Galactic stellar populations with MOONS (I)

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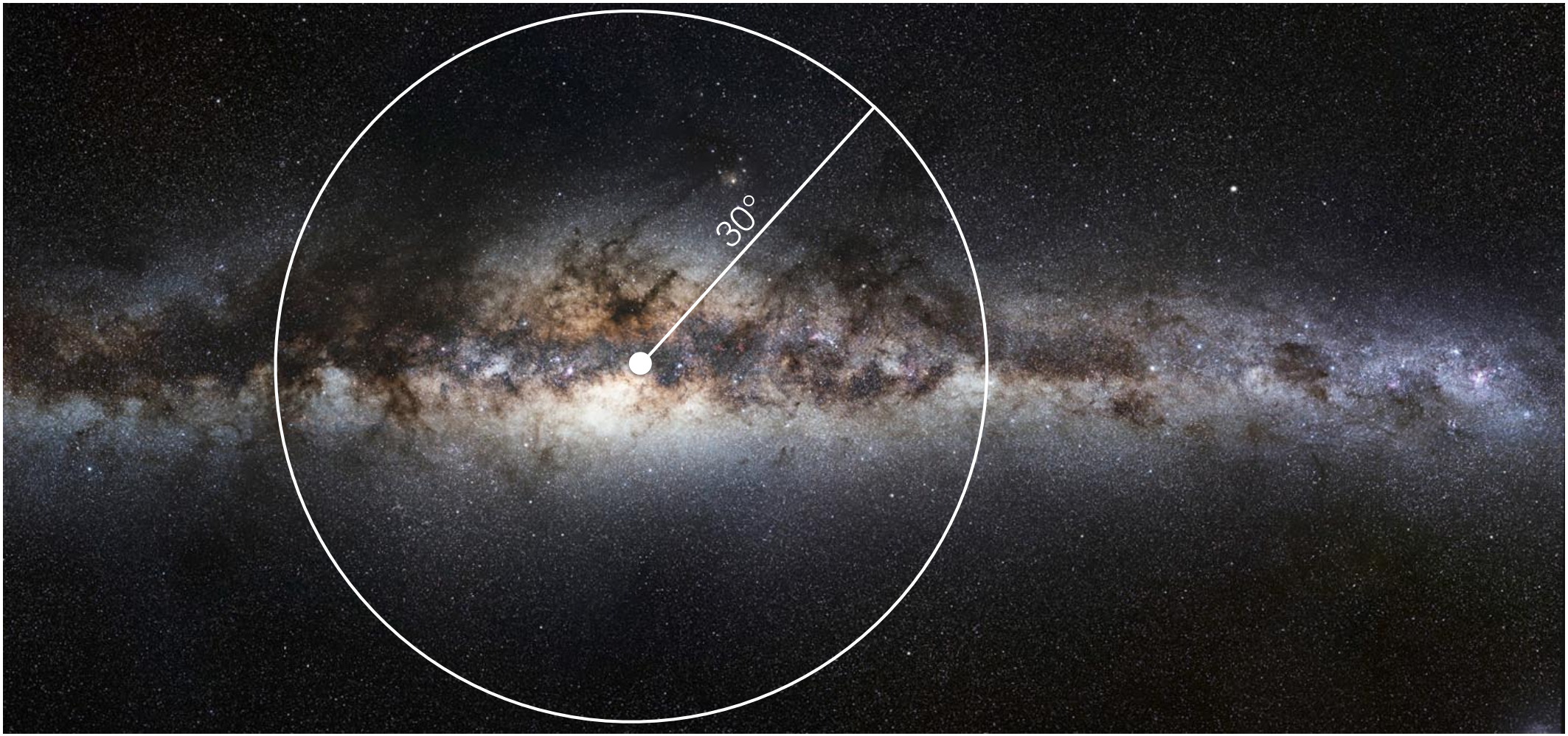
The inner Milky Way (<30° from the Galactic center direction) concentrates:

-most of the stellar mass
-possibly most of the accreted stellar mass
-60% of all G. clusters,
-the bar (inner, long), etc.



Why is MOONS important for the Milky Way stellar populations?

1- What was the mass-growth of the MW? What SFH in the inner disk? Which population dominated the stellar formation at z=2-4?

2 - What is the quenching episode in the MW? What's its origin?

3 - How complex was the chemical evolution of the inner MW?

(inner disk/bulge) Or was it simple?

4 - Can we age-date the formation of the bar ?

5 - What fraction of accreted mass in the inner MW?
from « large » galaxies ? from GC ?

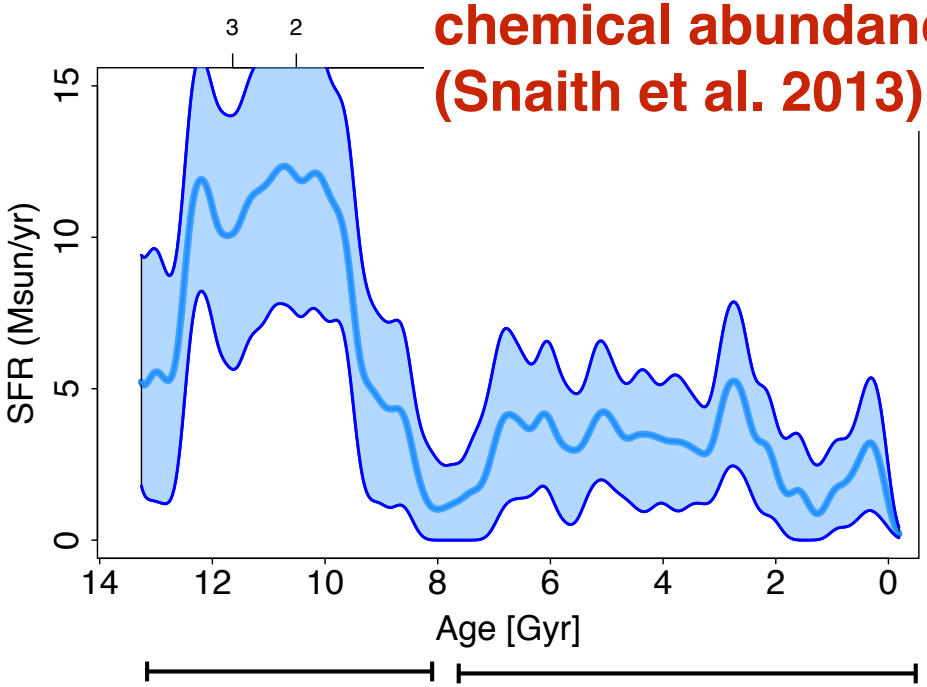
6 - What difference between the halo and thick disk at low

metallicities?

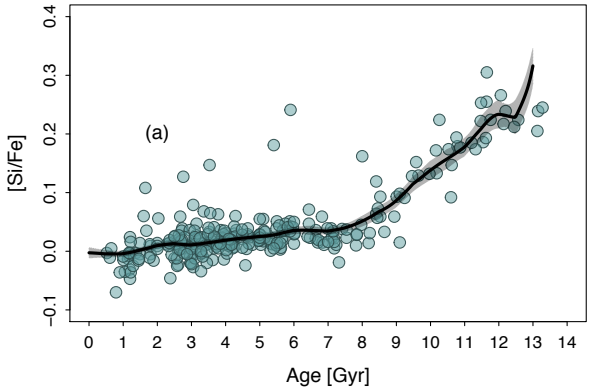
etc….

MW mass growth: local evidence (solar vicinity)

SFH of the Milky Way reconstructed from chemical abundances of 363 stars in the solar vicinity (Snaith et al. 2013)



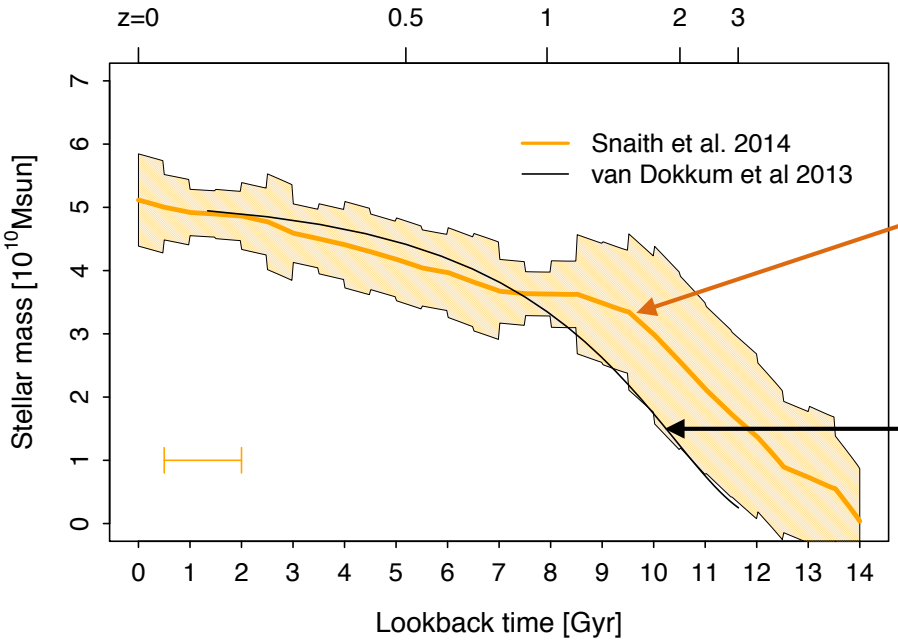
Two distinct phases thick & thin disks



The thick disk is massive (~ half the stellar mass)
Also compatible with the new (short) scale length measurements of the thick disk (Bensby+2011, Bovy+2012, Cheng+2012)

The thick disk possibly the main old population of the Milky Way

Milky Way-type galaxies dominate the SFH of galaxies since z=2-3 (e.g Nelson+2013), and formed half their mass before z=1, e.g. van Dokkum et al. 2013



Milky Way

Milky Way-type galaxies

- In the local universe: classical bulges are rare (Drory & Fisher, 2010, Kormendy et al. 2010), and the MW has a small or non-existent classical bulge

➡ points to the major importance of thick disks

In the MW, the thick disk is

- Responsible for most of the chemical enrichment of the Milky Way (Snaith+2014)
- Defined the initial conditions for the growth of thin disk (Nidever+2014, Haywood+2013)
- Likely responsible for most of the mass of the bulge (Ness+2013; Di Matteo+2014)

But most of the thick disk is in the inner Galaxy

What are the prospects to measure the mass growth of the MW in the « Gaia era »?

Age-dating of stars within a few kpc

Age distribution ≠ Star Formation History

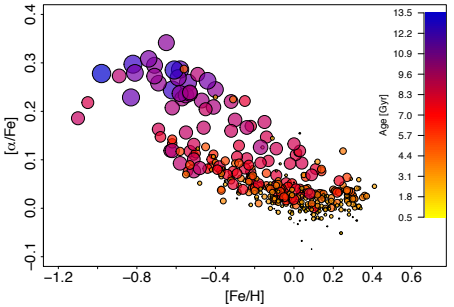
Even with Gaia, the volume in which we can measure representative age distribution will be limited and biased

➡ Need proxies for age, and abundances offer good proxies beyond the Gaia age ‘sphere’ (few kpc from the Sun)

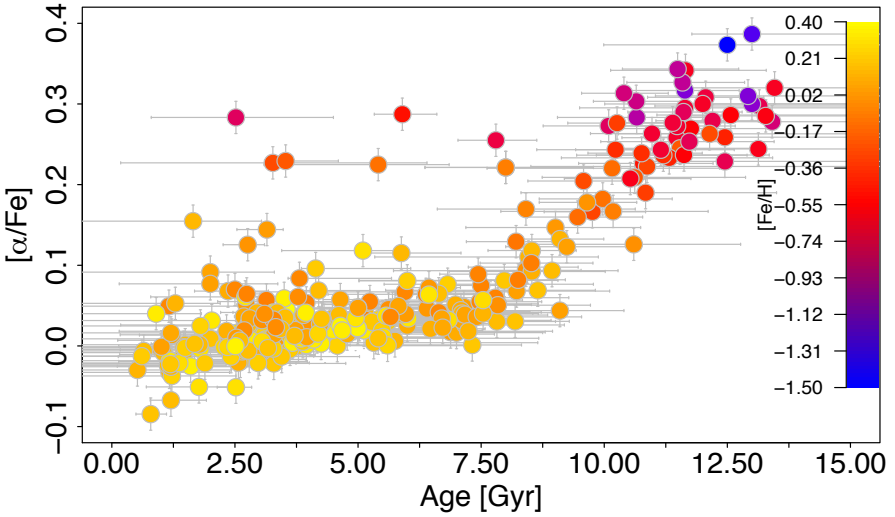
How can we measure the stellar mass growth of the Milky Way?

Empirical method:

Measure stellar densities in the MW (scale length, scale height) as a function of ([α/Fe],[Fe/H]), or « mono-abundance » population



[α/Fe] well correlated with age

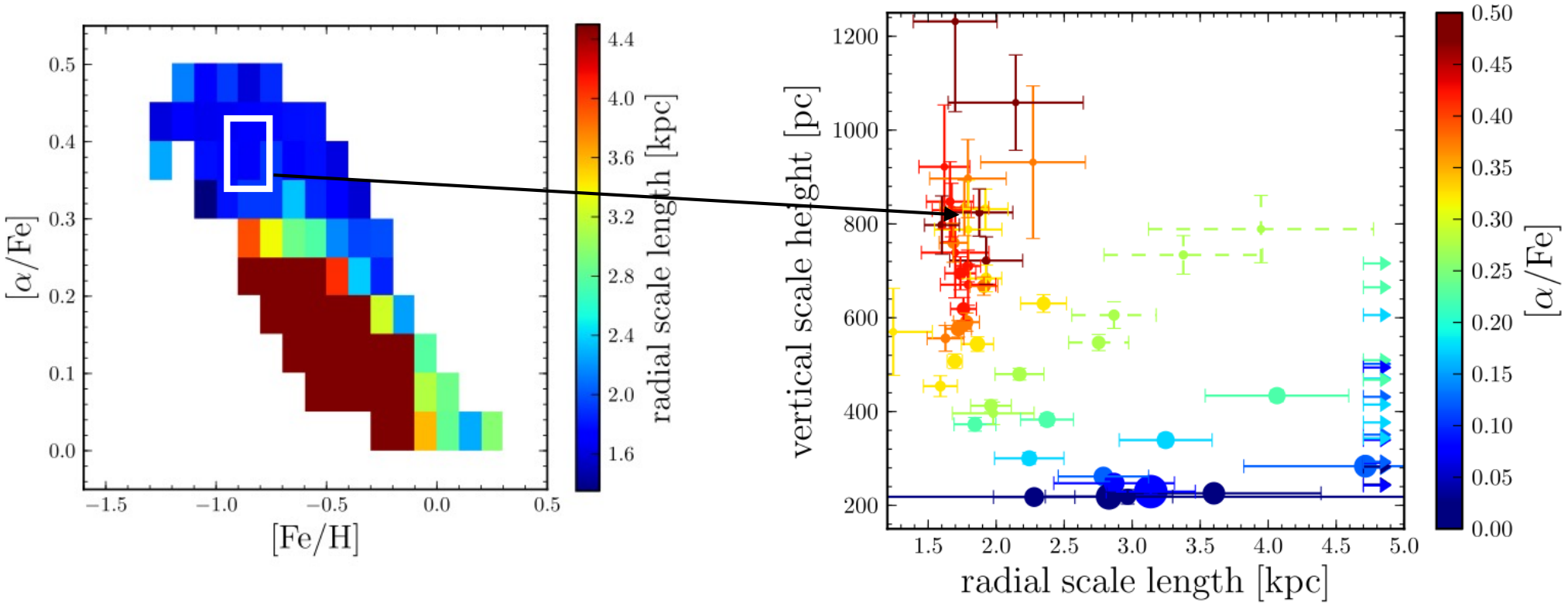


stellar mass densities as a function of age for the disks, or stellar mass-growth

Haywood et al. 2015

How can we measure the stellar mass growth of the Milky Way?

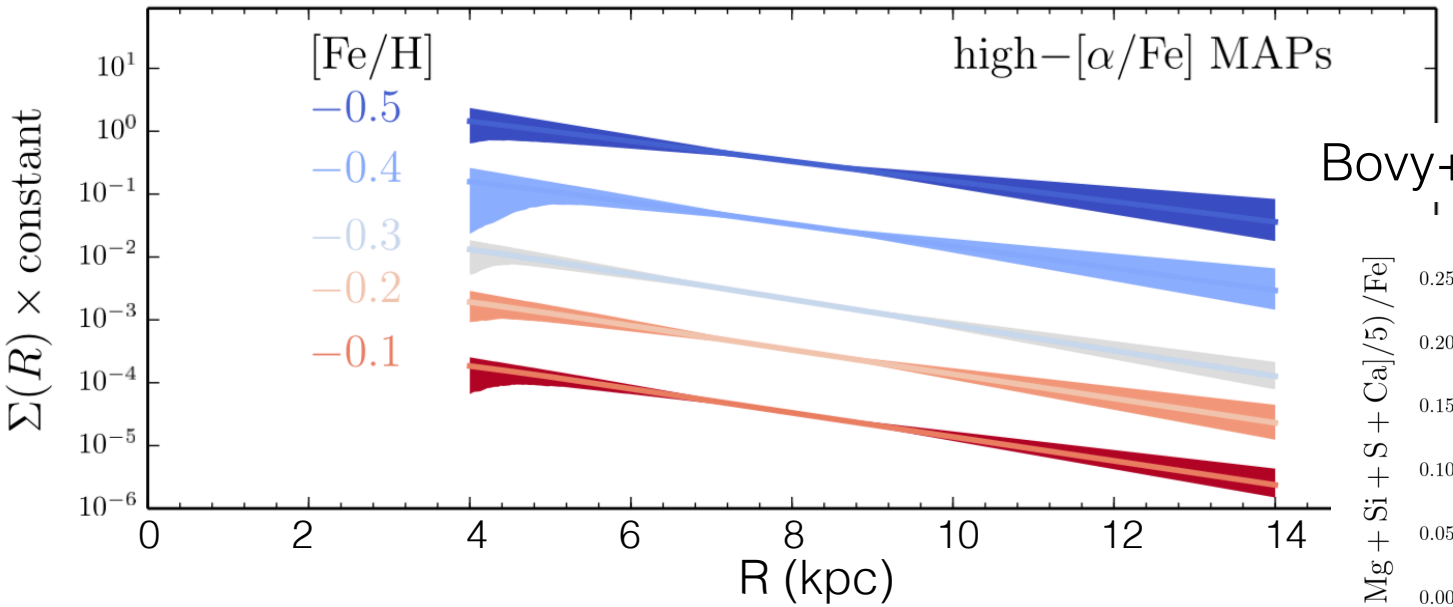
First attempts by (Bovy et al. 2012)



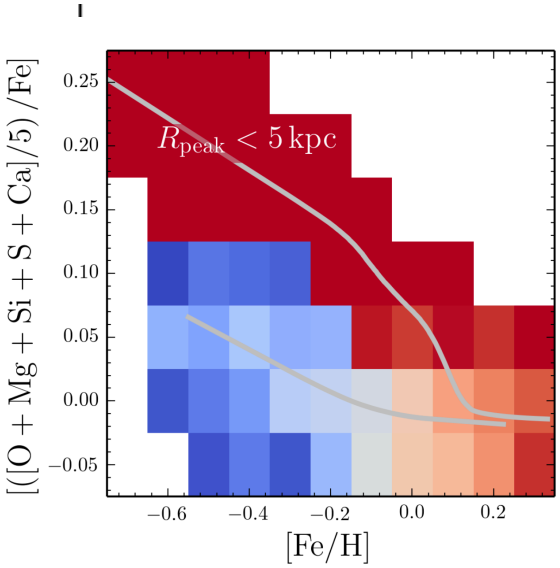
SEGUE data: F,G stars to 3-4 kpc

Bovy et al. 2012

Even better with APOGEE…



Bovy+2016



But…. while being a significant progress, the above maps are noisy:

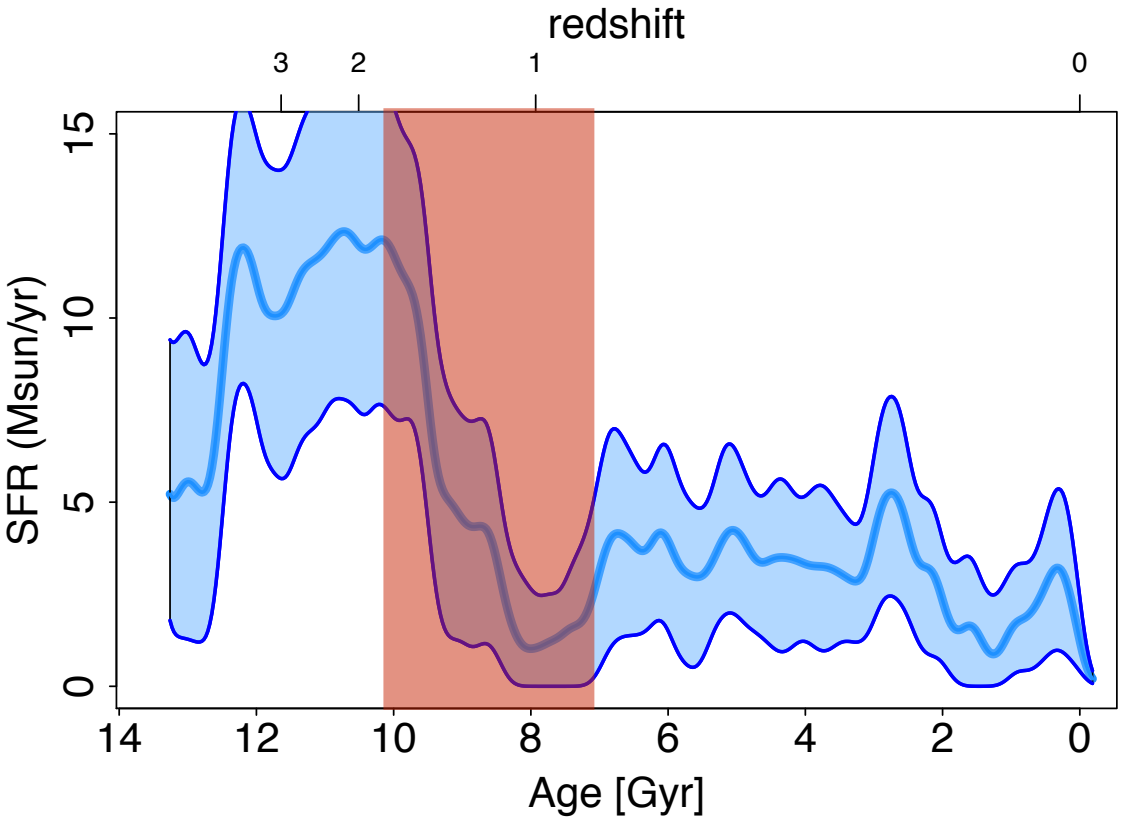
- Too few stars (sampling insufficient)
- Too few remote stars

Need of a deeper and more extensive sampling

Once accurate mono-abundance density laws are measured, mass growth of the MW can be reconstructed

2 - What is the quenching episode in the MW? What's its origin?

With accurate mass-growth estimates, even specific episodes of SFH can be measured



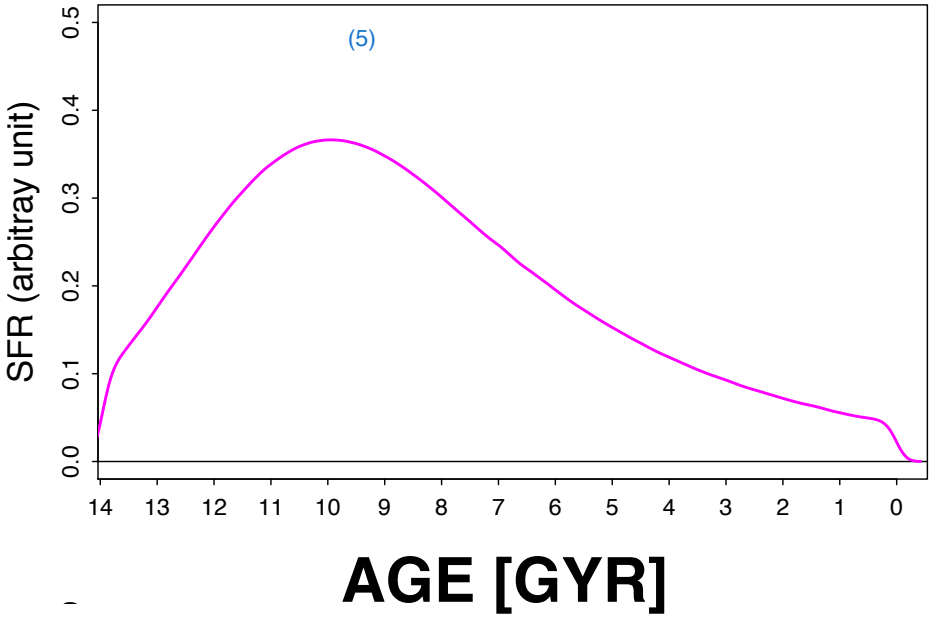
SFR decreased by a factor of 10
Similar to what is observed on MW-like galaxies? (Morishita+2016)

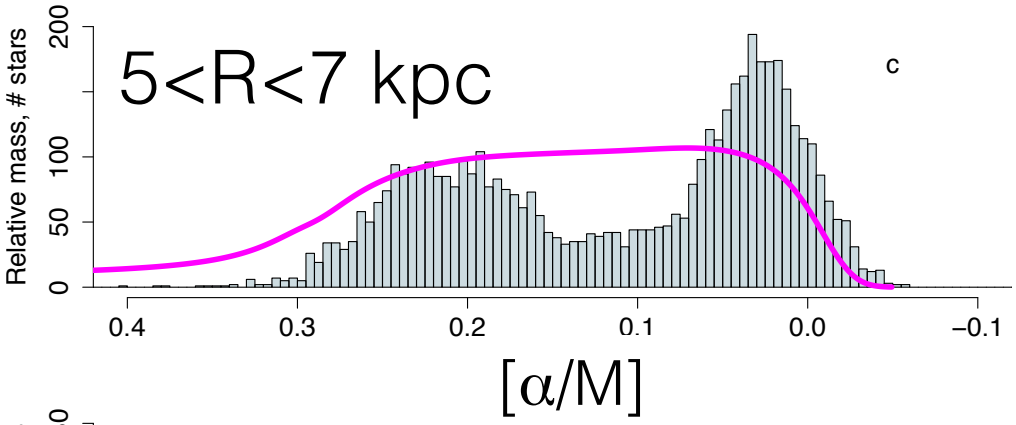
Haywood et al. 2016

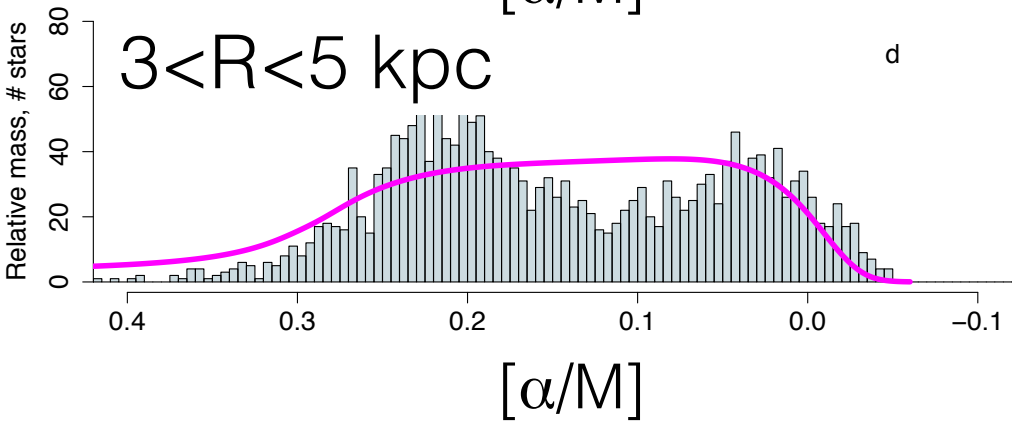
Quenching episode

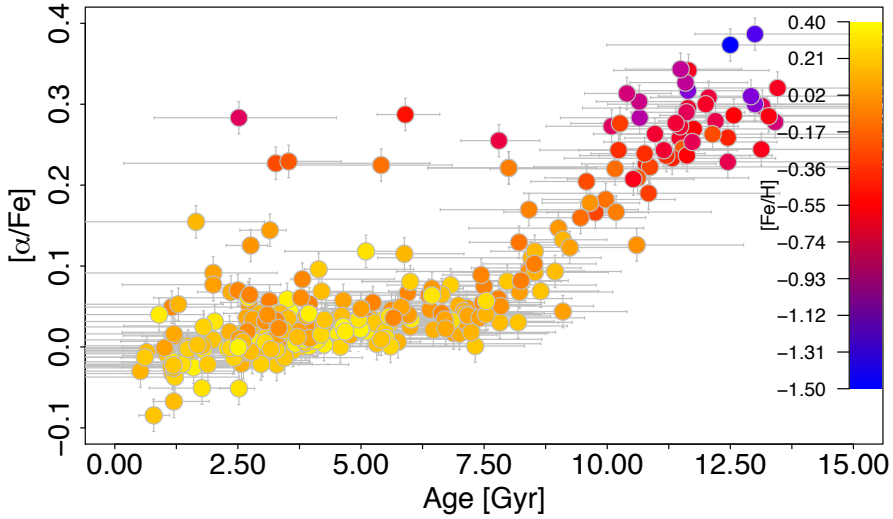
➡ First evidence that it happened in the MW also from inner disk stars.

APOGEE [α/M] distribution in the inner disk



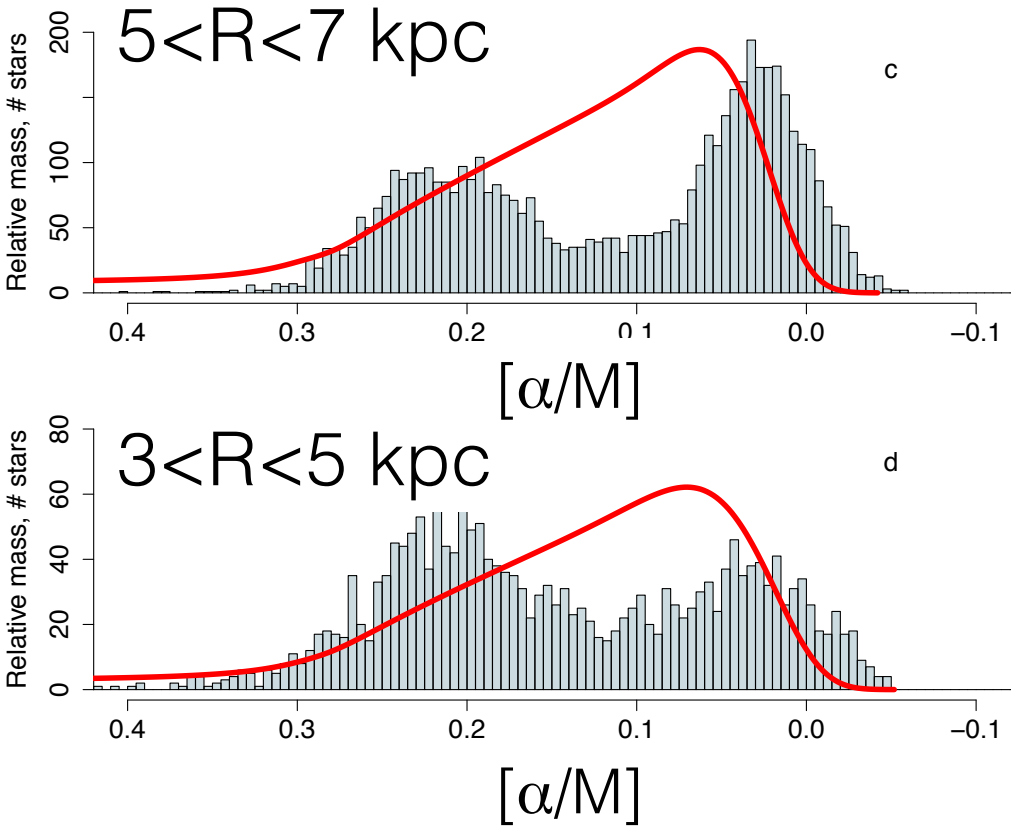


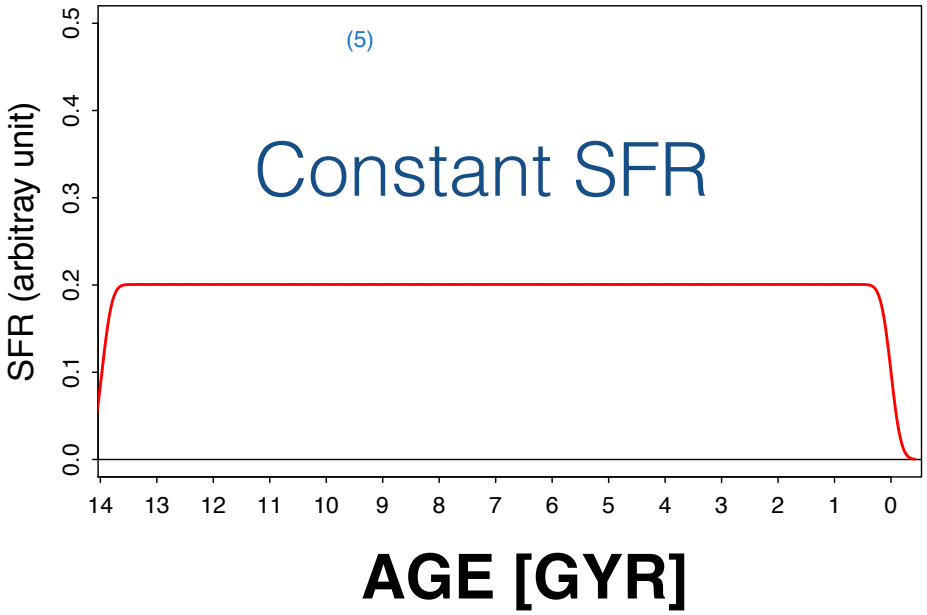


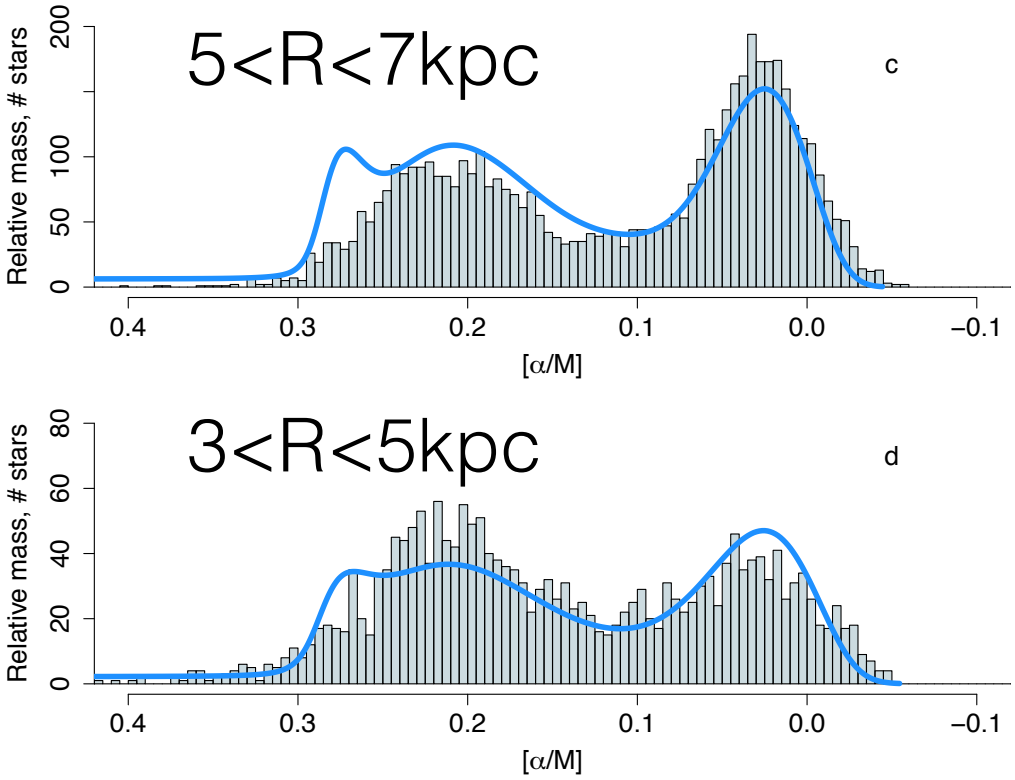


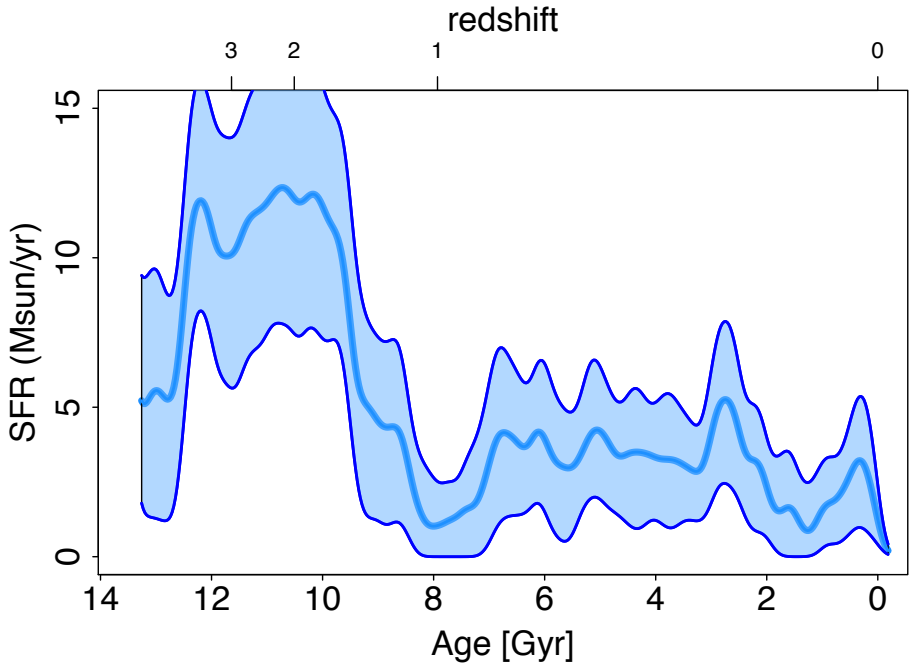
A *very* specific SFH is required

APOGEE [α/M] distribution in the inner disk









Needs from the data:

- better estimation of the quenching amplitude, duration in the inner disk (synergy with Gaia)
- Can we determine the SFH of the bulge from abundances ? Is the quenching episode also visible in the bulge?

➡ Need more extensive and accurate data

3 - How complex was the chemical evolution of the inner MW? Or was it simple?

Standard questions:

What was the chemical evolution of the inner disk?
(Just at the beginning with APOGEE)

What was the chemical evolution of the bulge?

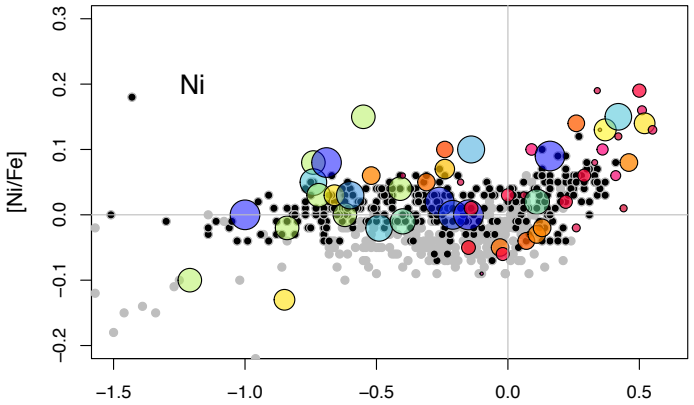
Is there something different between the two?

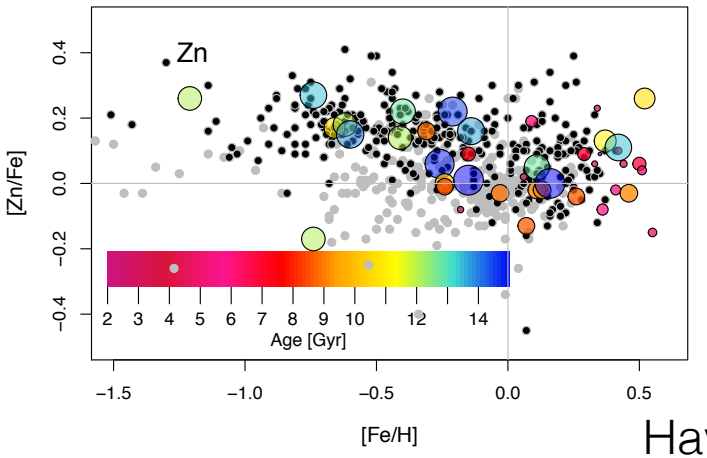
MW bulge is a pseudo-bulge:
we expect to find (mainly) the same stars, and to observe the same chemical evolution in the inner disk and in the bulge
Is it the case?

Some evidence from chemical abundances are consistent with these expectations

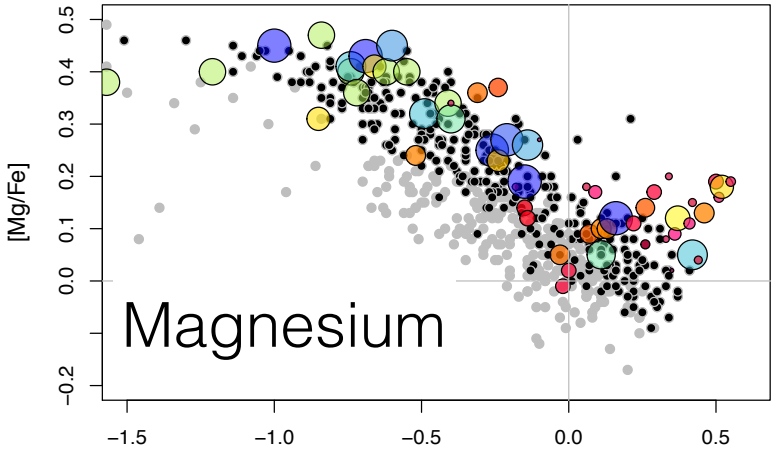
Coloured points  **: bulge stars (Bensby+13)**

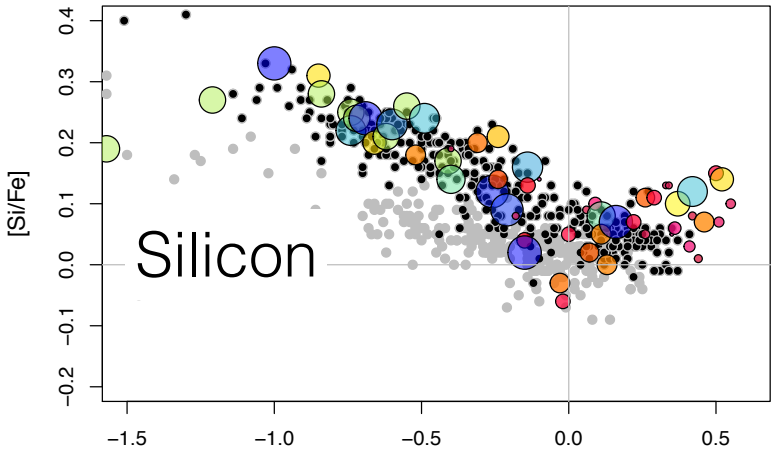
Black dots: « inner disk » stars of the solar vicinity

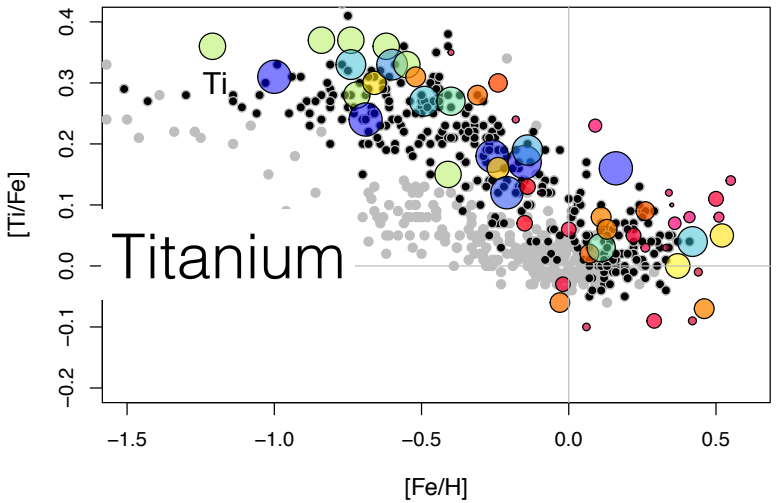




Haywood+2016, in prep

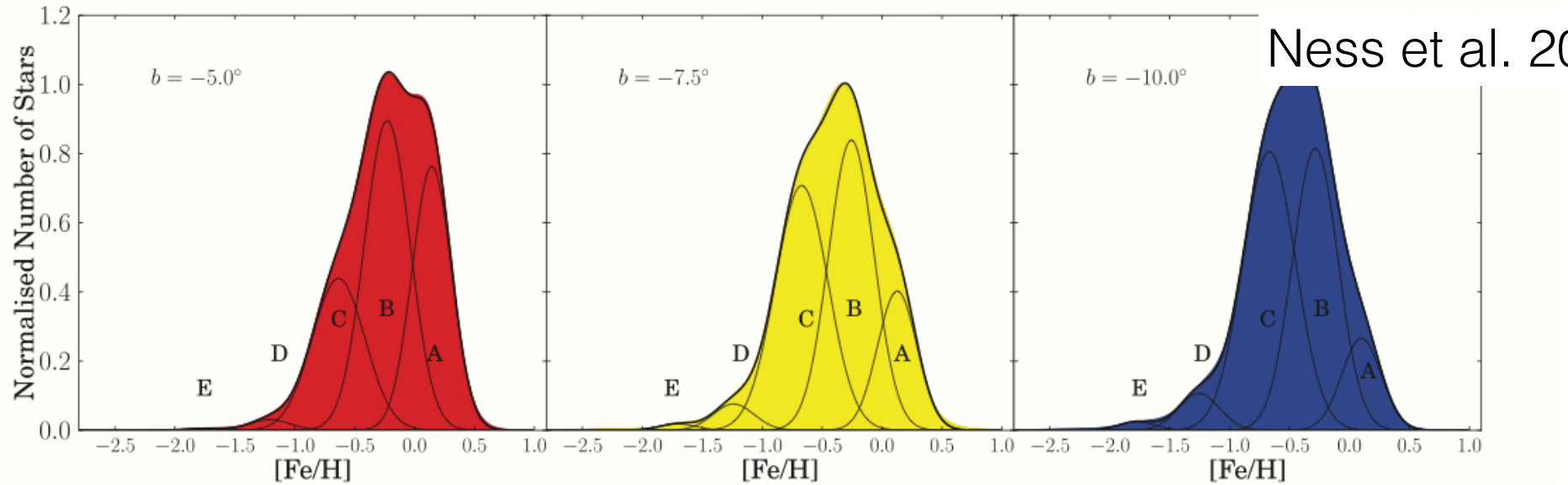






3 - How complex was the chemical evolution of the inner MW?

Metallicity distribution of the bulge is complex

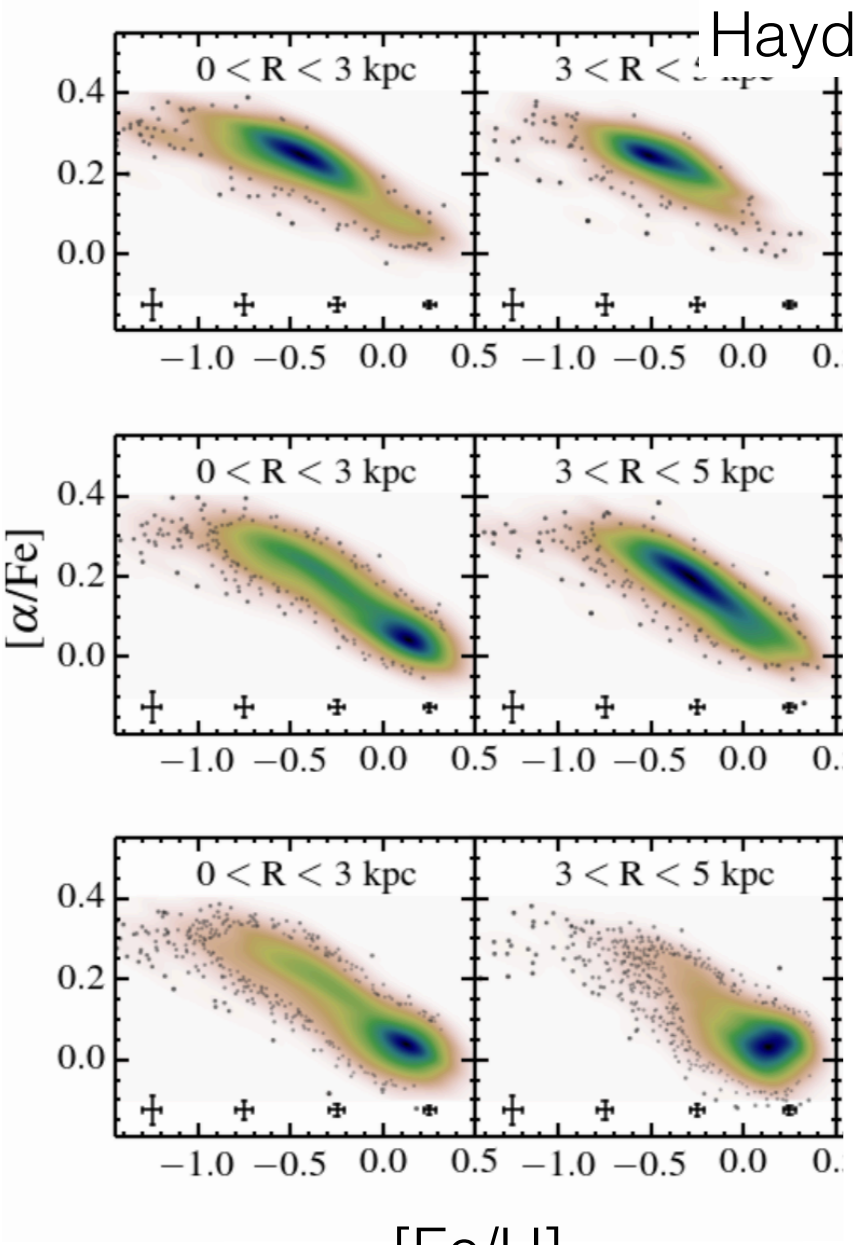


Ness et al. 2013

Most observed MDF show at least 2 components

Present models (Grieco+2012, Tsujimoto & Bekki 2012) represent the CGE of the bulge as an independent system. At present difficult to explain the data without adding adhoc parameters.
2 components: 2 infall episodes, 2 different infall time scales, 2 different star formation efficiencies, etc..

3 - Or was it simple?



First hints with APOGEE that the bulge and inner disk chemical evolution may have been simple

But too many uncertainties/unknown

Age distribution?

Metallicity distribution?

Chemical abundances?

Can the thick/thin disks in the bulge explain all?
Do we need other components?

Need for more extensive high quality data on the bulge/inner disk

Résumé

The inner regions of the MW concentrate several important questions on the evolution of our Galaxy

SFH,
chemical evolution,
accretion history (both gas and stars),
formation of structures (bar),
etc..

Chemical abundances provide a clock that can be used to probe the evolution of the Milky Way much beyond the Gaia age sphere

Moons survey of inner regions highly desirable to understand these problems!