Sesto, Italy 2016-1-25

The radially migrated population unveiled from the age-metallicity relation of the LAMOST survey data

Chao Liu (National Astronomical Observatories, CAS, Beijing)

Outlines

- An introduction of the LAMOST survey
- Brief overview of radial migration
- The evidence from the LAMOST RGB stars
- Summary

An introduction of the LAMOST survey

- 4-m quasi-meridian reflective Schmidt telescope
- 5-degree wide FoV
- 4000 fibers with 16 spectrographs
- low resolution spectroscopic survey (R=1800)
- limiting magnitude r=17.8-18.5
- >7 million spectra after 5-year survey (2012-2017)

Figure 1 LAMOST

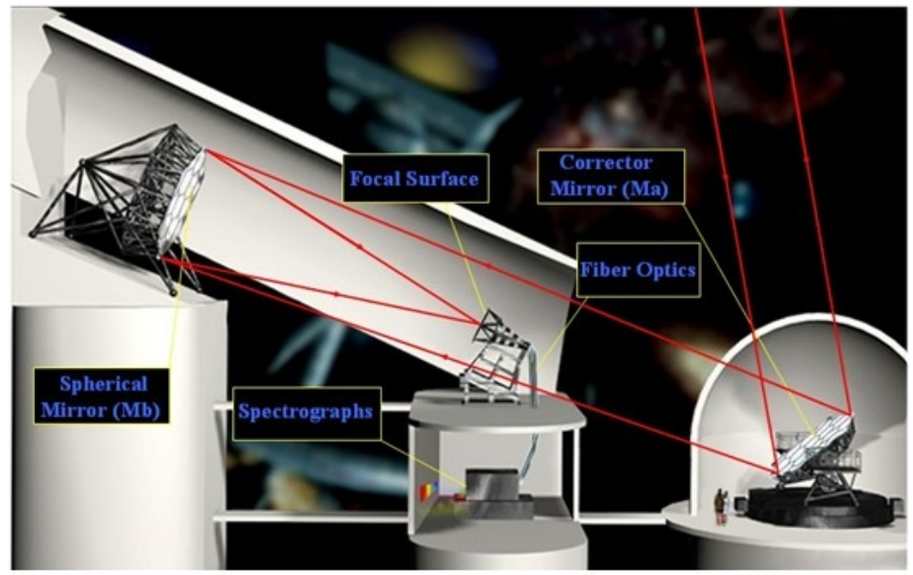
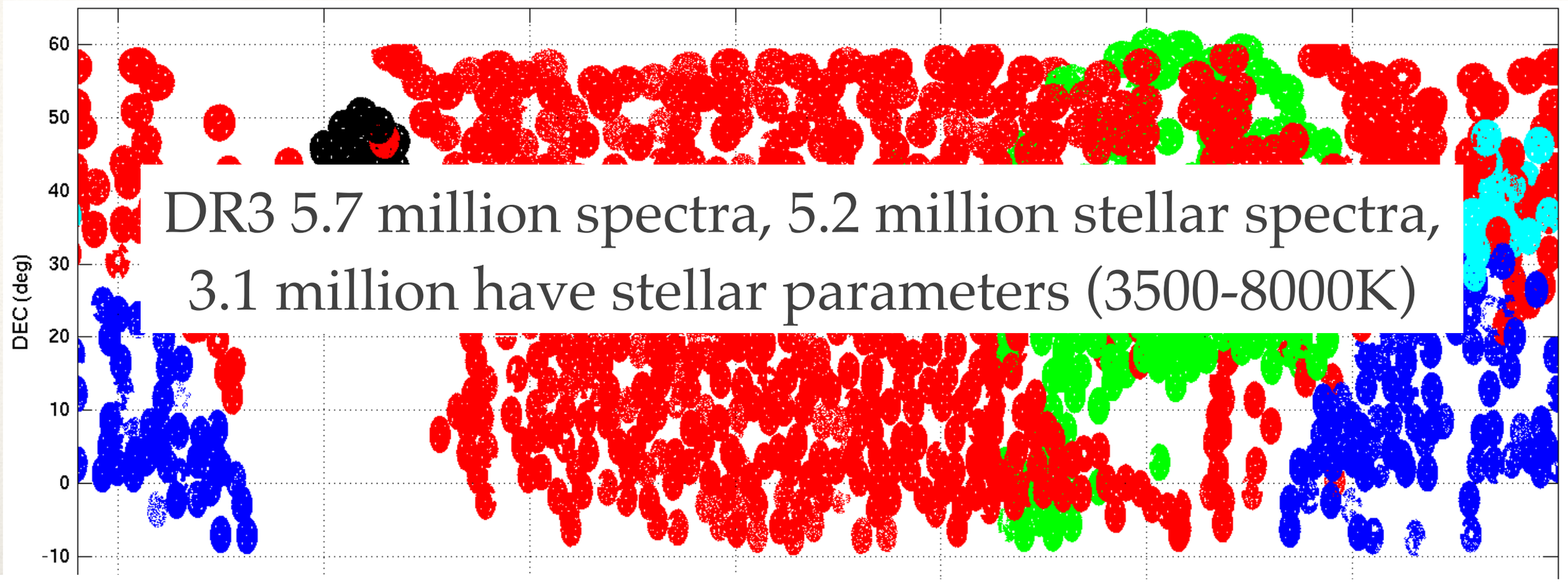
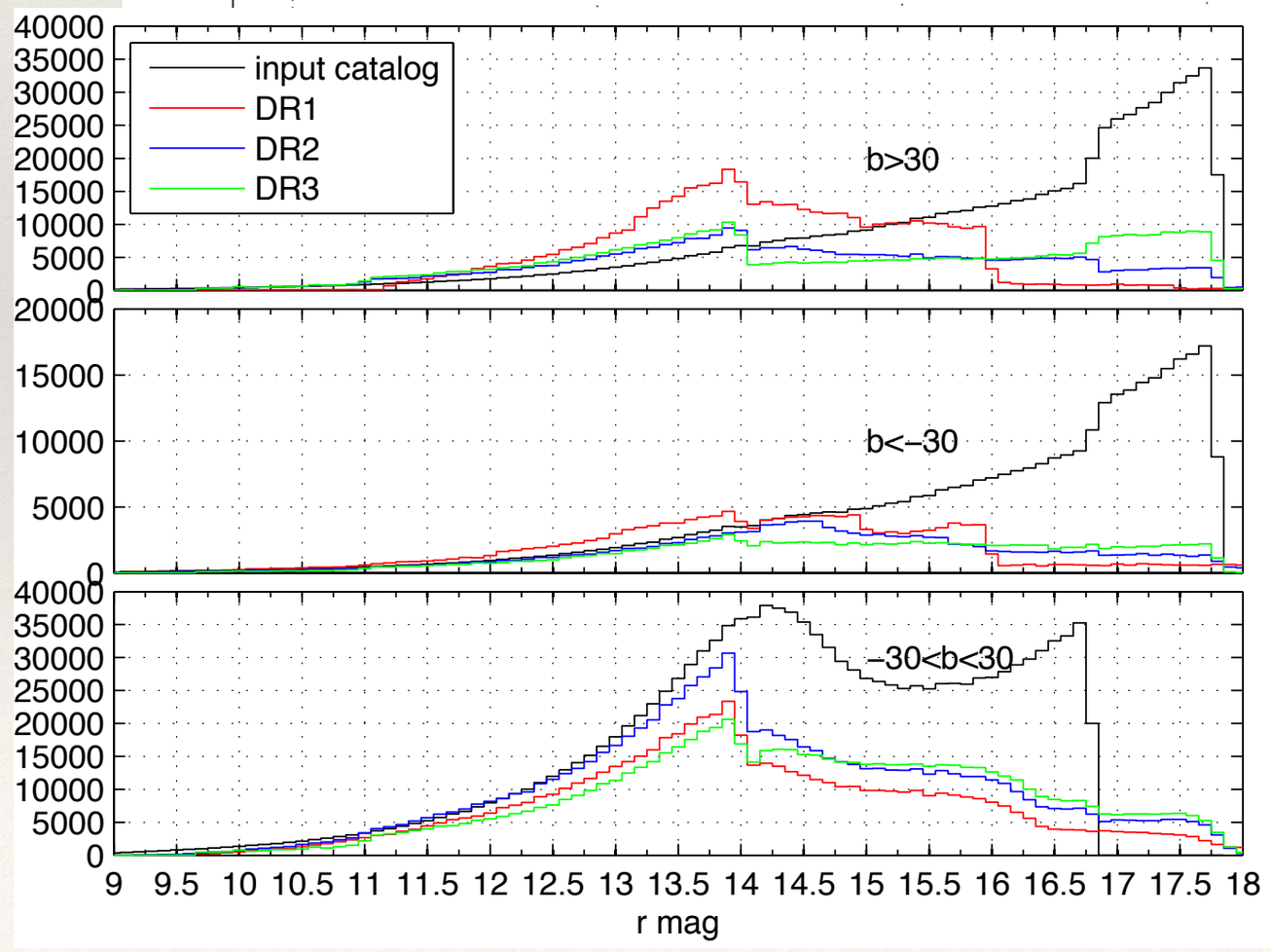
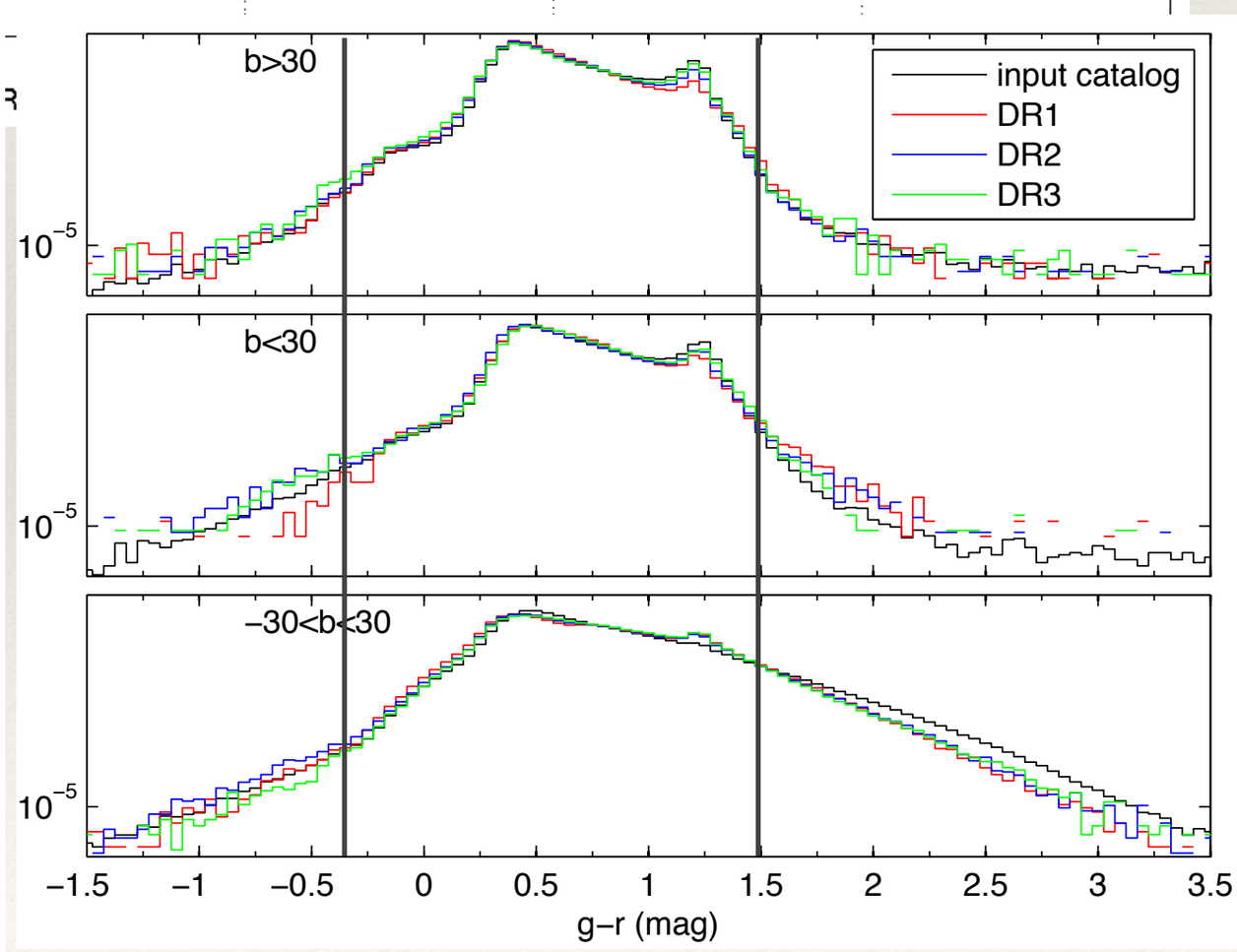


Figure 2 LAMOST overview


DR3 5.7 million spectra, 5.2 million stellar spectra,
3.1 million have stellar parameters (3500-8000K)
DEC (deg)
60
50
40
30
20
10
0
-10


input catalog
DR1
DR2
DR3
b>30
b<−30
−30<b<30
r mag


b>30
b<30
−30<b<30
input catalog
DR1
DR2
DR3
g−r (mag)

Comparison with PASTEL

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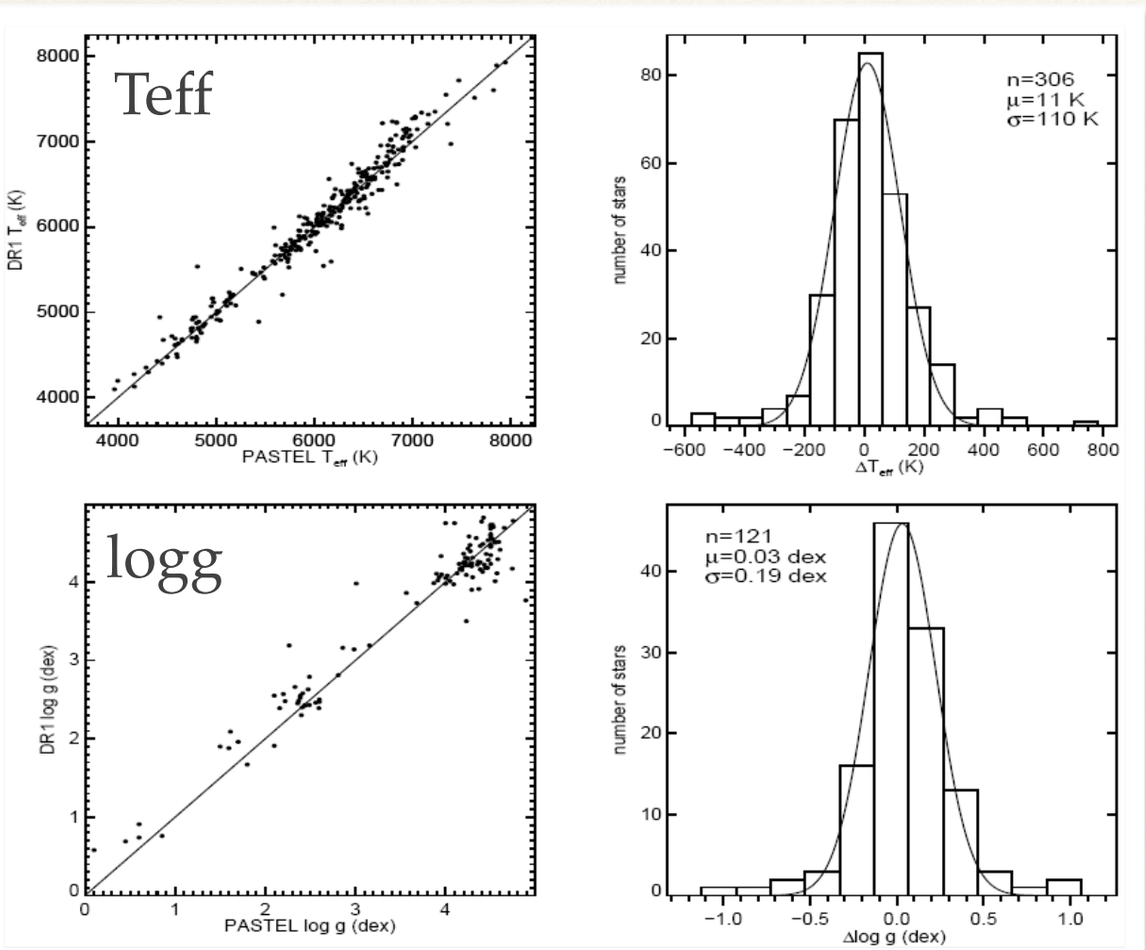
sigma=110K

offset=0.01
sigma=0.11



offset=0.03
sigma=0.19

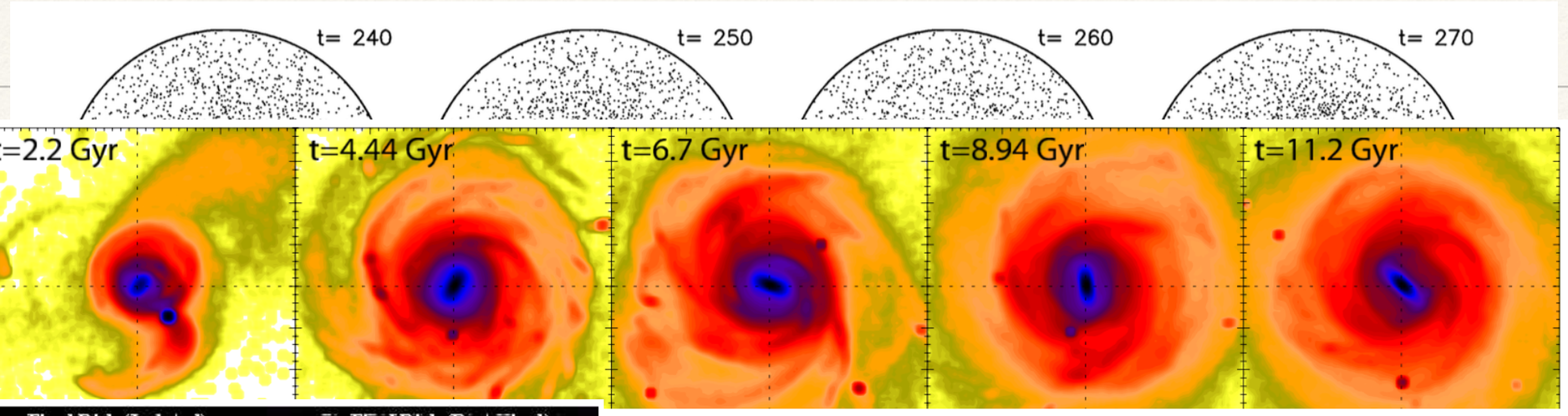
offset=-3.78 km/s
sigma=4.91 km/s

Scientific goals

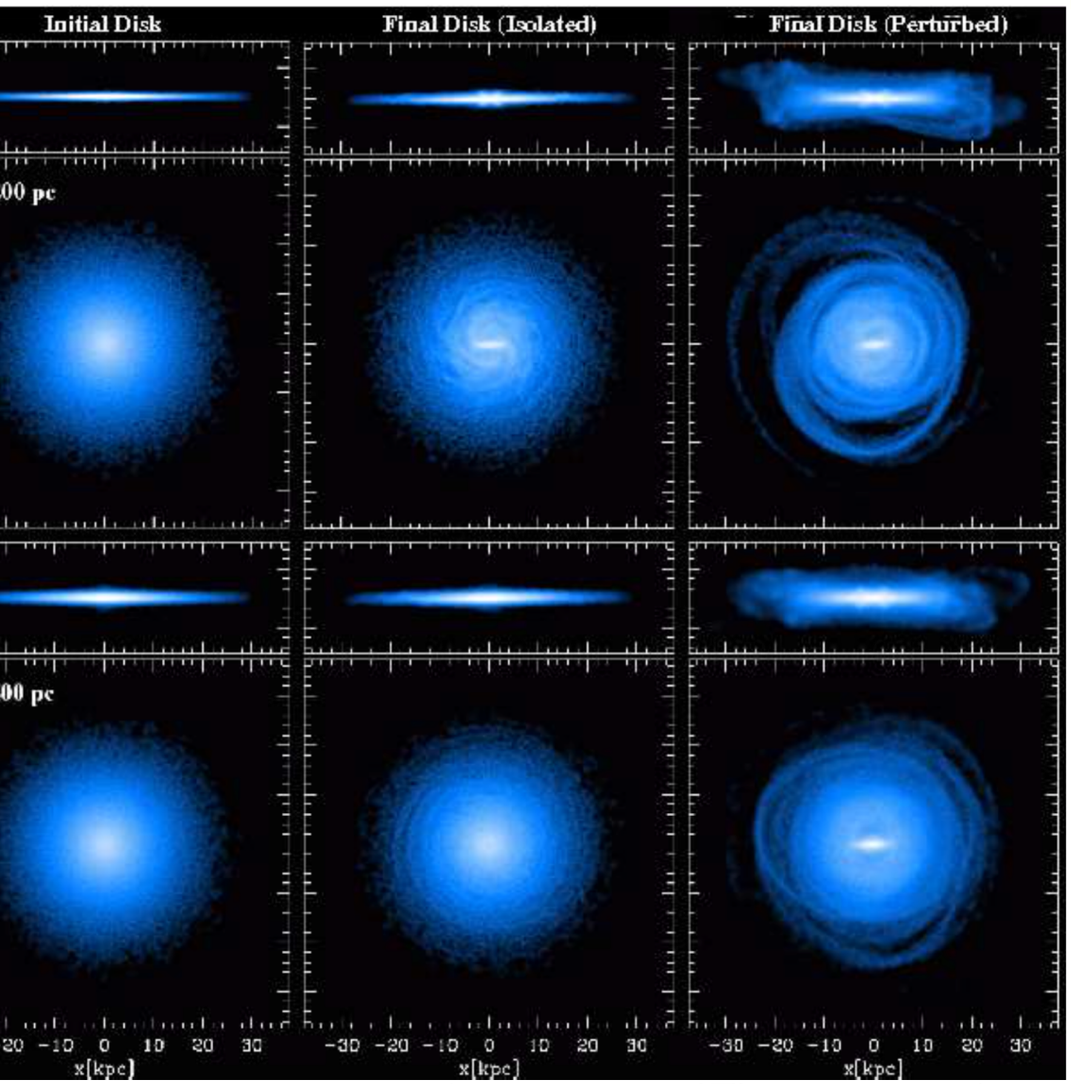
- The Milky Way spectroscopic survey
  - Well covers the Galactic anti-center region (outer disk)
  - Chemo-dynamical study of the Galactic outer disk
    - The structure/sub-structure in the halo (<50 kpc)
    - The dynamics of the Galactic halo
    - Searching for rare but valuable objects: extremely metal-poor stars, hyper-velocity stars etc.
- External galaxies survey

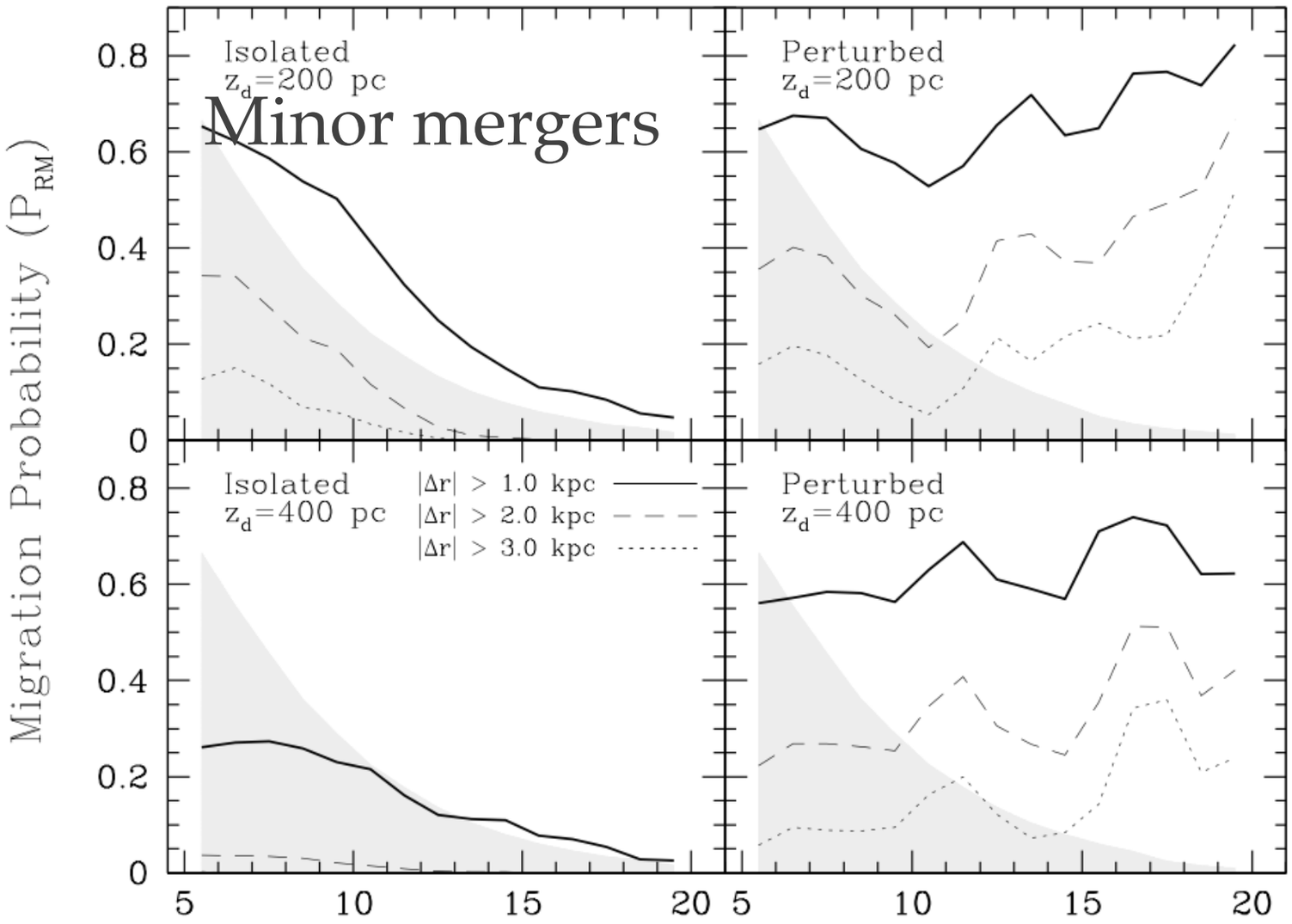
Data releases

- DR1 is public released (2.2 million spectra)
  - http://dr1.lamost.org
- DR2 will be released in July 2016 (4.1 million spectra)

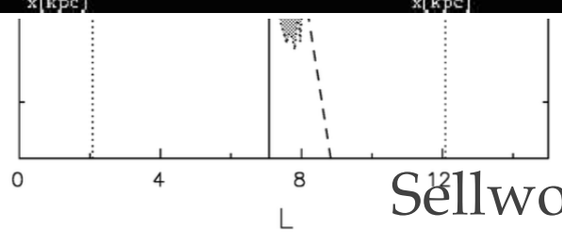


k

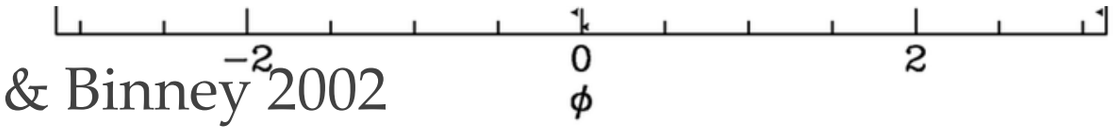




Bird et al. 2012

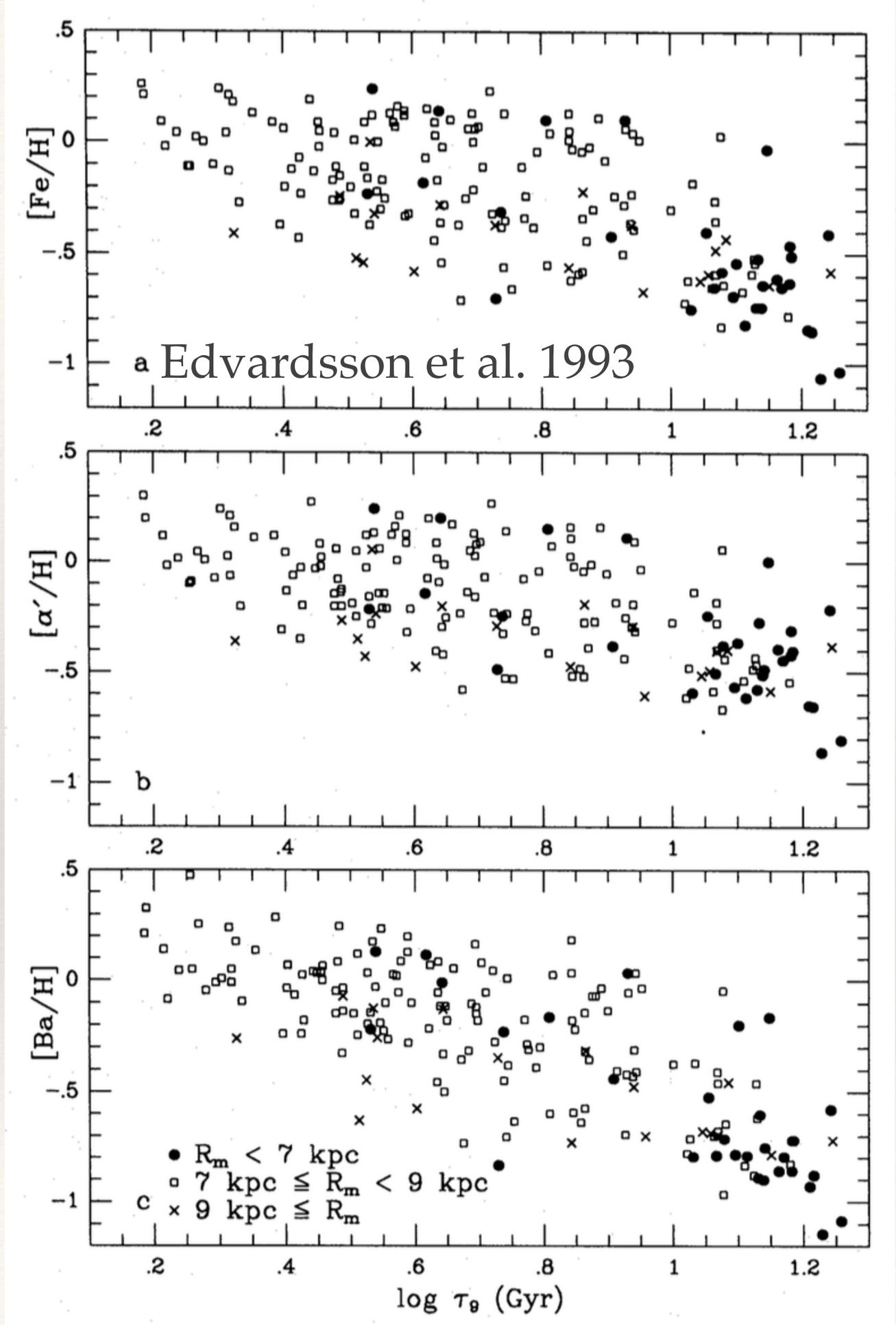


Sellwood & Binney 2002

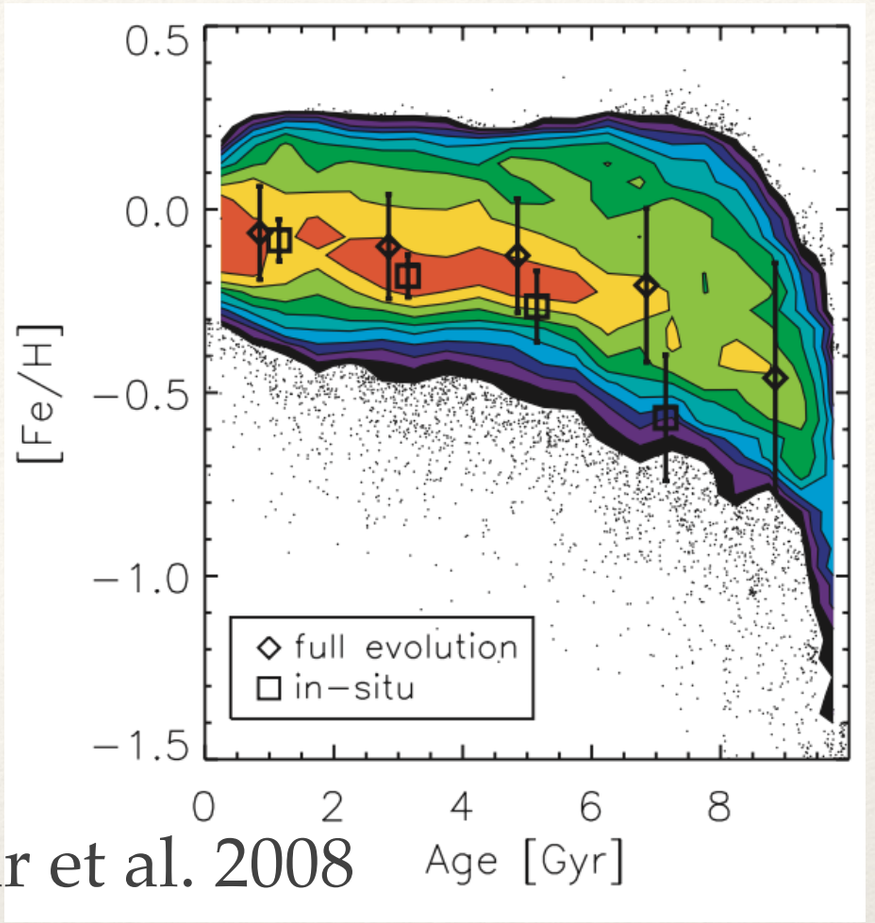


Observational predictions in the solar neighborhood

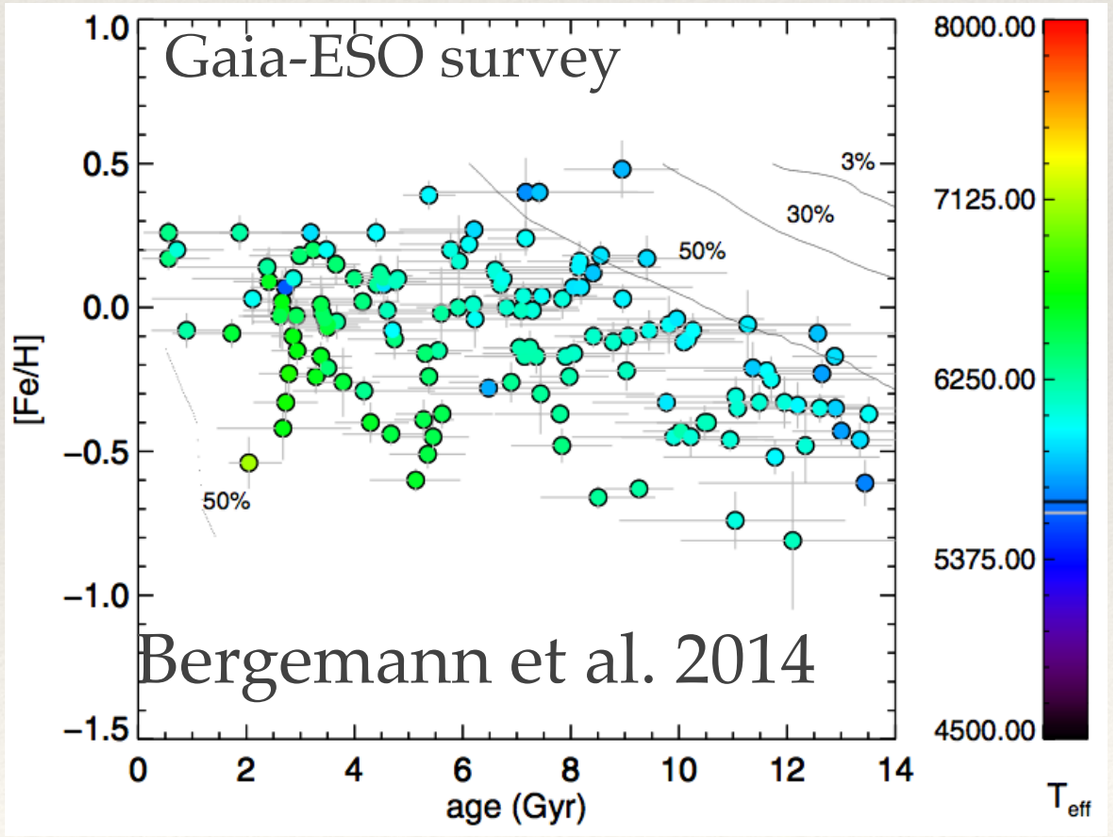
- **Flat and disperse age-metallicity relation**
- Flat radial [Fe/H] gradient for old populations
  - Vanishing of V_Φ-[Fe/H] anti-correlation
- Strange stellar populations, e.g. metal-rich old stars or metal-poor young stars
- Thick disk?
  - Debate: does the radial migration directly lead to thickening



Edvardsson et al. 1993



Roskar et al. 2008



Bergemann et al. 2014

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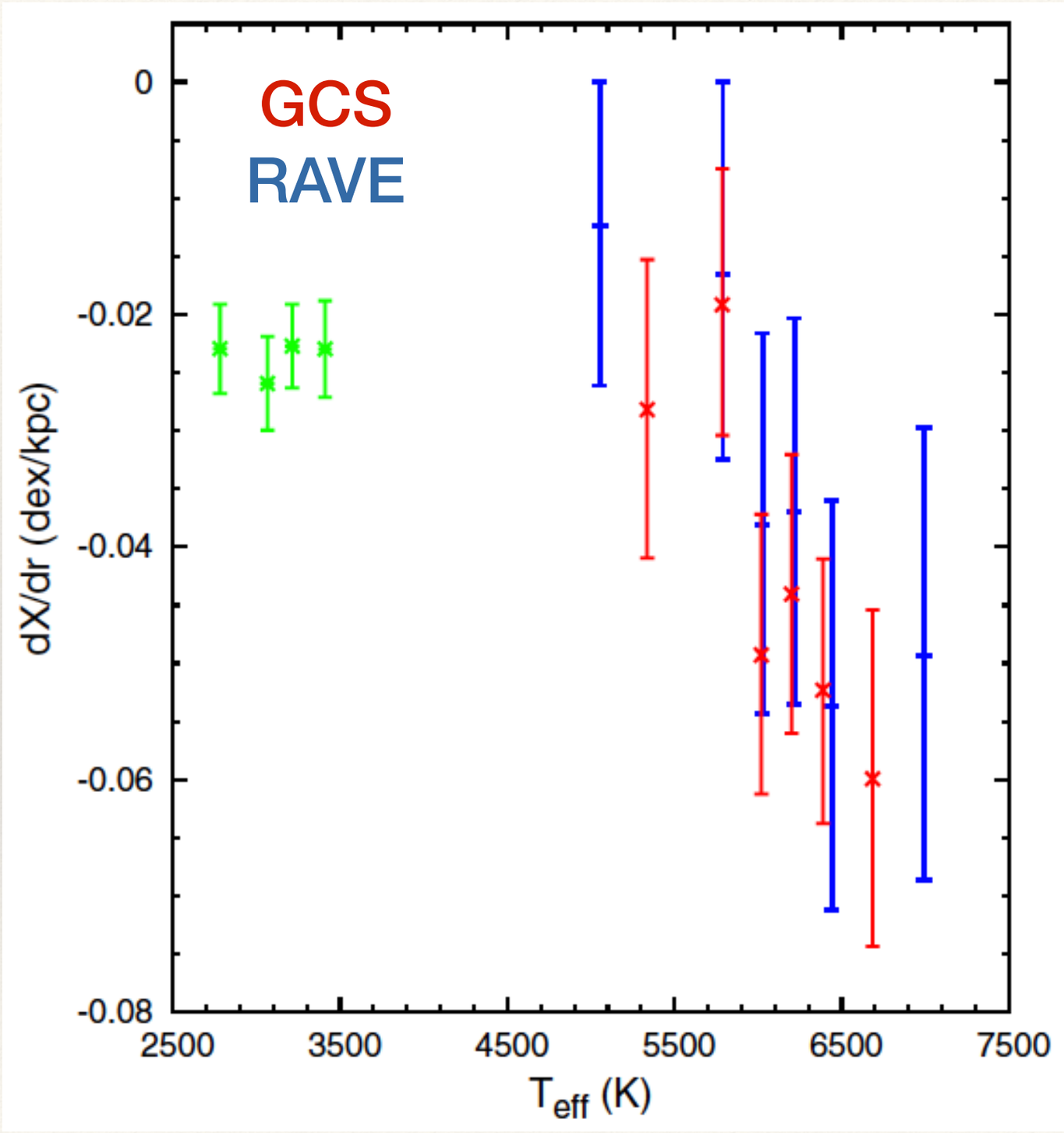
Yu et al. 2012


GCS
RAVE
0
-0.02
-0.04
-0.06
-0.08
dX/dr (dex/kpc)
2500
3500
4500
5500
6500
7500
T_eff (K)

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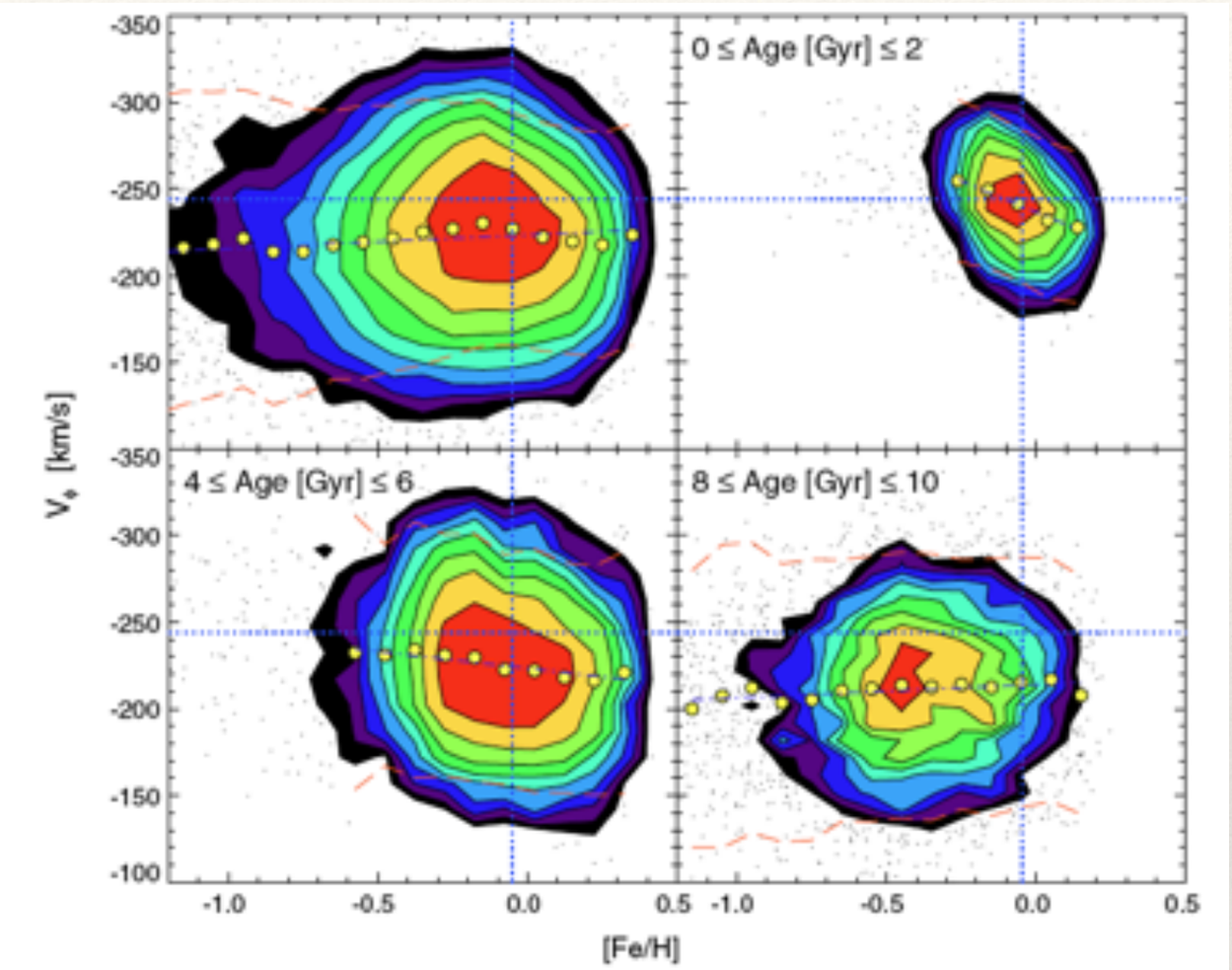
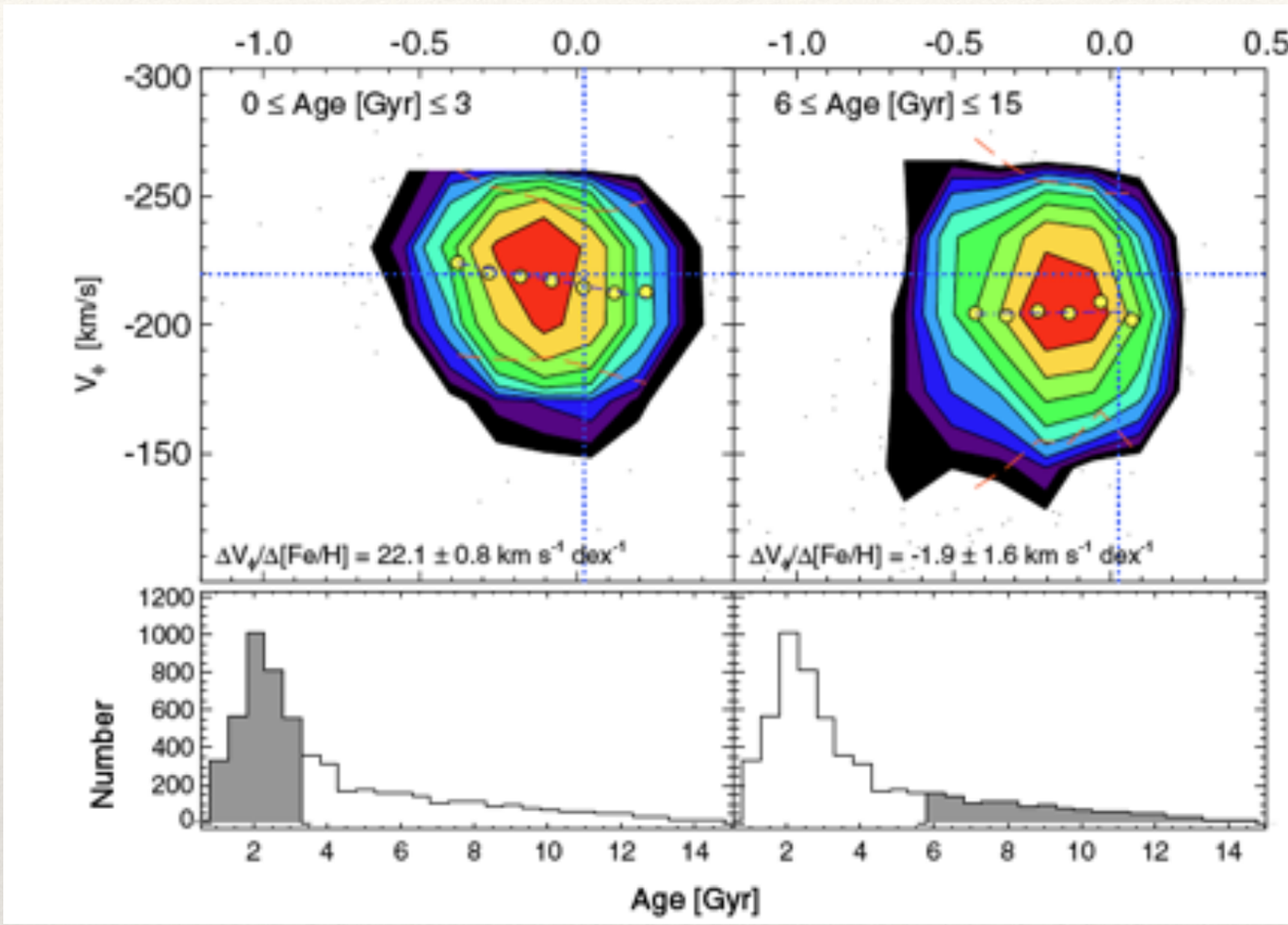
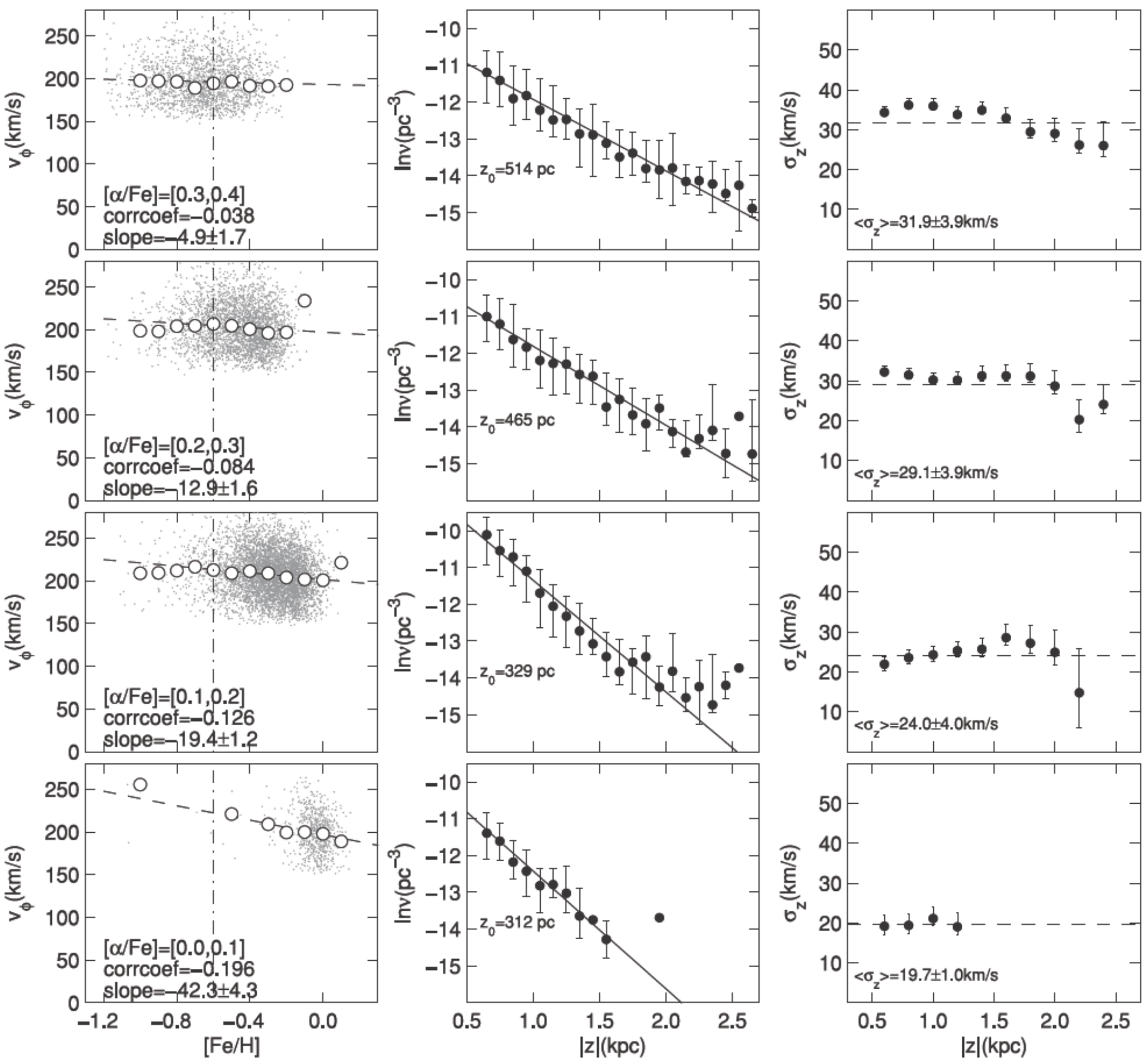




Loebman et al. 2011

Old



Young

Liu & van de Ven 2012

Observational predictions in the solar neighborhood

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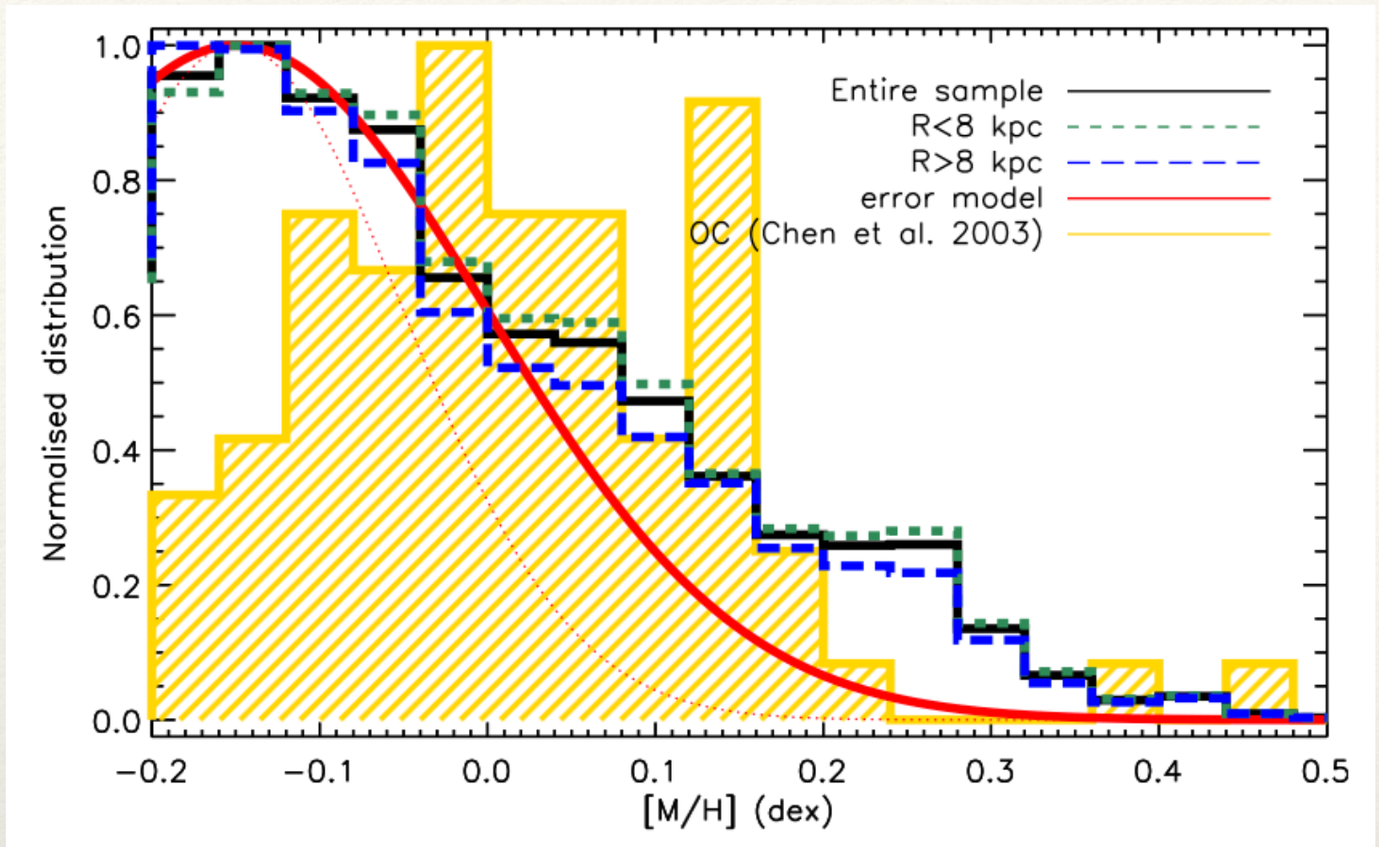
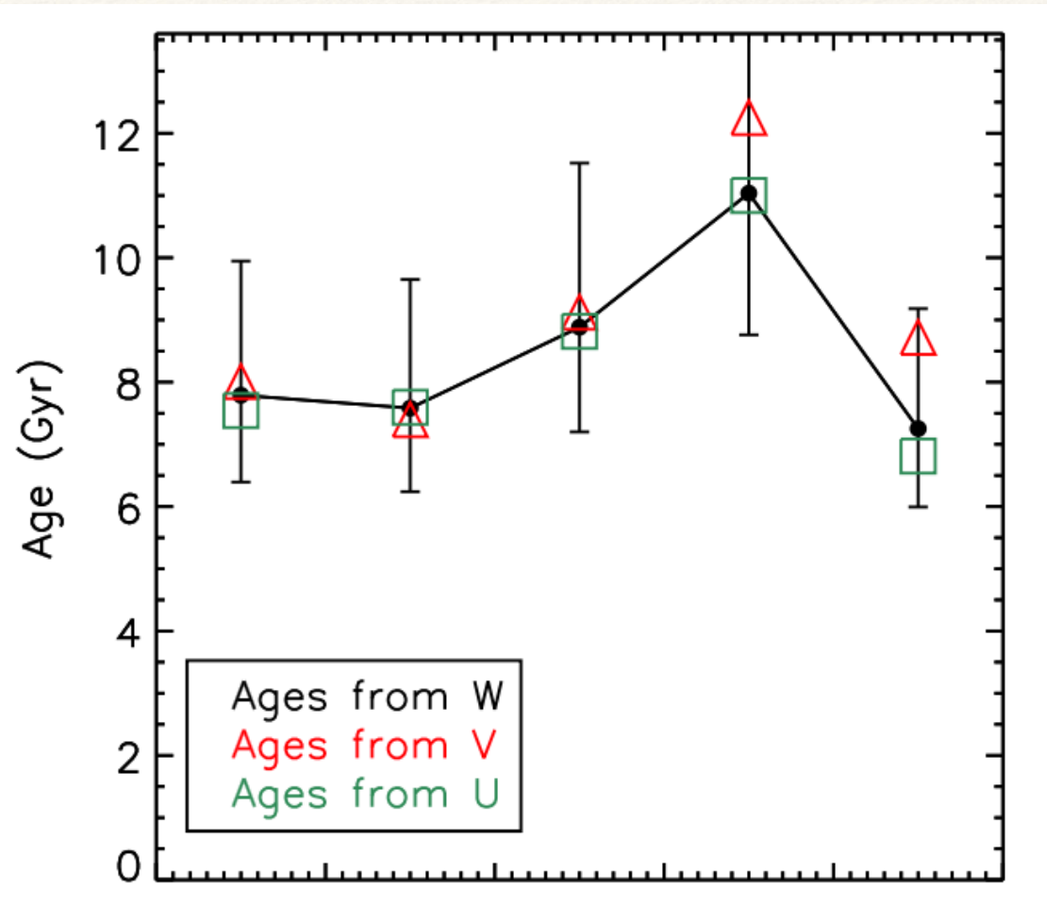
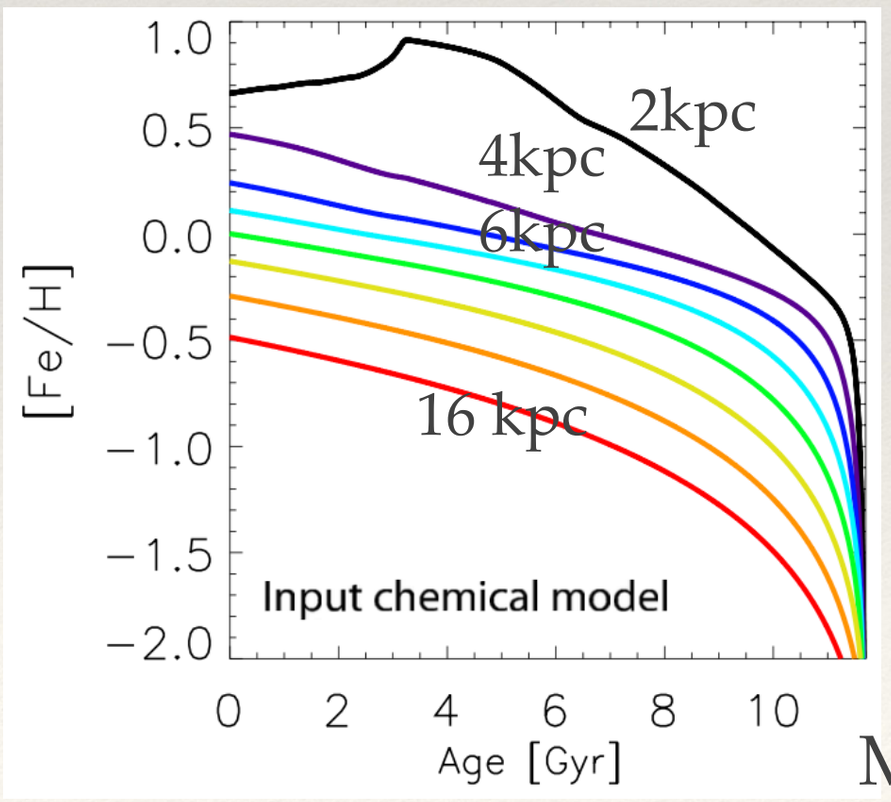




Kordopatis et al. 2015



The metal-rich, old stars must formed in inner disk with R=3-5 kpc and later radially migrated to the solar neighborhood

Minchev et al. 2013

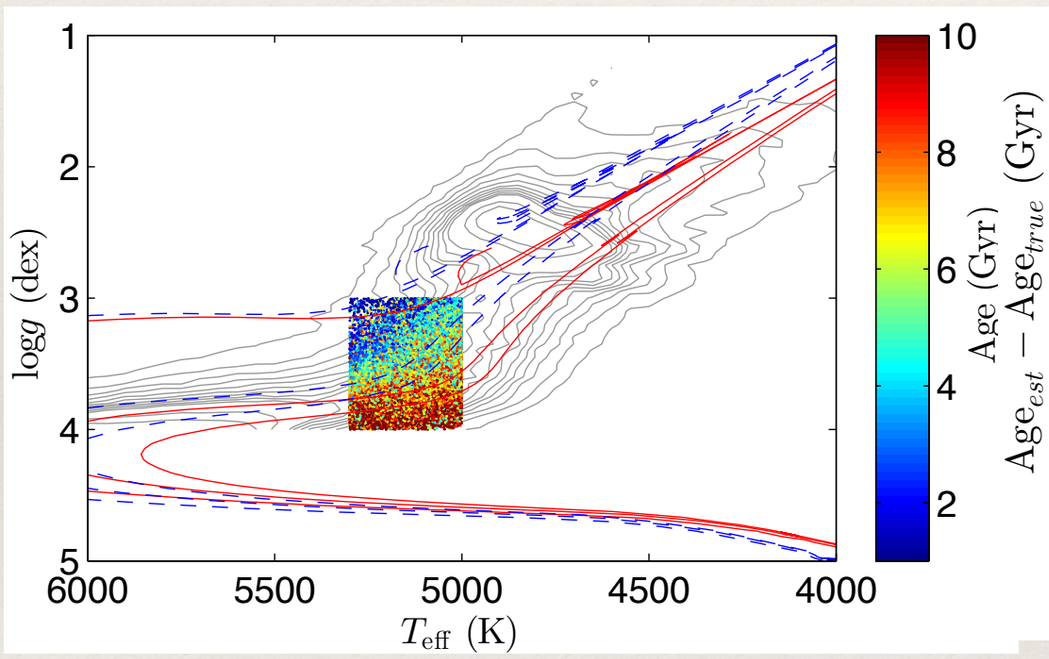
Questions to be solved

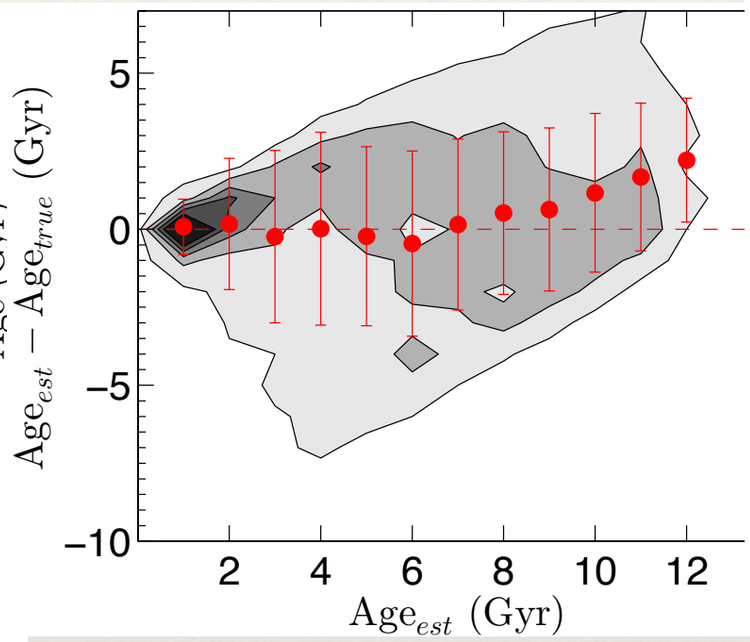
- Which individual star is migrated?
- What the efficiency of radial migration in the evolution of the Galactic disk?
- Can radial migration is responsible for disk thickening?

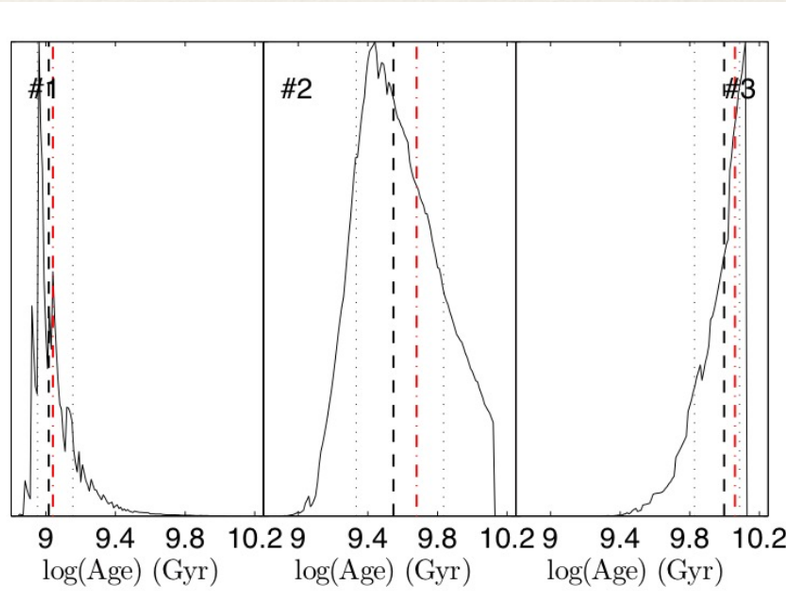
Age determination

Liu et al. 2015 (ArXiv:1510.06123)

~20000 low-RGB/SGB stars with high S/N from 500,000 K giant stars
The sampling is unbiased within distance of 1.5 kpc

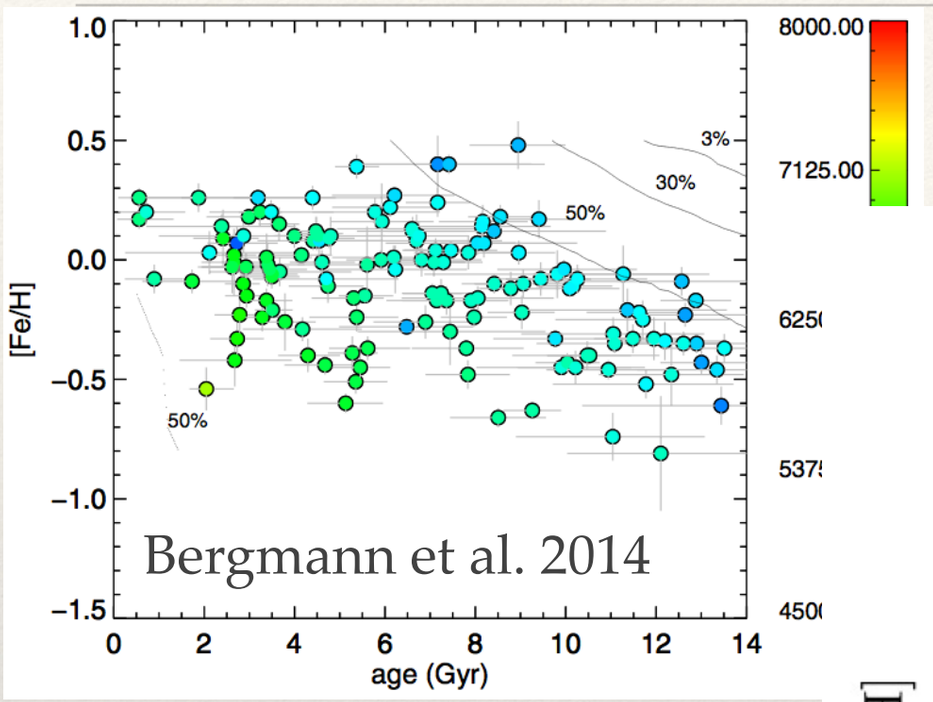


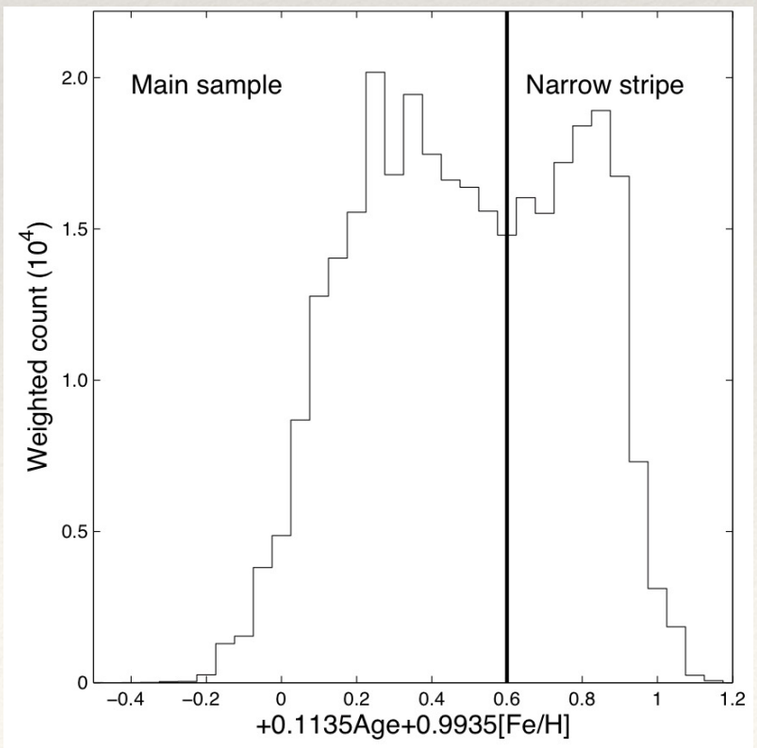


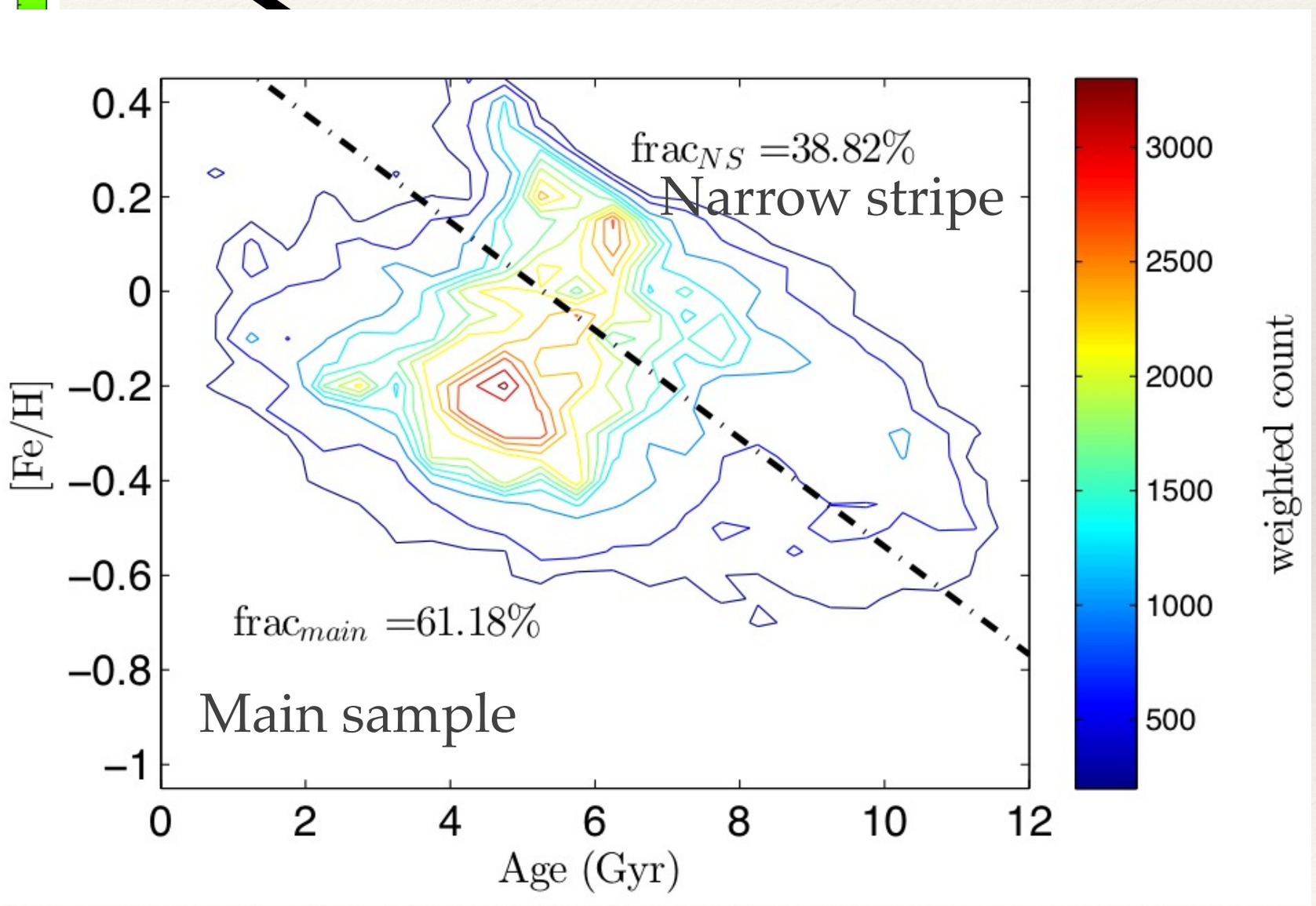


Age error~2 Gyr

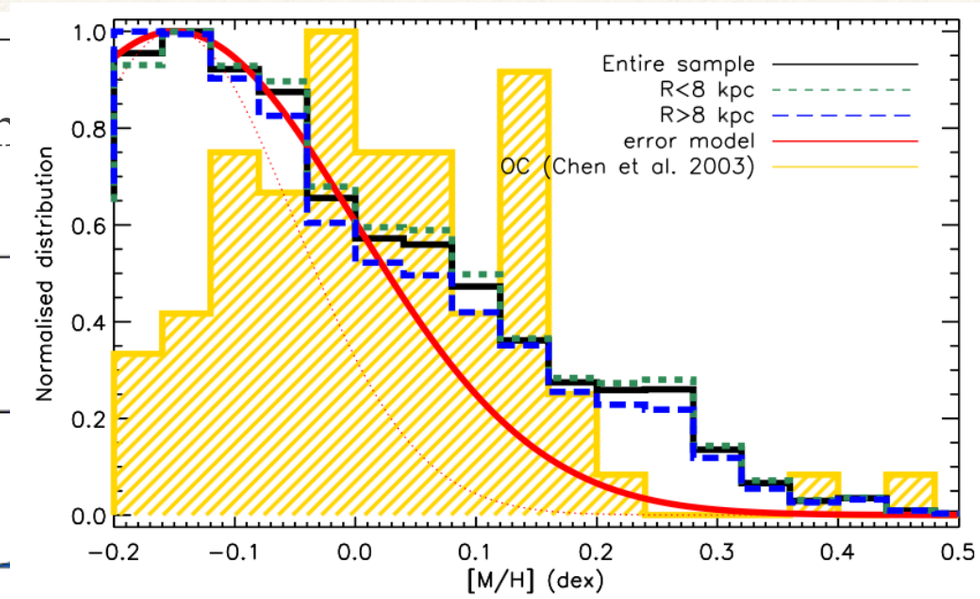
Age-metallicity relation







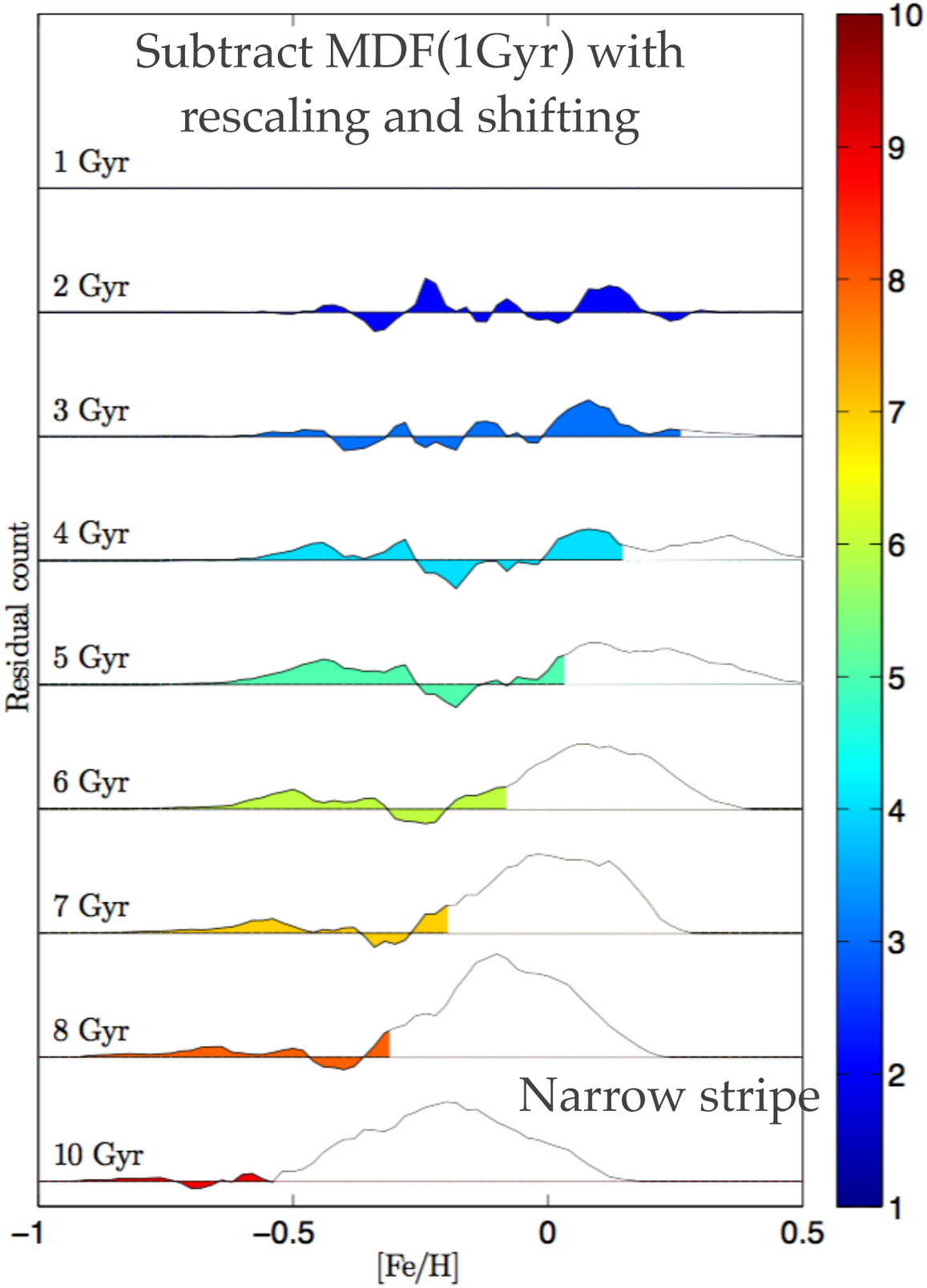
Kordopatis et al. 2015



Main sar

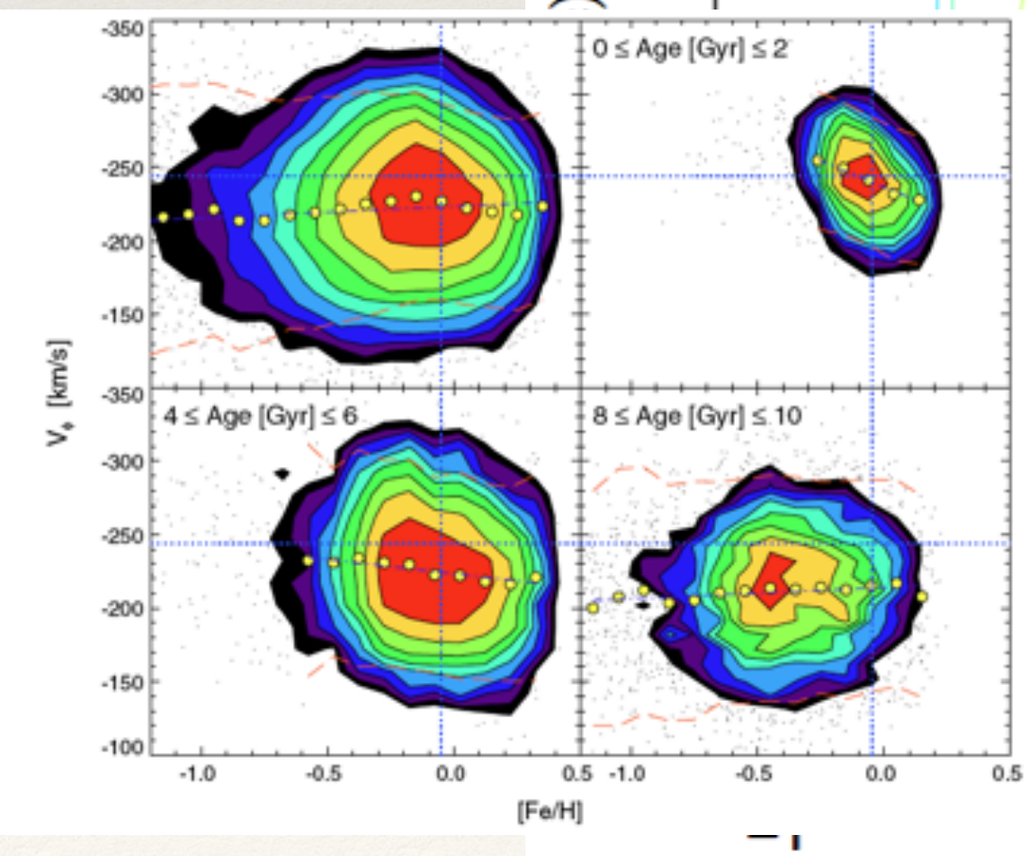
Narrow stripe

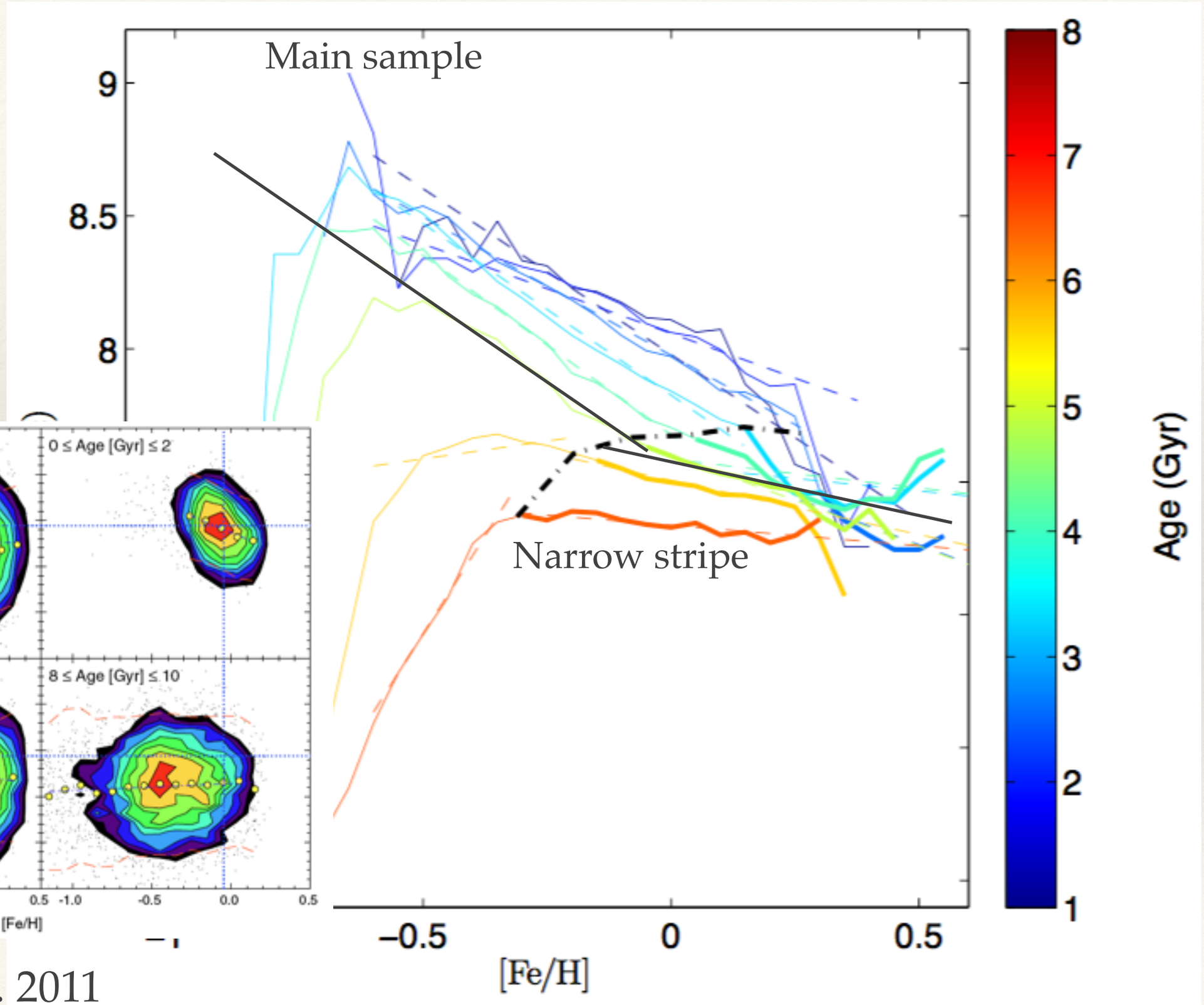
Subtract MDF(1Gyr) with rescaling and shifting



Narrow stripe

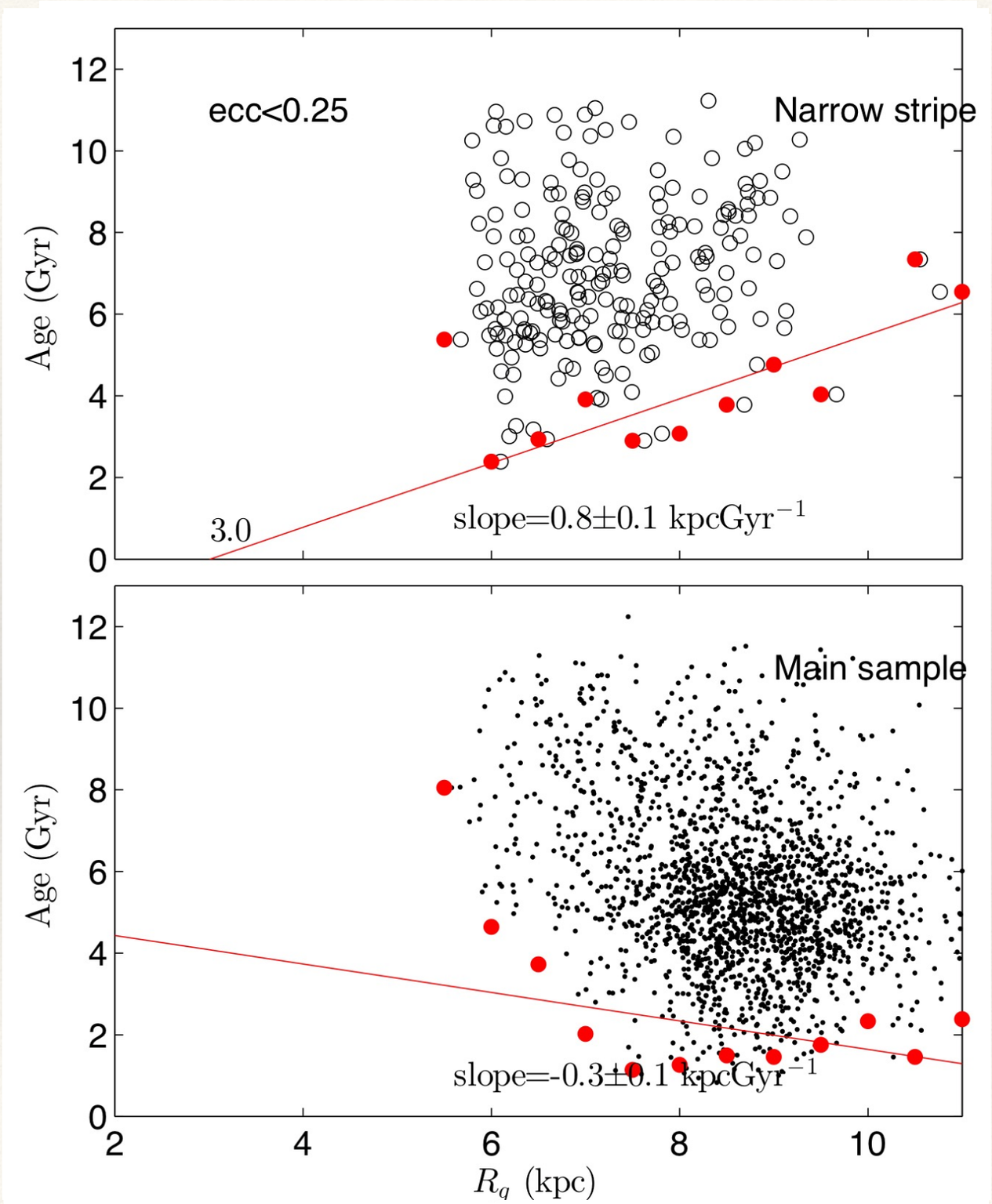
The Rg-[Fe/H] relation is similar to the VΦ-[Fe/H] relation



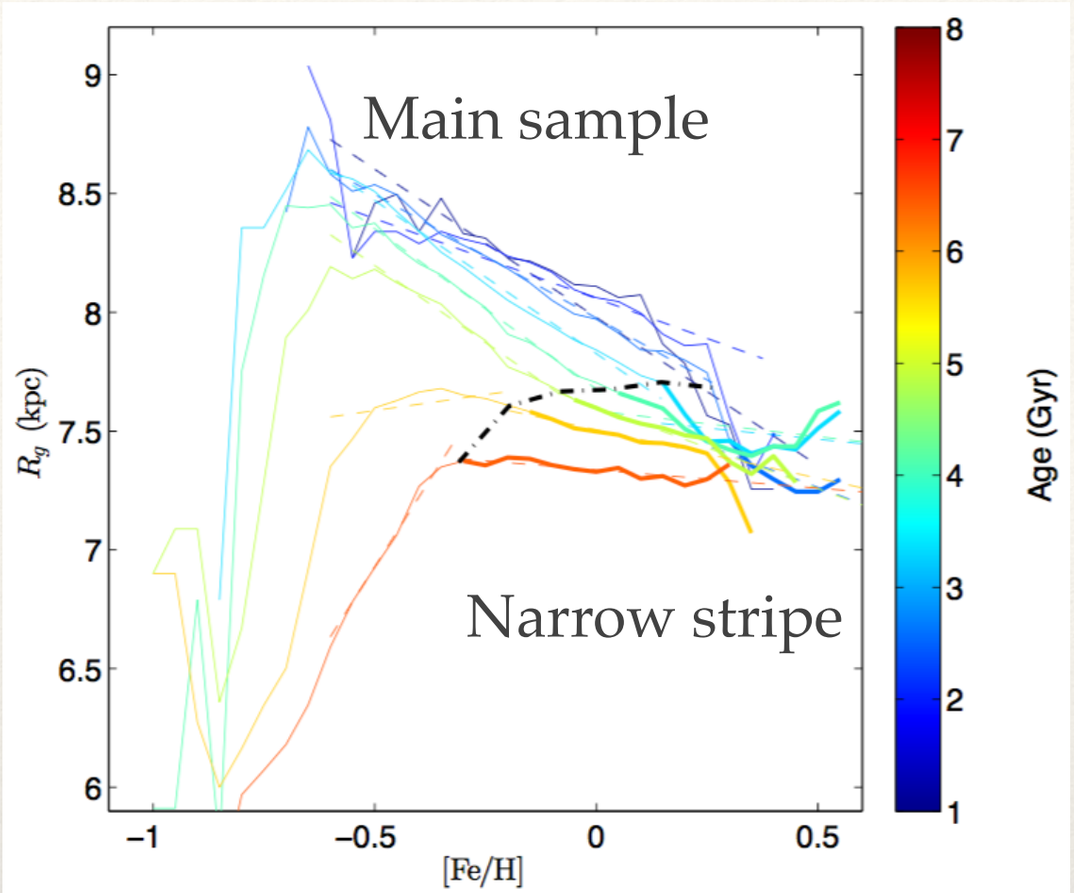


Loebman et al. 2011

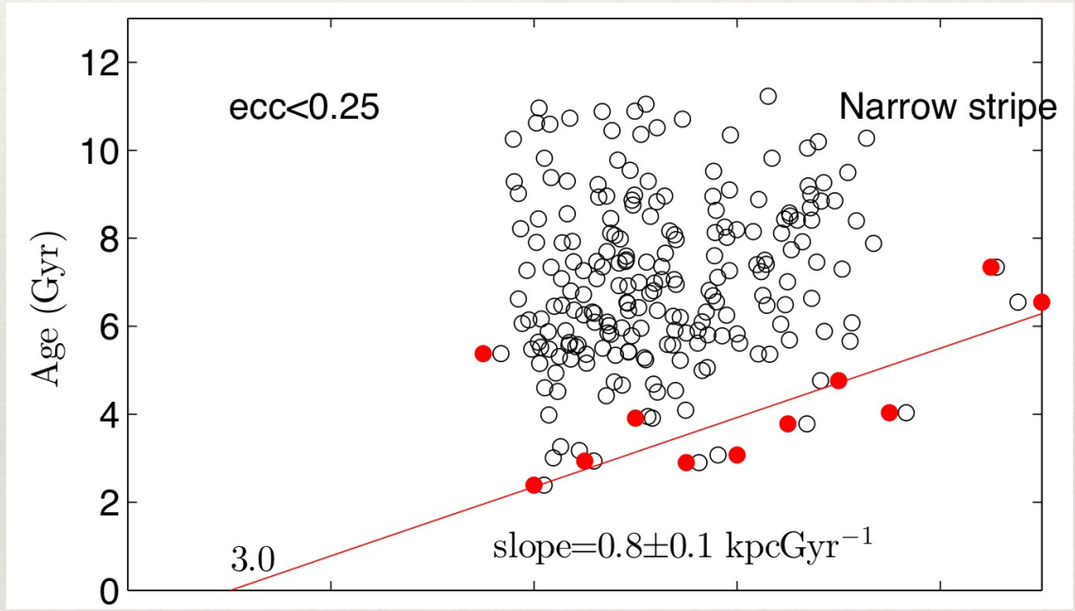
Age-Rg relation

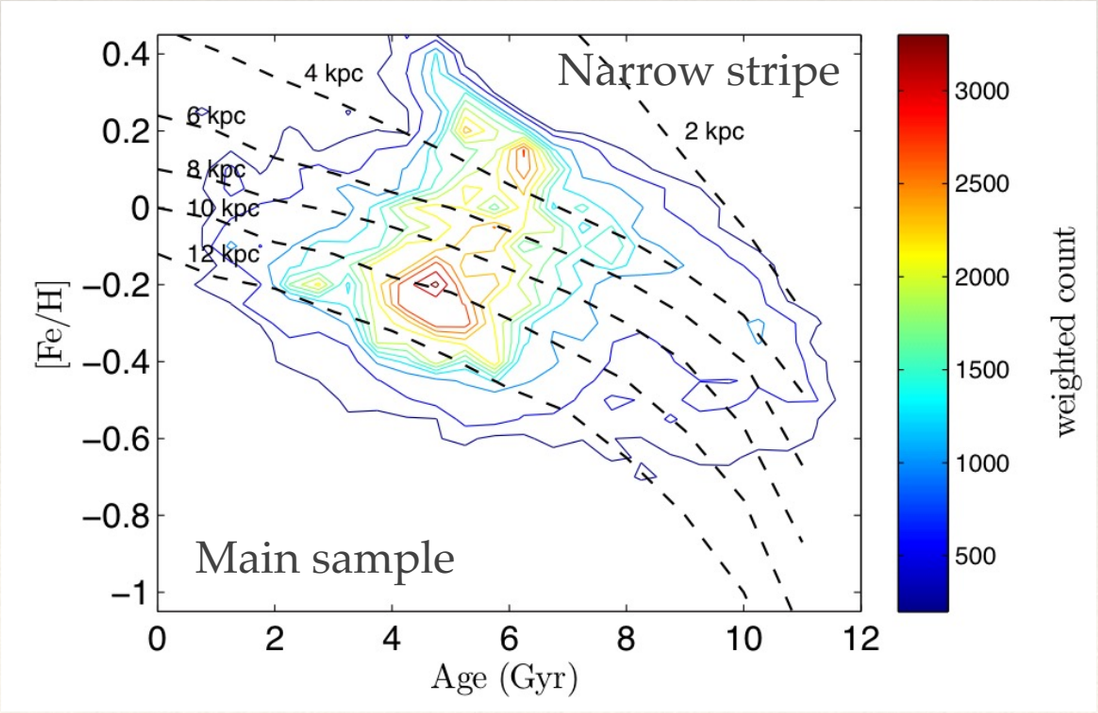


- The lower limiting age at some Rg hints that the group of stars may experience a travel from inner disk to their current location
- Their starting (birth) radius can be obtained by extrapolating the line back to age=0 point, which is Rg~3kpc
- The mean traveling speed can be derived as 0.8±0.1 km/s
- This effect may be weakened for stars with larger eccentricity due to the scattering (blurring).

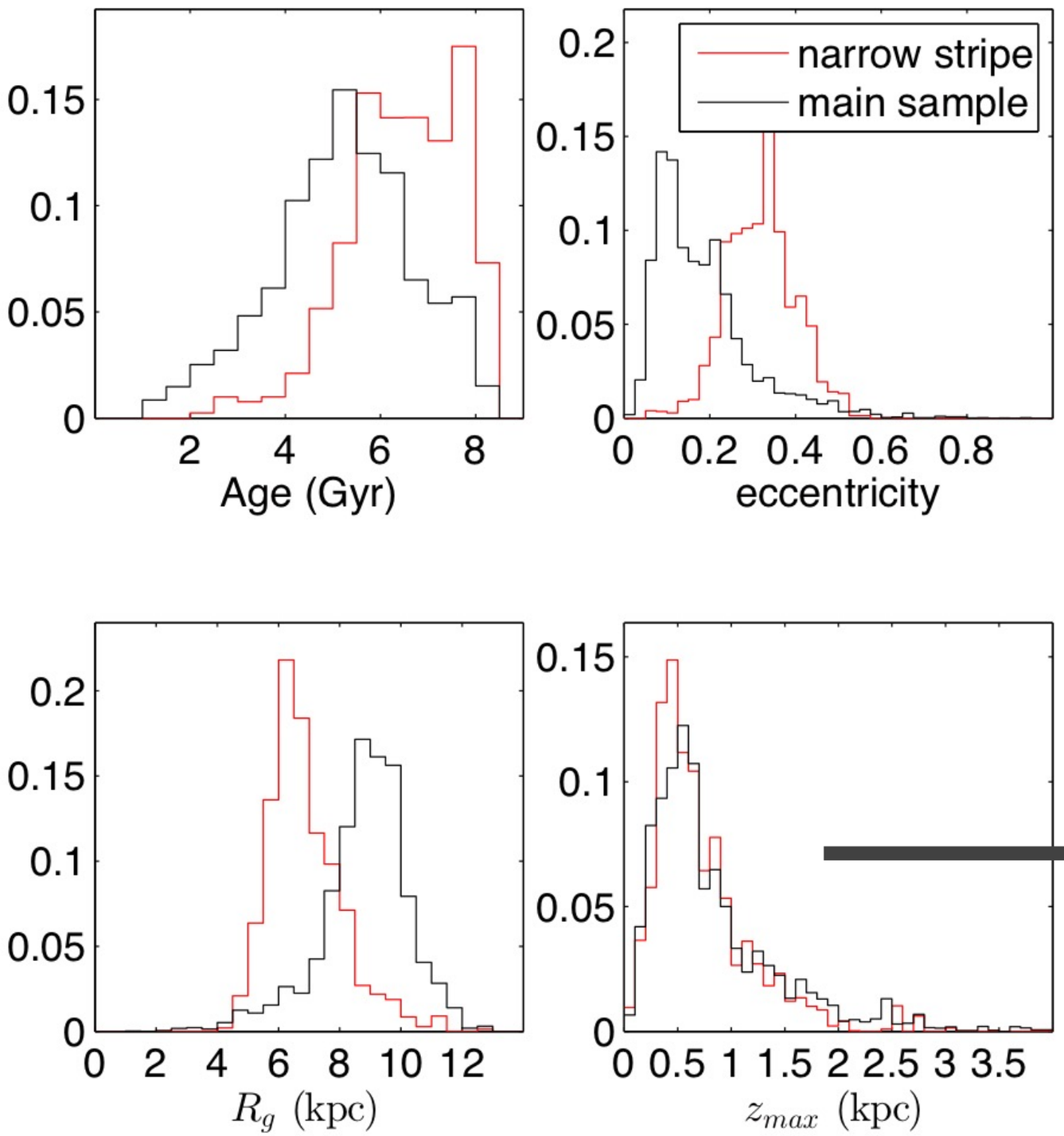


- Rg-[Fe/H] anti-correlation fading
- Age-Rg relation
- **Narrow stripe is a group of stars radially migrated from ~3 kpc**
- Comparison with evolution model





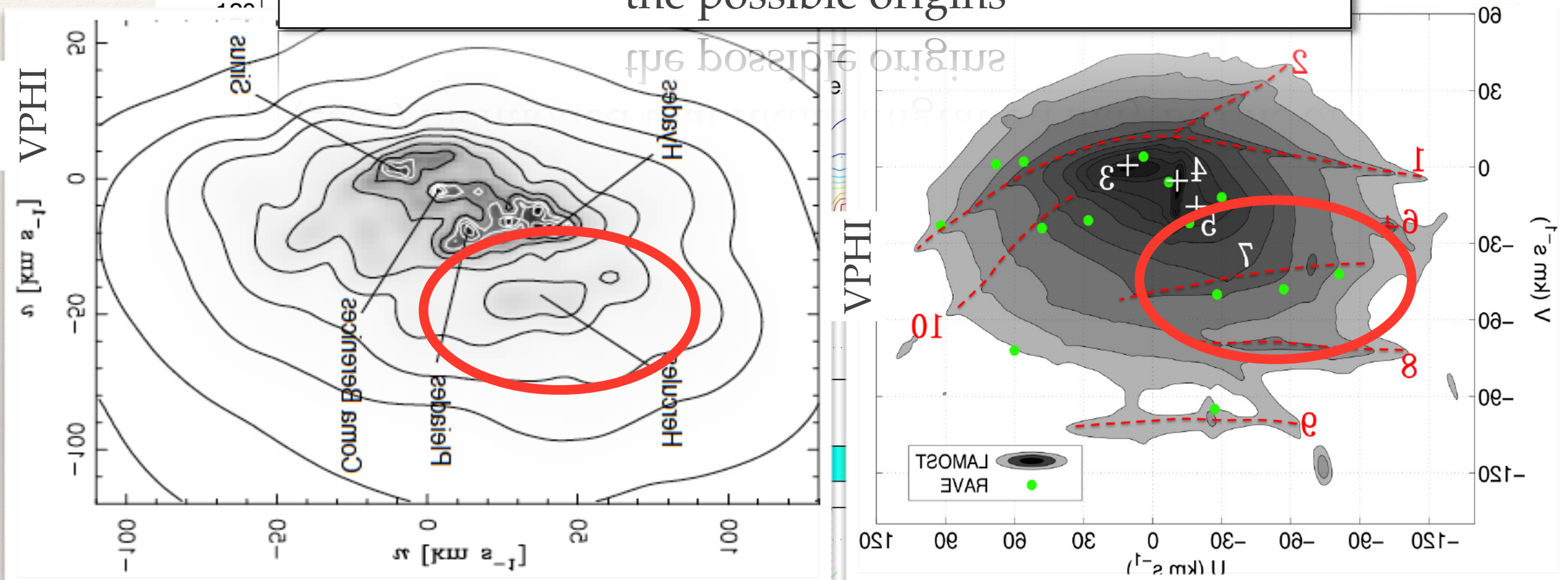
Evolution model from Minchev, Chiappini & Martig 2013



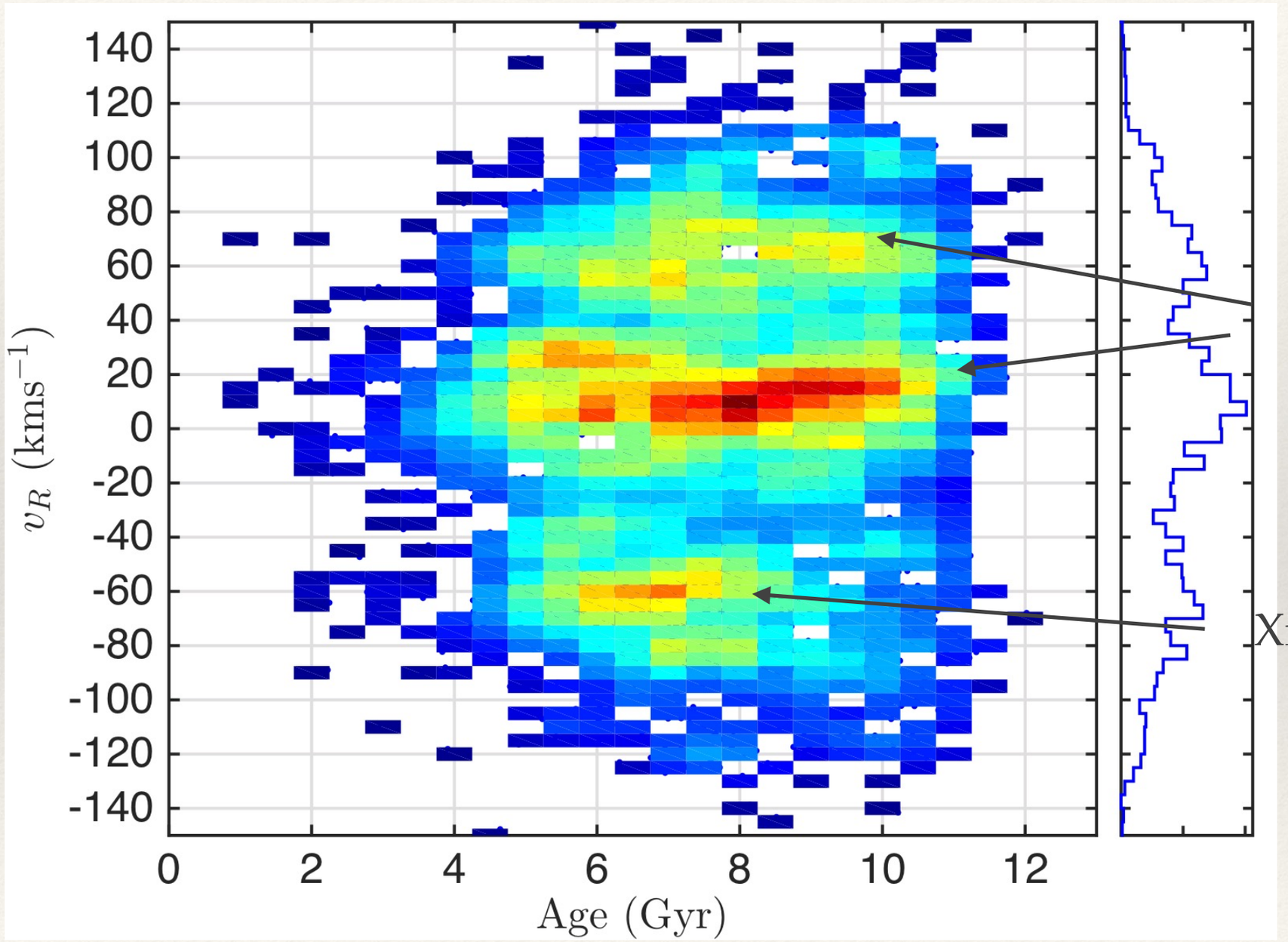
Radial migration does not additionally thicken the disk

Note that Fux (2001) thought the Hercules stream is the kinematically hot bar stars and Famaey et al. (2005) mentioned that radial migration may be one of the possible origins

Dehnen 1998



VR-Age for narrow stripe



Hercules stream

Xia-10/Dehnen98

Conclusions

- The **narrow stripe**, which is about one-third of the whole sample, are radially migrated from ~3 kpc to the solar neighborhood
- The average traveling speed of radial migration is 0.8 km/s, giving a tight constraint on the efficiency of radial migration
- The radial migration does NOT additionally thicken the disk
- The *Hercules stream* is in the radially migrated population. It is not due to the resonance of the local stars induced by the rotating bar, but for some unclear reason probably related to the radial migration