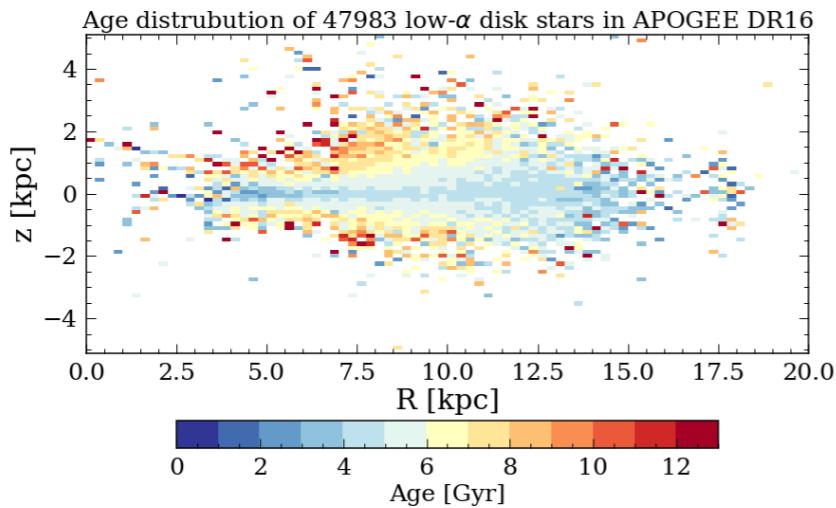


Results: Global age distribution

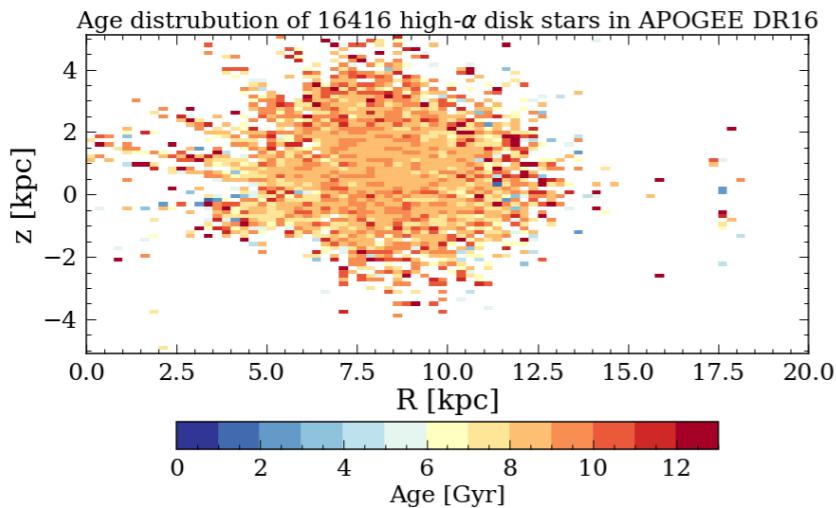
All



low- α
(Young)

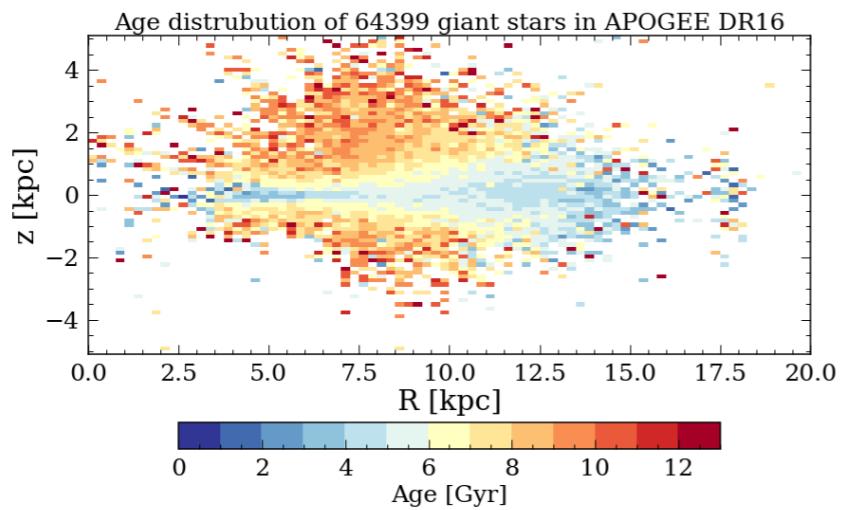


high- α
(old)

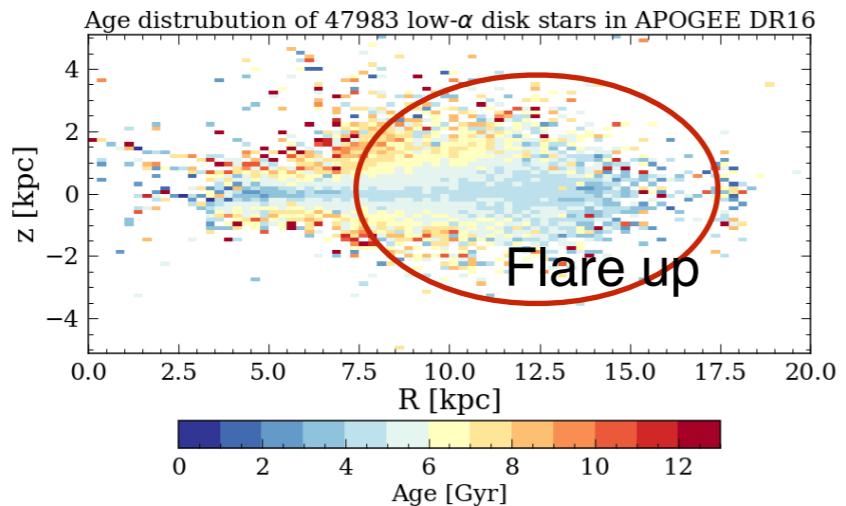


Results: Global age distribution

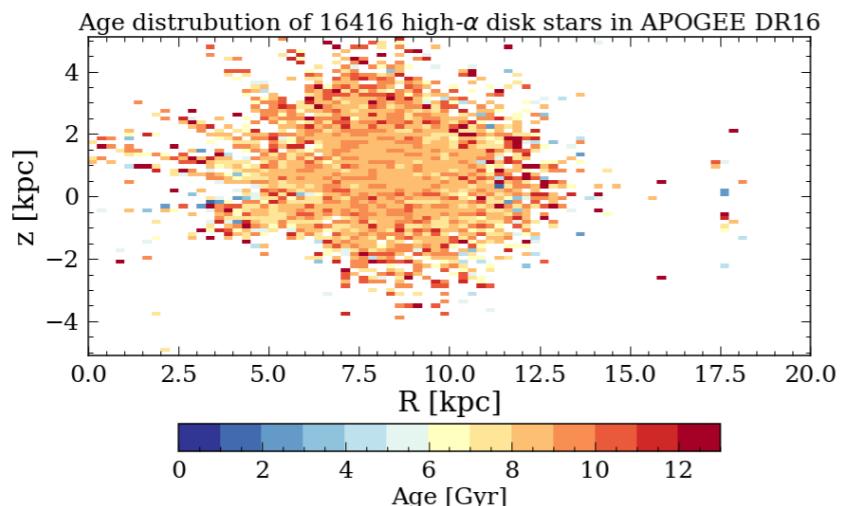
All



low- α
(Young)

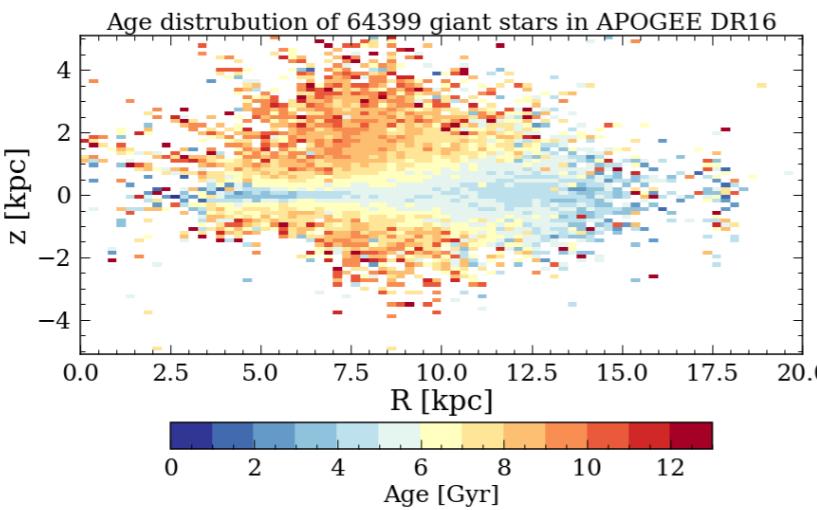


high- α
(old)

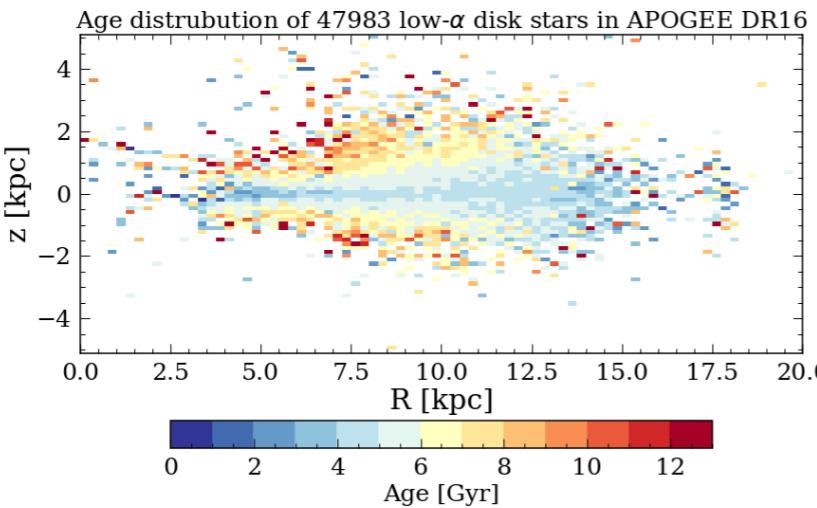


Results: Global age distribution

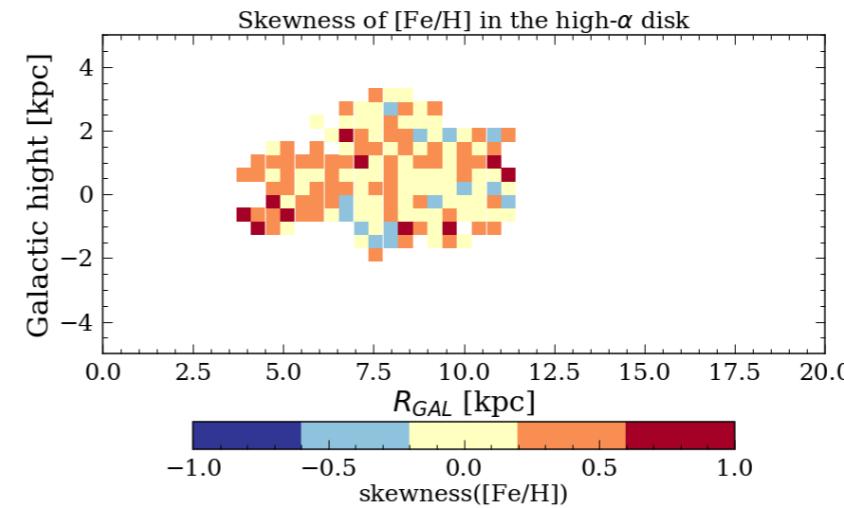
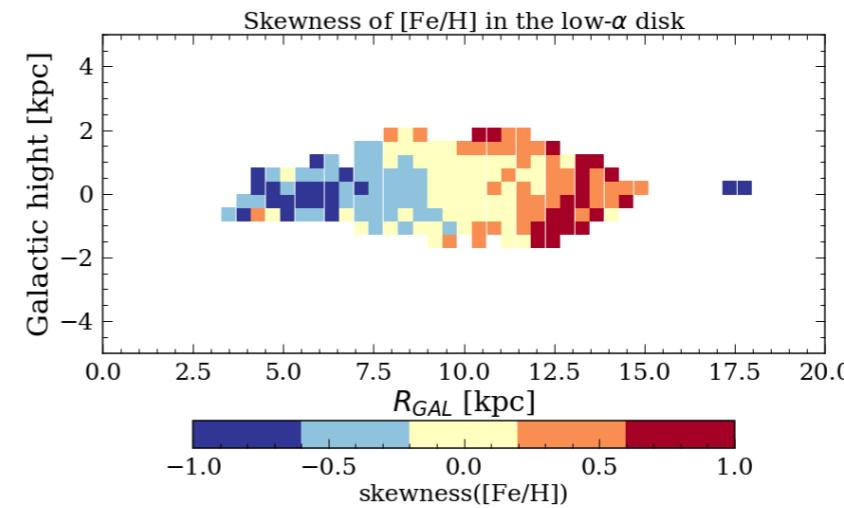
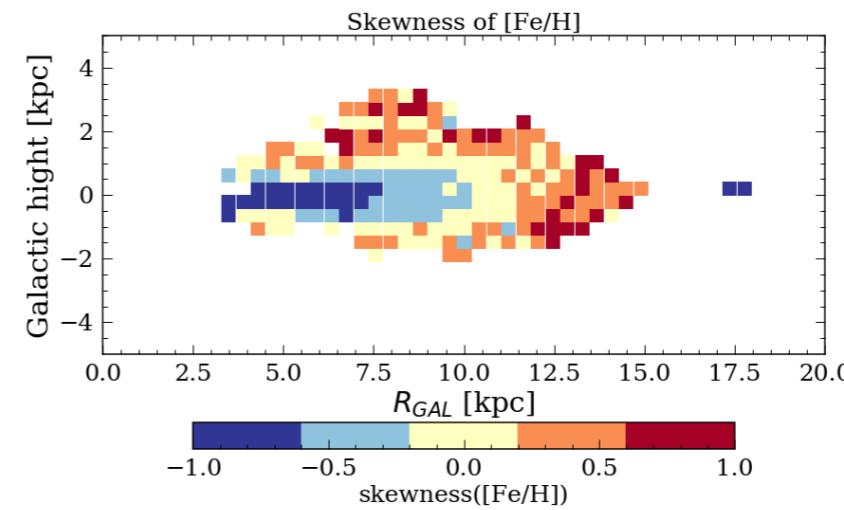
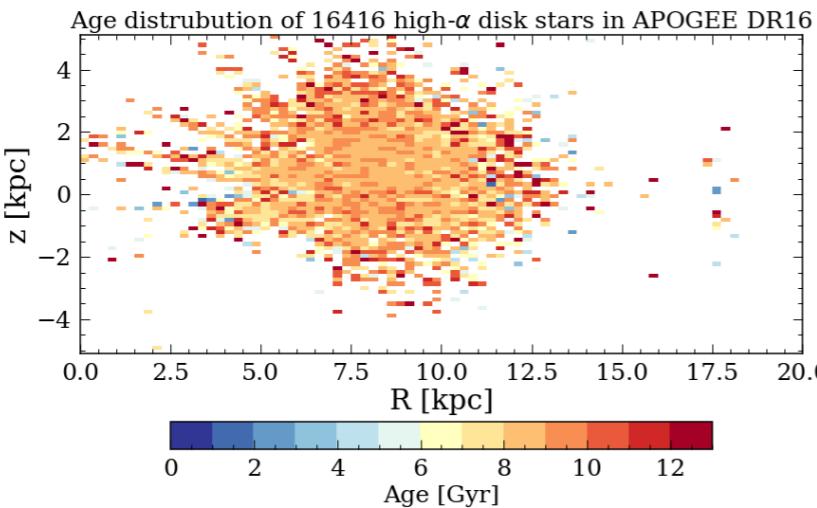
All



low- α
(Young)

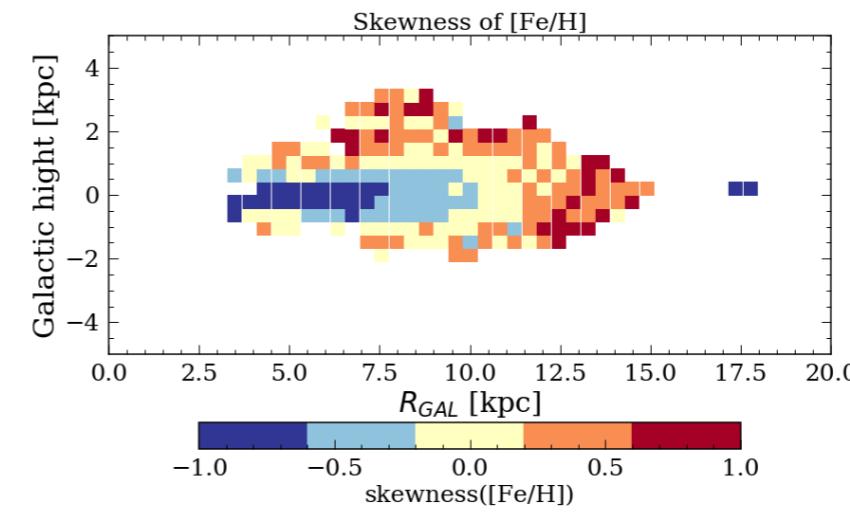
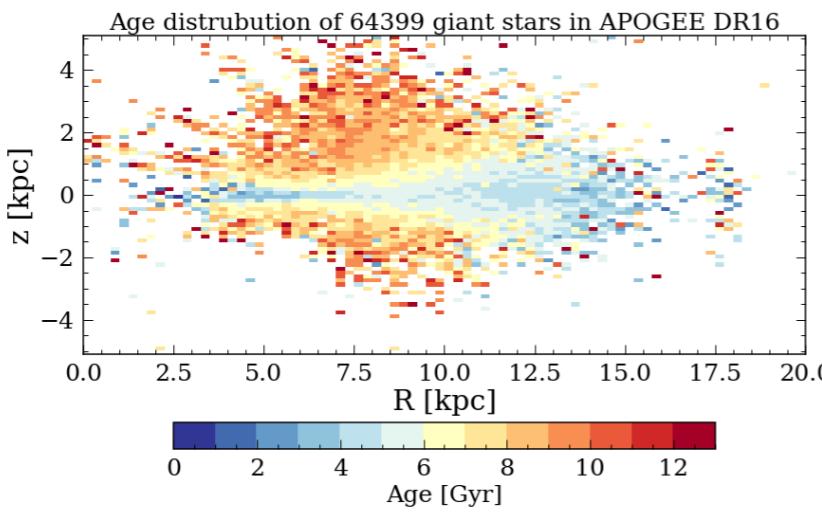


high- α
(old)

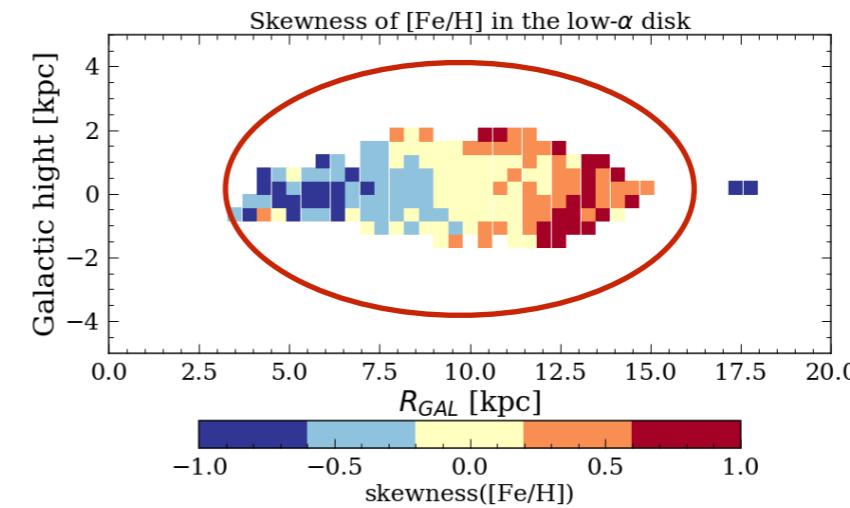
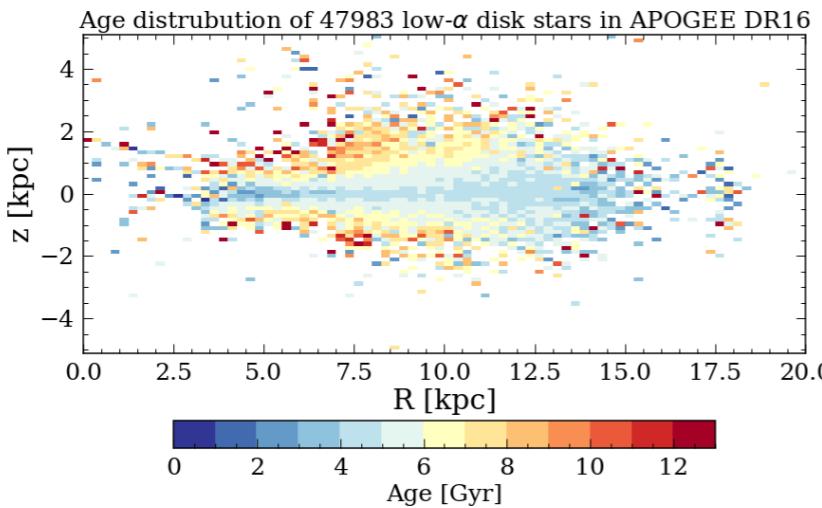


Results: Global age distribution

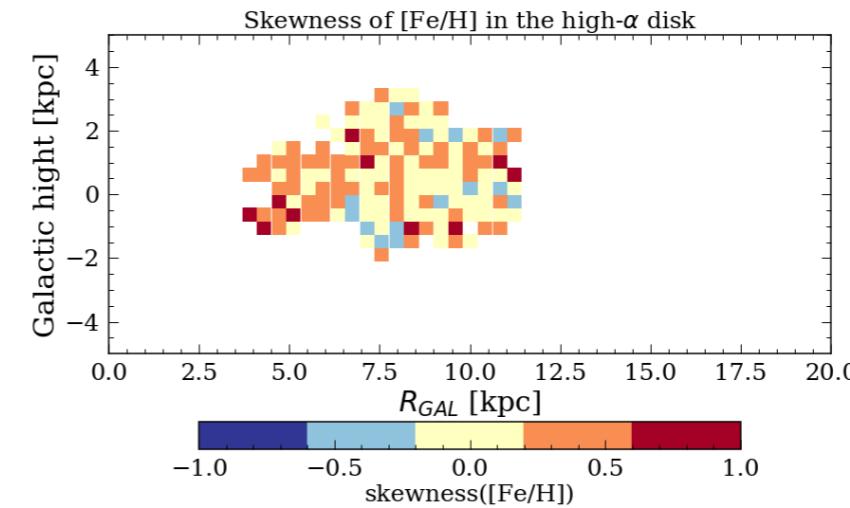
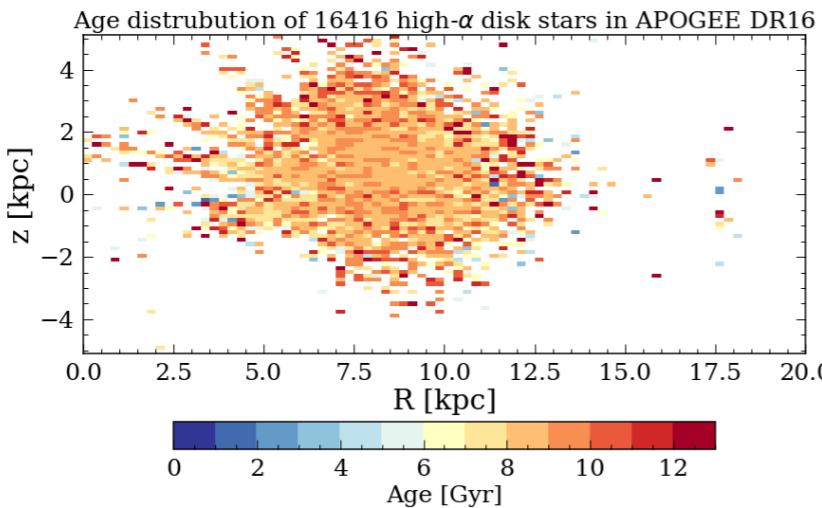
All



low- α
(Young)



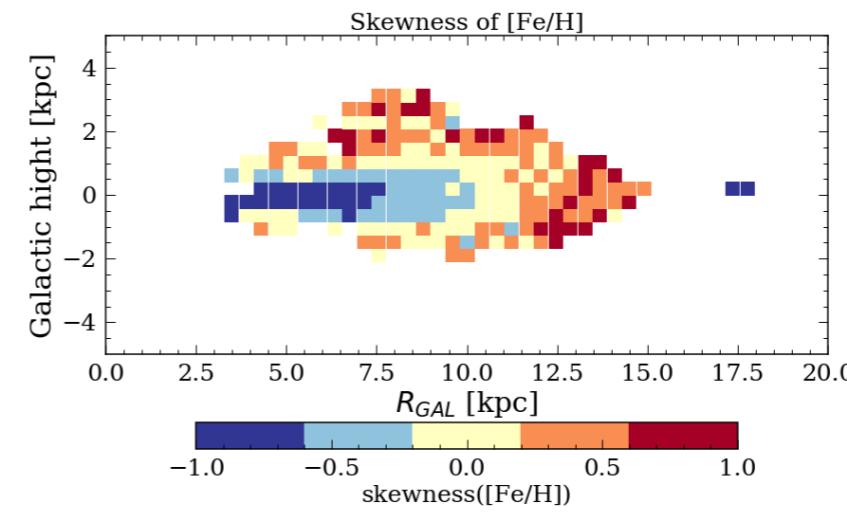
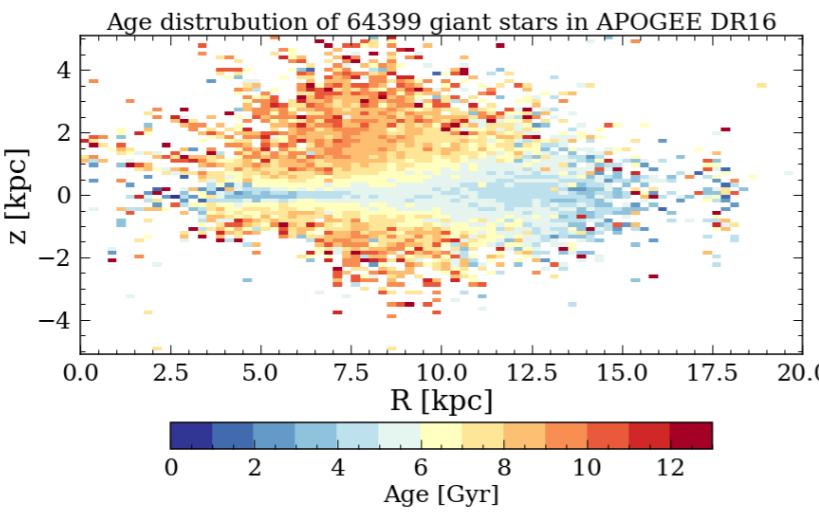
high- α
(old)



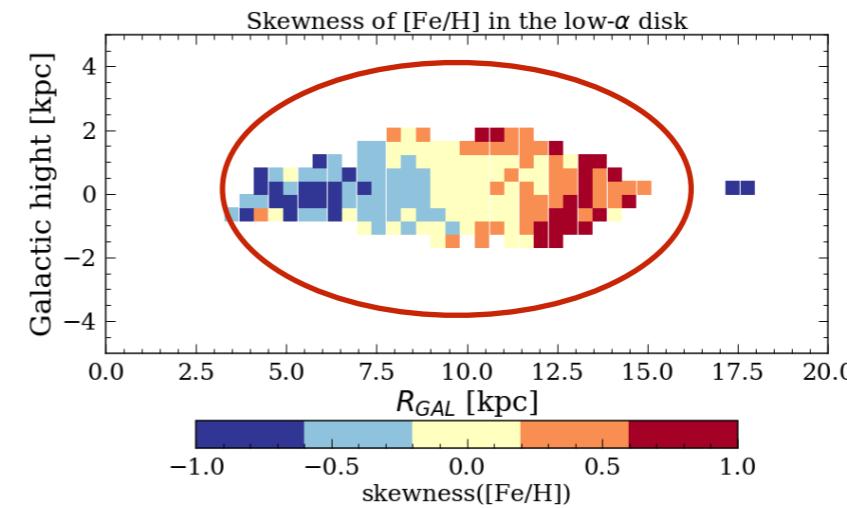
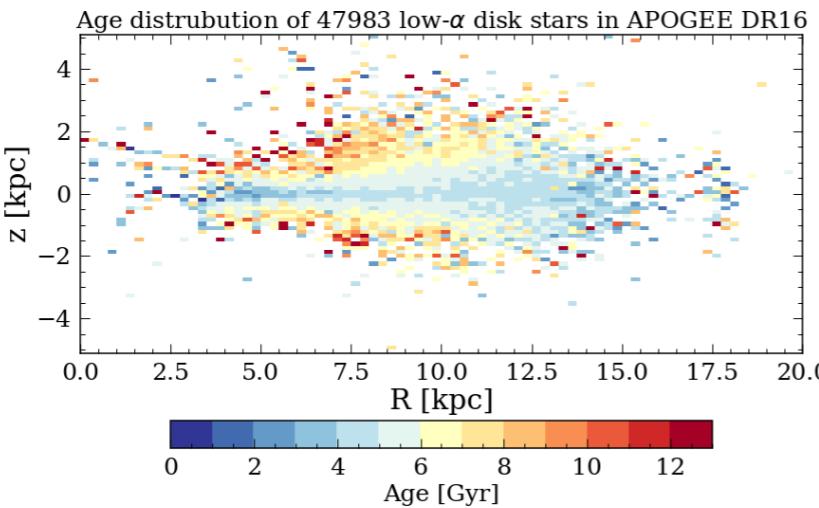
gradient in skew
→ radial
migration
(Hayden+2015,
Loebman+2016)

Results: Global age distribution

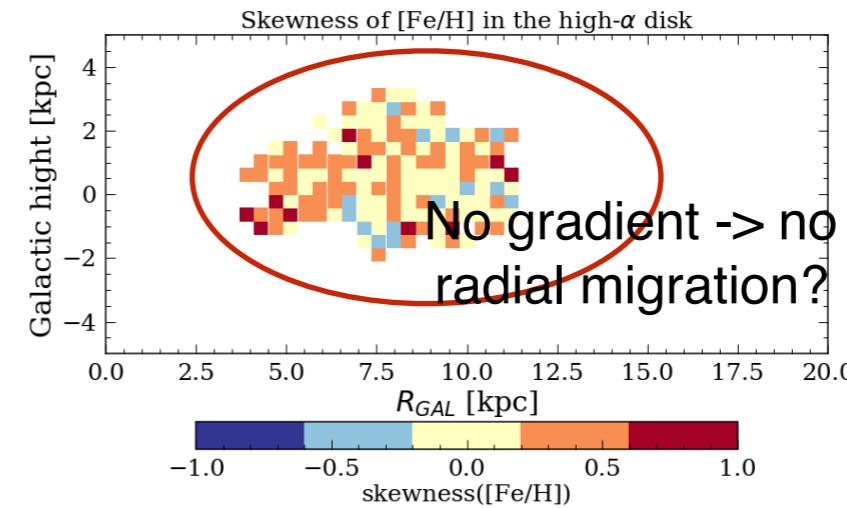
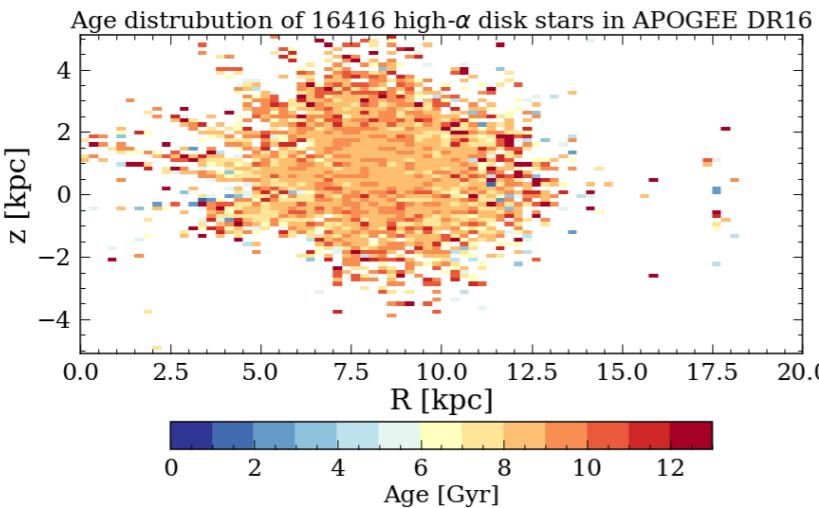
All



low- α
(Young)



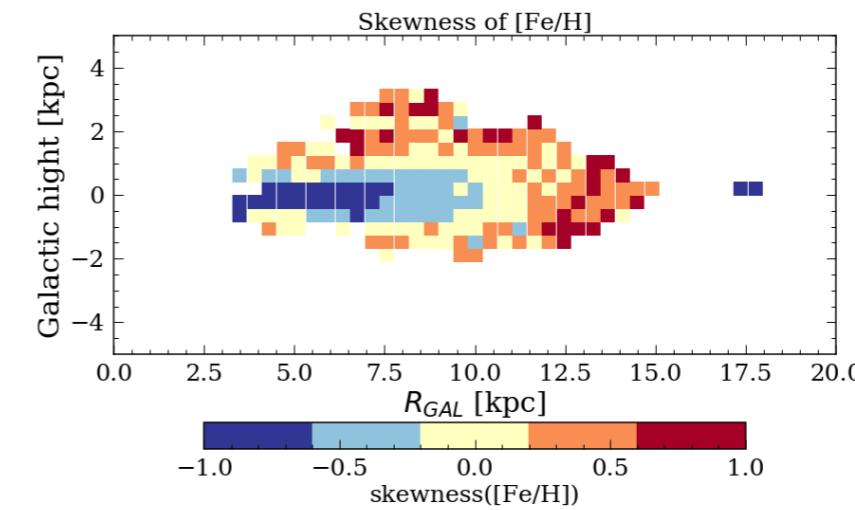
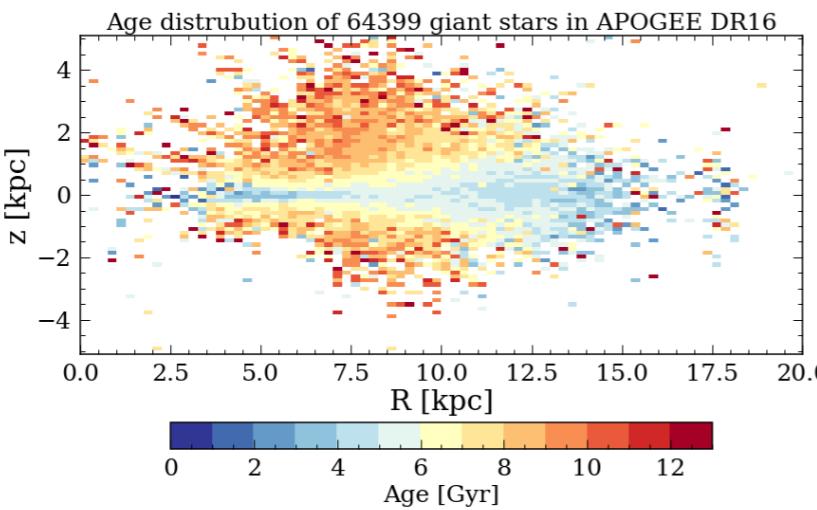
high- α
(old)



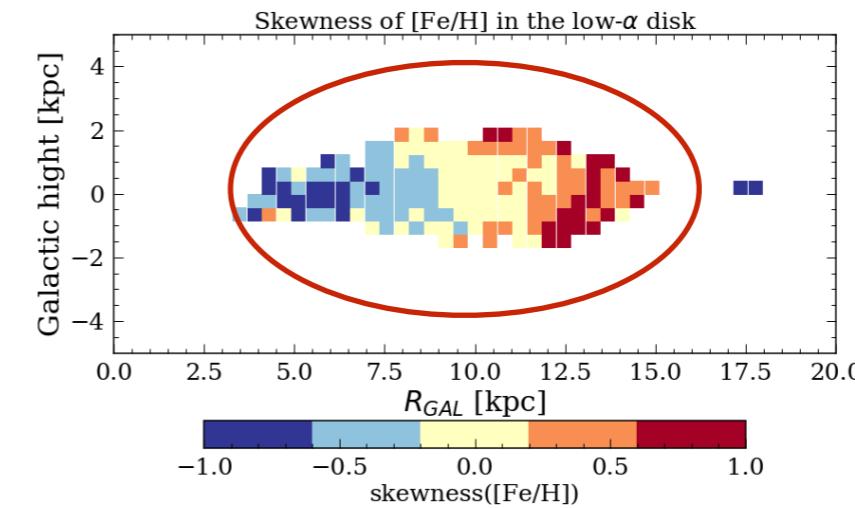
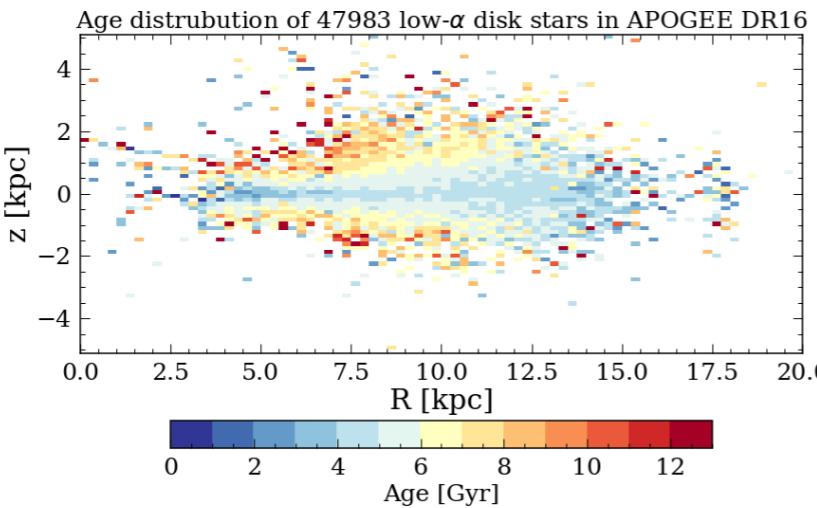
gradient in skew
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migration
(Hayden+2015,
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Results: Global age distribution

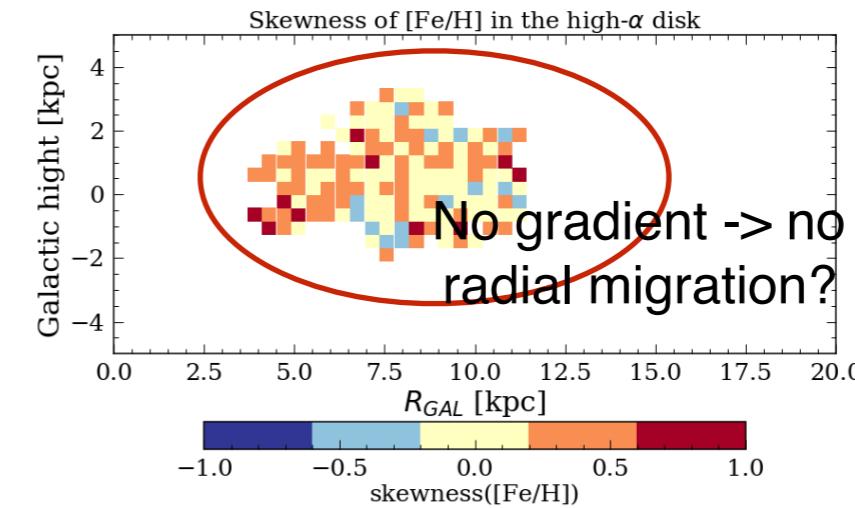
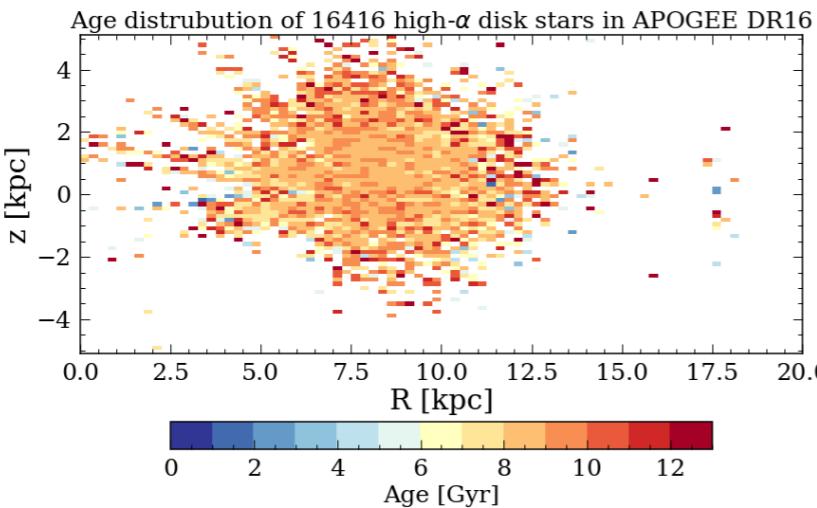
All



low- α
(Young)



high- α
(old)

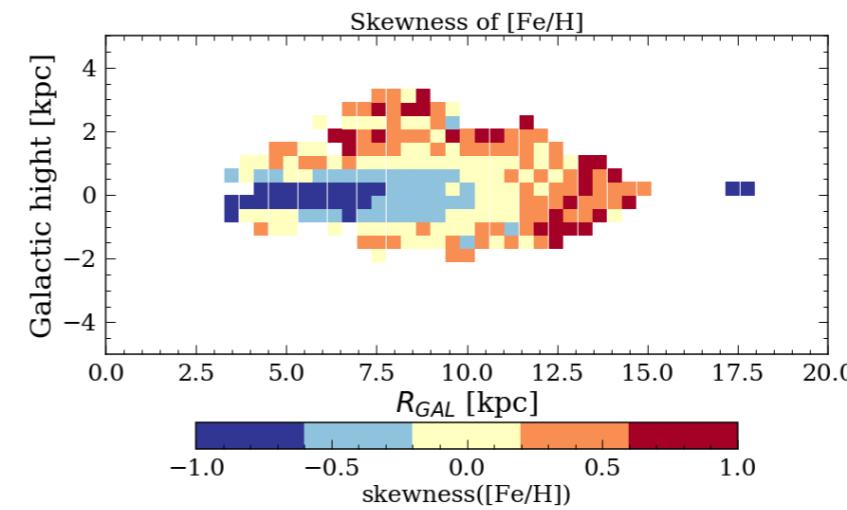
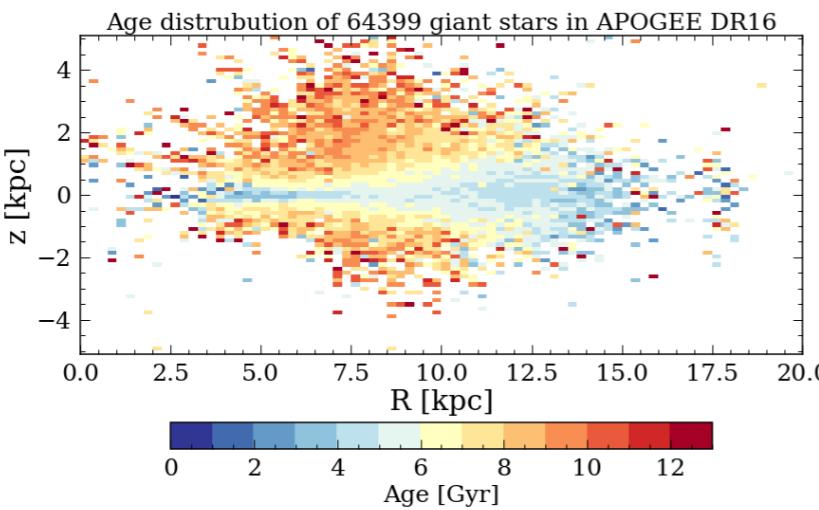


gradient in skew
-> radial
migration
(Hayden+2015,
Loebman+2016)

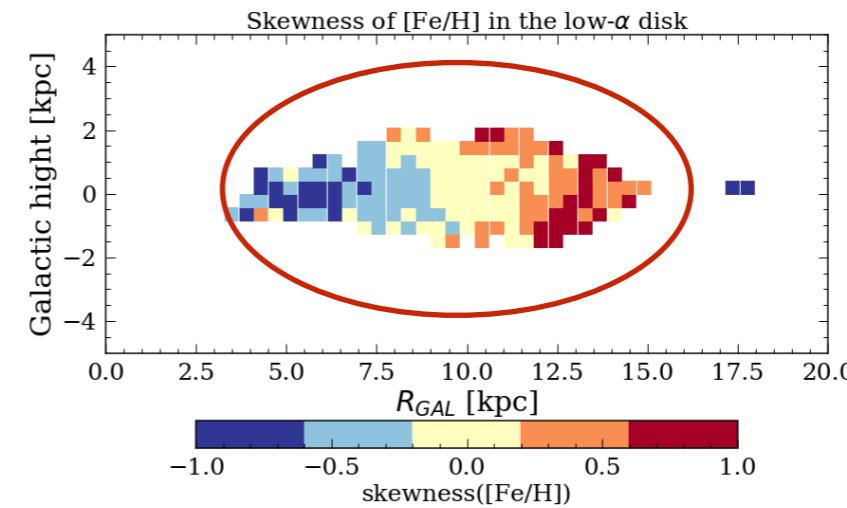
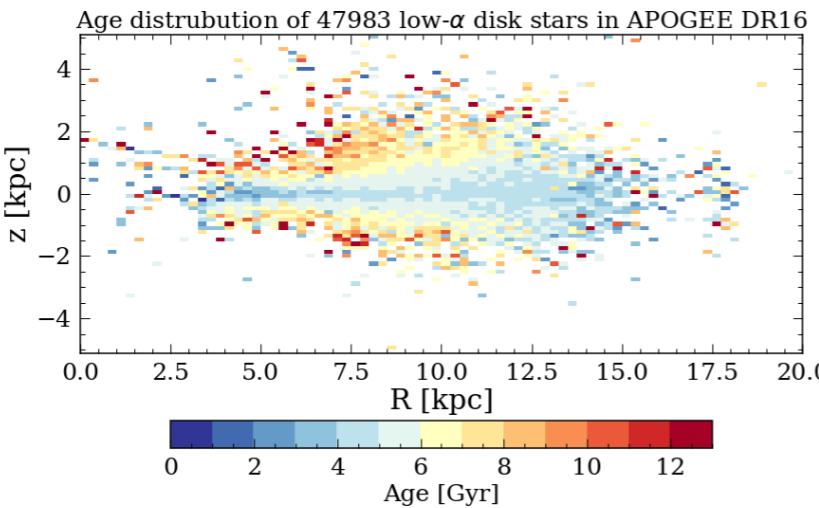
no radial migration

Results: Global age distribution

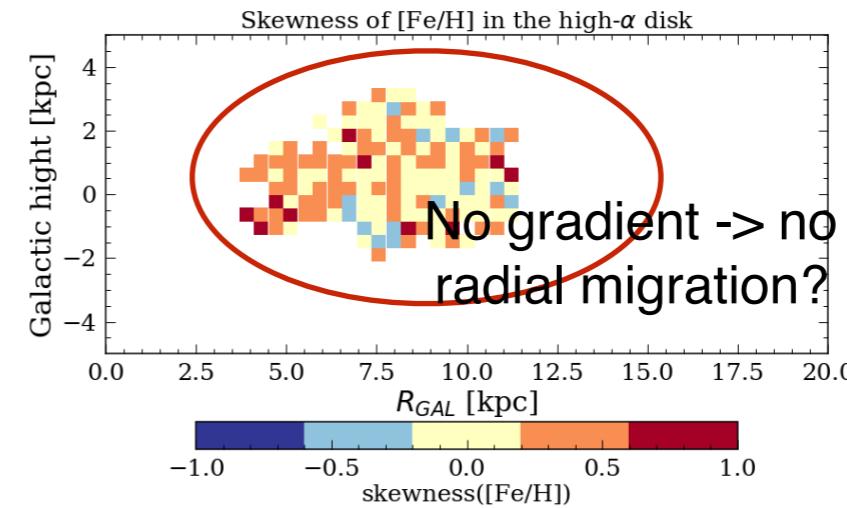
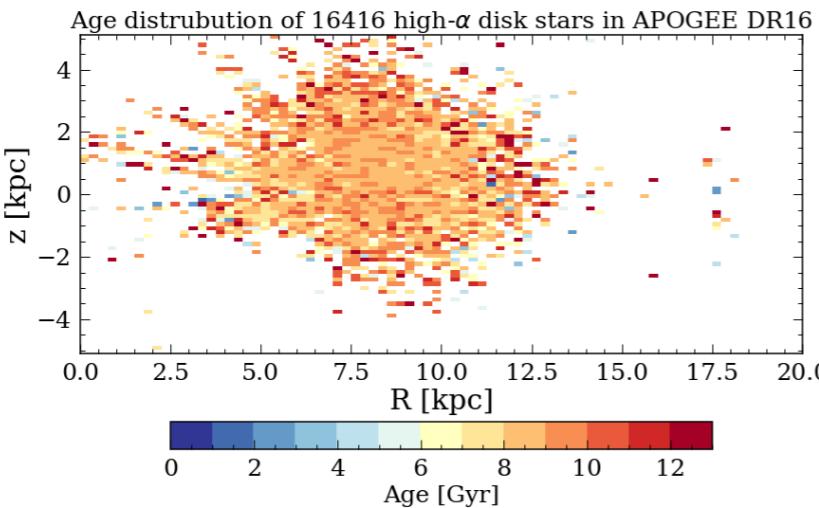
All



low- α
(Young)



high- α
(old)

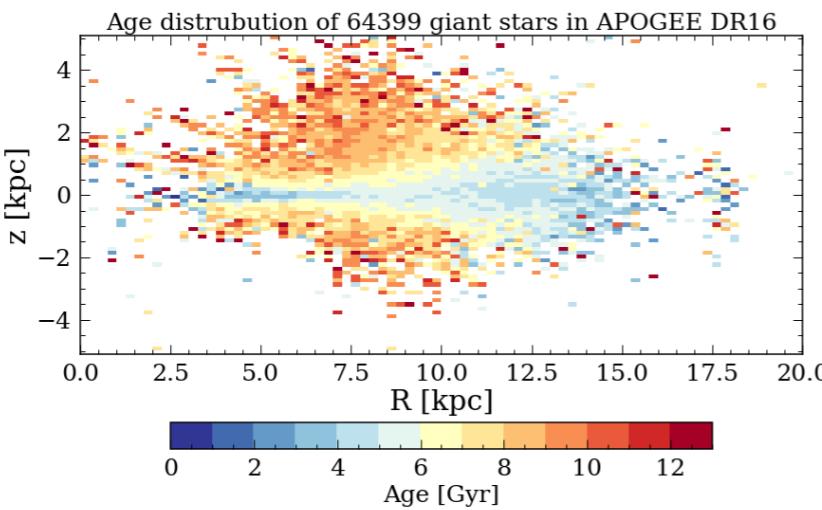


gradient in skew
-> radial
migration
(Hayden+2015,
Loebman+2016)

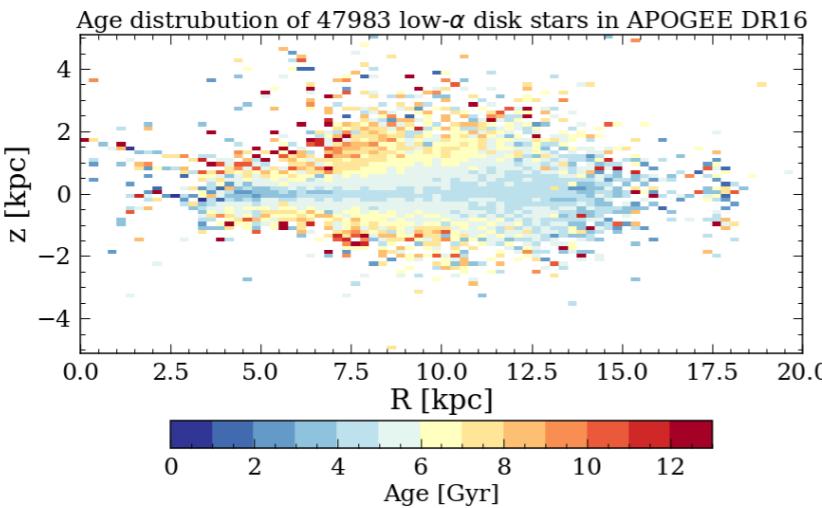
no radial migration
no metallicity gradient

Results: Global age distribution

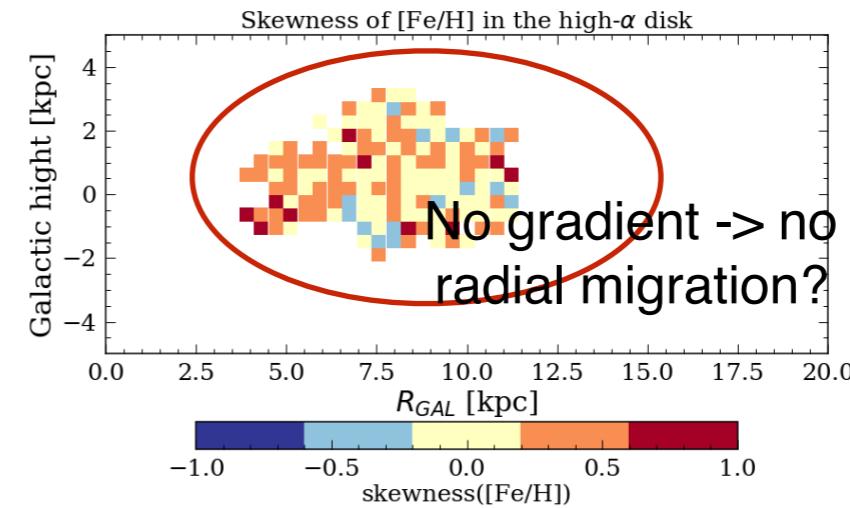
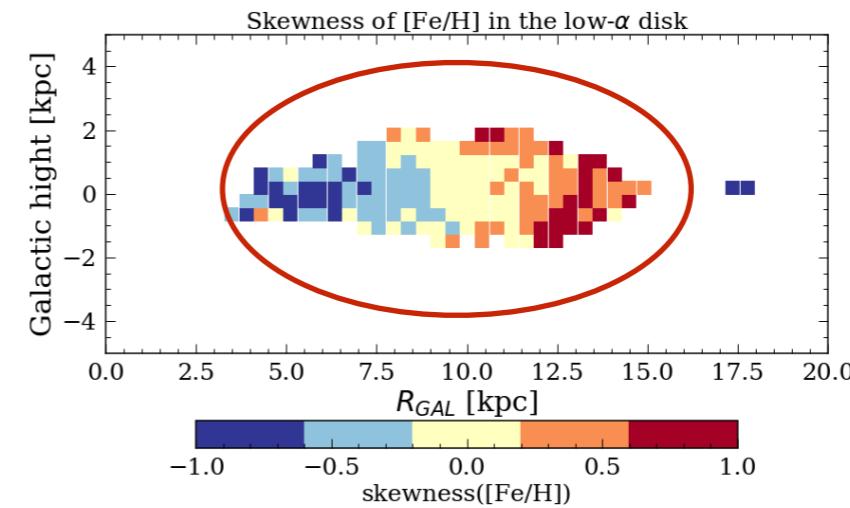
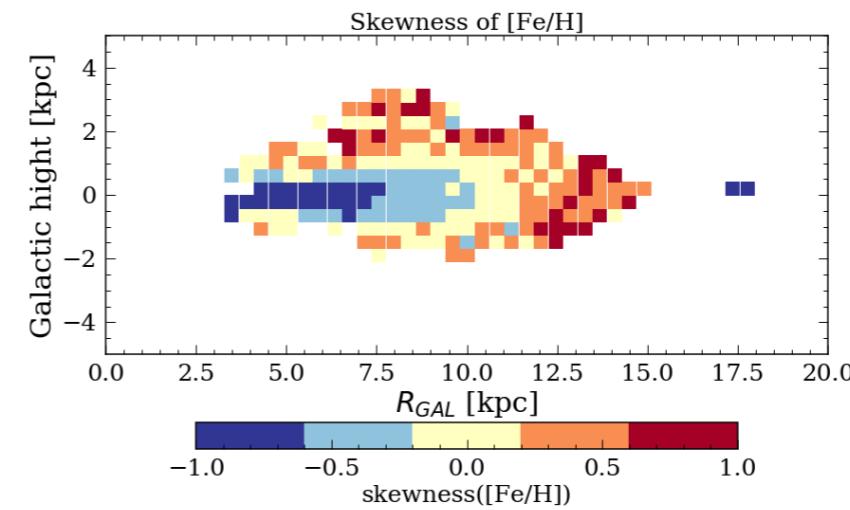
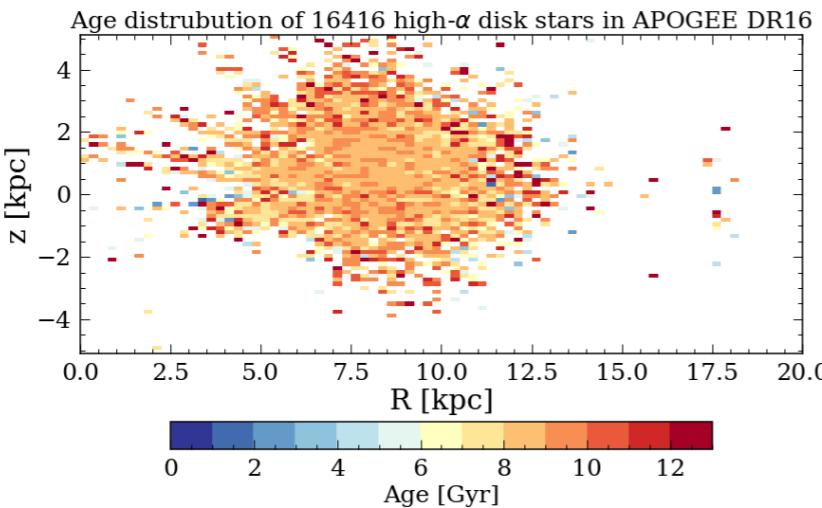
All



low- α
(Young)



high- α
(old)



gradient in skew
-> radial
migration
(Hayden+2015,
Loebman+2016)

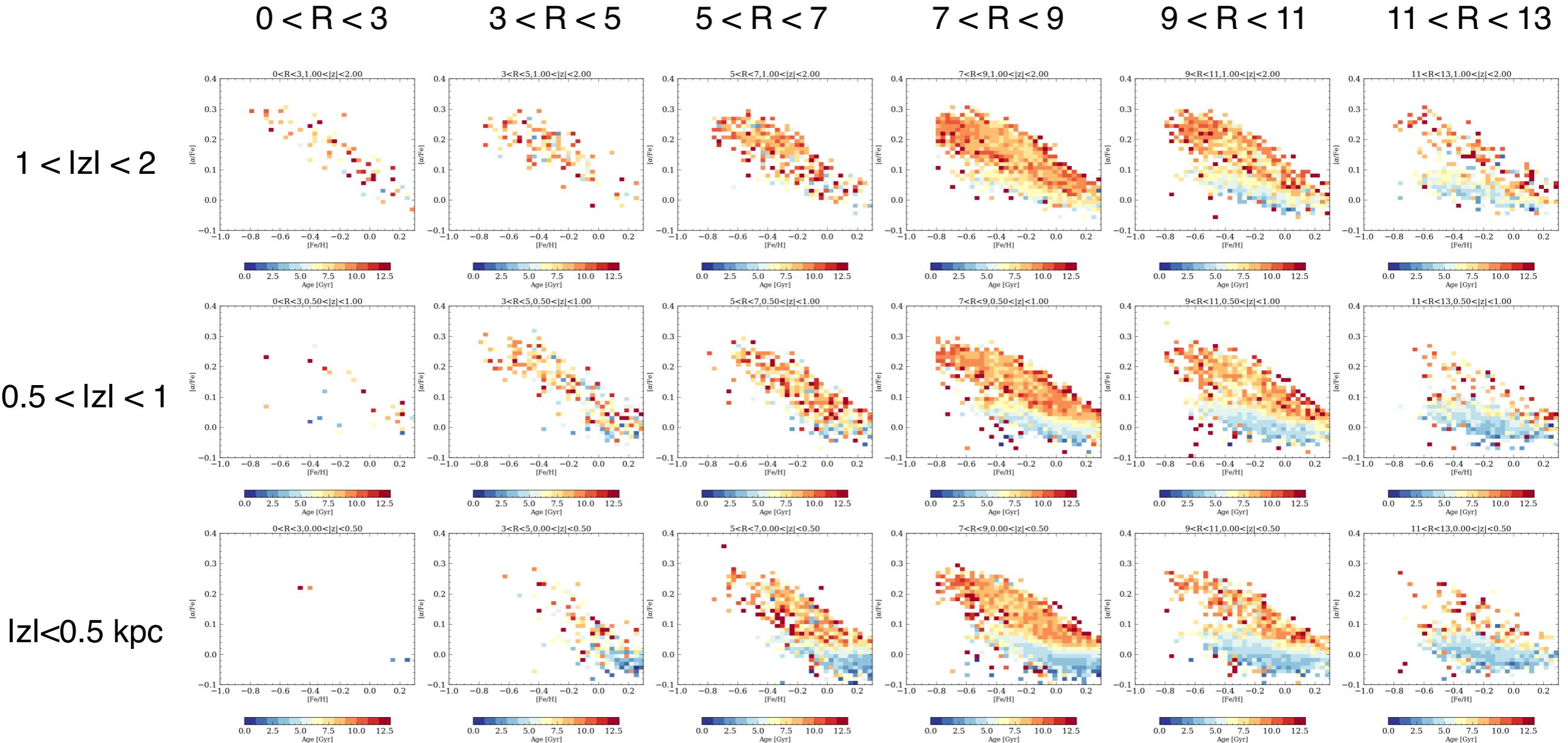
no radial migration
no metallicity gradient

Positive skewness could indicate fast
enrichment of the **high- α** disk

Results: Age distribution in mono-spacial/chemical bins

Spacial bins

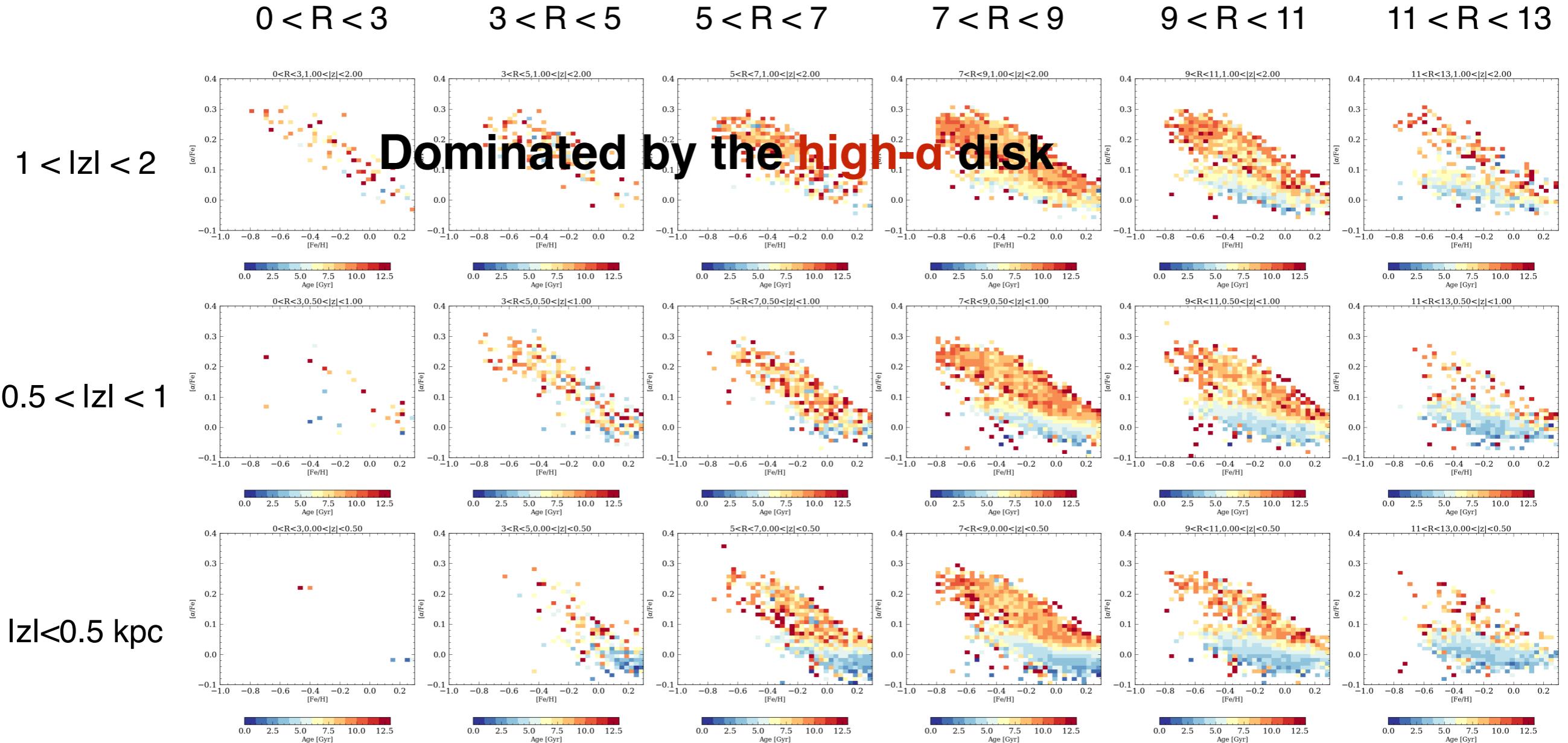
Inspired from Hayden+ Fig4



Results: Age distribution in mono-spacial/chemical bins

Spacial bins

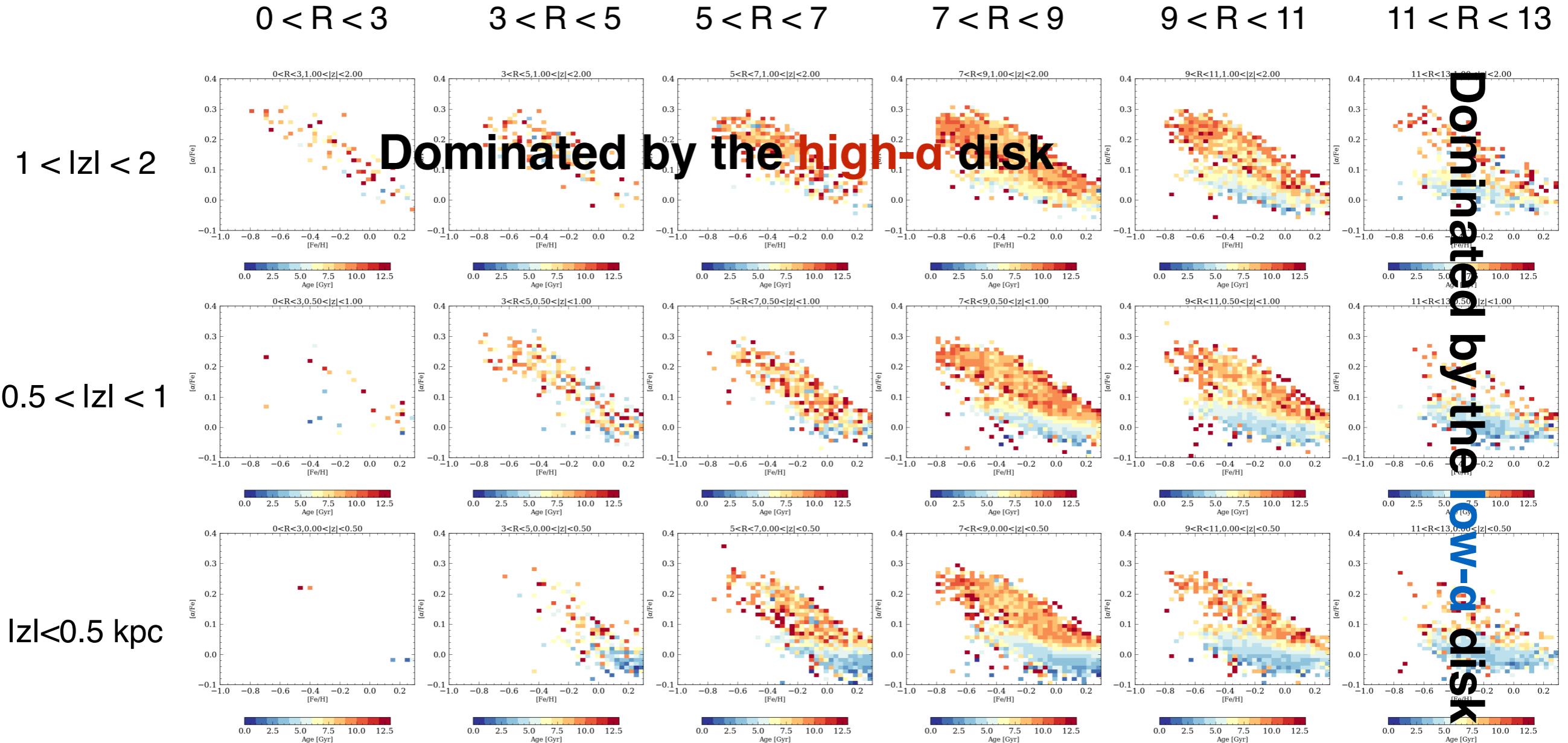
Inspired from Hayden+ Fig4



Results: Age distribution in mono-spacial/chemical bins

Spacial bins

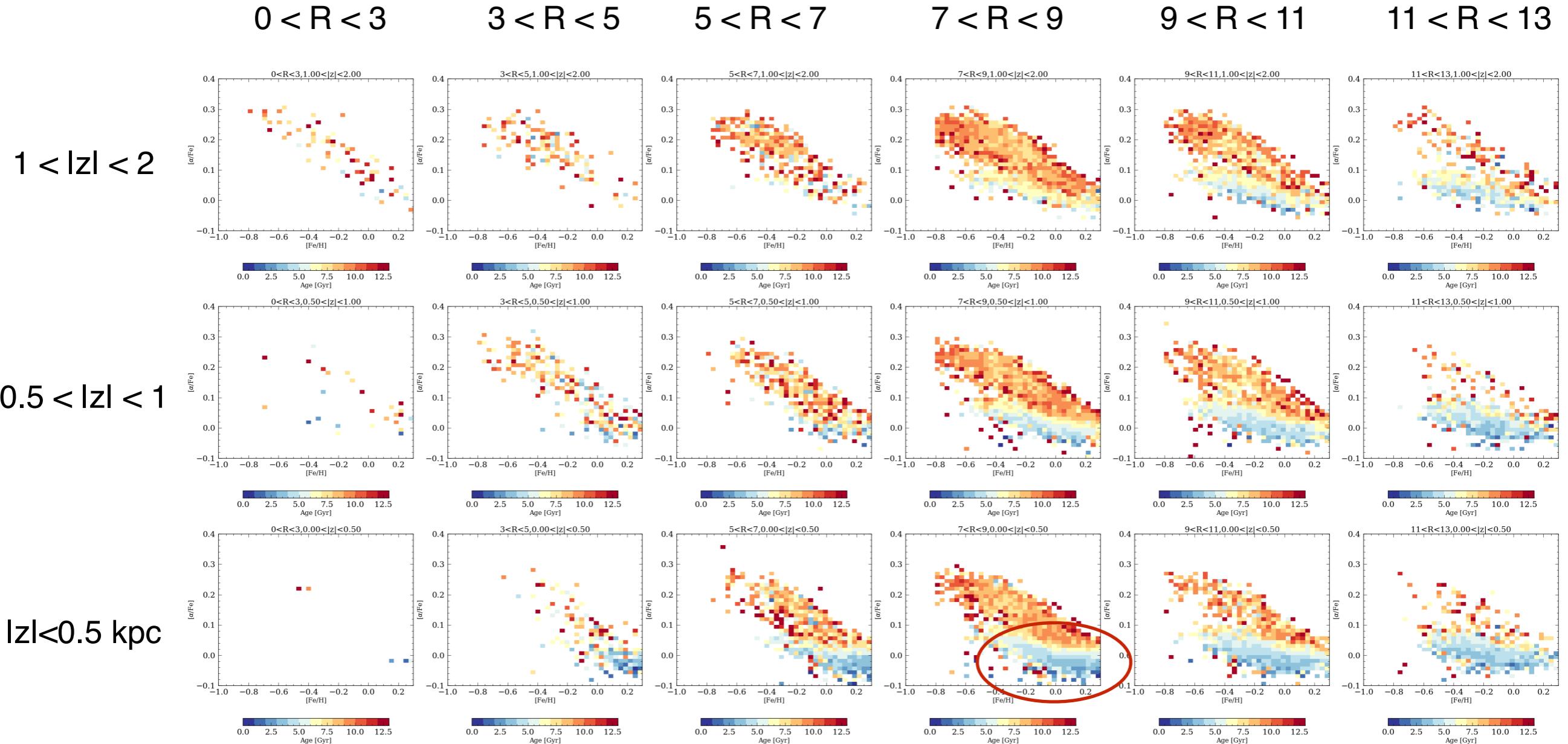
Inspired from Hayden+ Fig4



Results: Age distribution in mono-spacial/chemical bins

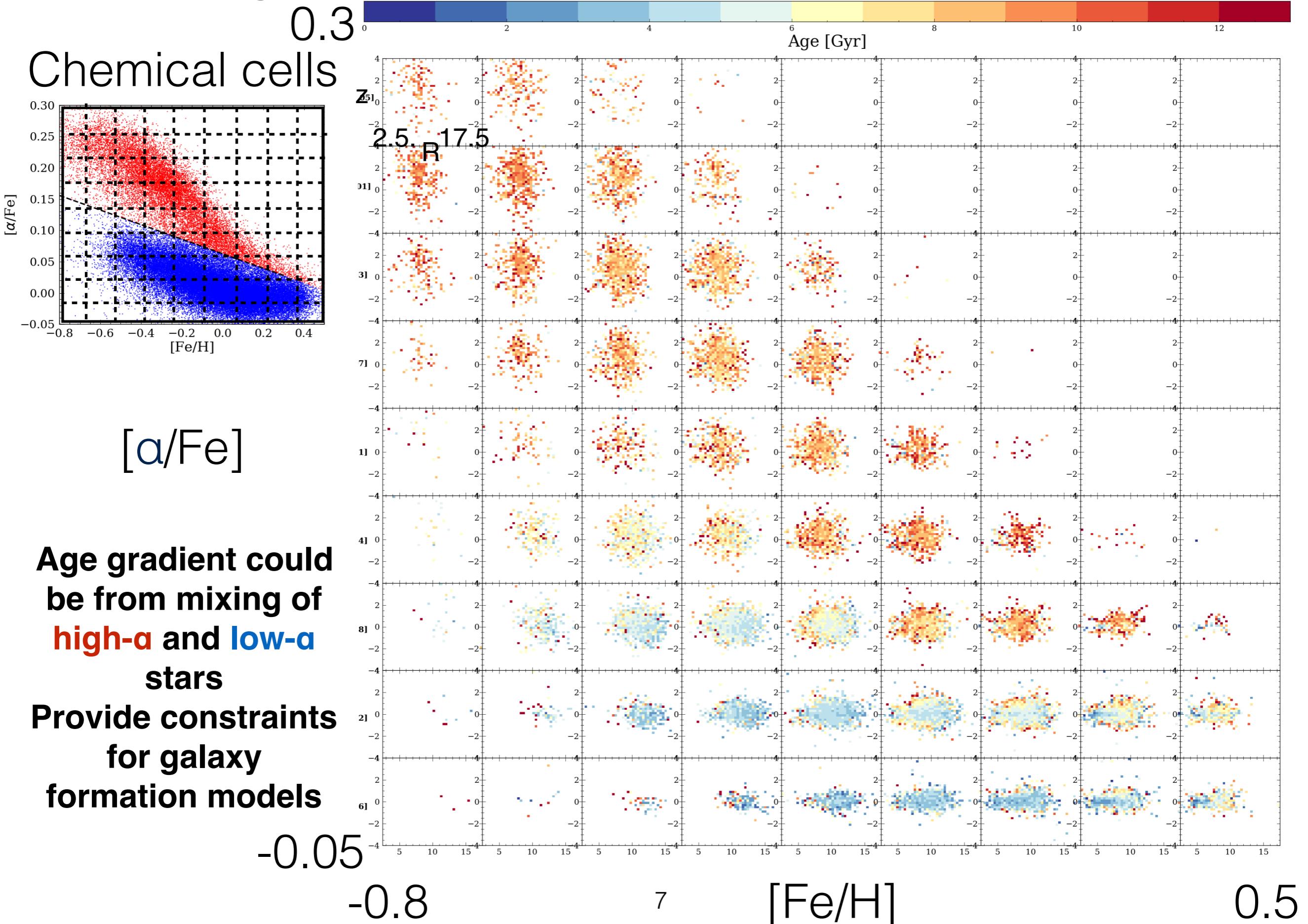
Spacial bins

Inspired from Hayden+ Fig4

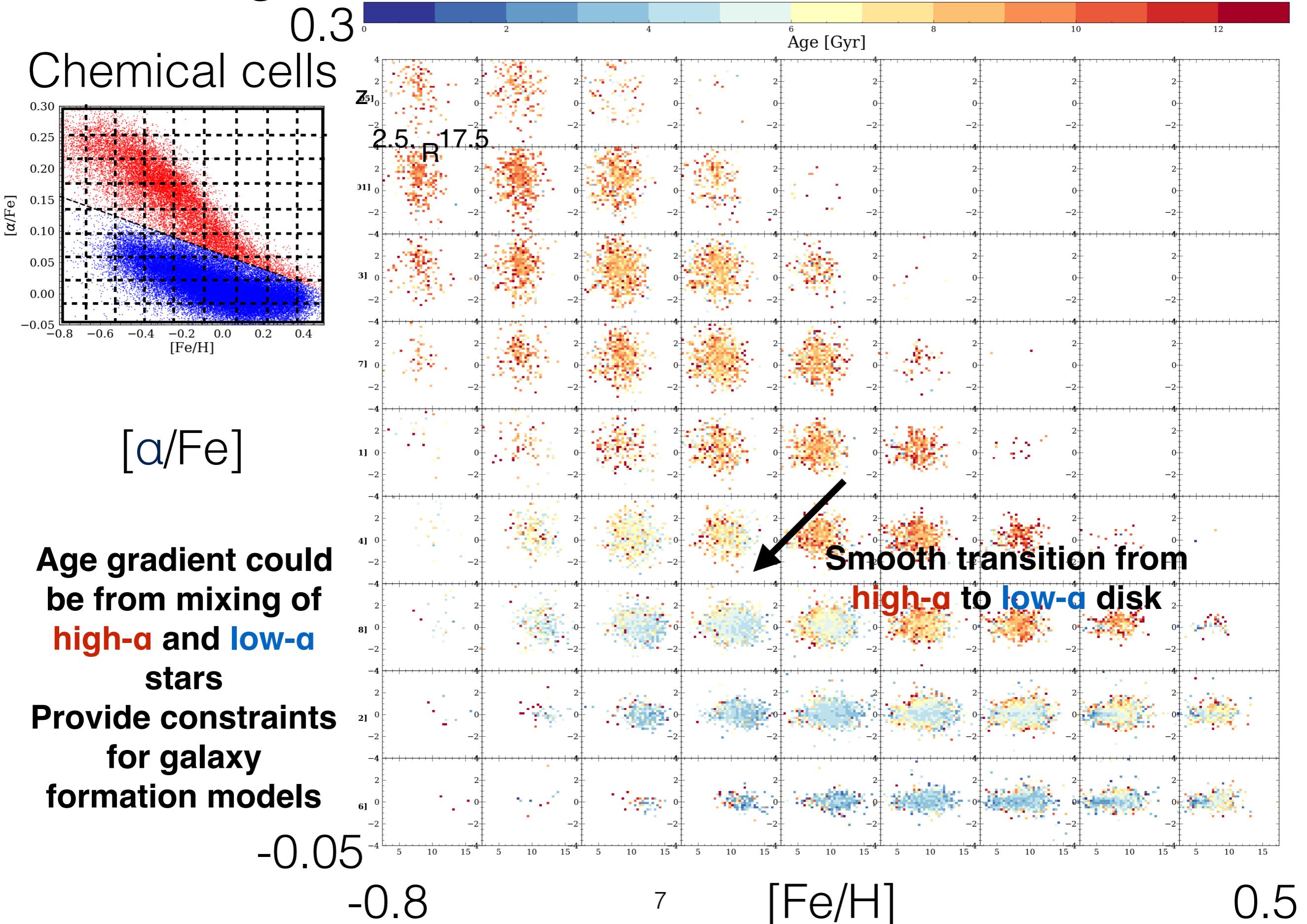


- Age gradient in **low- α** disk, no age gradient in **high- α** disk?
- Almost no metallicity age gradient at fixed $[\alpha/\text{Fe}]$

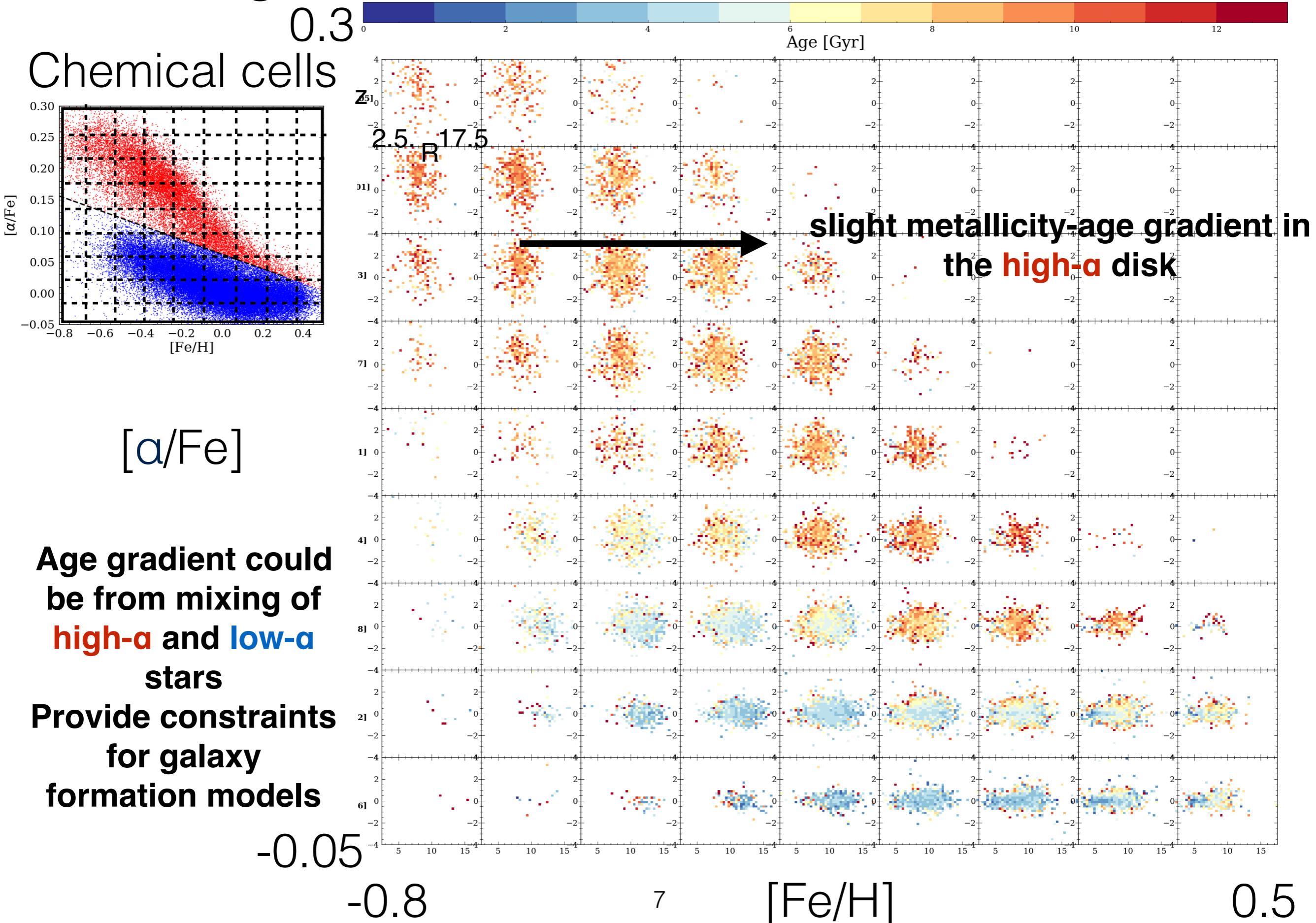
Results: Age distribution in mono-spatial/chemical bins



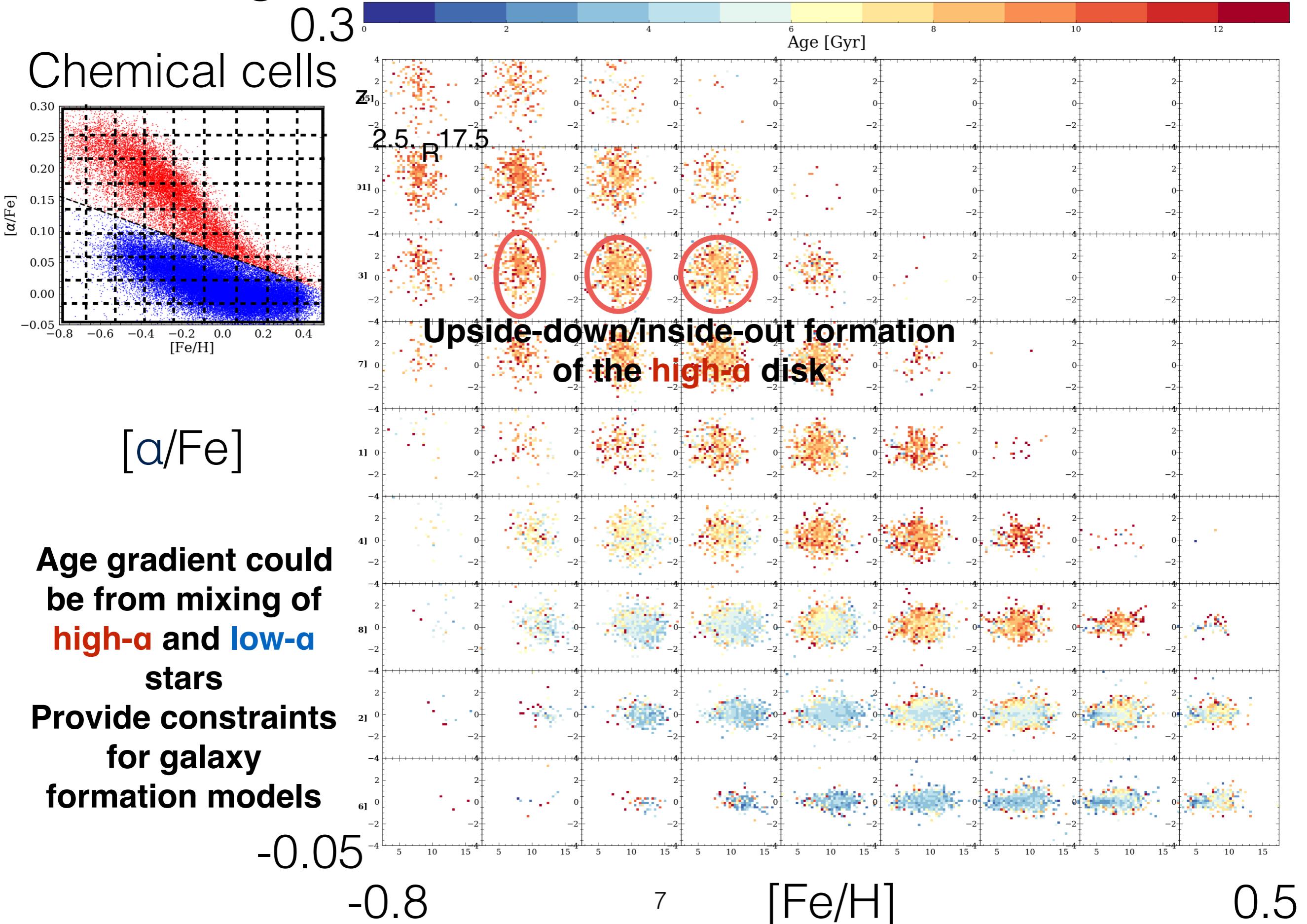
Results: Age distribution in mono-spatial/chemical bins



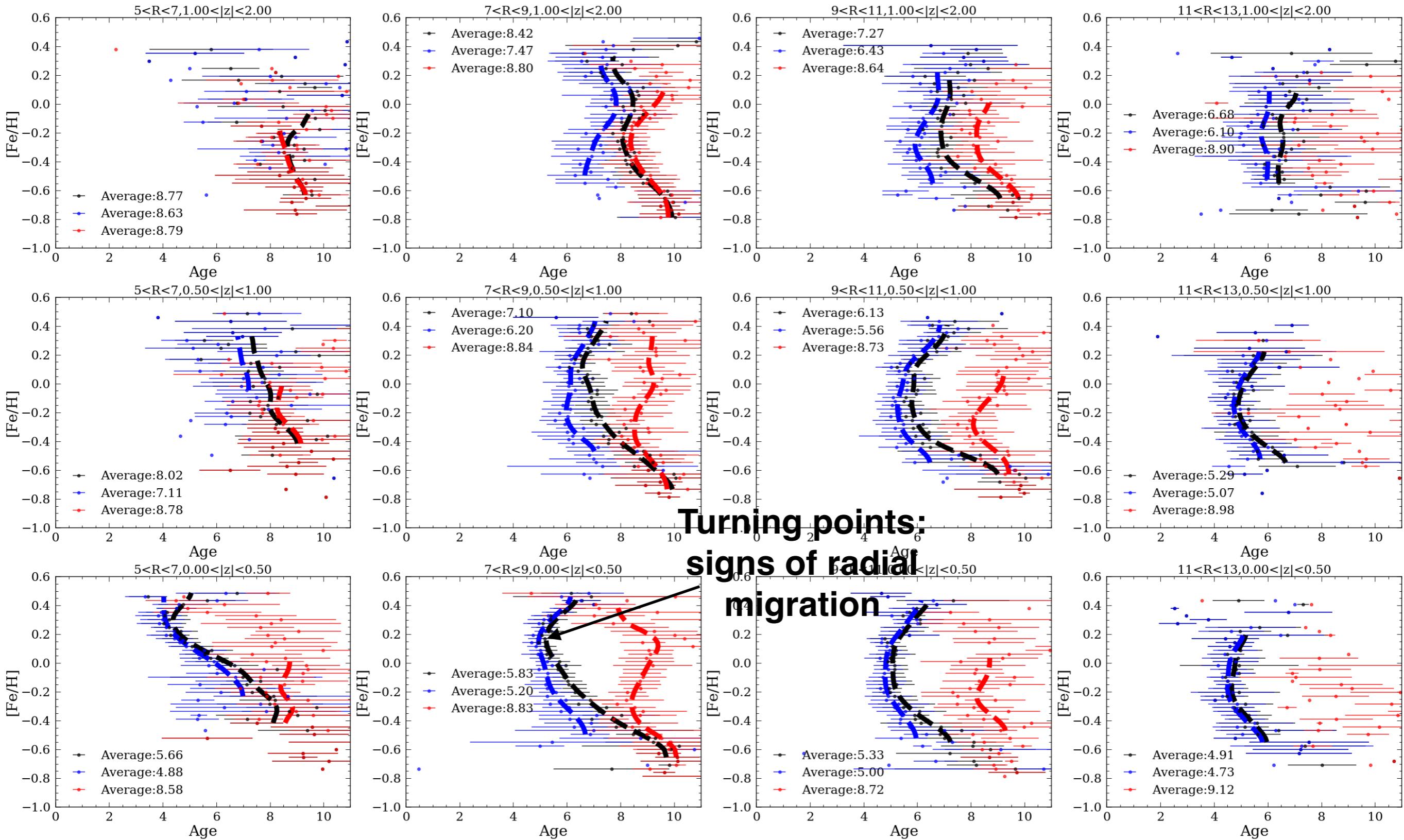
Results: Age distribution in mono-spatial/chemical bins



Results: Age distribution in mono-spatial/chemical bins

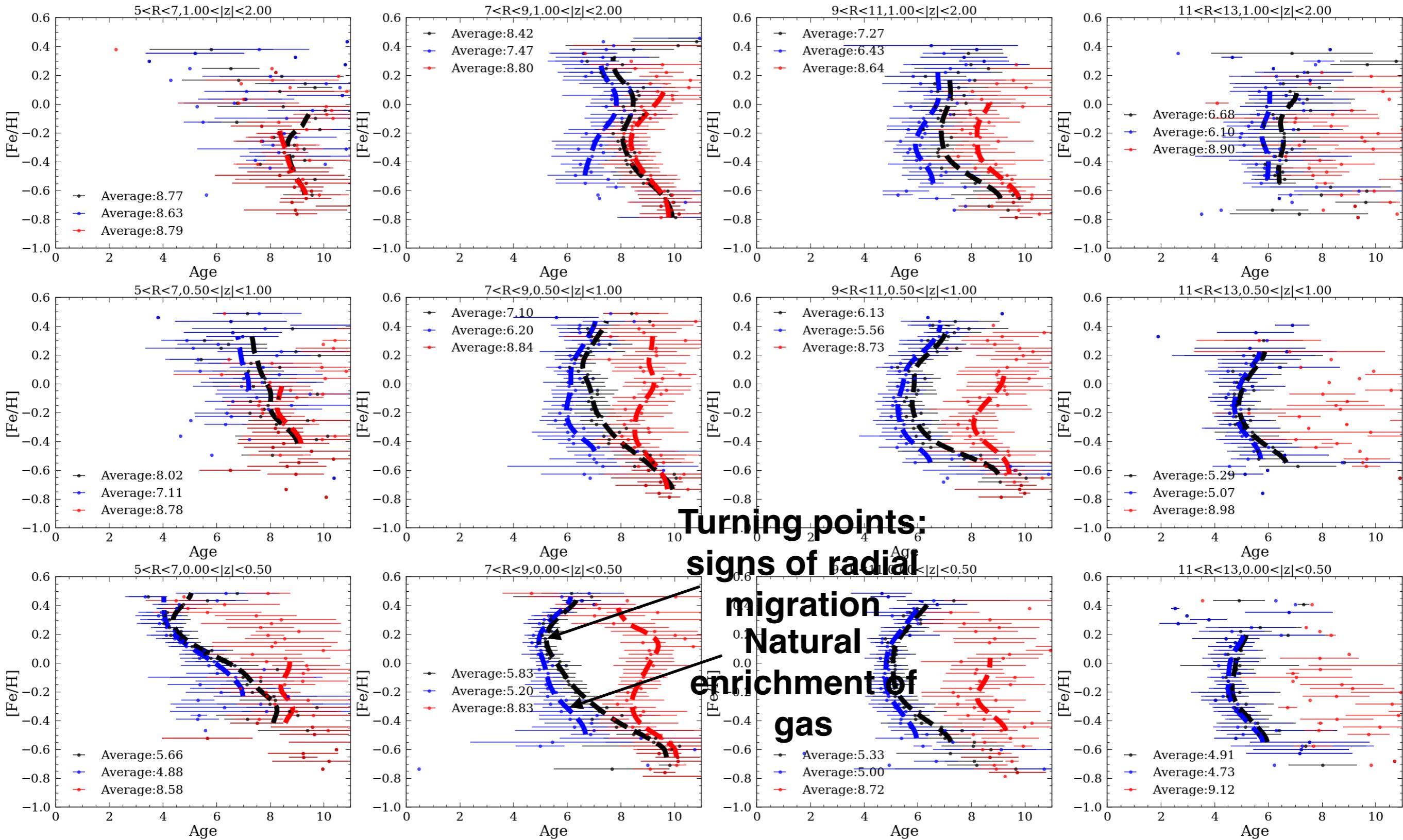


Results: Age metallicity relations



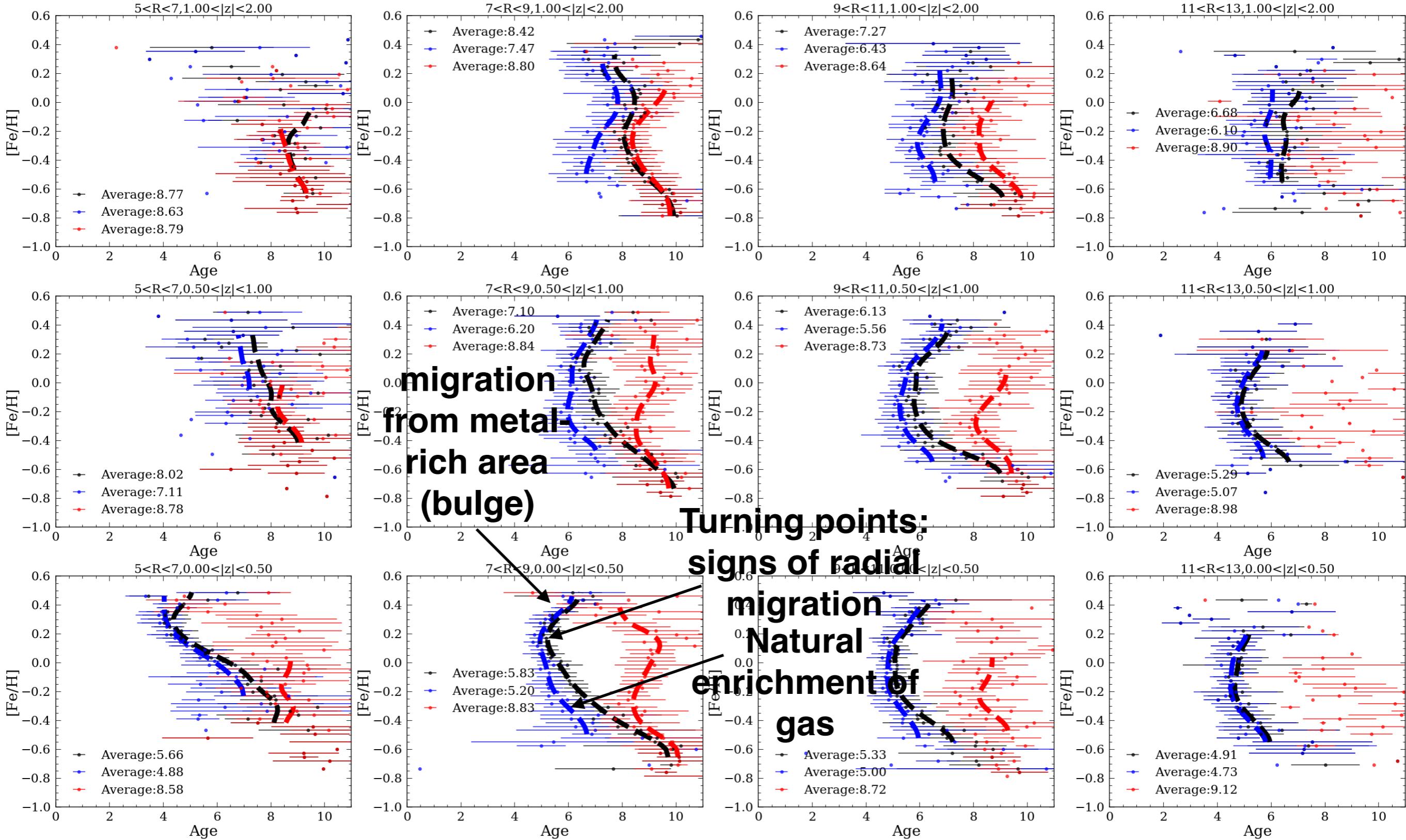
Radial migration in both the **high- a** and the **low- a** disk

Results: Age metallicity relations



Radial migration in both the **high- a** and the **low- a** disk

Results: Age metallicity relations



Radial migration in both the **high- a** and the **low- a** disk

Results: Detailed age-element abundance relation

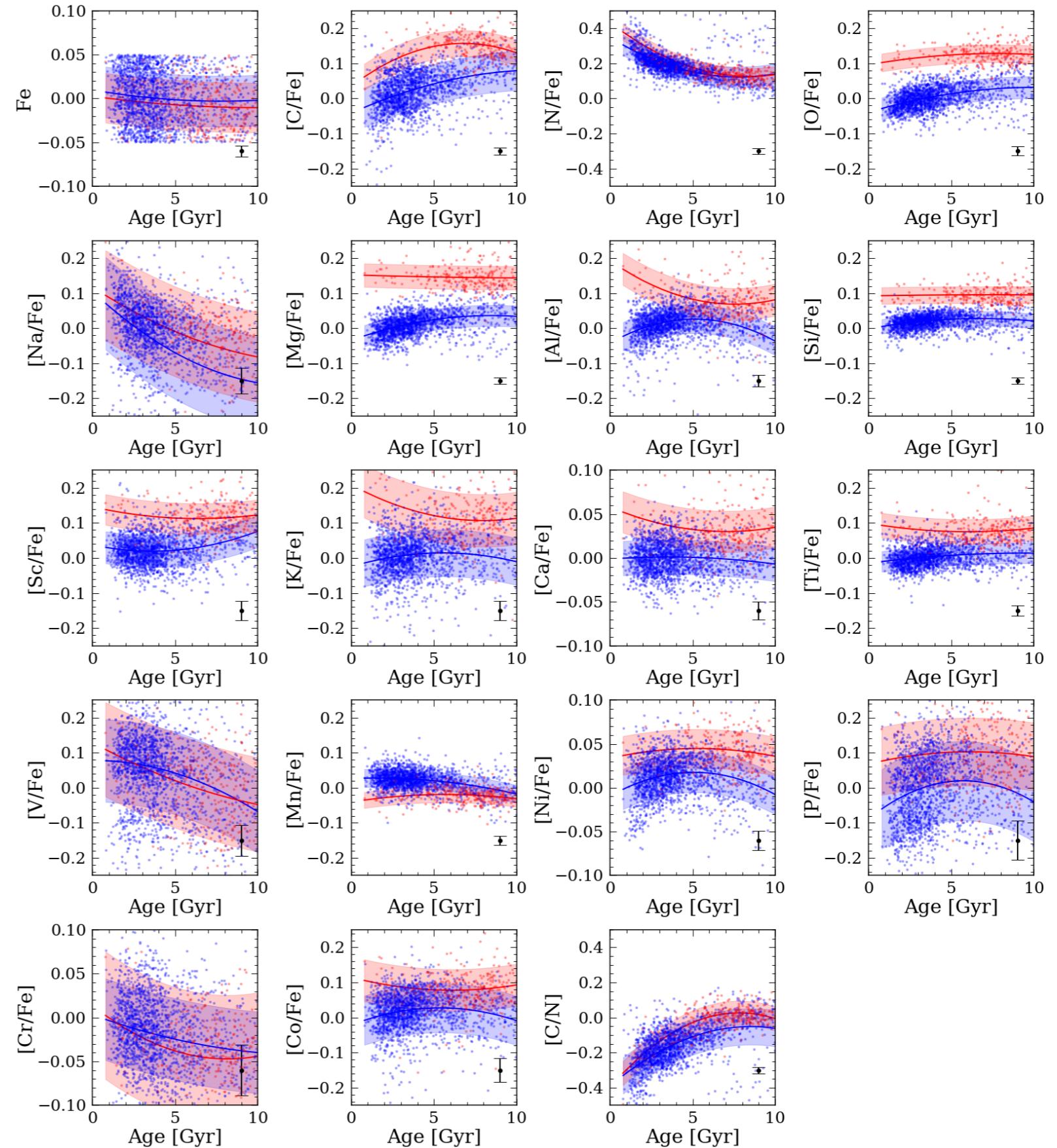
Selections:

- RC stars
- $|[\text{Fe}/\text{H}]| < 0.05 \text{ dex}$
- Age $< 10 \text{ Gyr}$



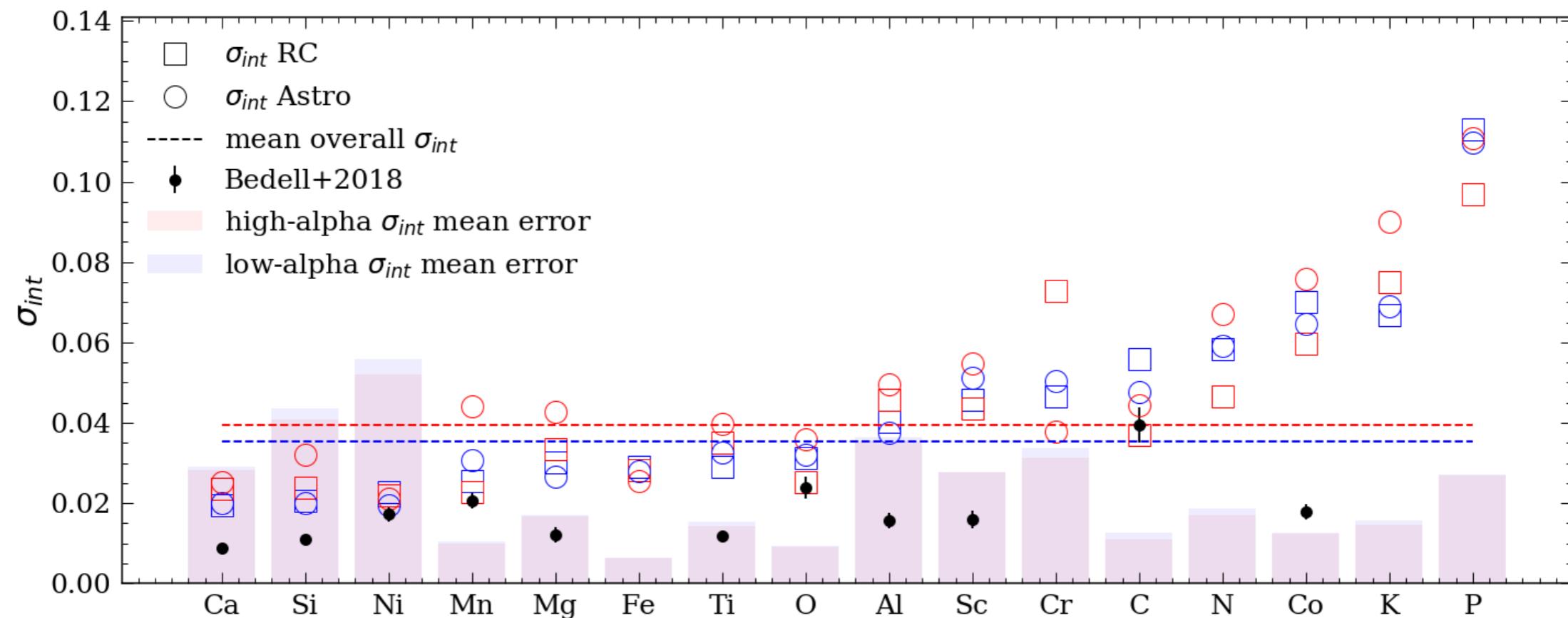
1,819 low-a and
255 high-a

Different age-element
abundance relation
for the high-a and the
low-a disk



Results: Detailed age-element abundance relation

Intrinsic dispersion: how well we can determine the elements from just metallicity and age?



Similar (small) intrinsic dispersion:

- **Similar stellar yields** (no need to add different enrichment processes for the two disks in simulations)
- The two disks share **universal star formation properties**

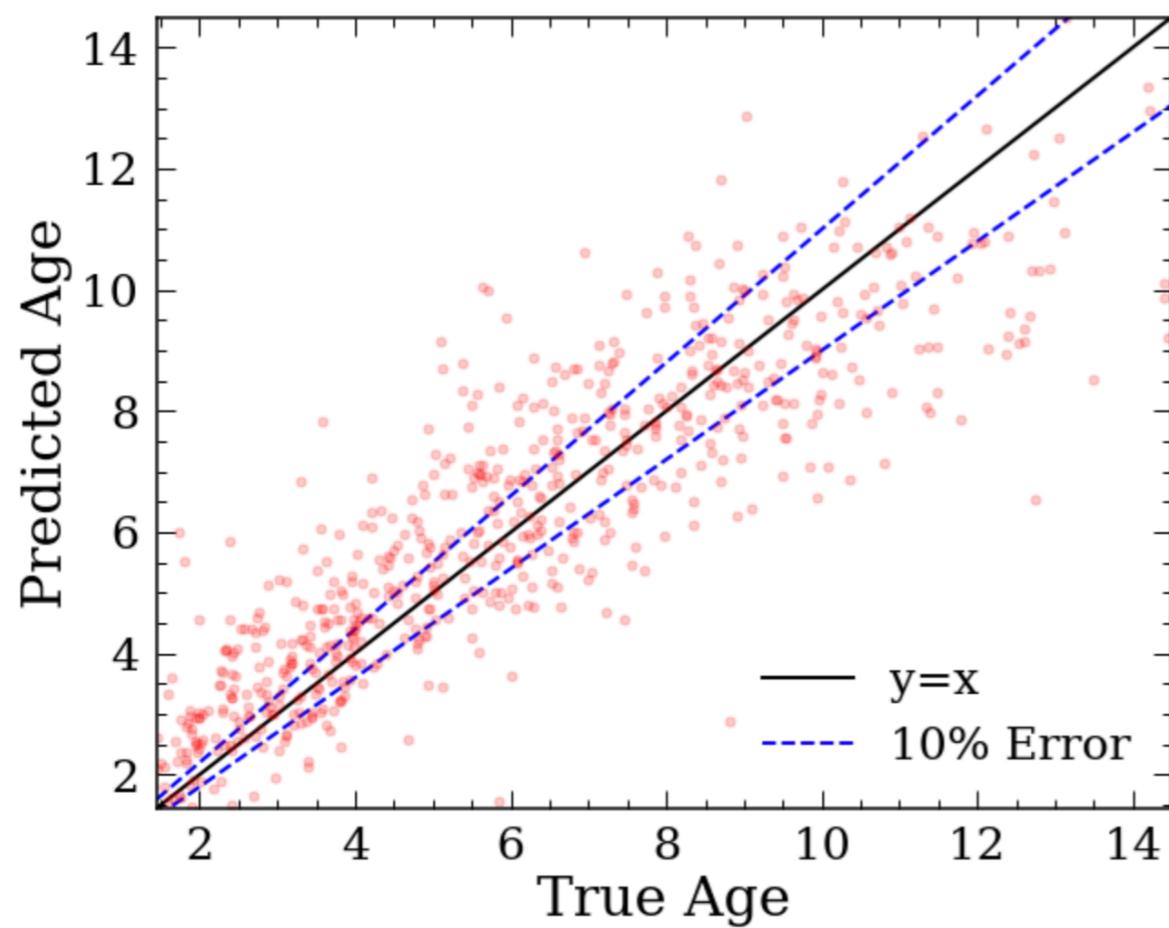
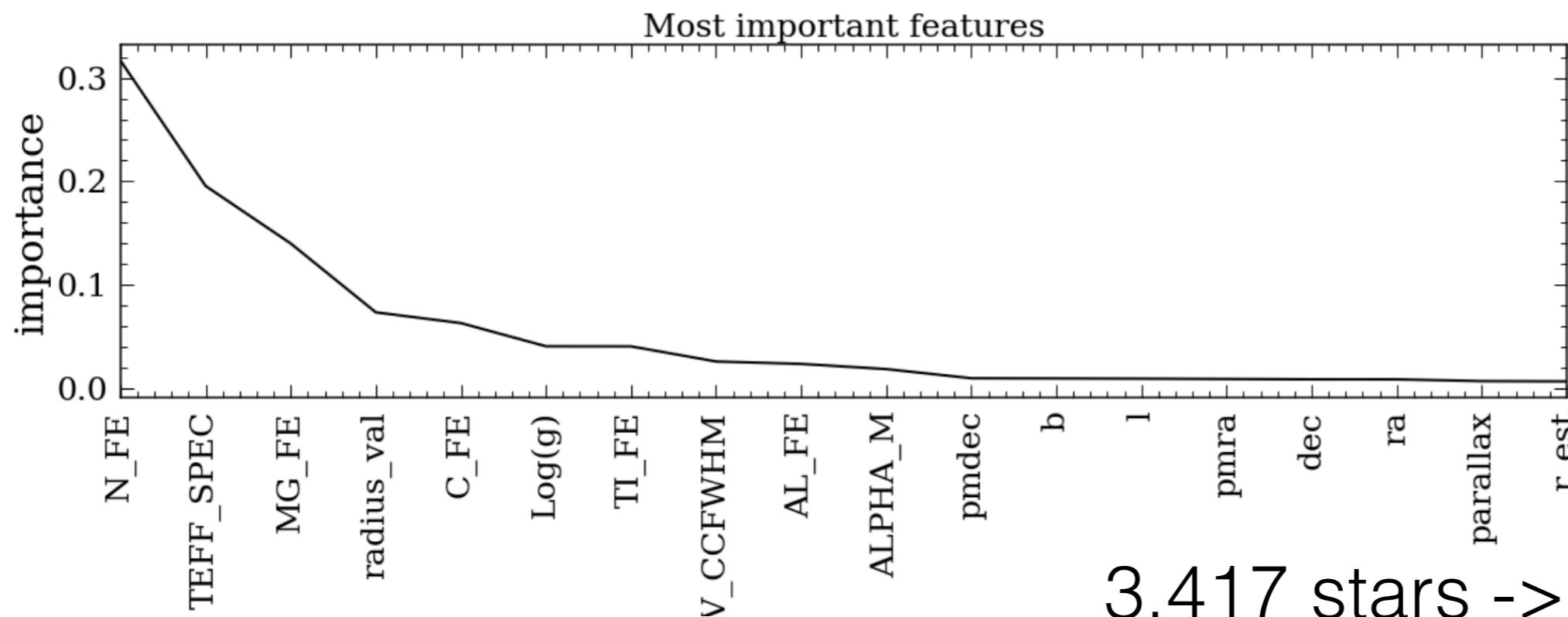
Conclusion

Similarities:

- No age gradient in chemical cells
- Radial migration
- Stellar yields are similar

Differences:

- Old/young
- large/small z scale and small/large R scale
- Absence/presence of spacial metallicity gradient
- Different age-element abundance relations



3,417 stars \rightarrow predicting ages with 20% uncertainty

Predicting ages for all stars with spectroscopic data??!!



Ages are amazing

