Disc metallicity trends with Galah (iDR3) + Apogee (DR14)

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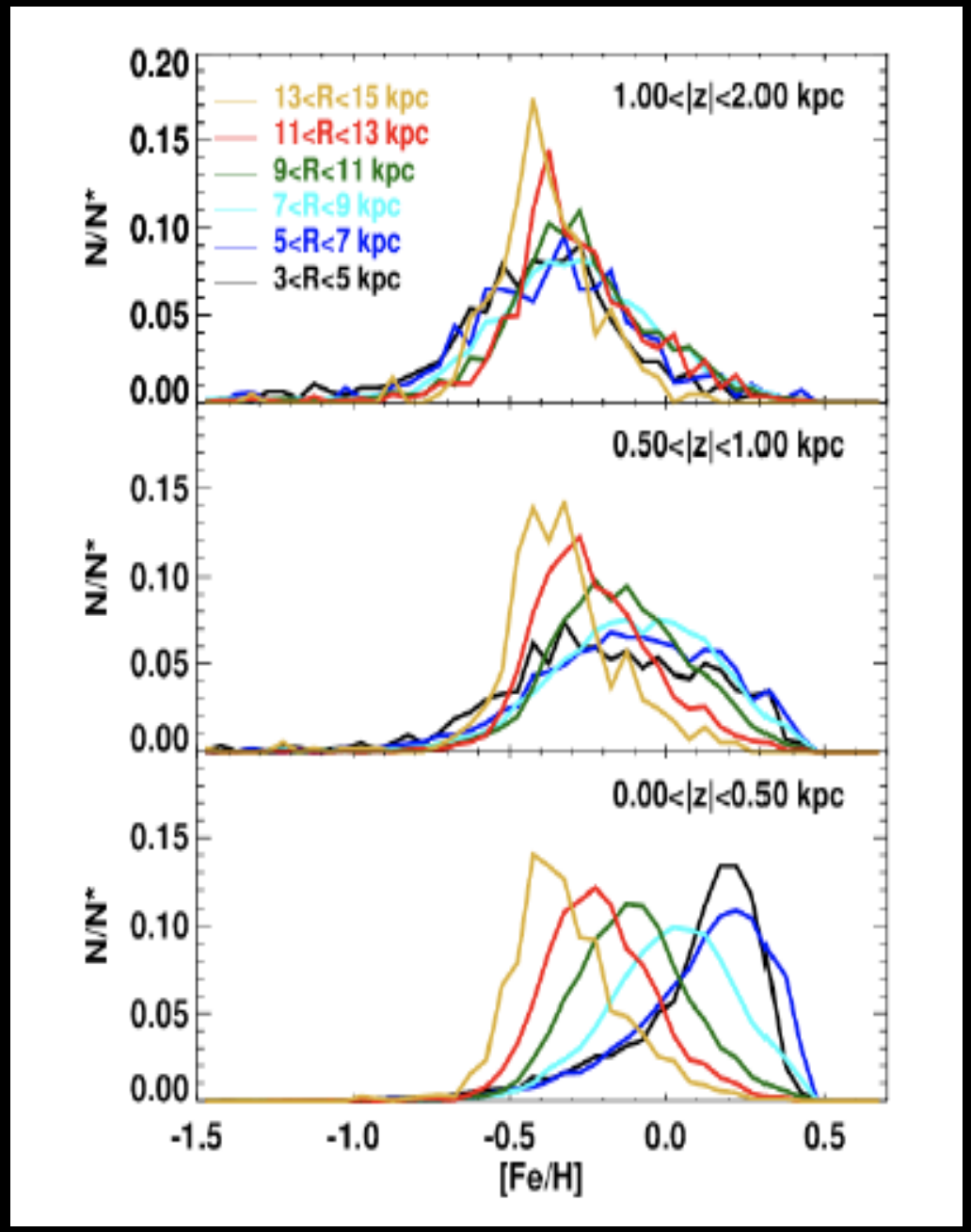
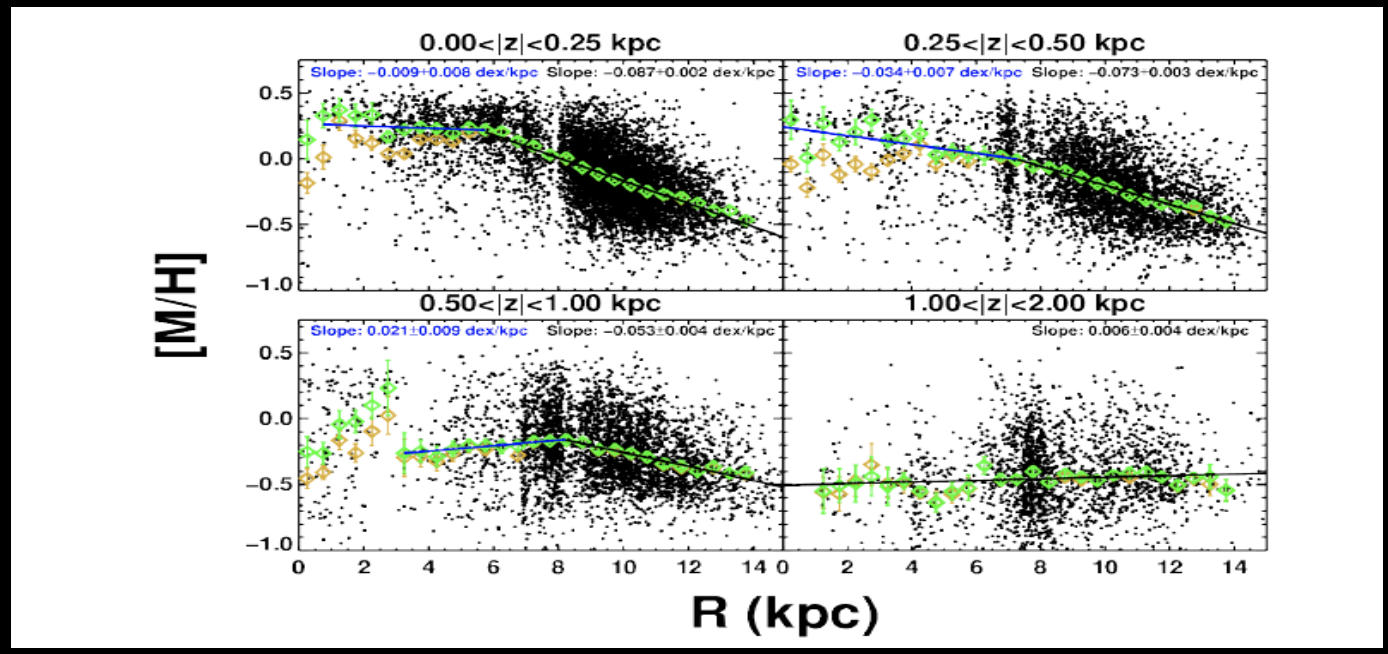
with Martin Asplund, Michael Hayden and Sven Buder

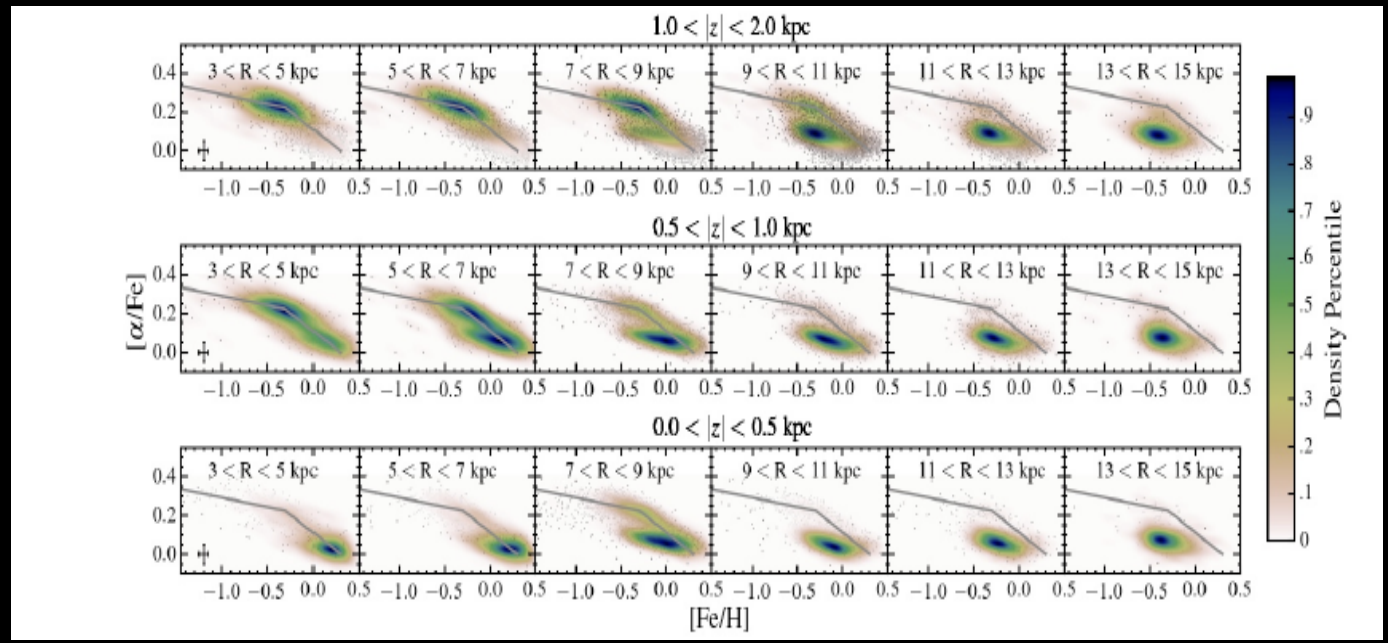
- Chemical imprint of birth cloud preserved by stellar atmospheres (Freeman & Bland-Hawthorn 2002)

- Galactic chemical evolution history :
  - Elemental abundances of stars
  - Their distribution
  - Their variation along and away from Galactic mid plane

Hayden et al. 2014,2015

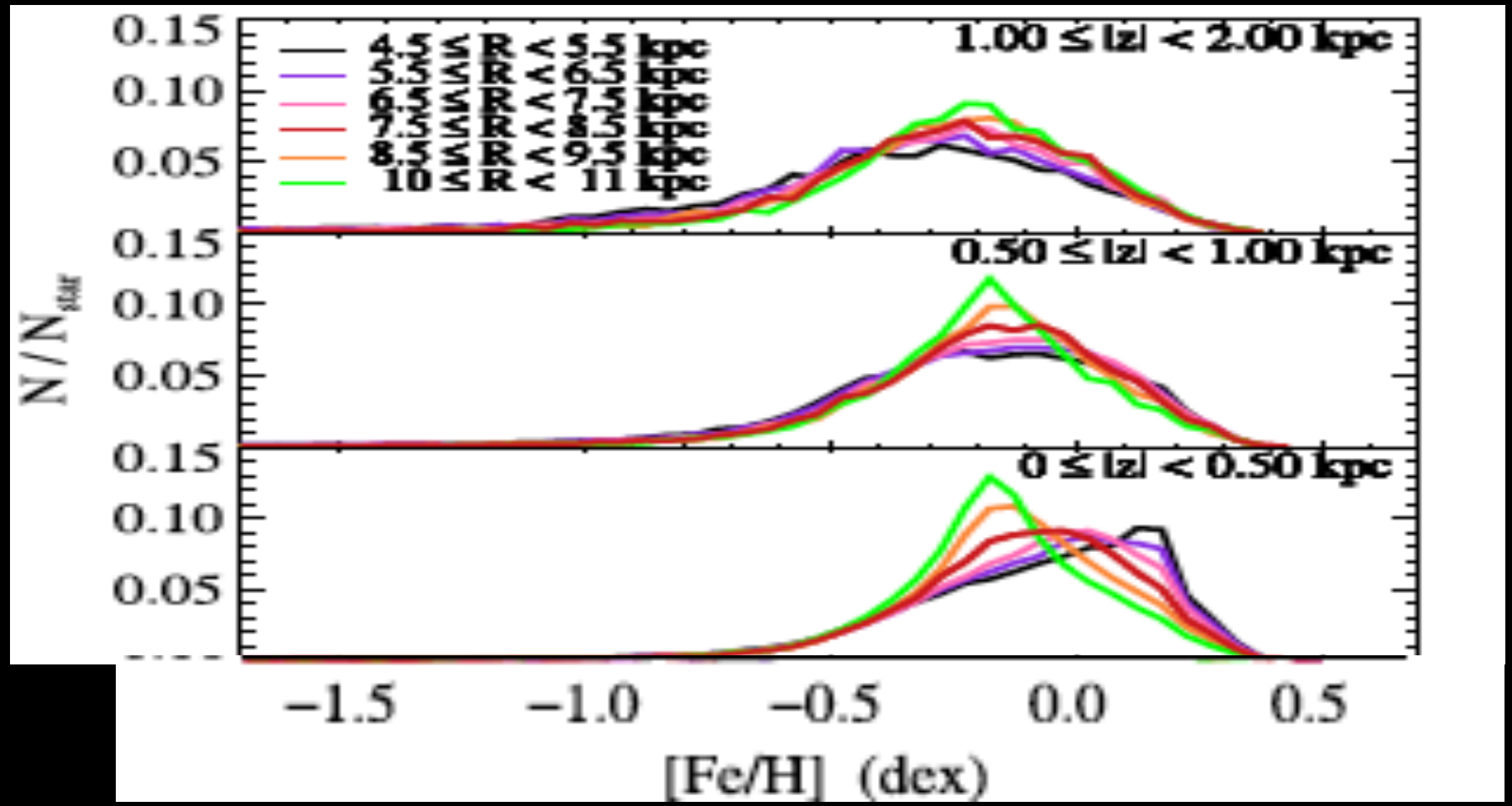






Migration

Interaction with spiral arms, churning and/or blurring
(Sellwood & Binney 2002, Schonrich & Binney 2009 etc)



Loebman et al. 2016

Metallicity Gradients

- Large scale spectroscopic surveys

  e.g. APOGEE (Majewski et al. 2015), GES (Gilmore et al. 2012), GALAH (Freeman et al. 2012), RAVE (Steinmetz et al. 2006) etc.

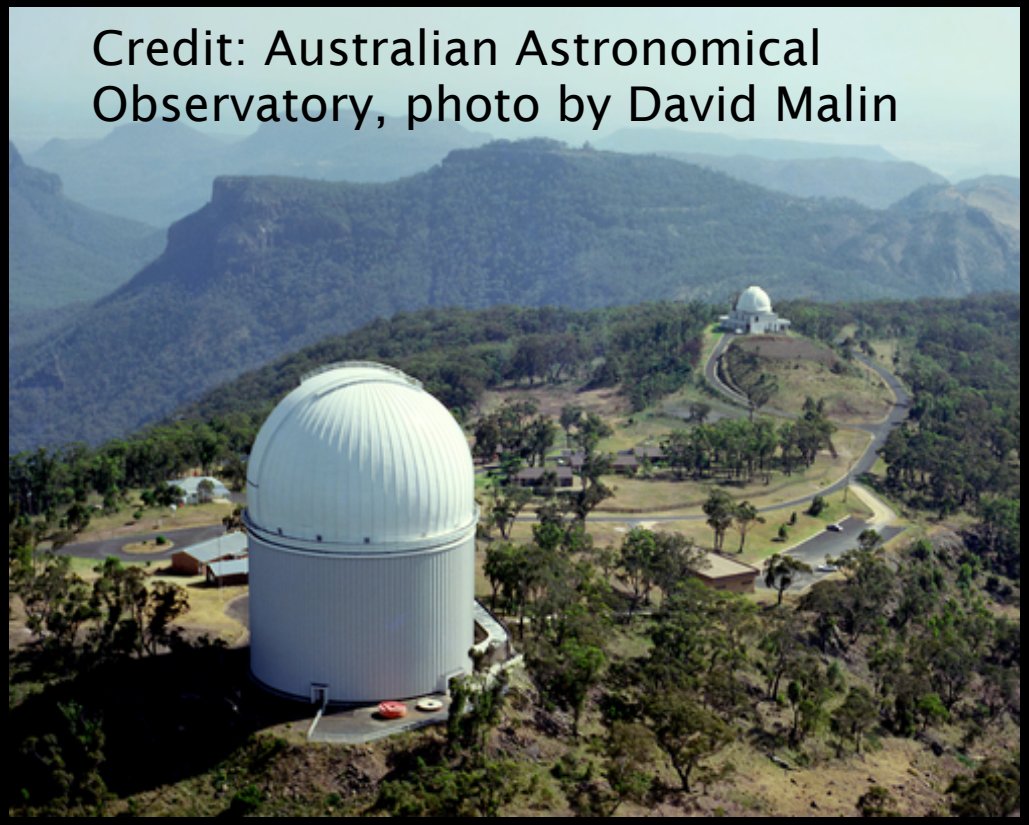
- Significant scatter :
  - Radial metallicity gradients → -0.03 dex kpc^{-1}(Mikolaitis et al. 2014) to -0.17 dex kpc^{-1}(Sestito et al. 2008)
  - Vertical metallicity gradients → -0.11 dex kpc^{-1}(Boeche et al. 2012) to -0.31 dex kpc^{-1}(Hayden et al. 2014)

APOGEE

- Sloan 2.5-m telescope at Apache Point Observatory
- NIR H-band (1.5-1.7 μm)
- R~22500
- FoV~3^o , 300 fibers

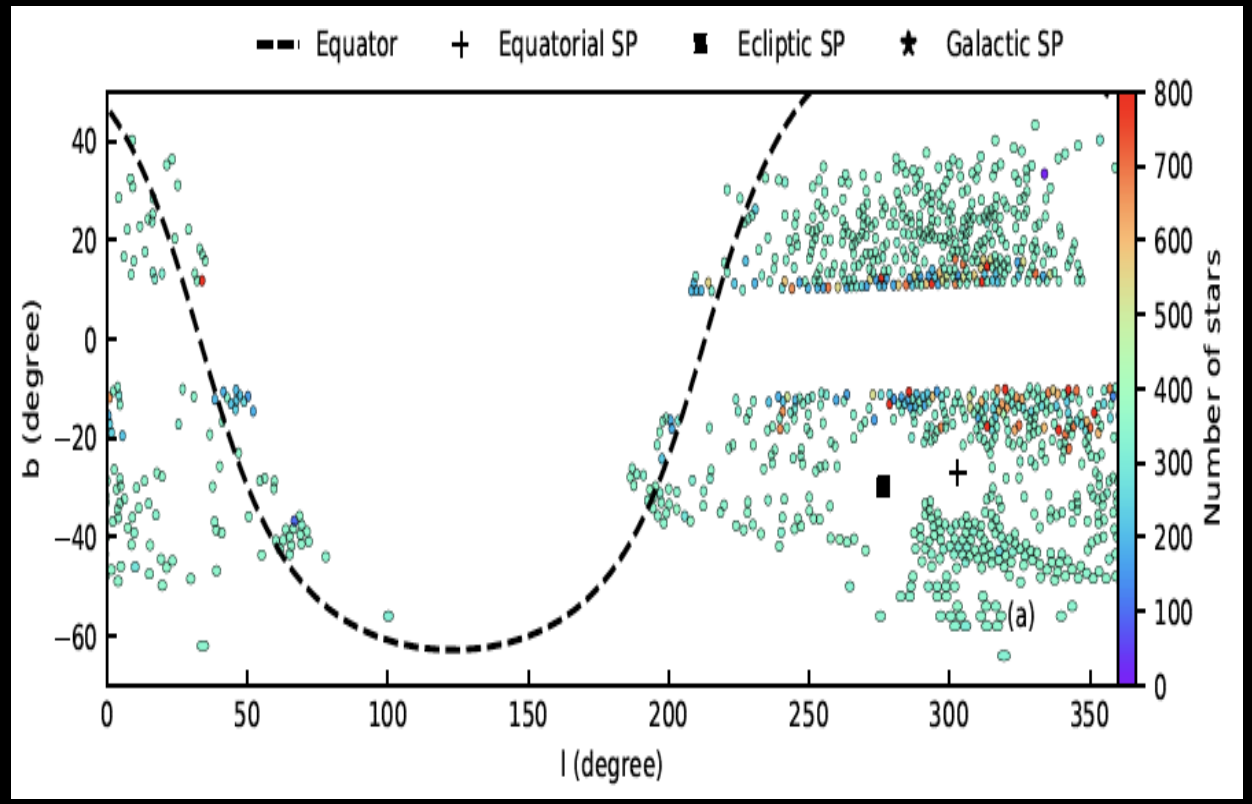
GALAH

- 3.9-m Anglo-Australian Telescope at Siding Spring Observatory.
- HERMES spectrograph
- optical wavelengths (~0.47-0.67 μm)
- R~28000
- FoV~2^o , 400 fibers

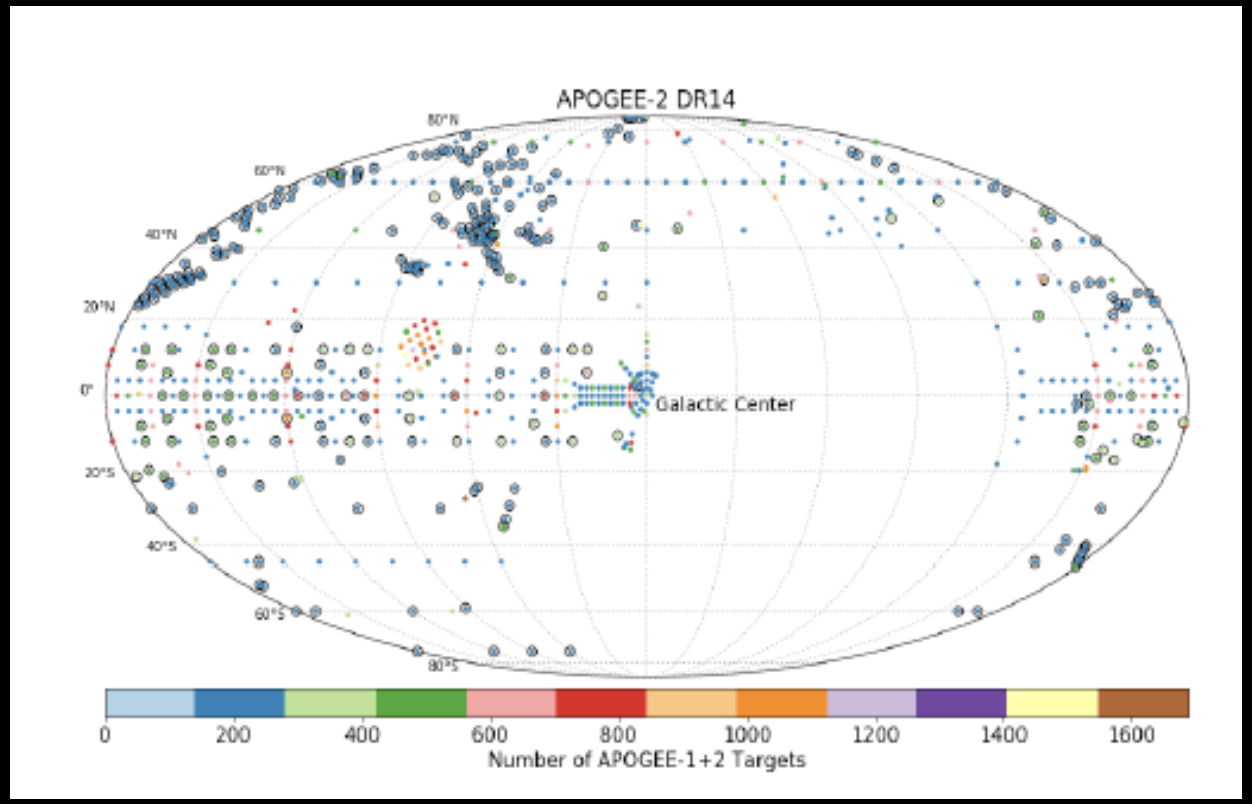


Fields

GALAH DR2 (Buder et al. 2018)



APOGEE DR14 (Holtzmann et al. 2018)

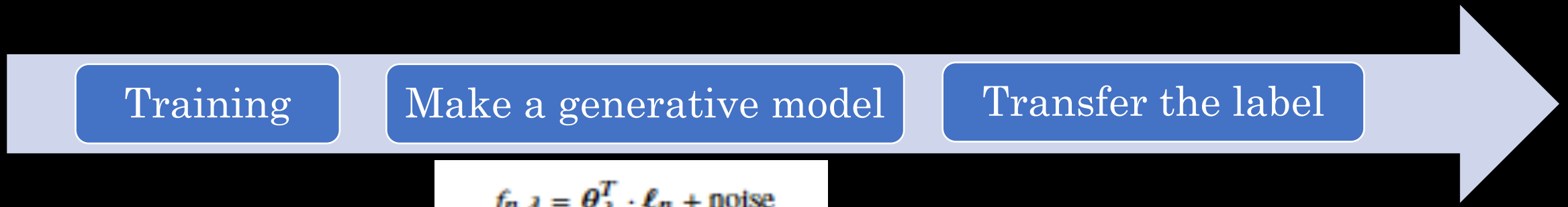


Plan

- Combine APOGEE and GALAH
- Use *the Cannon* to bring Apogee stellar parameters to Galah scale.
- Use the combined sample to study the metallicity gradients, their distributions and alpha abundance-metallicity trends.

The Cannon

- Data driven approach to determine stellar parameters from spectroscopic data (Ness et al. 2015)



$$f_{n,\lambda} = \theta_\lambda^T \cdot \ell_n + \text{noise}$$

- Ho et al. 2016 generated stellar labels from ~450000 low resolution LAMOST giant spectra with model built from APOGEE (training set)

- Buder et al. 2018 used *the Cannon* to derive stellar parameters and abundances in GALAH DR2

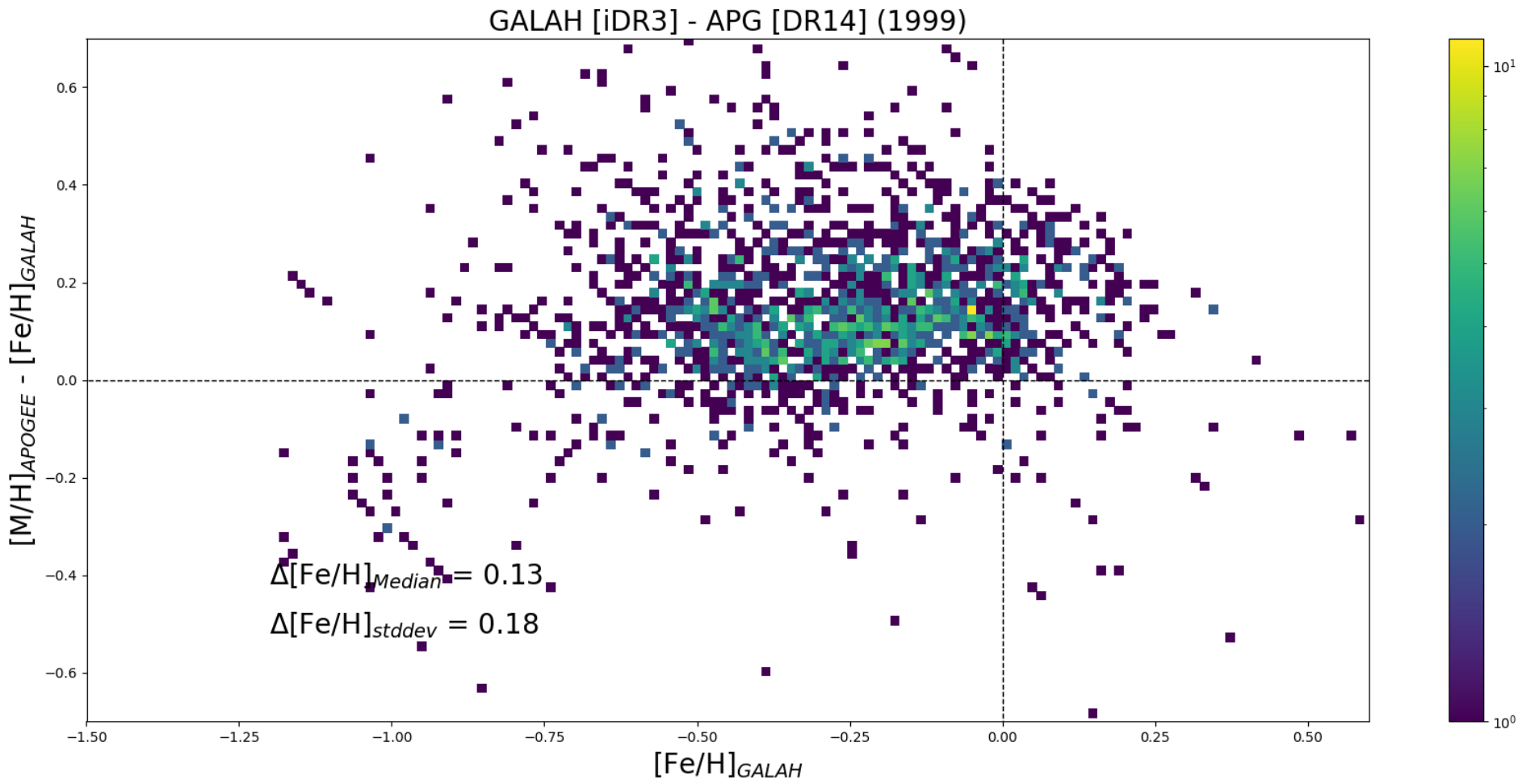
Training set

- X match between Apogee DR14 and Galah iDR3 gives ~6000 observations.

- Considering only giants (logg<3.5), and Galah quality cuts(flag_sp==0, valid [α/Fe]) lead to ~2000 stars in the training set.

- Train *Cannon* using Galah Teff, logg, [Fe/H] and [α/Fe]

Training set



Test set and label transfer

- Pseudo continuum normalized Apogee spectra of giants (valid stellar parameters), all on same pixel scale.

- Used *Cannon* model to transfer the labels.

Cuts

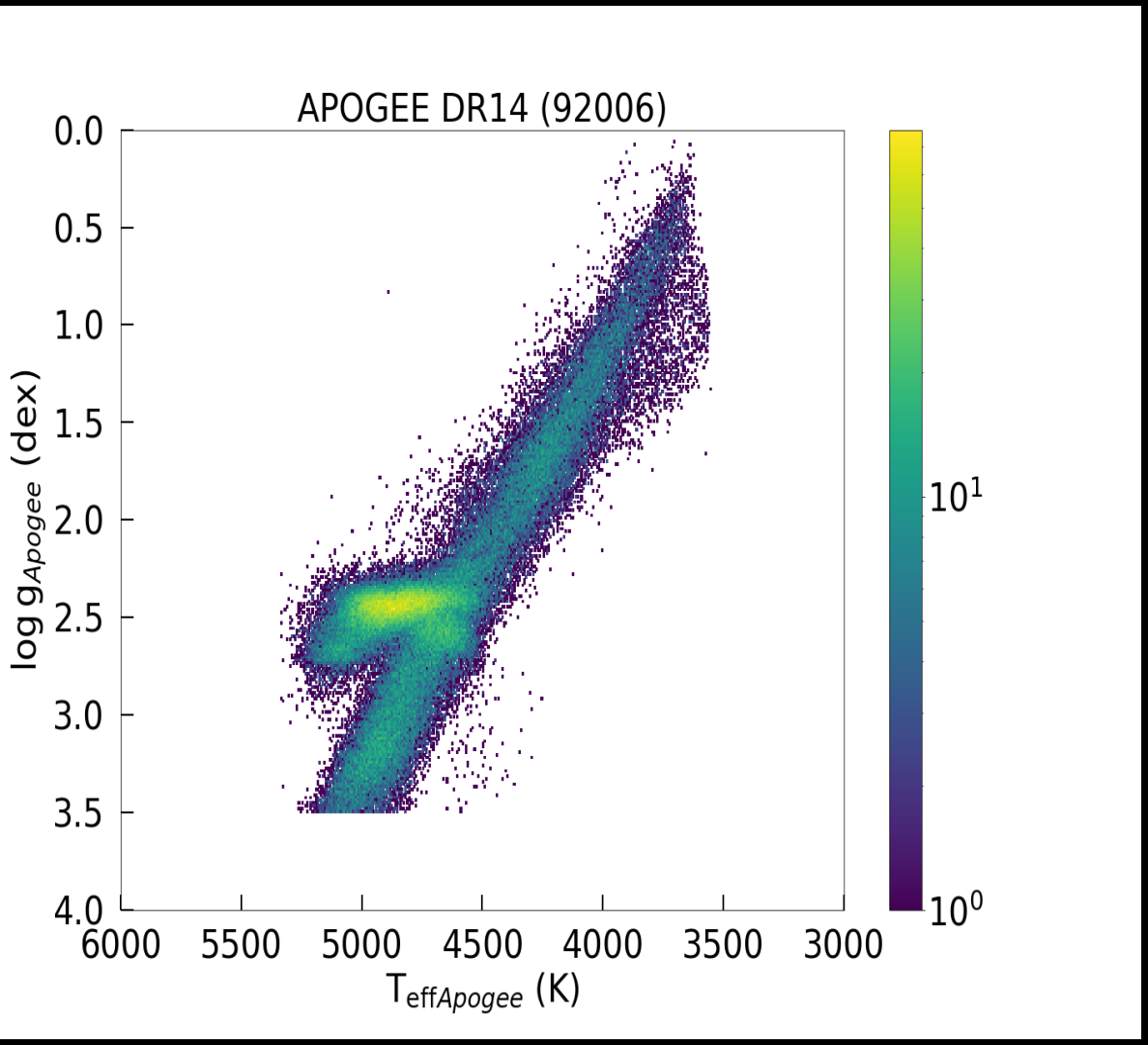
- Estimated distances by isochrone fitting (Rojas-Arriagada et al. 2015)

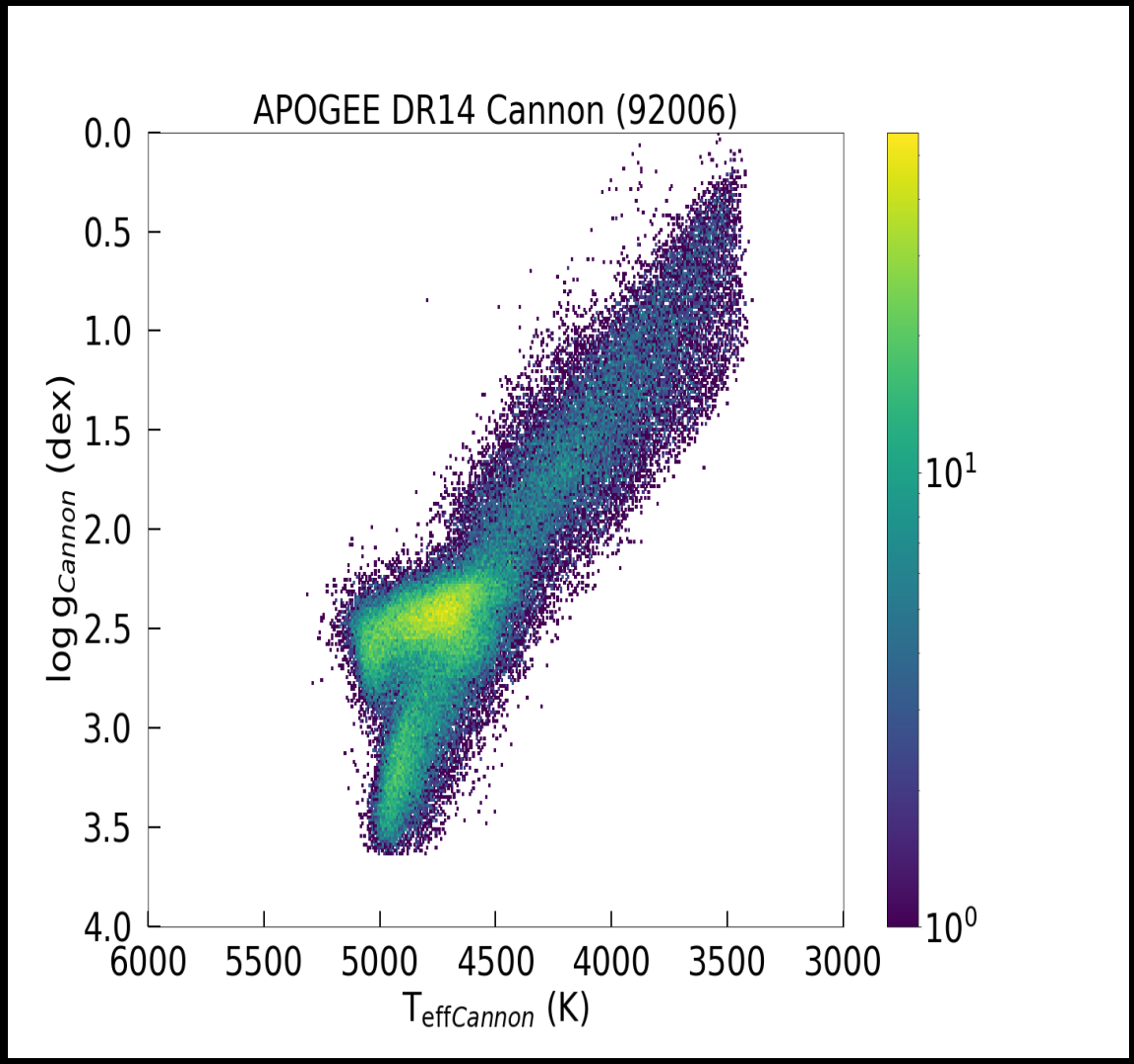
- Made cut in distances, i.e., $\sigma D/D < 0.2$

- After following cuts :
  - $|[M/H]_{Apogee} - [Fe/H]_{Cannon}| < 0.5$
  - $|logg_{Apogee} - logg_{Cannon}| < 0.15$
  - $|Teff_{Apogee} - Teff_{Cannon}| < 200$
  - $[Fe/H]_{Cannon} > -1.2$

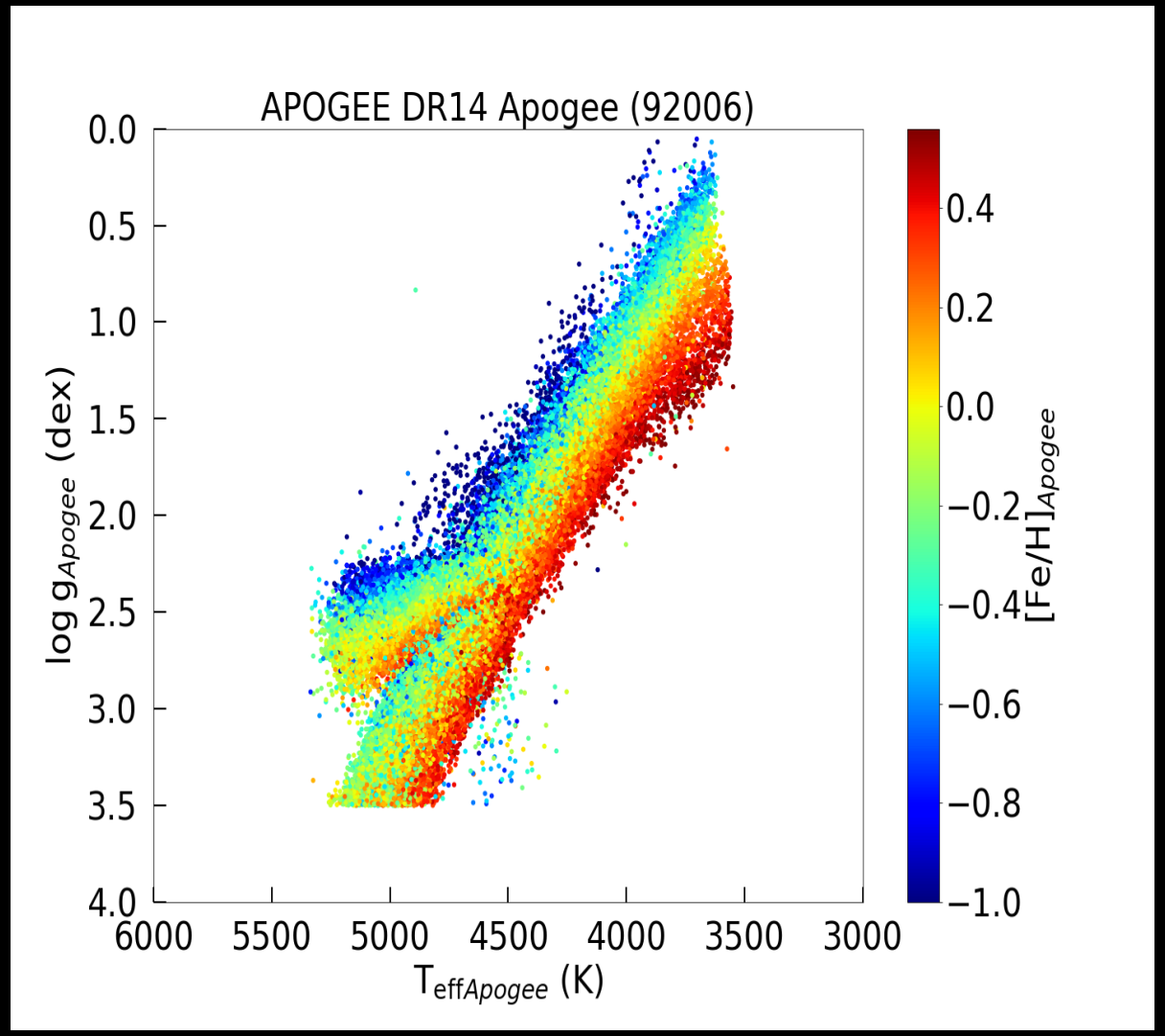
~92000

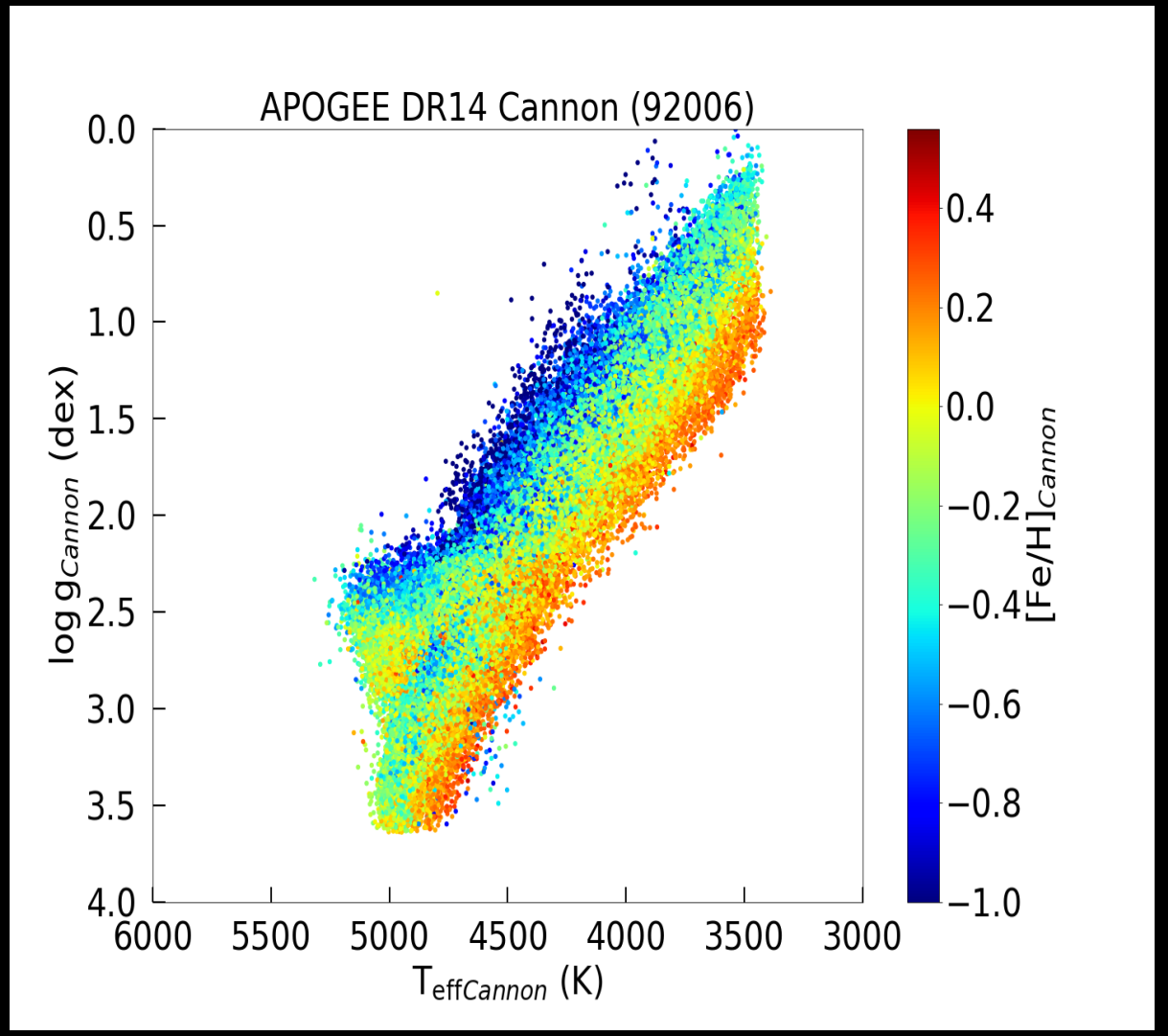
Test set


APOGEE DR14 (92006)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
log g Apogee (dex)
6000
5500
5000
4500
4000
3500
3000
T eff Apogee (K)
10^1
10^0

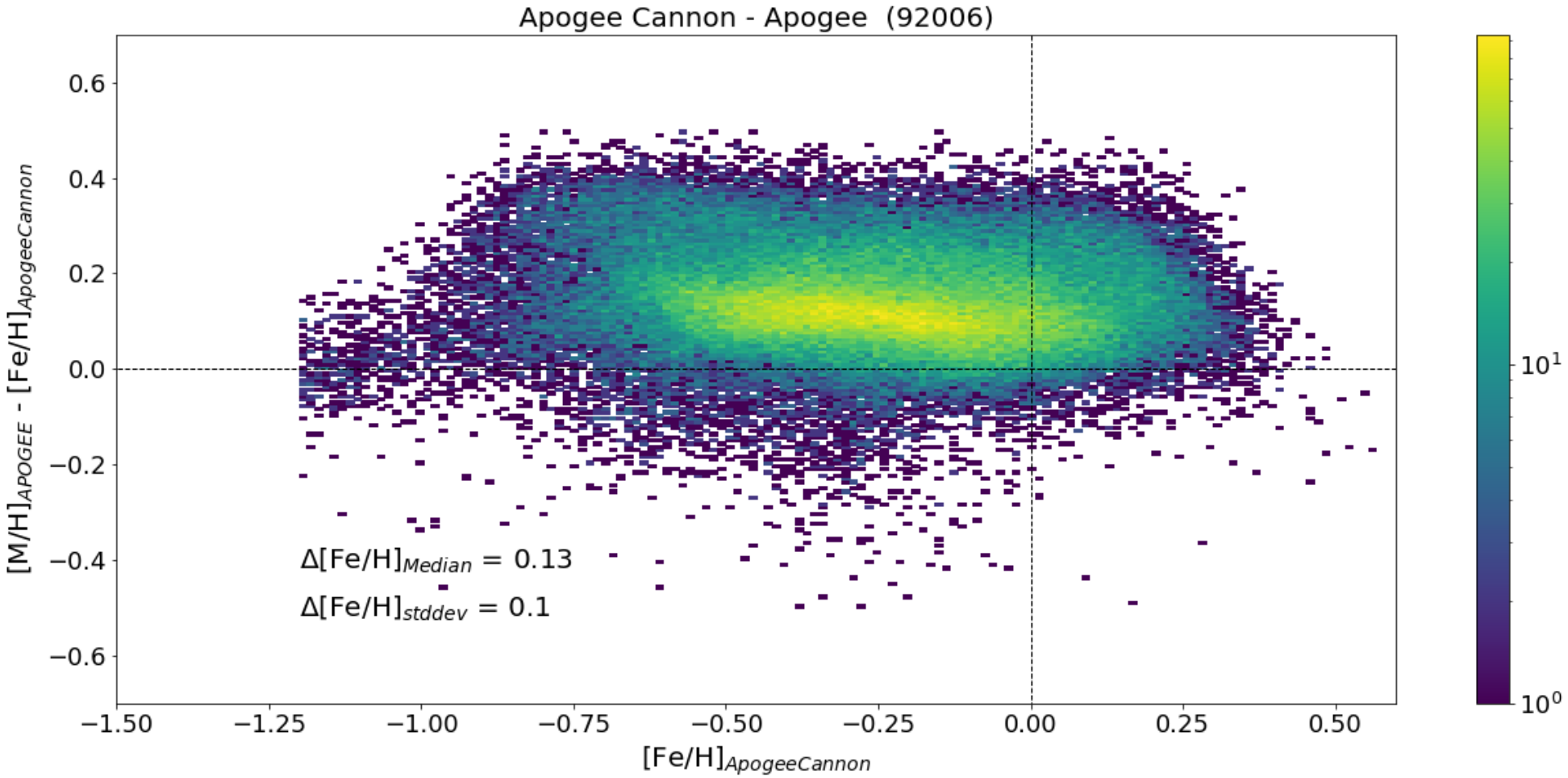

APOGEE DR14 Cannon (92006)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
log g Cannon (dex)
6000
5500
5000
4500
4000
3500
3000
T eff Cannon (K)
10^1
10^0

Test set


APOGEE DR14 Apogee (92006)
log g_Apogee (dex)
T_effApogee (K)
[Fe/H]_Apogee
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
6000
5500
5000
4500
4000
3500
3000
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0

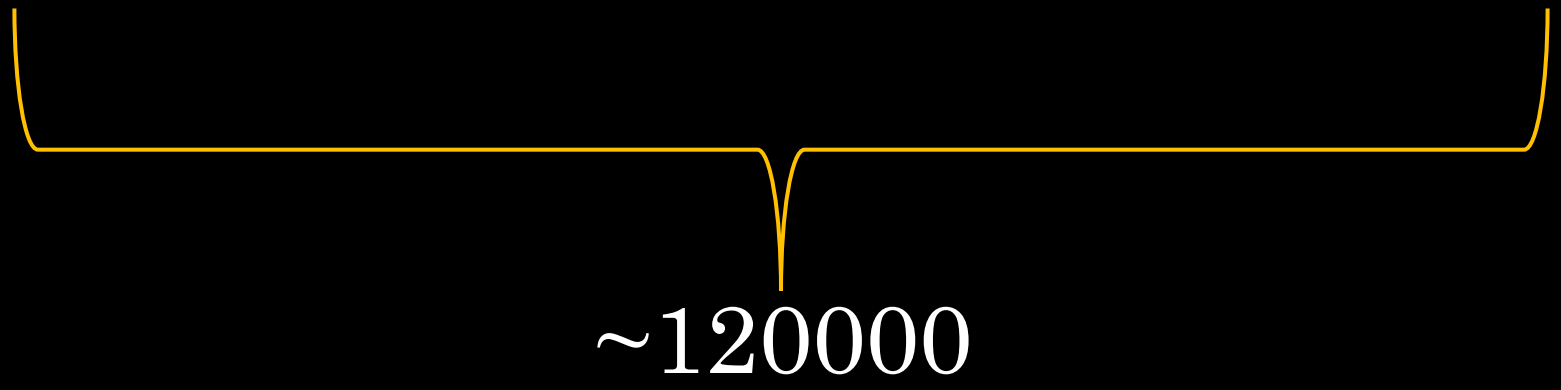

APOGEE DR14 Cannon (92006)
log g_Cannon (dex)
T_effCannon (K)
[Fe/H]_Cannon
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
6000
5500
5000
4500
4000
3500
3000
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0

Test set

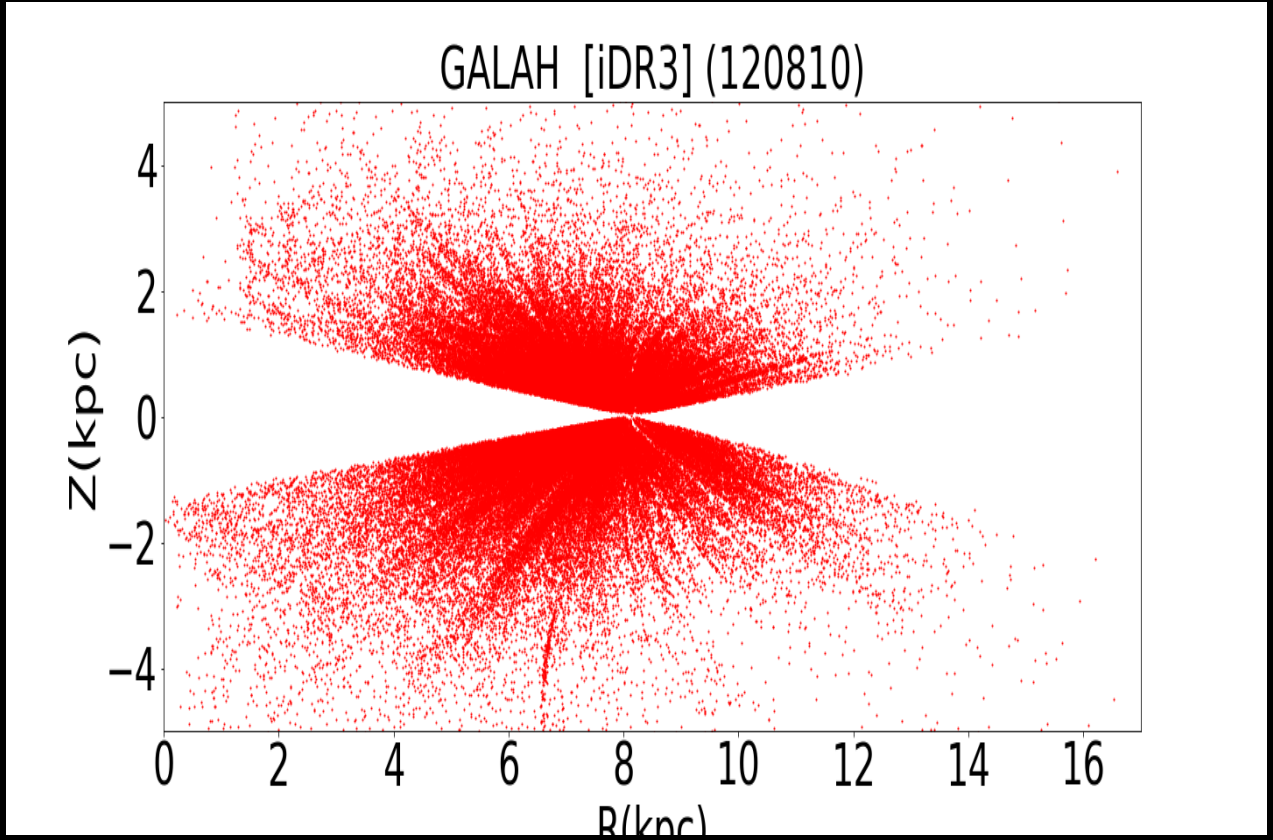

Apogee Cannon - Apogee (92006)
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
[M/H]APOGEE - [Fe/H]ApogeeCannon
Δ[Fe/H]Median = 0.13
Δ[Fe/H]stddev = 0.1
−1.50
−1.25
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
[Fe/H]ApogeeCannon
10^1
10^0

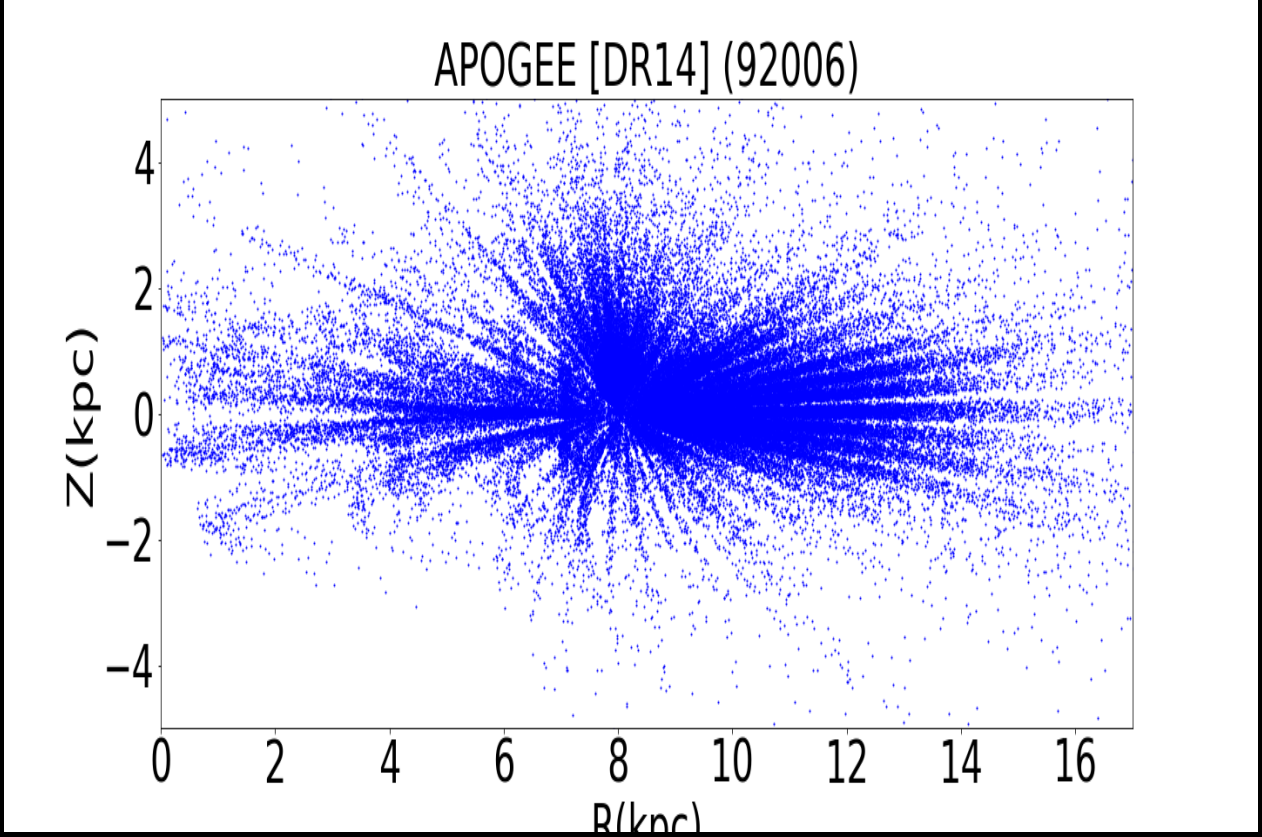
Galah giant sample

- Giants (logg<3.5), and Galah quality cut(flag_sp==0)
- Estimated distances by isochrone fitting (Rojas-Arriagada et al. 2015)
- Made further cut in distances, i.e., $\sigma D/D < 0.2$

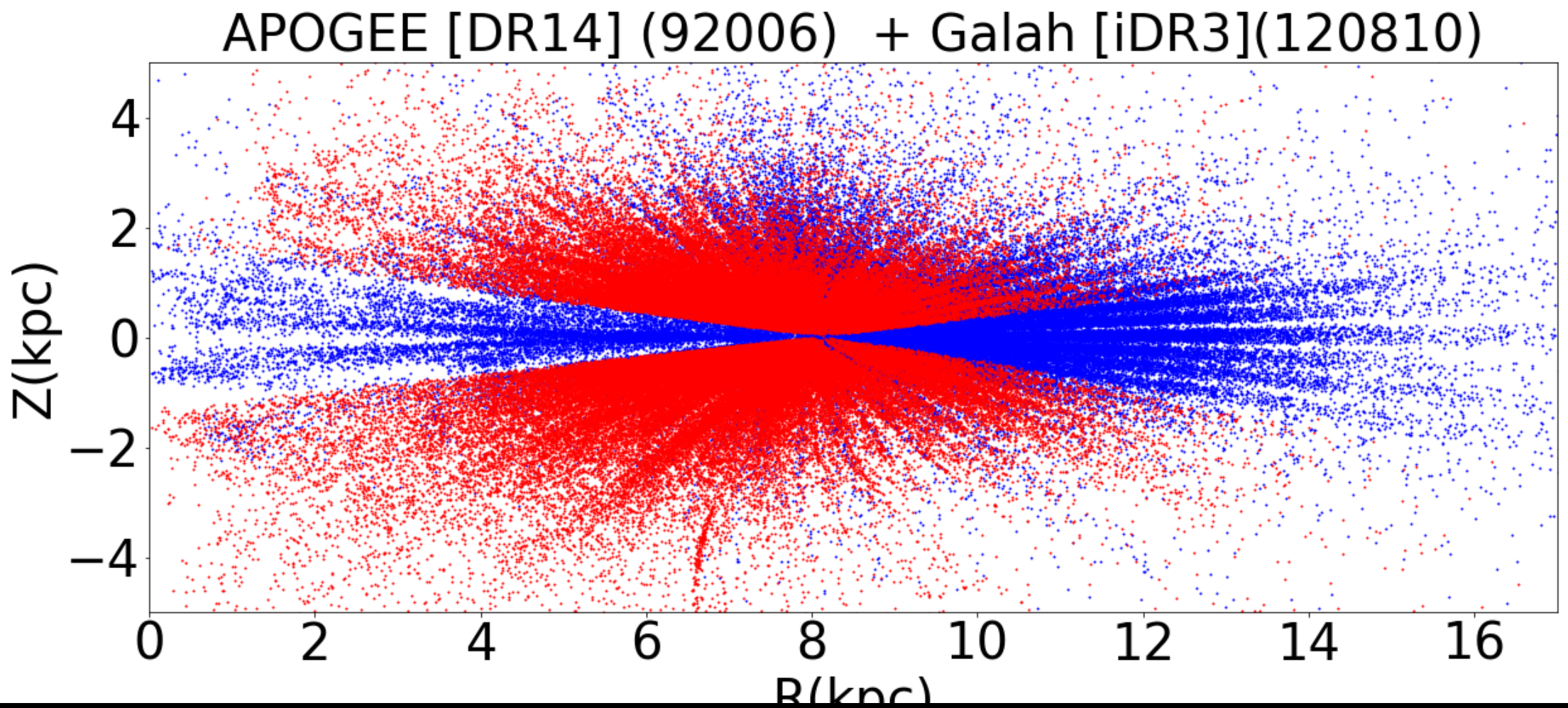


R-Z Giant distribution





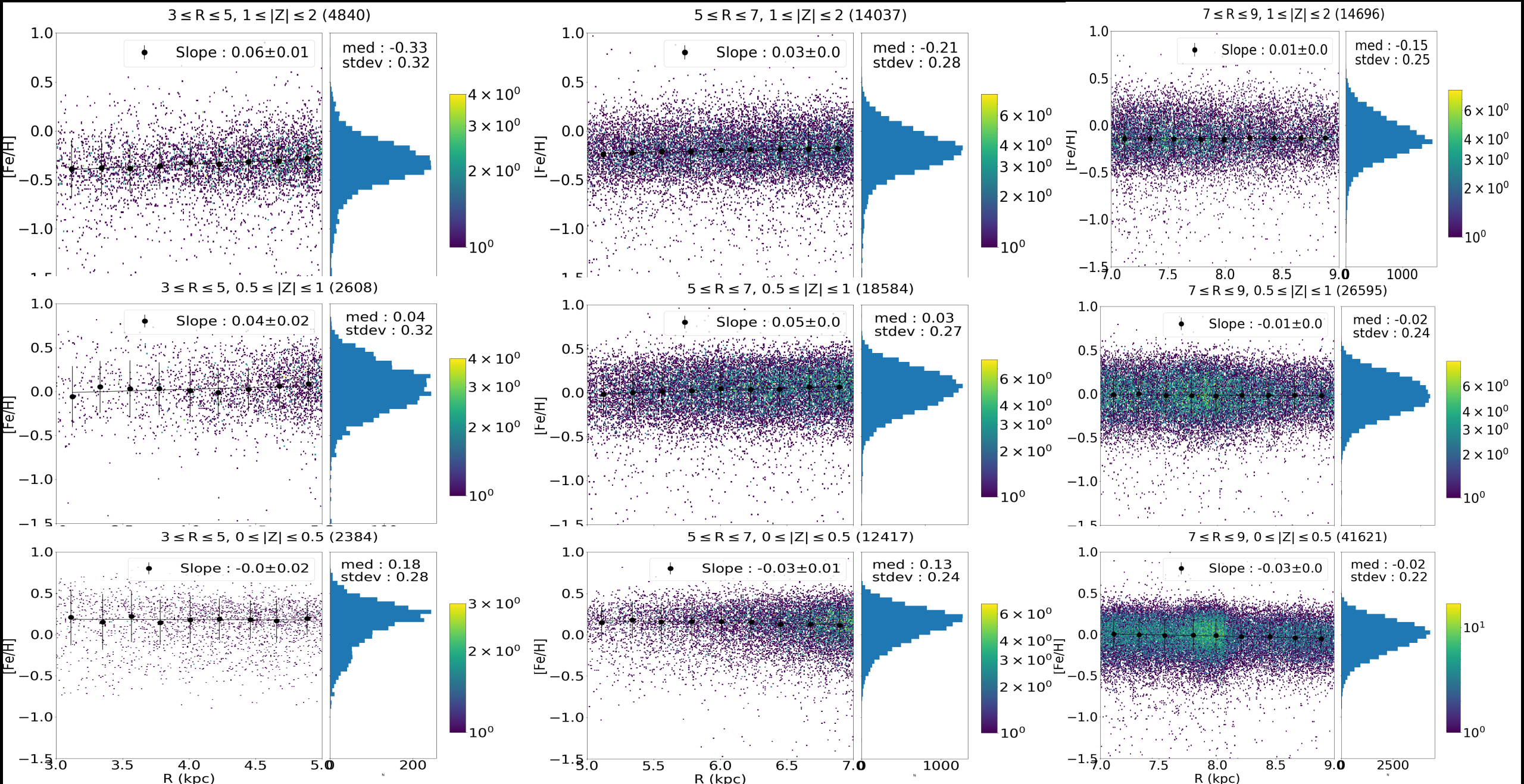
R-Z Giant distribution



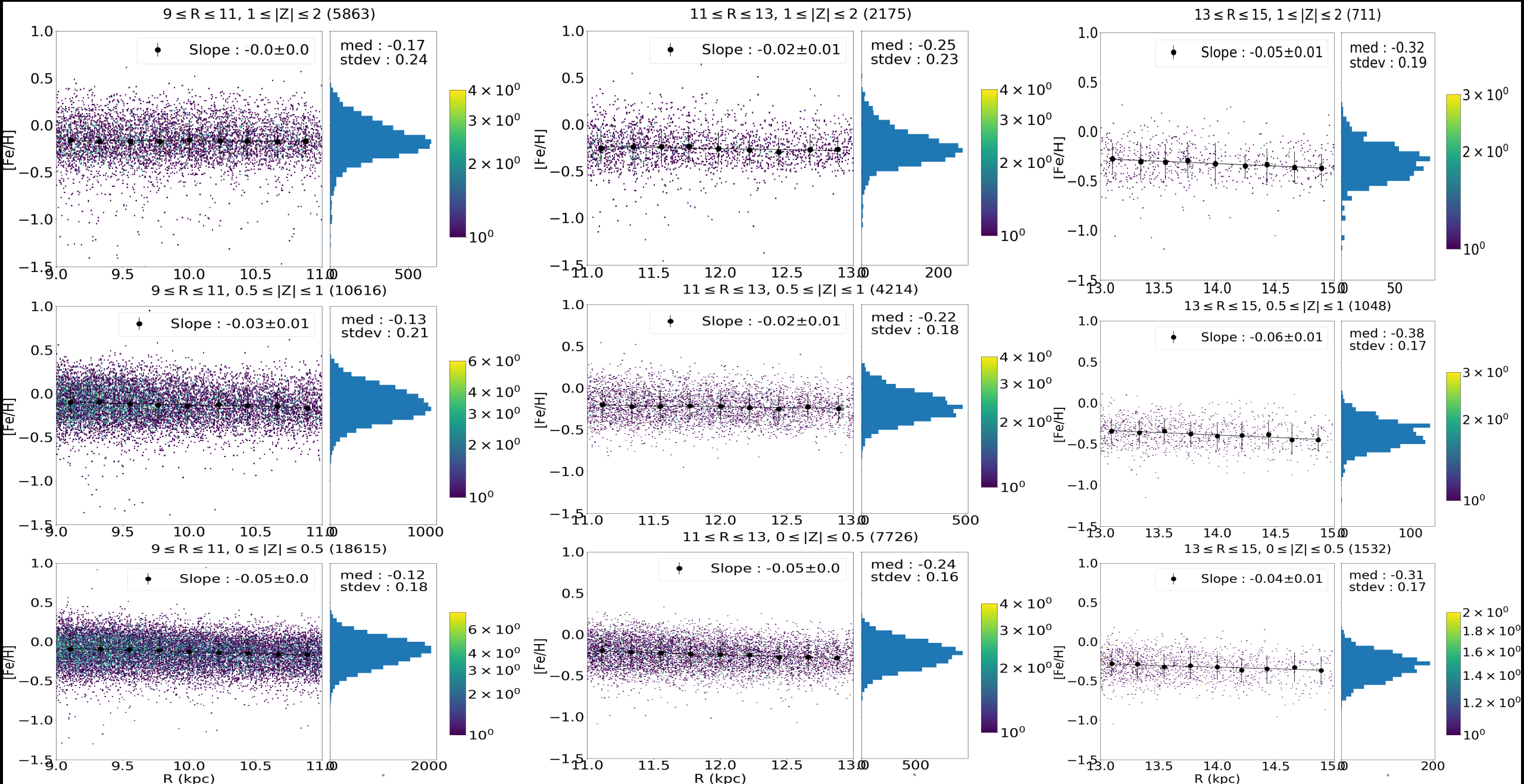
Radial gradient

- Divided radial Galactocentric distance, R, into 2 kpc bins within 3 to 15 kpc.
- Height from Galactic midplane, $|Z|$, into 3 ranges – [0,0.5], [0.5,1] and [1,2].
- Linear least-squares regression fit to the median metallicities in 0.2 kpc bins in each R range to get slope

Radial gradient



Radial gradient

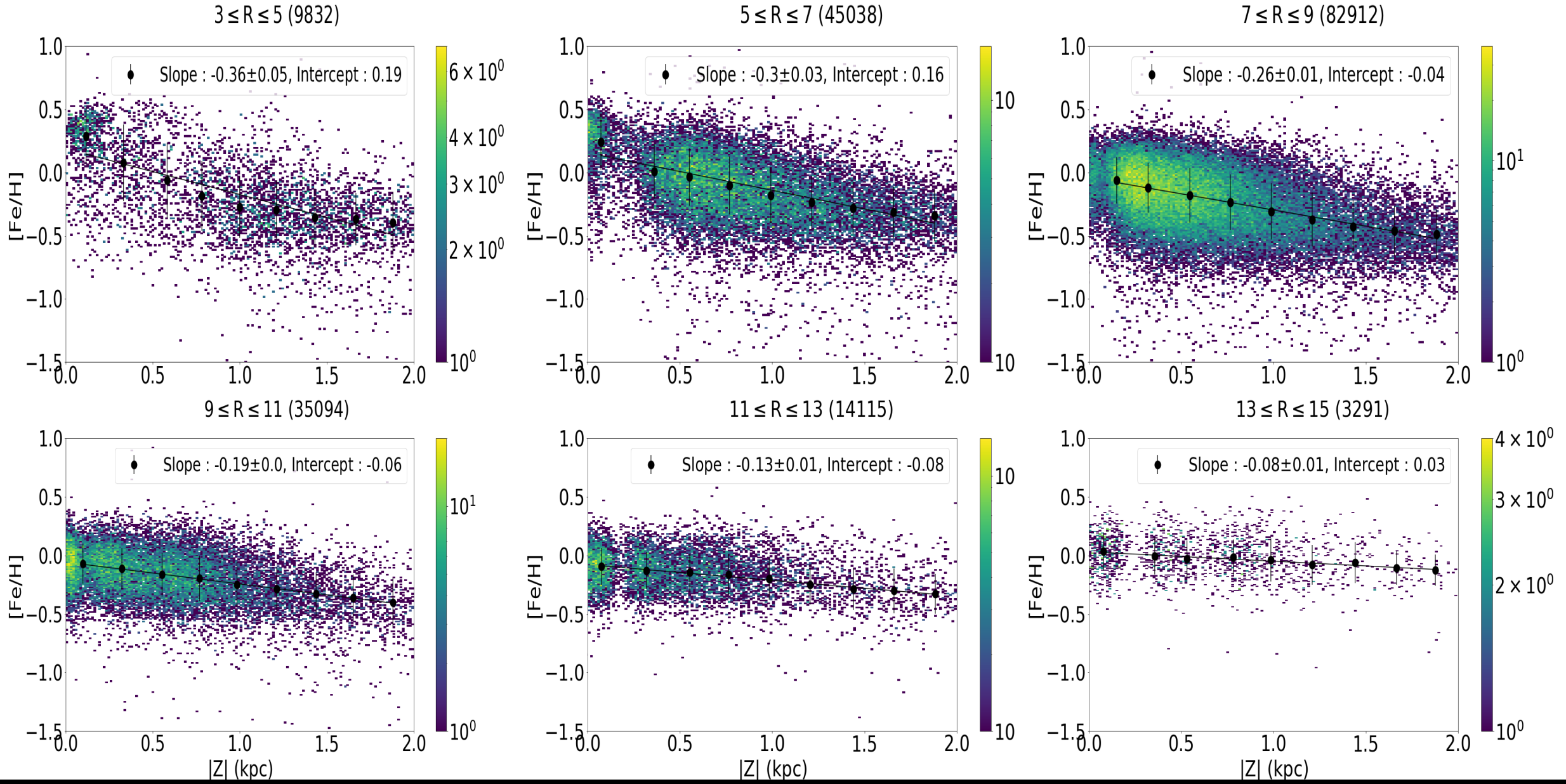


Vertical gradient

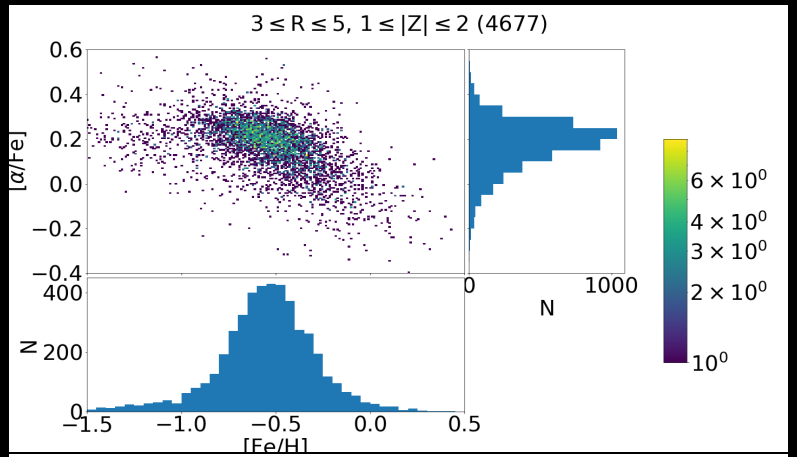
- Divided radial Galactocentric distance, R, into 2 kpc bins within 3 to 15 kpc.

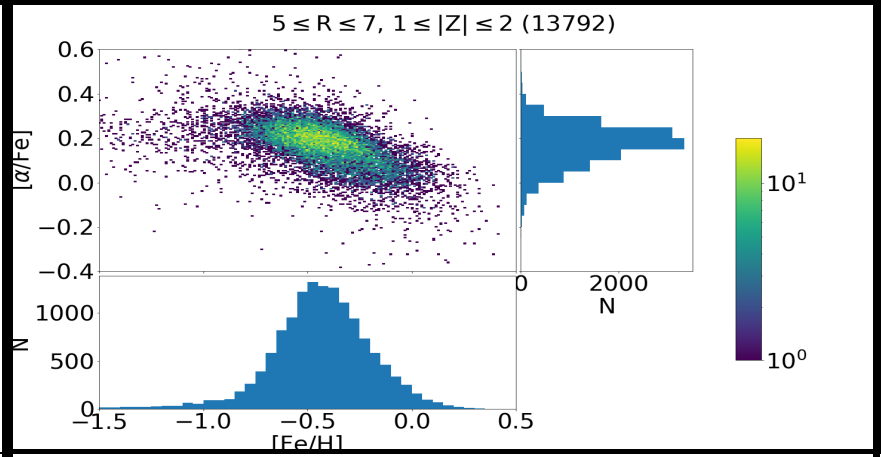
- Linear least-squares regression fit to the median metallicities in 0.2 kpc bins in 0 to 2 kpc range of |Z| to get the slope.

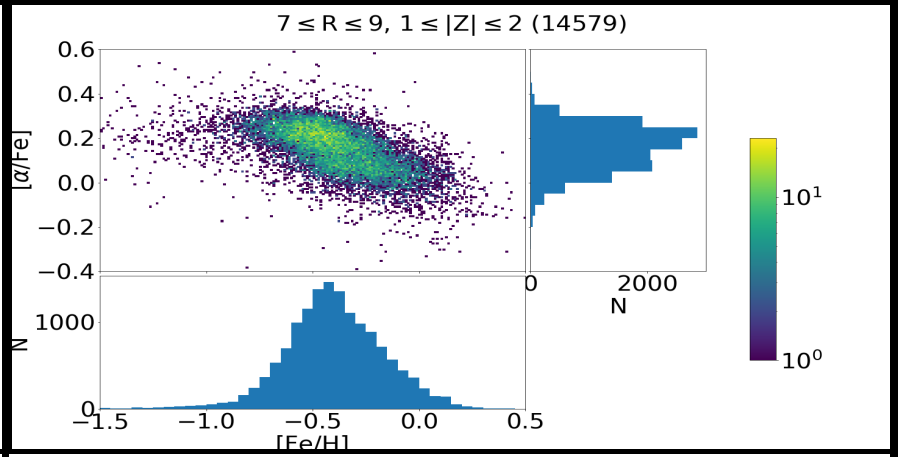
Vertical gradient

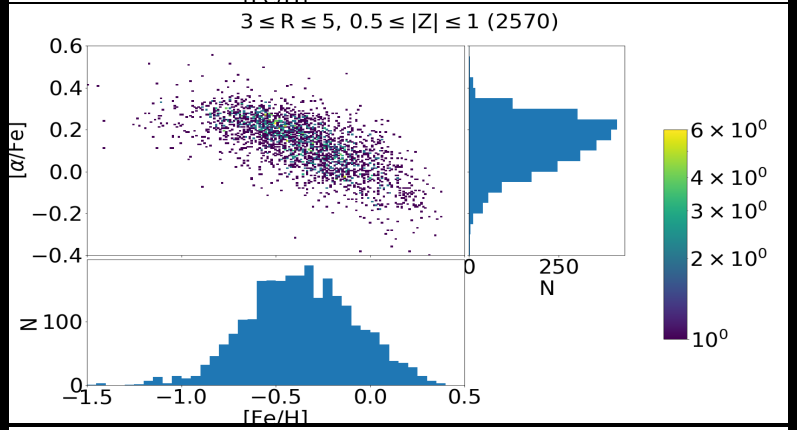


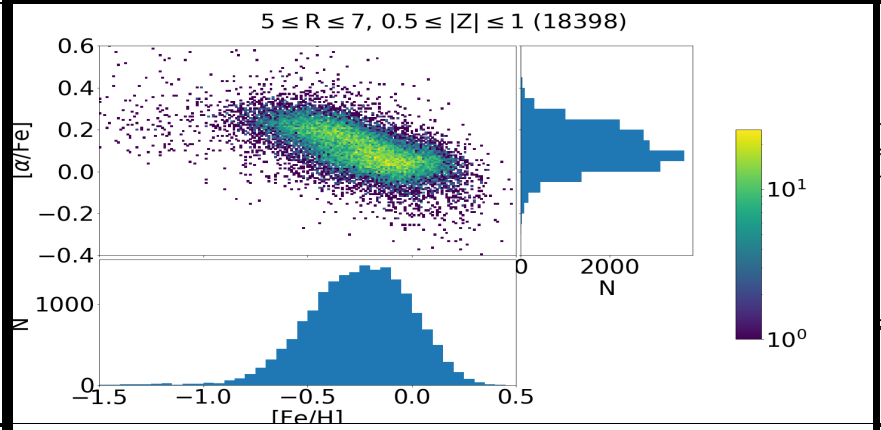
[α/Fe] vs [Fe/H]

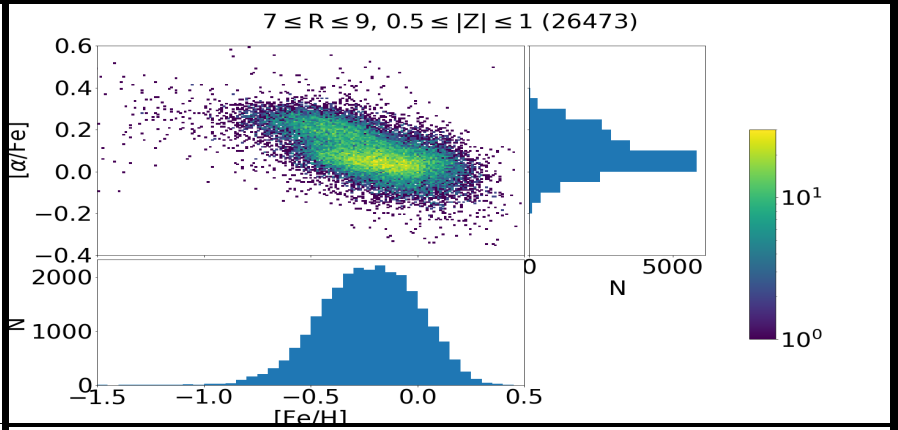

3 ≤ R ≤ 5, 1 ≤ |Z| ≤ 2 (4677)
[α/Fe]
[Fe/H]
N

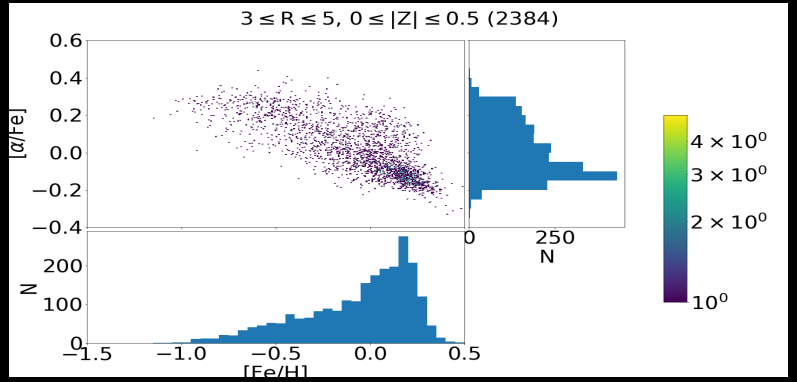

5 ≤ R ≤ 7, 1 ≤ |Z| ≤ 2 (13792)
[α/Fe]
[Fe/H]
N

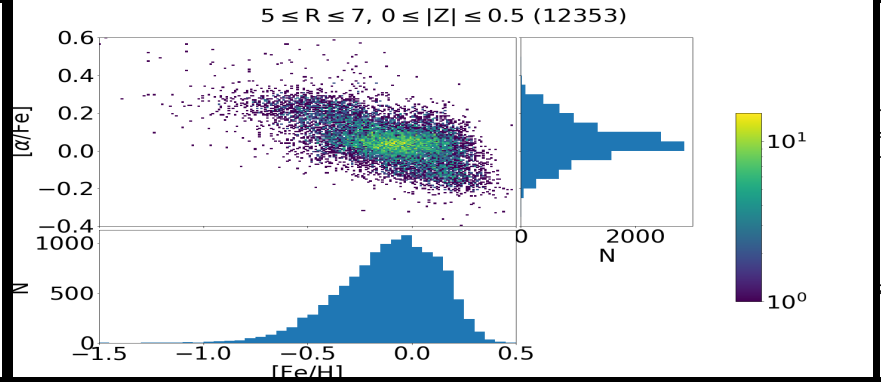

7 ≤ R ≤ 9, 1 ≤ |Z| ≤ 2 (14579)
[α/Fe]
[Fe/H]
N

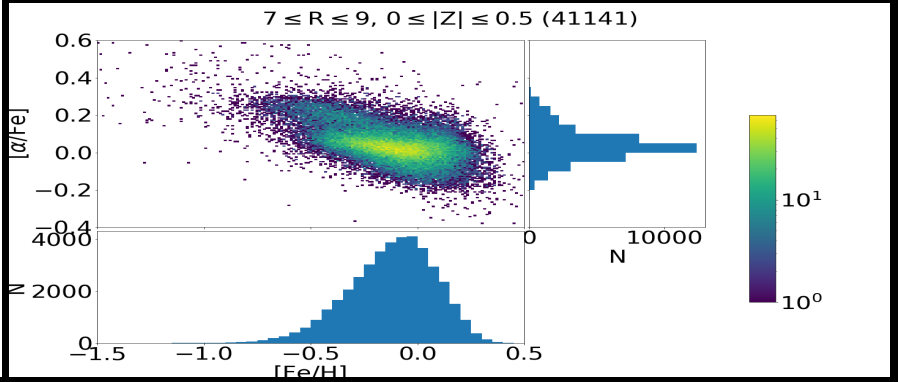

3 ≤ R ≤ 5, 0.5 ≤ |Z| ≤ 1 (2570)
[α/Fe]
[Fe/H]
N


5 ≤ R ≤ 7, 0.5 ≤ |Z| ≤ 1 (18398)
[α/Fe]
[Fe/H]
N

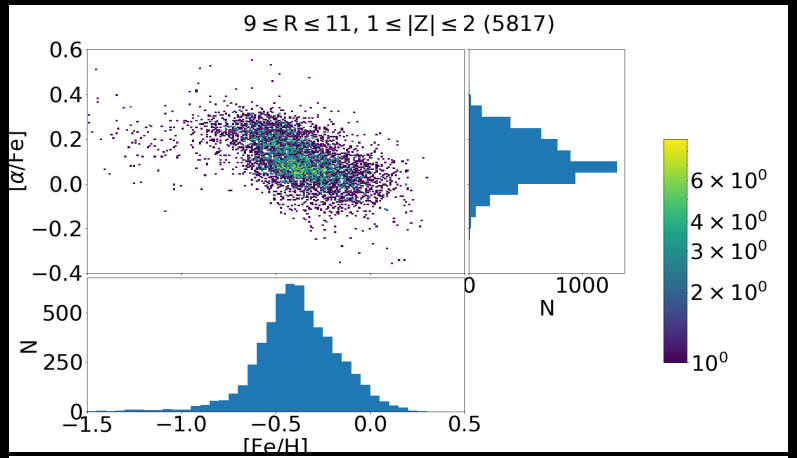

7 ≤ R ≤ 9, 0.5 ≤ |Z| ≤ 1 (26473)
[α/Fe]
[Fe/H]
N

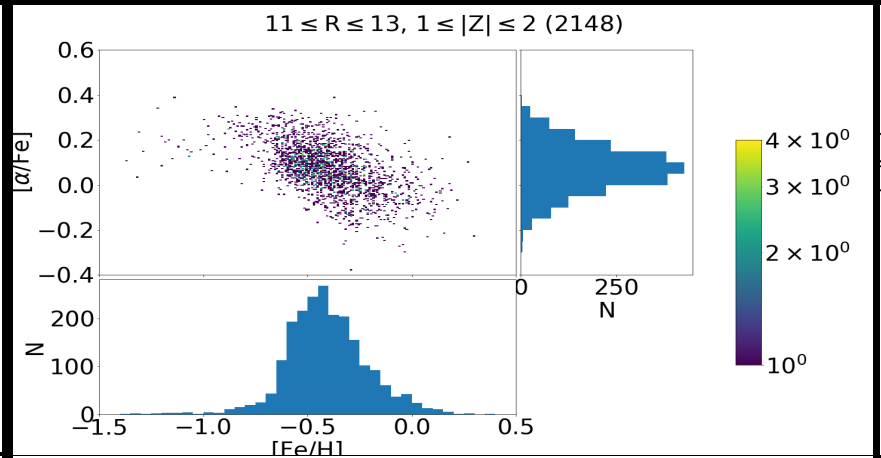

3 ≤ R ≤ 5, 0 ≤ |Z| ≤ 0.5 (2384)
[α/Fe]
[Fe/H]
N

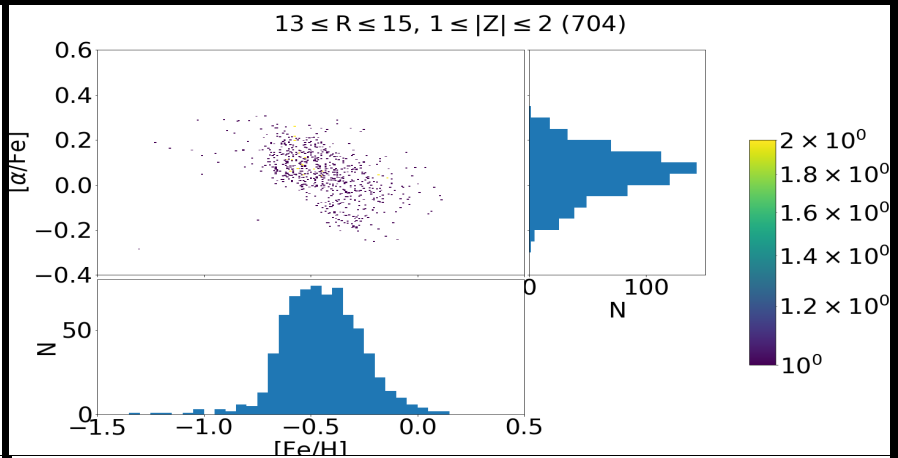

5 ≤ R ≤ 7, 0 ≤ |Z| ≤ 0.5 (12353)
[α/Fe]
[Fe/H]
N

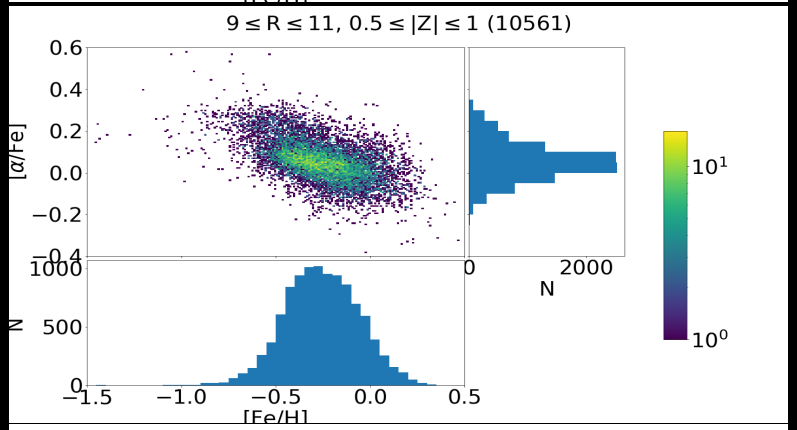

7 ≤ R ≤ 9, 0 ≤ |Z| ≤ 0.5 (41141)
[α/Fe]
[Fe/H]
N

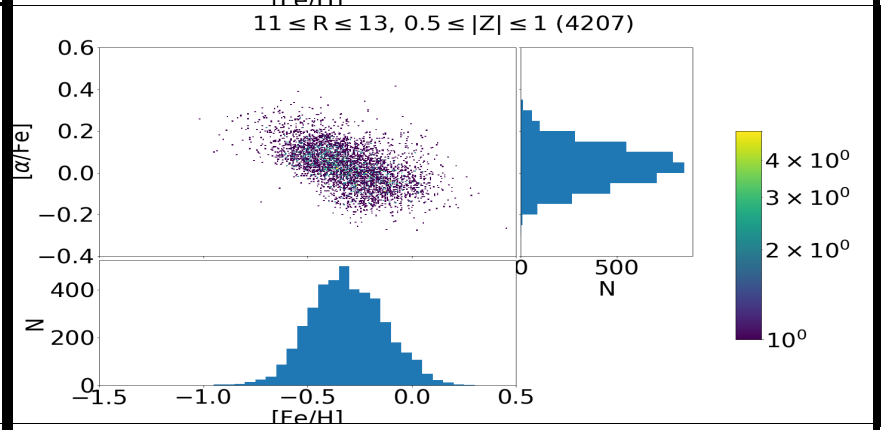
[α/Fe] vs [Fe/H]

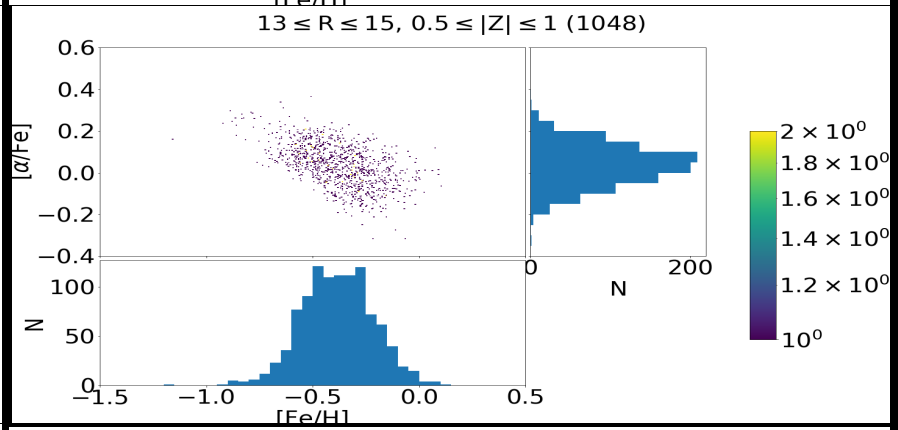

9 ≤ R ≤ 11, 1 ≤ |Z| ≤ 2 (5817)
[α/Fe]
[Fe/H]
N

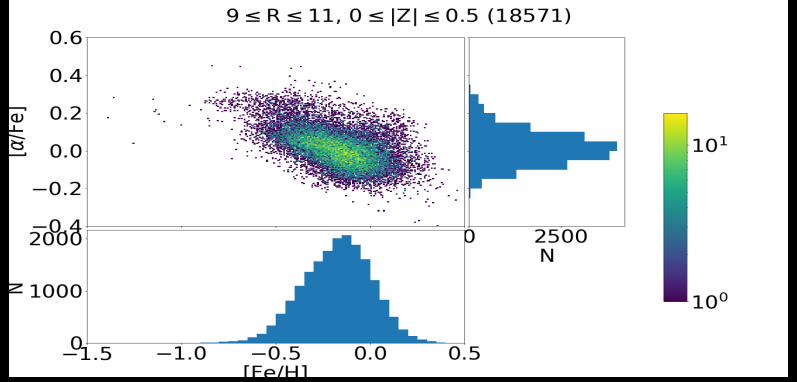

11 ≤ R ≤ 13, 1 ≤ |Z| ≤ 2 (2148)
[α/Fe]
[Fe/H]
N

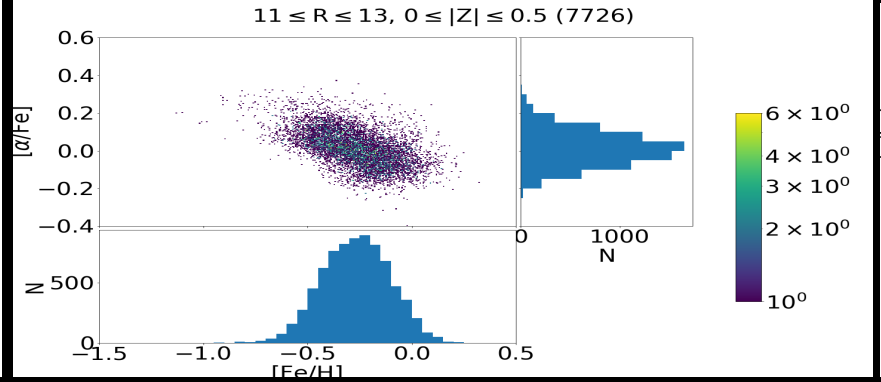

13 ≤ R ≤ 15, 1 ≤ |Z| ≤ 2 (704)
[α/Fe]
[Fe/H]
N

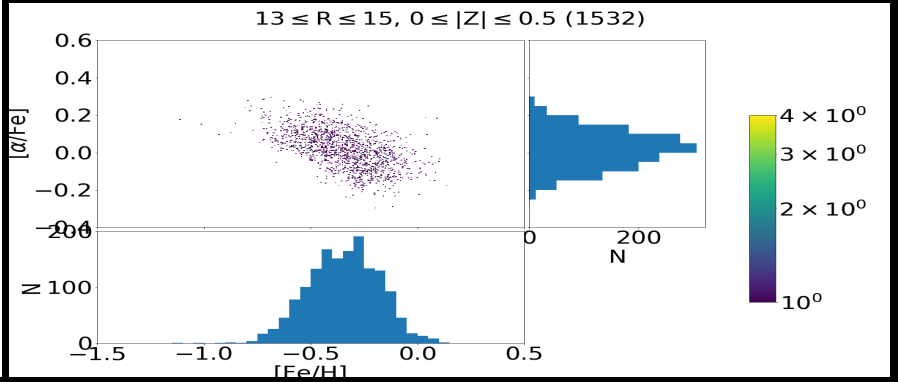

9 ≤ R ≤ 11, 0.5 ≤ |Z| ≤ 1 (10561)
[α/Fe]
[Fe/H]
N


11 ≤ R ≤ 13, 0.5 ≤ |Z| ≤ 1 (4207)
[α/Fe]
[Fe/H]
N


13 ≤ R ≤ 15, 0.5 ≤ |Z| ≤ 1 (1048)
[α/Fe]
[Fe/H]
N


9 ≤ R ≤ 11, 0 ≤ |Z| ≤ 0.5 (18571)
[α/Fe]
[Fe/H]
N


11 ≤ R ≤ 13, 0 ≤ |Z| ≤ 0.5 (7726)
[α/Fe]
[Fe/H]
N


13 ≤ R ≤ 15, 0 ≤ |Z| ≤ 0.5 (1532)
[α/Fe]
[Fe/H]
N

Summary

- Used *Cannon* to transfer Galah labels to Apogee spectra
- Resulting combined Galah+Apogee Giant sample is statistically large to cover wide ranges of R and Z.
- Radial and vertical metallicity gradients, alpha abundance-metallicity trends similar to Trends found by Apogee (except for systematic difference)

Future works

- Need to make the training set cleaner and statistically larger. (Sven's talk : Apogee DR16 vs Galah iDR3 looks promising)

- Take into account the selection function effects for stars in both the surveys (explained in Jane lin's talk)

- Accurate interpretations need age, kinematics etc (Ivan Minchev's talk)