THE MILKY WAY ABOVE REDSHIFT 1

WHERE ARE THE RELICS OF THE EARLY FORMATION HISTORY OF THE GALAXY ?

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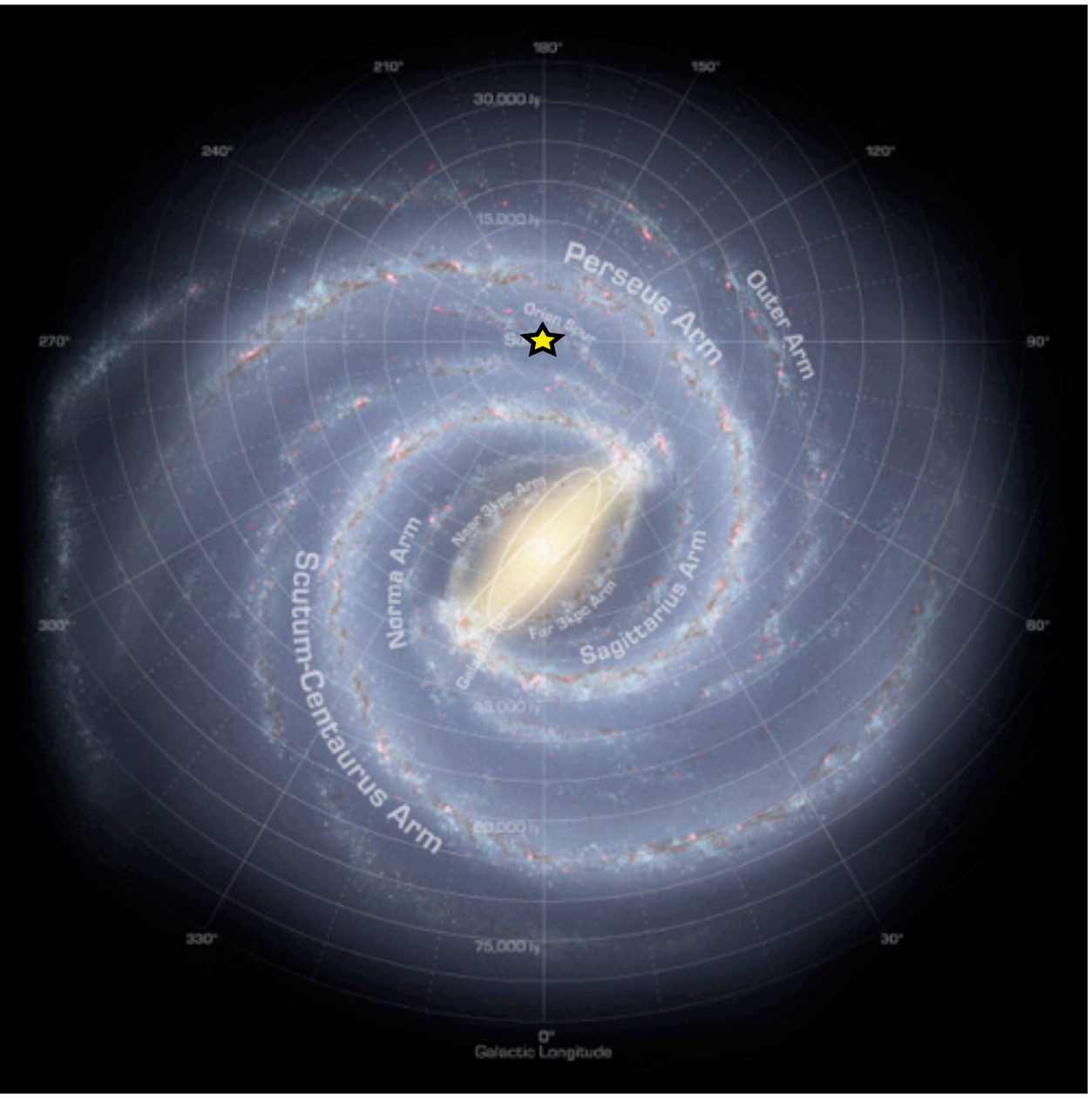
EXCITING TIMES FOR MILKY WAY STUDIES



/ A number of spectroscopic surveys (SEGUE, APOGEE, GES, ARGOS,..) are revealing **the large scale structure (~several kpc from the Sun) of stellar populations in the disk and bulge of our Galaxy**, quantifying how stars with different kinematics and chemical compositions are redistributed in our Galaxy

/ High resolution spectroscopic data are revealing the complexity of chemical patterns in the MW, allowing us to trace with **unprecedented accuracy the detailed enrichment history of the different Galactic stellar populations**

/ and of course Gaia !
(first two catalogues by summer 2016 and early 2017)

CLASSICAL PICTURE OF THE MW GALAXY

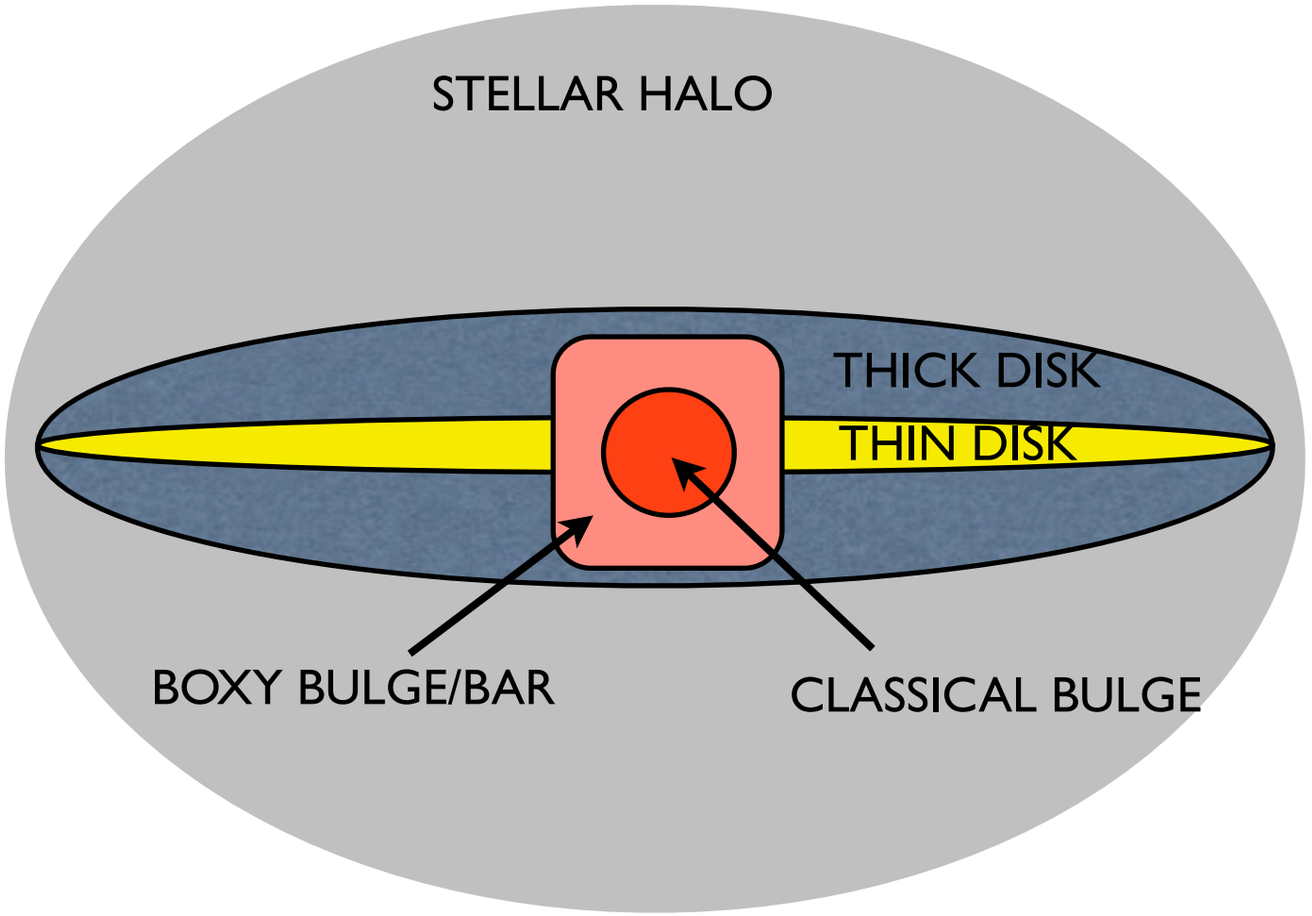
Stellar components

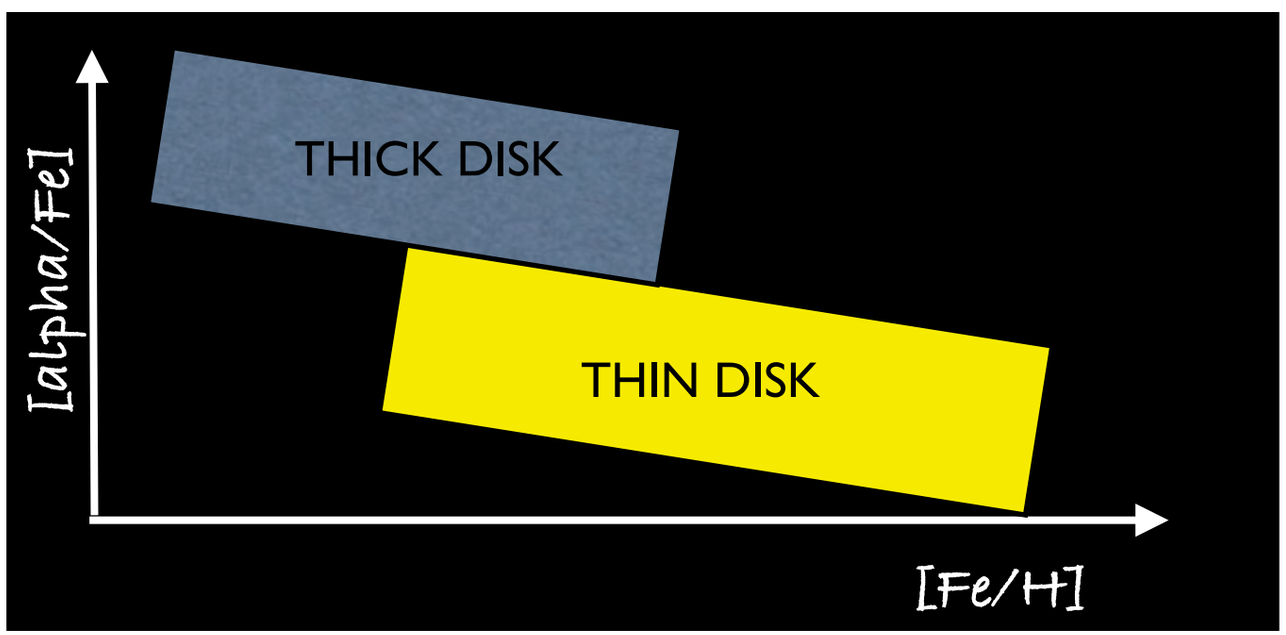
Thin disk : most (> 70%) of the stellar mass of the Galaxy,
exponential scale height ~ 0.3 kpc
exponential scale length ~ 3.5 kpc

Classical bulge : ~10-20% of the disk mass

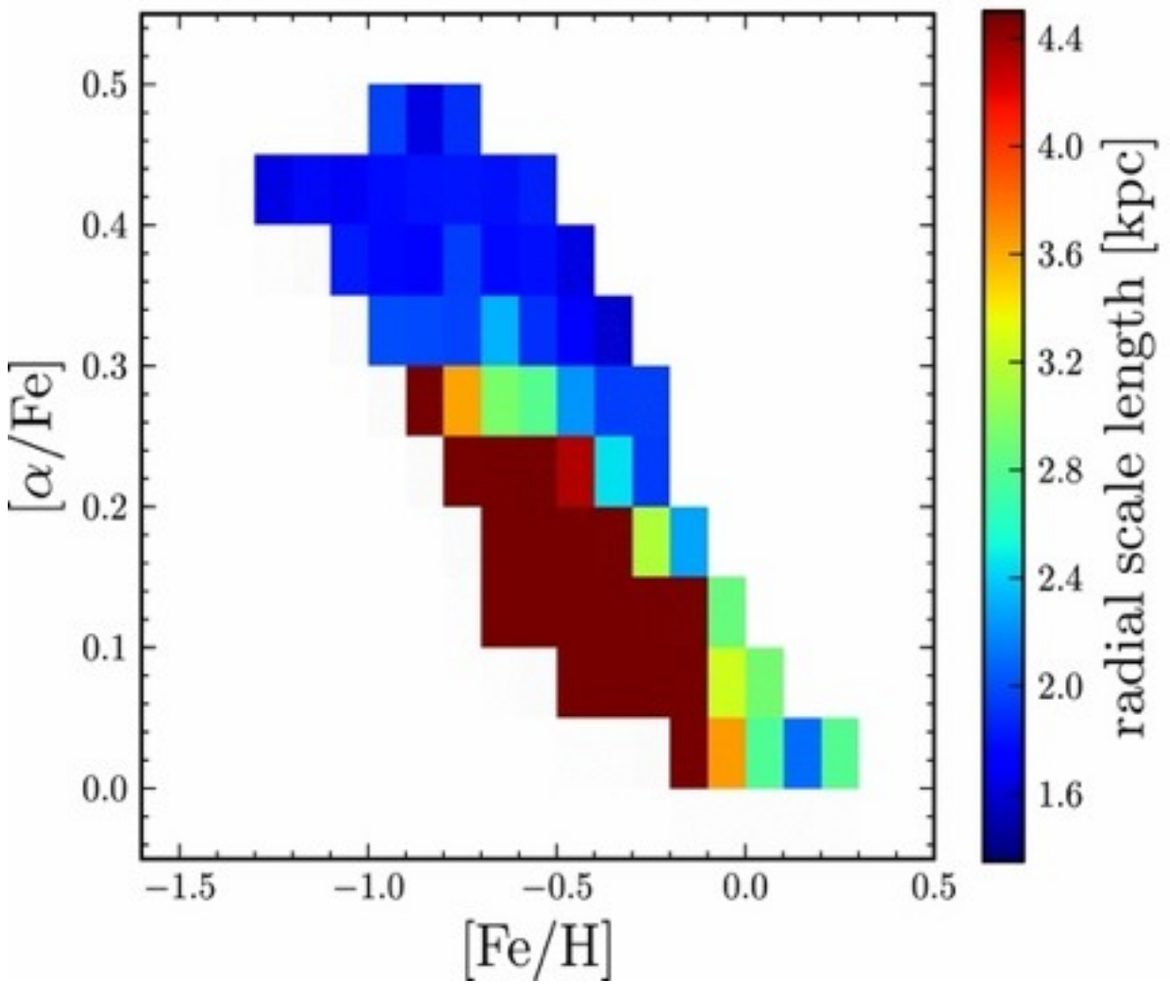
Thick disk : ~10-15% of the stellar mass,
exponential scale height ~1kpc
exponential scale length ~ 3.5 kpc

Stellar halo : few percent of the total stellar mass





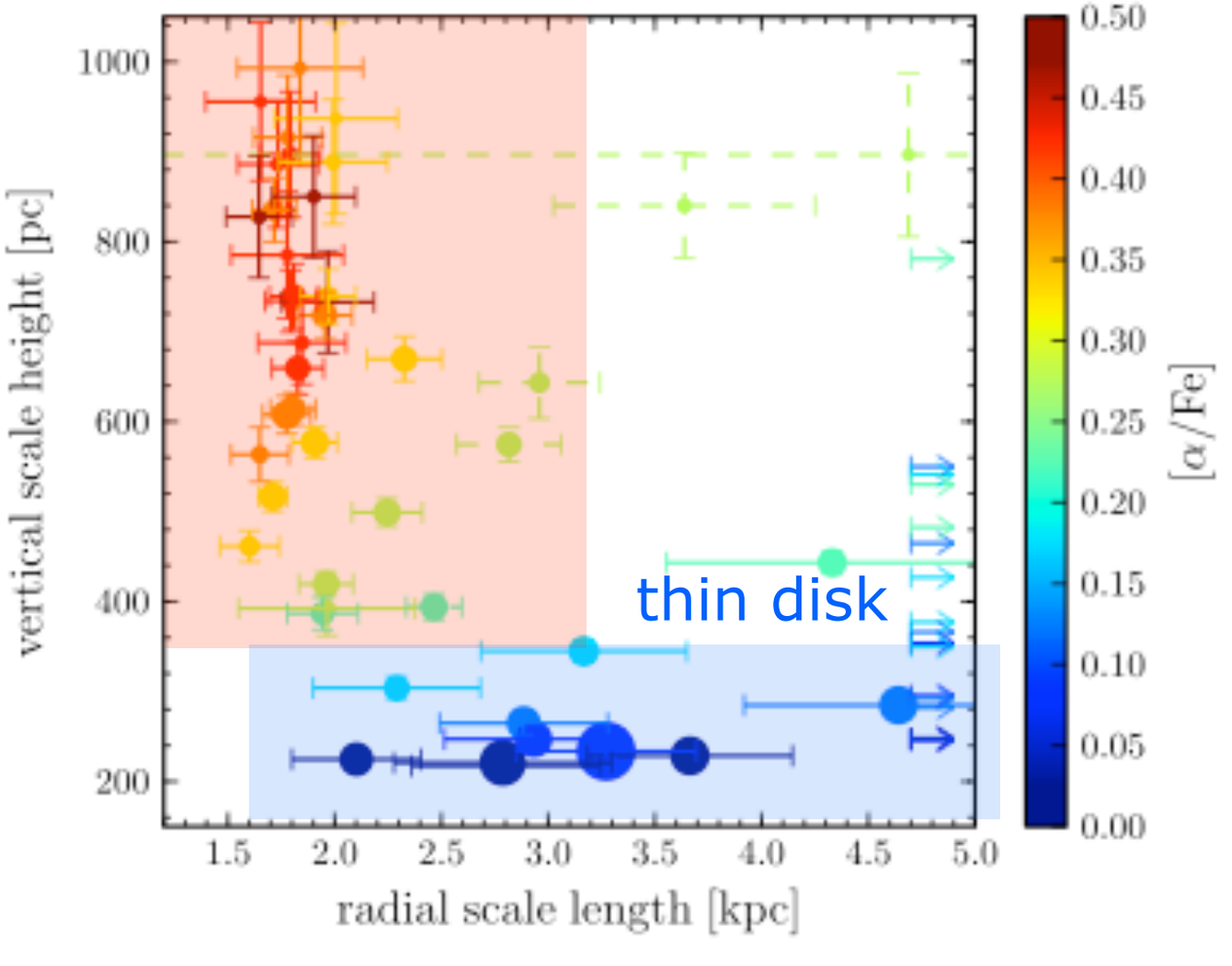
REVISITING THE DISK STRUCTURE: THE THICK DISK SCALE LENGTH IS SHORT (1)



[α/Fe]–[Fe/H] plane, color coded by radial scale lengths
SEGUE data, Bovy et al. 2012

thick disk

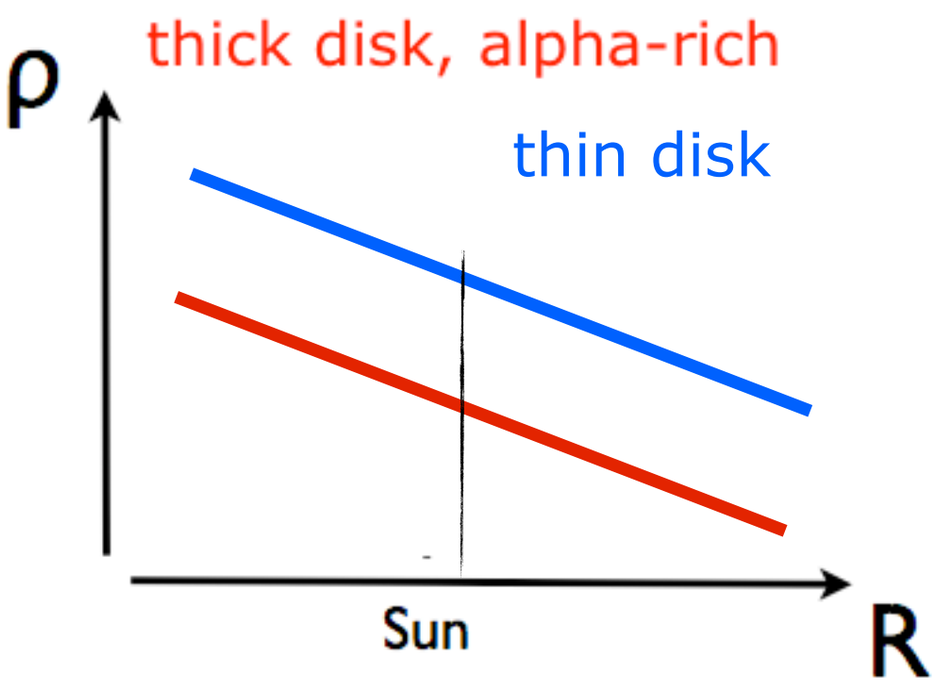
Bovy & Rix 2012

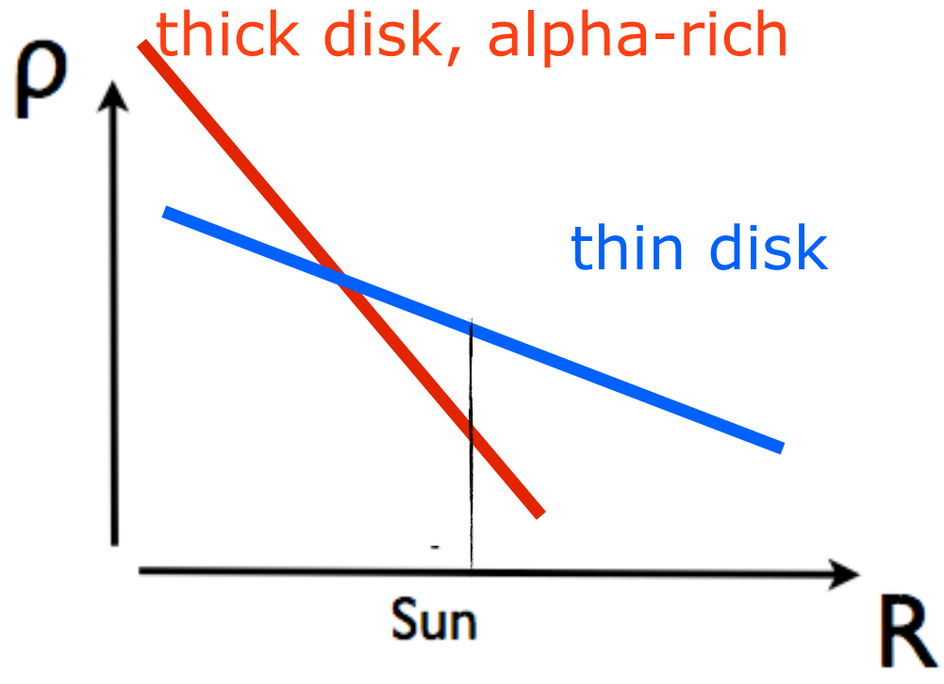


Scale length varies according to the [α/Fe] and [Fe/H] abundances, from thick to thin disks

REVISITING THE DISK STRUCTURE: THE THICK DISK SCALE LENGTH IS SHORT (2)

Thick disk scale length ~ 2.0 kpc
Bovy et al. 2012
Bensby et al. 2011





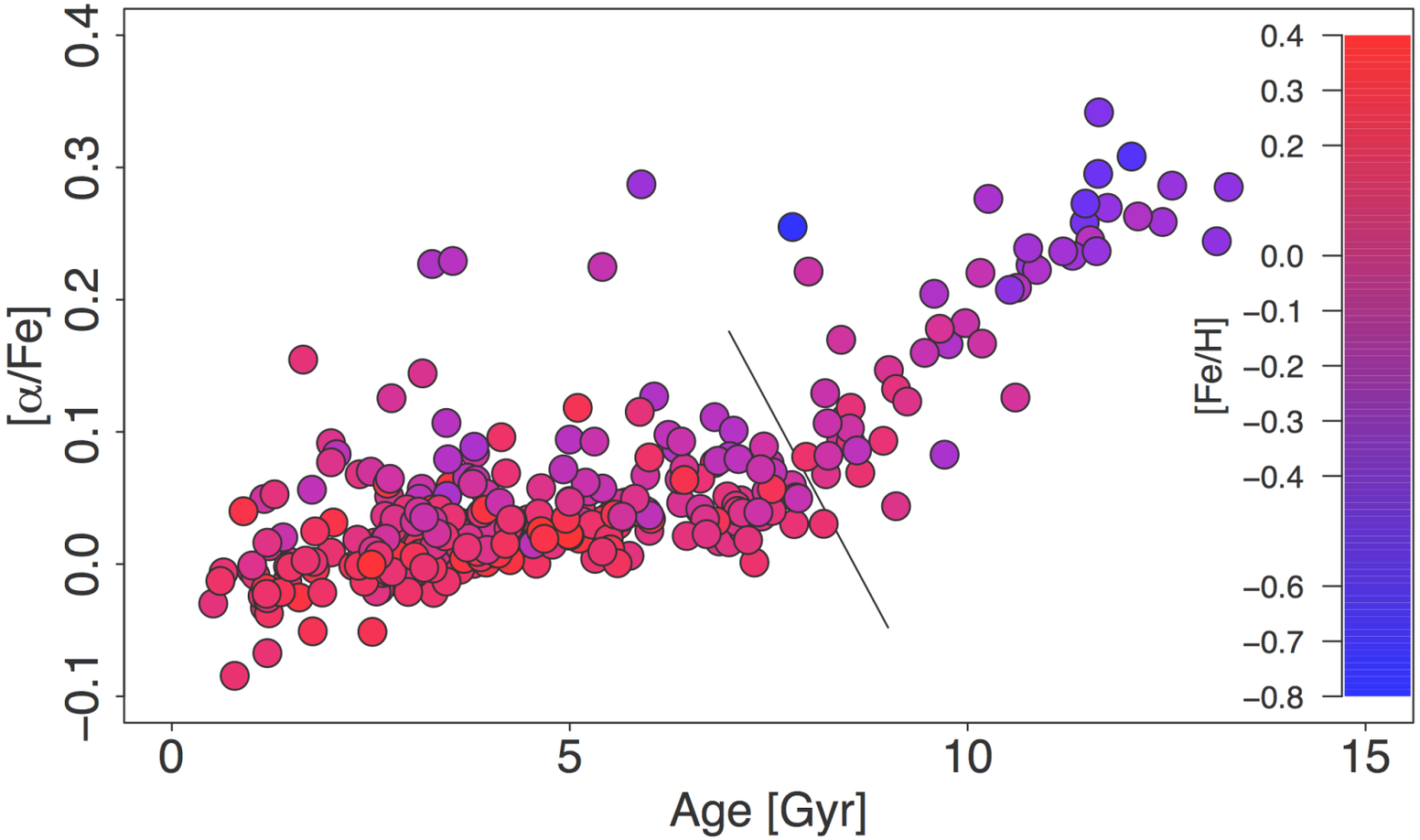
The thick/thin density ratio as the solar vicinity is not representative of the entire Galaxy

First indication that the mass estimates of the two components need to be revised (Snaith et al 2014)

REVISITING THE MASS BUDGET OF GALACTIC STELLAR POPULATIONS:

THE THICK DISK IS MASSIVE

The Age-alpha relation at the solar vicinity



Haywood et al. 2013
(Abundances from
Adibekyan et al 2012)

Solar vicinity F&G dwarfs

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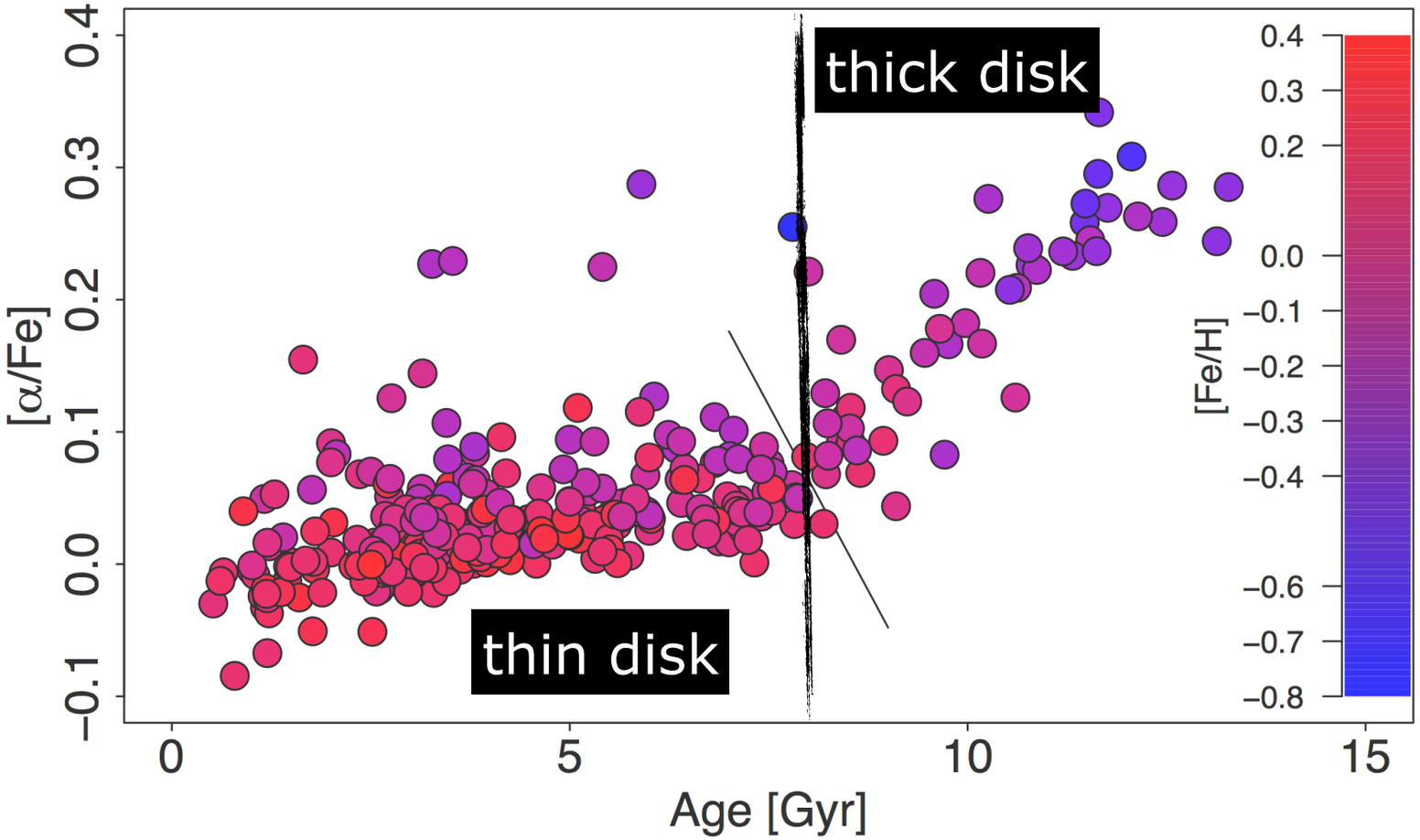

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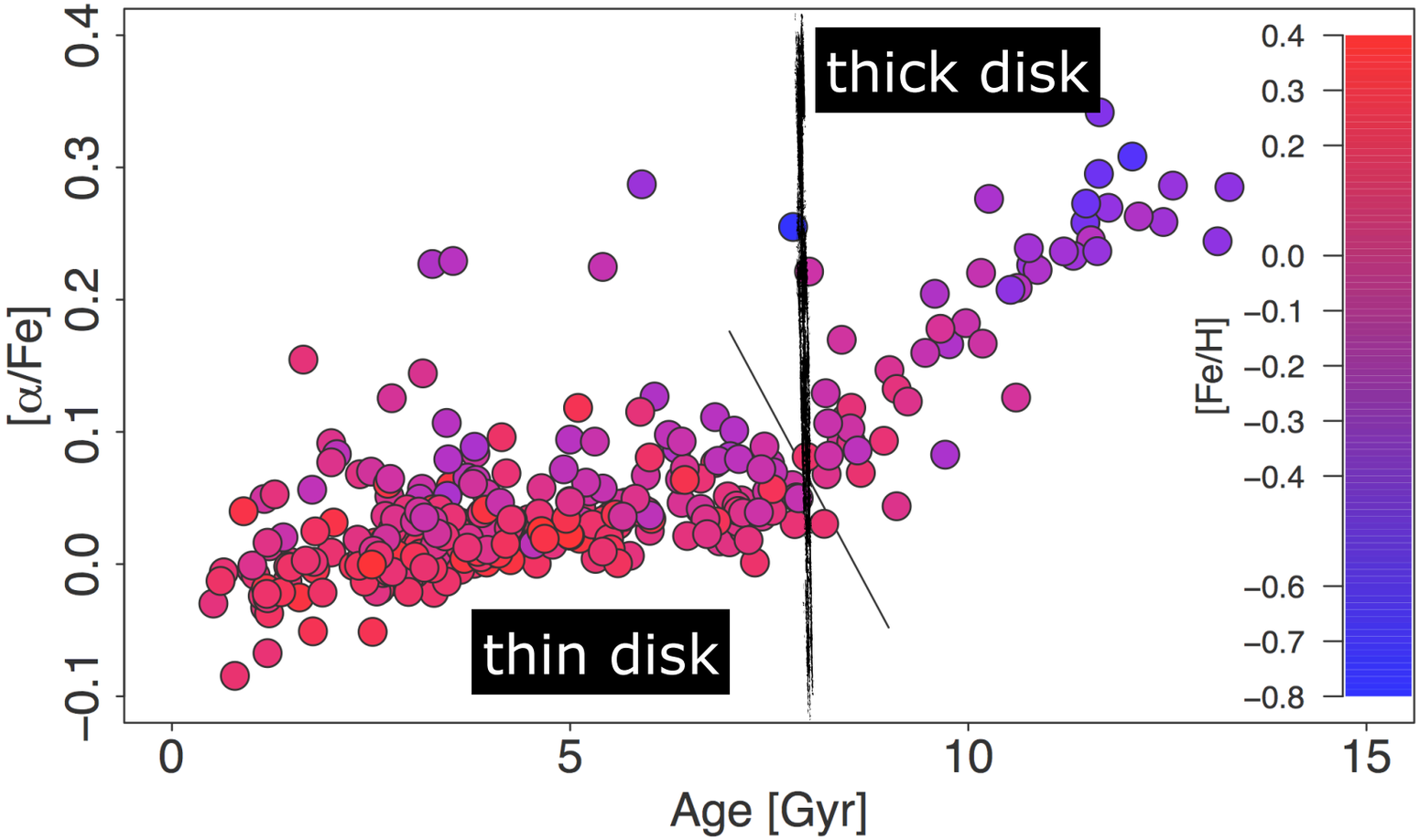

Haywood et al. 2013
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Solar vicinity F&G dwarfs

➡ **Two different regimes** of chemical enrichment corresponding to **two different star formation epochs**

➡ The thick disk shows a steep decrease in [alpha/Fe] due to a steep increase in iron abundance

➡ **Continuity between thick and thin disks**: the thin disk starts where the thick disk ends

REVISITING THE MASS BUDGET OF GALACTIC STELLAR POPULATIONS:

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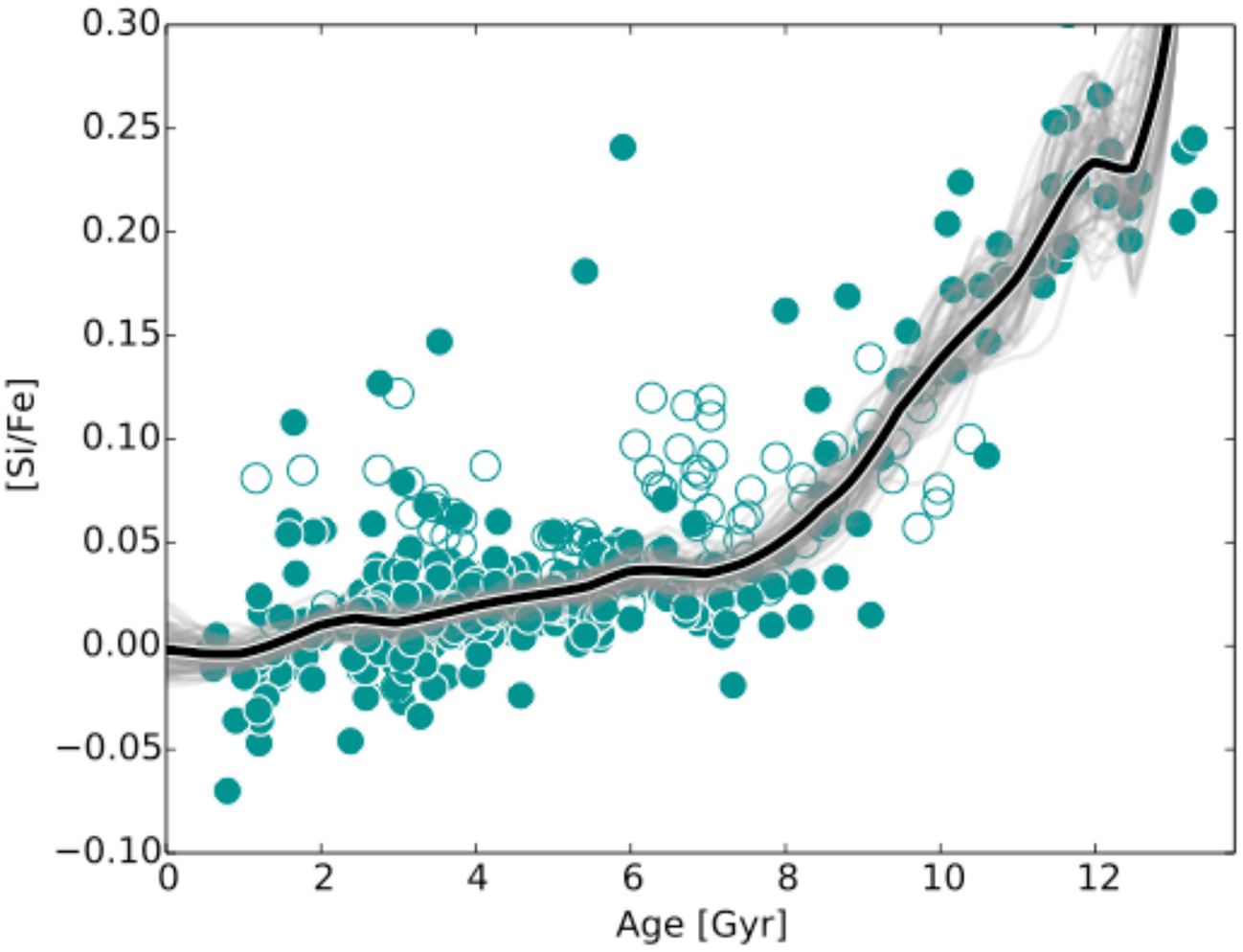
Fit to the Age-alpha relation at the solar vicinity



Snaith et al 2014b, A&A in press

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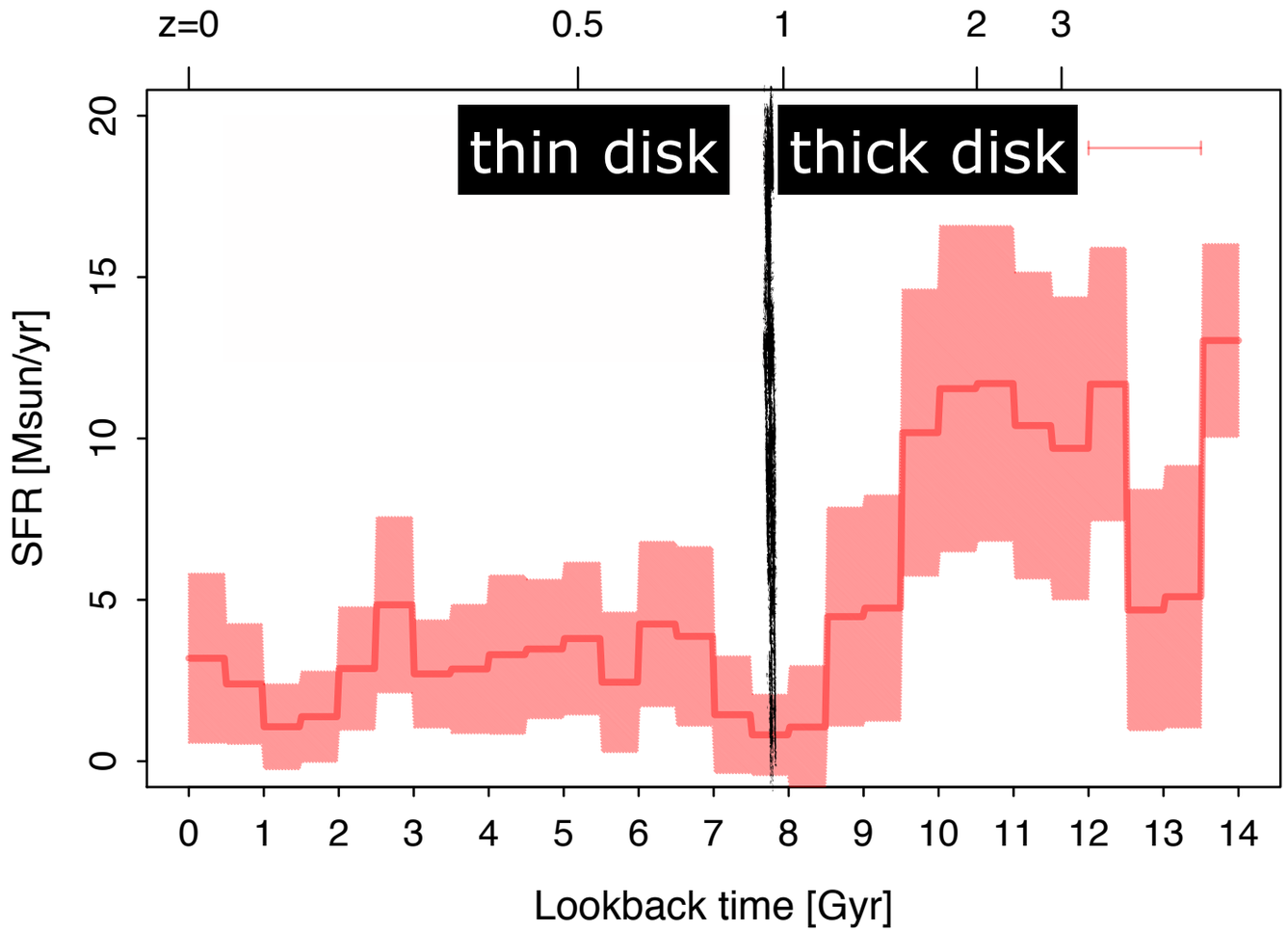

Snaith et al 2014a,b

Two main periods of SFR
corresponding to:

1/ 13.5-8.5 Gyr :
thick disk at SFR ~12 $M_\odot$/yr

2/ 7.5 Gyr - Now
thin disk at SFR ~2-3 $M_\odot$/yr

(Normalized to have an integrated stellar mass of 5. 10^{10} $M_\odot$)

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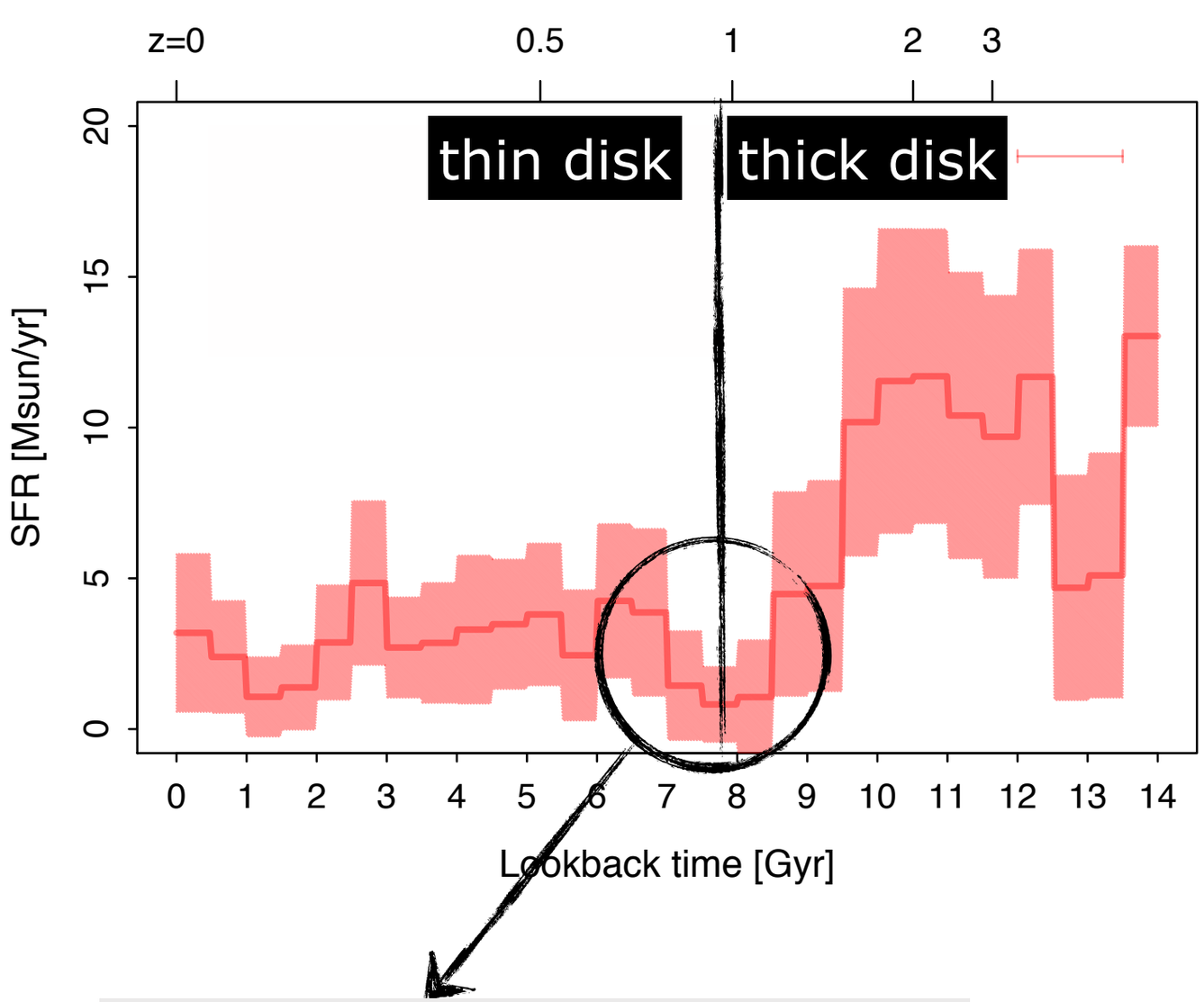

Snaith et al 2014, ApJL

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~1Gyr dip at 8Gyr
local or global feature ?

(Normalized to have an integrated stellar mass of 5. 10^{10} $M_\odot$)

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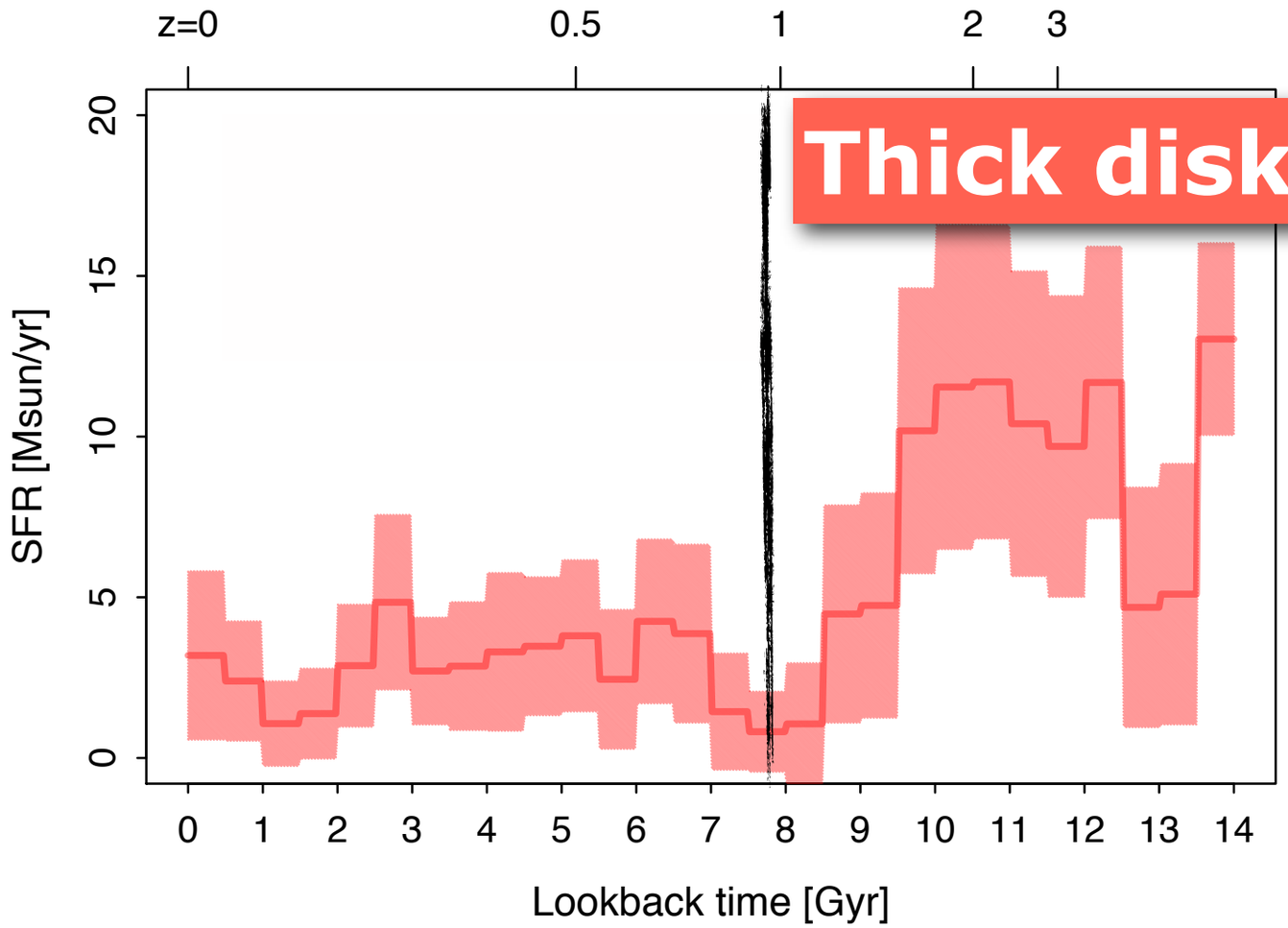


Thick disk ~ 50% of disk mass

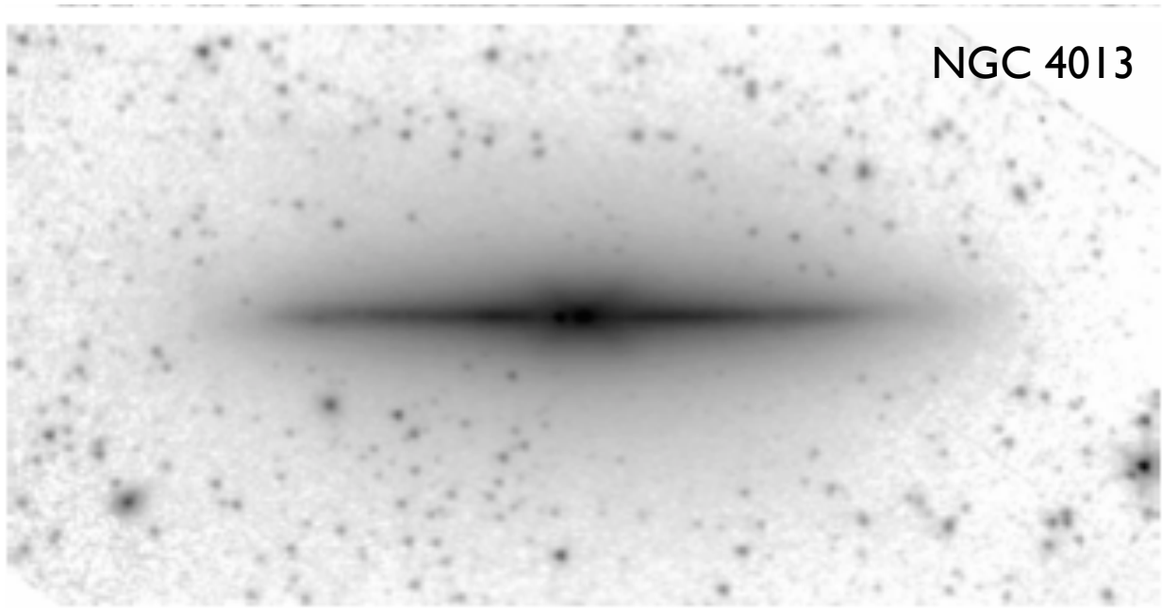
Consistent with :

1/ the mass estimate for a thick disk scale length of ~ 2 kpc

Snaith et al 2014, ApJL

(Normalized to have an integrated stellar mass of 5. 10^{10} $M_{\odot}$)

Comeron et al 2011: "THICK DISKS AS LAIR OF MISSING BARYONS ?"



The thick disk is a major stellar component of the MW, and of many of the extragalactic disk galaxies as well
(see Comeron et al 2011, 2014)

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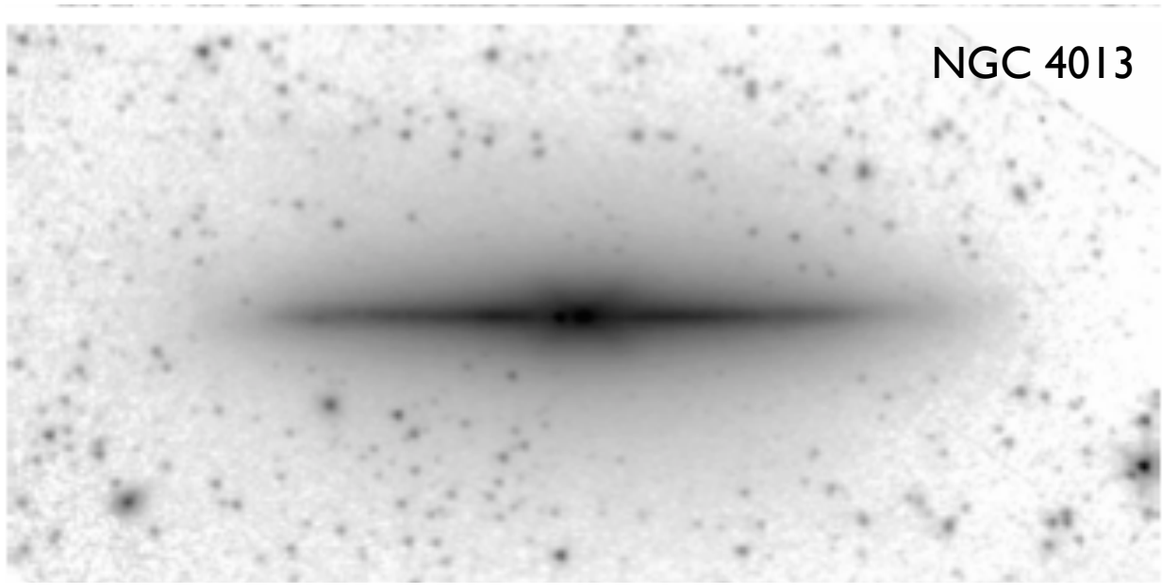


Thick and thin disks
have comparable masses
(see also Comeron et al 2011, 2014, S^{4}G survey)

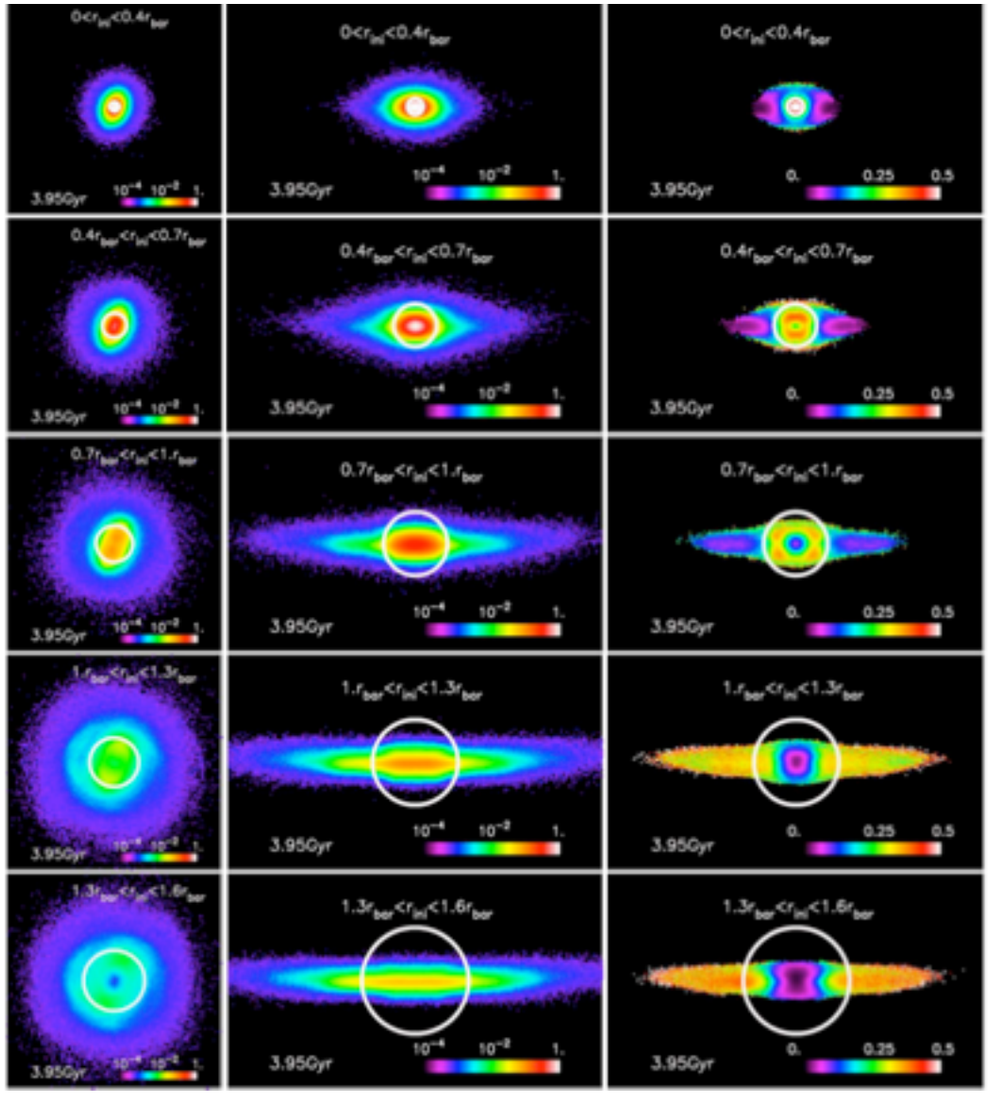
The thick disk is a major stellar component of the MW, and of many of the extragalactic disk galaxies as well
(see Comeron et al 2011, 2014)

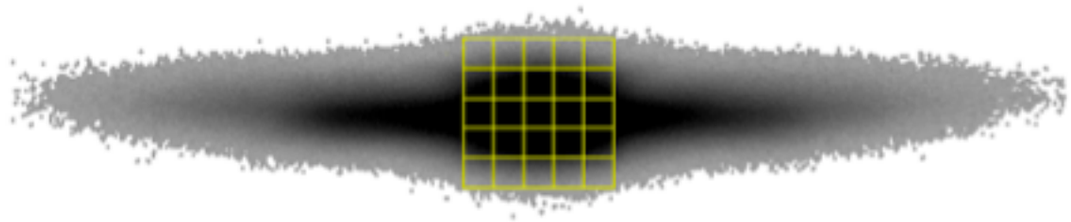
DOES THE MW CONTAIN ANY SIGNIFICANT CLASSICAL BULGE ?

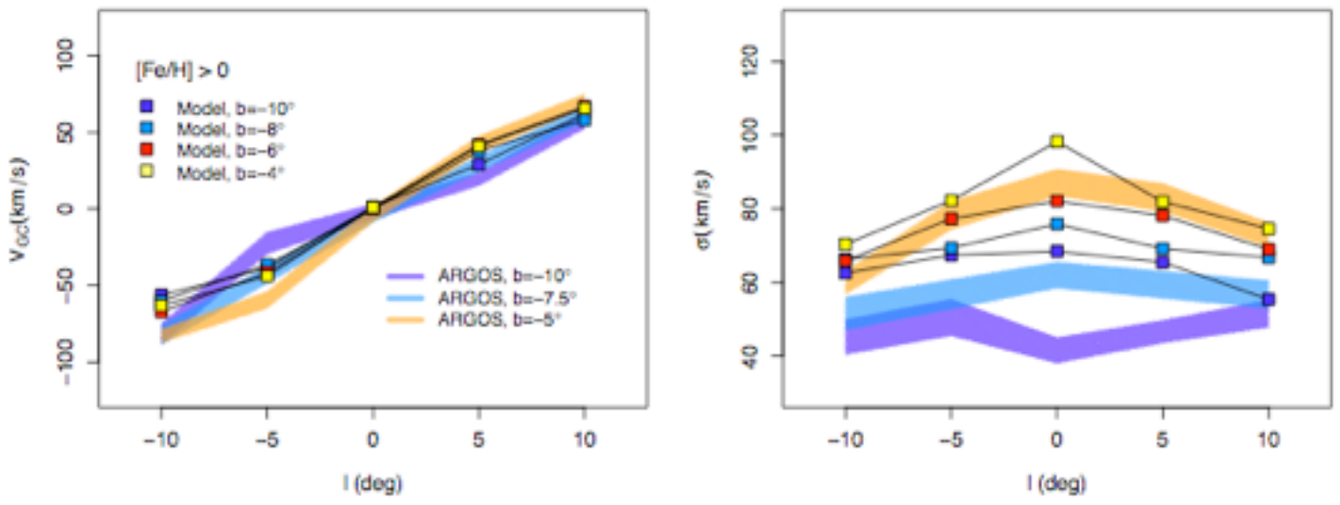
Kormendy & Ho 2013 :

"Classical bulges are defined purely by observational criteria:
They are **indistinguishable from elliptical galaxies**,
except that they are embedded in disks (Renzini 1999)."

DOES THE MW CONTAIN ANY SIGNIFICANT CLASSICAL BULGE ?







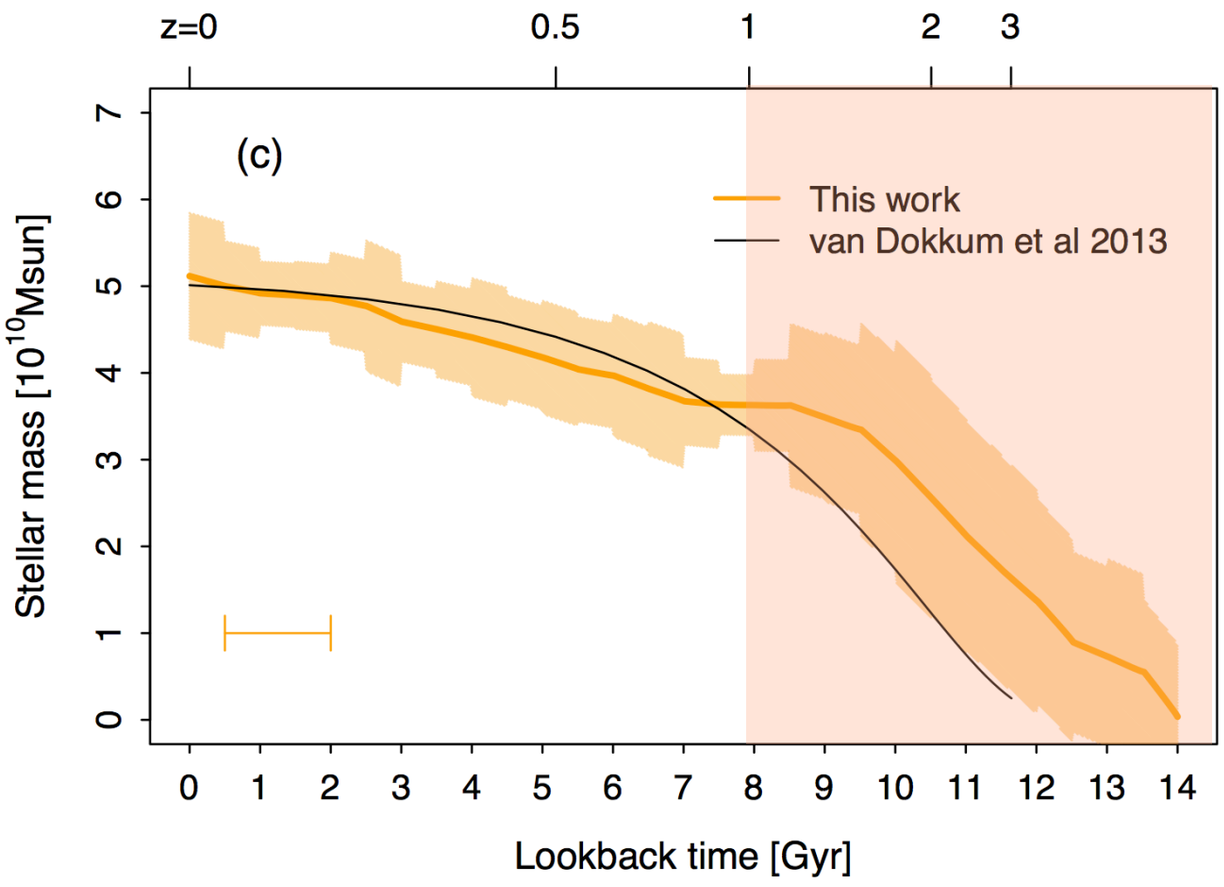
see Di Matteo et al 2014a, Di Matteo et al 2014b

Our conclusion is that the classical bulge in the MW is small (B/D~10%) or non-existent (see also, among others, Shen et al 2010, Kunder et al 2012).

This result is consistent with a number of studies of bulges in external galaxies, which show that MW mass galaxies with no significant classical bulges are common in the nearby Universe

(Kormendy et al 2010, Fisher & Drory 2011, Laurikainen et al 2014).

THE THICK DISK AS THE RELIC OF THE EARLY SFH OF THE GALAXY



Snaith et al 2014, ApJL

Half of their stellar mass of MW progenitors formed by redshift 1
(among others : Leitner 2012, van Dokkum et al 2013)

It is the formation of the thick disk that allows the Milky Way to form half of its stellar mass by z=1.

The relics of the early formation of the Milky Way and the physical conditions of the ISM at those times are now imprinted in the Galactic thick disk
(Haywood et al 2013; Snaith et al 2014a,b; Lehnert et al 2014; I. Jean-Baptiste et al in prep)

van Dokkum et al 2013

CONCLUSIONS

1. The Galactic thick disk is massive, and has a short scale length.

2. It is the main old stellar population of the Galaxy, which traces its early phases of evolution

3. Only a very limited or non-existing contribution of a classical spheroid in the MW bulge

Exciting times where **we are witnessing at a change of paradigm** in the study and interpretation of galaxy structure and stellar populations:

➡ the **role of classical bulges in disk galaxies has probably been overestimated**
➡ **thick disks as major relics of the early evolution** of galaxy disks

Both Galactic and extragalactic studies seem to support this new vision.
One of the main challenges for galaxy evolution studies in the coming years.