973项目“基于LAMOST大科学装置的银河系研究及多波段天体证认”2016年度学术会议

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Understanding the formation and evolution of the Galactic disc(s) using Mono-Age Population Phase-spacE Distributions (MAPPED) analysis I: LAMOST-TGAS

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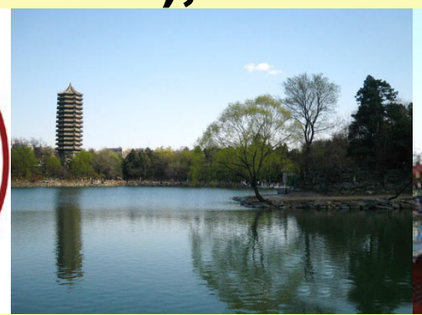
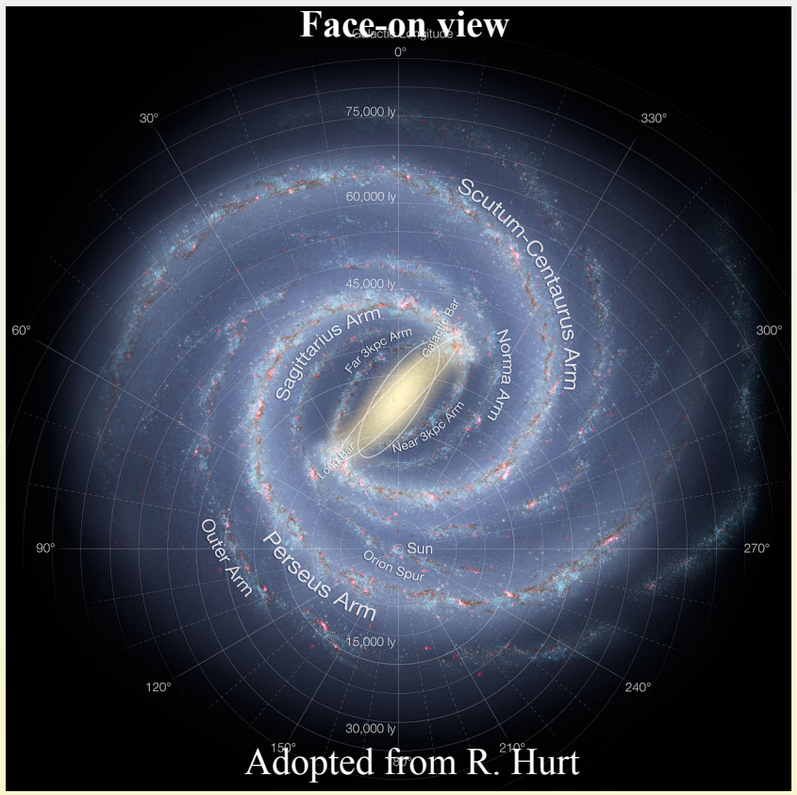


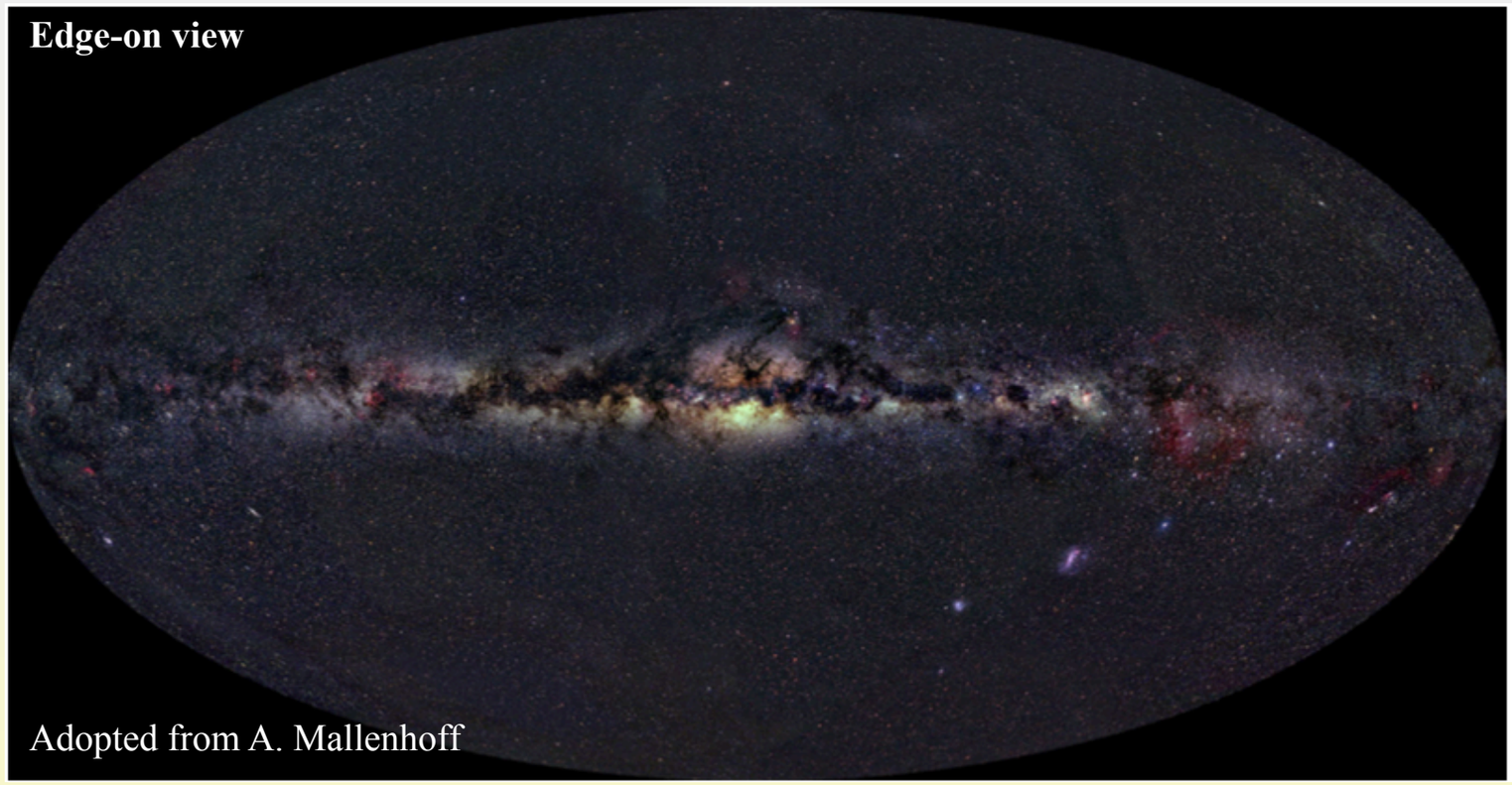

Outline

- **Background**
- **LAMOST-TGAS MSTO-SG sample**
- **Study the Galactic disc(s) using Mono-Age Population Phase-spacE Distributions (MAPPED) analysis**
- **Summary & Future plan**

Background

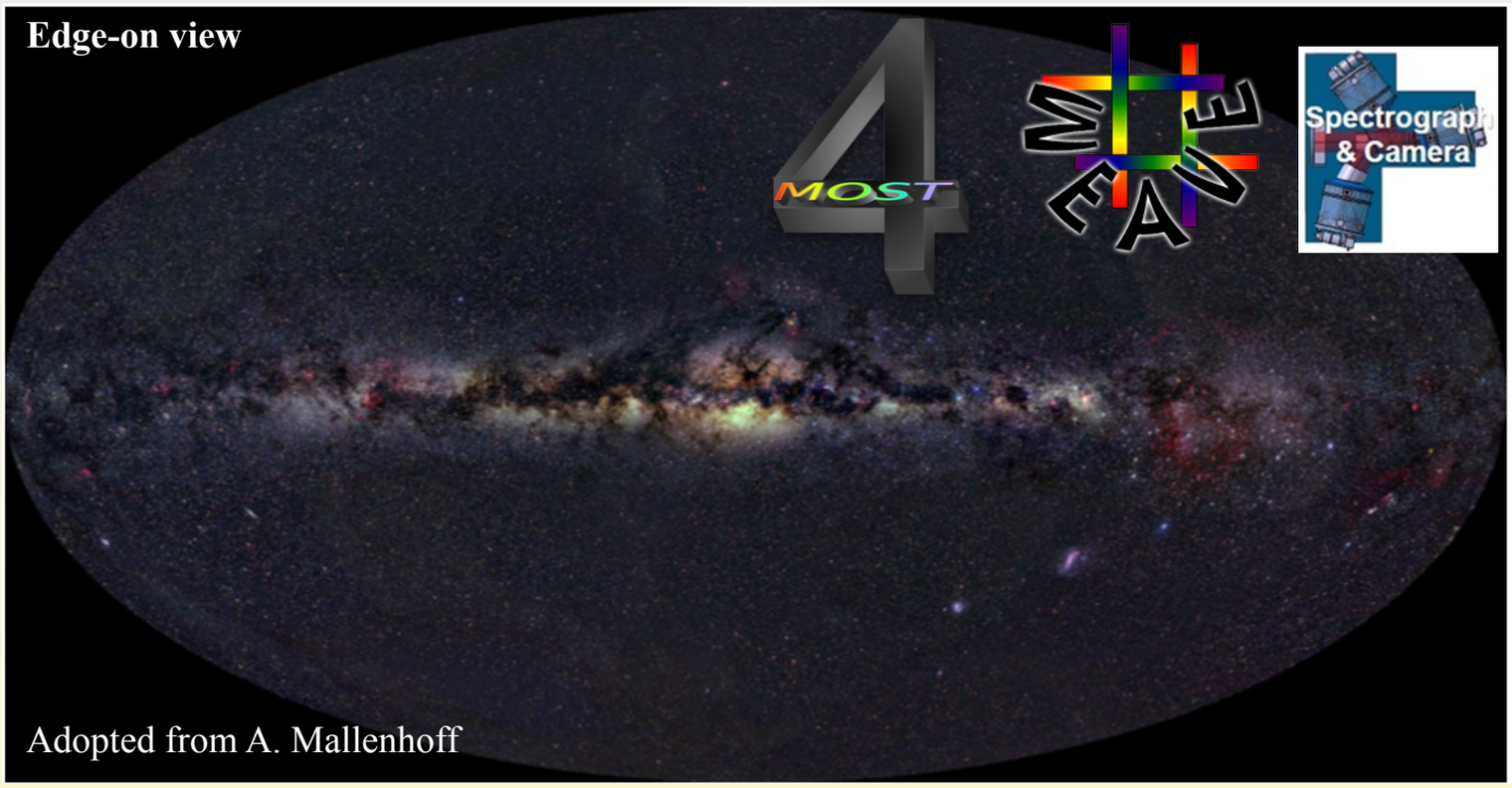
The Milky Way as a benchmark galaxy





Milky Way is the only galaxy that can be studied in great detail and a good understanding of its stellar populations is important for our understanding of galaxy formation in general

The Milky Way as a benchmark galaxy



Milky Way is the only galaxy that can be studied in great detail and a good understanding of its stellar populations is important for our understanding of galaxy formation in general

Galactic discs: observational view

Properties	Thin disc	Thick disk
Scale height	Short	Large
Scale length	Large/short (count)	Short/large (count)
Metallicity	Iron-rich, low alpha	Iron-poor, high alpha
Metallicity gradient	Strong	Near flat
Velocity dispersion	Small	Large
Eccentricity	Small	Large
V-[Fe/H]	Negative	Positive
Age	Young	Old

Galactic discs: observational view

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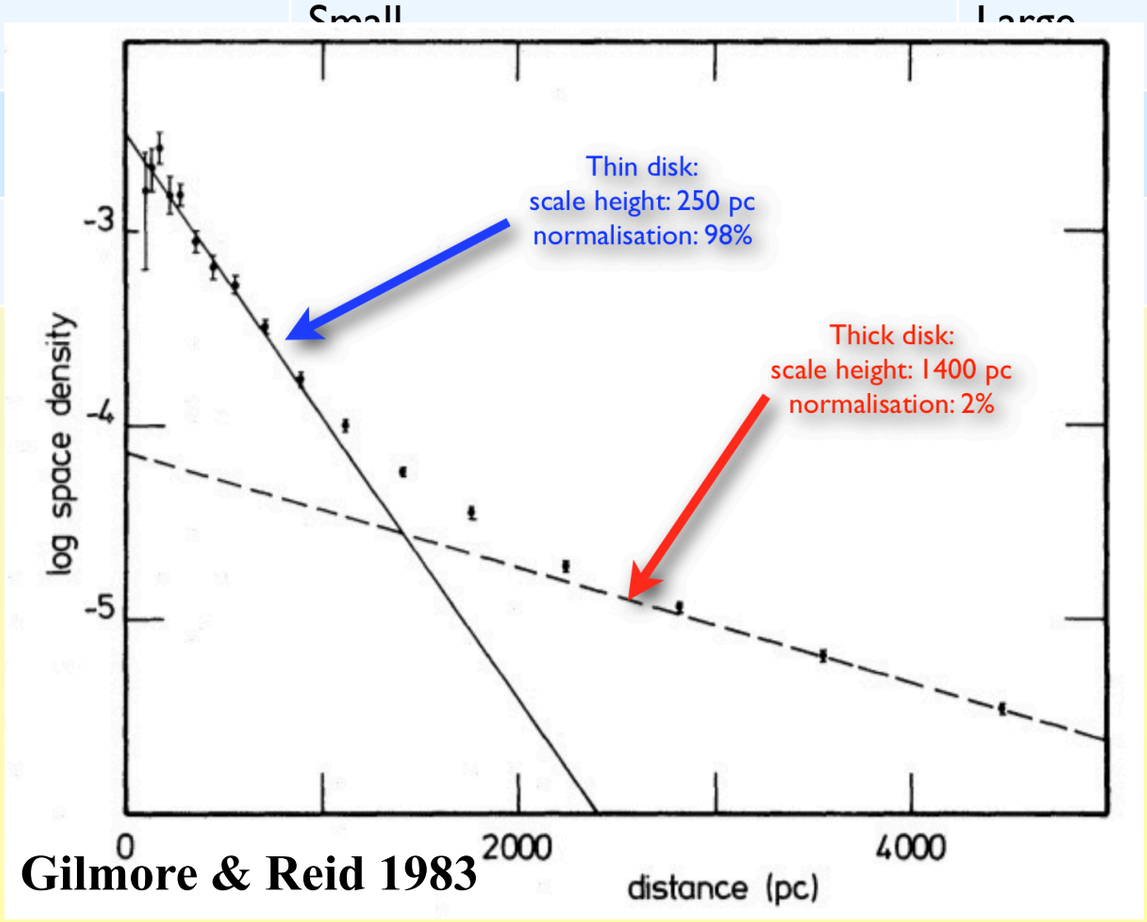

Gilmore & Reid 1983

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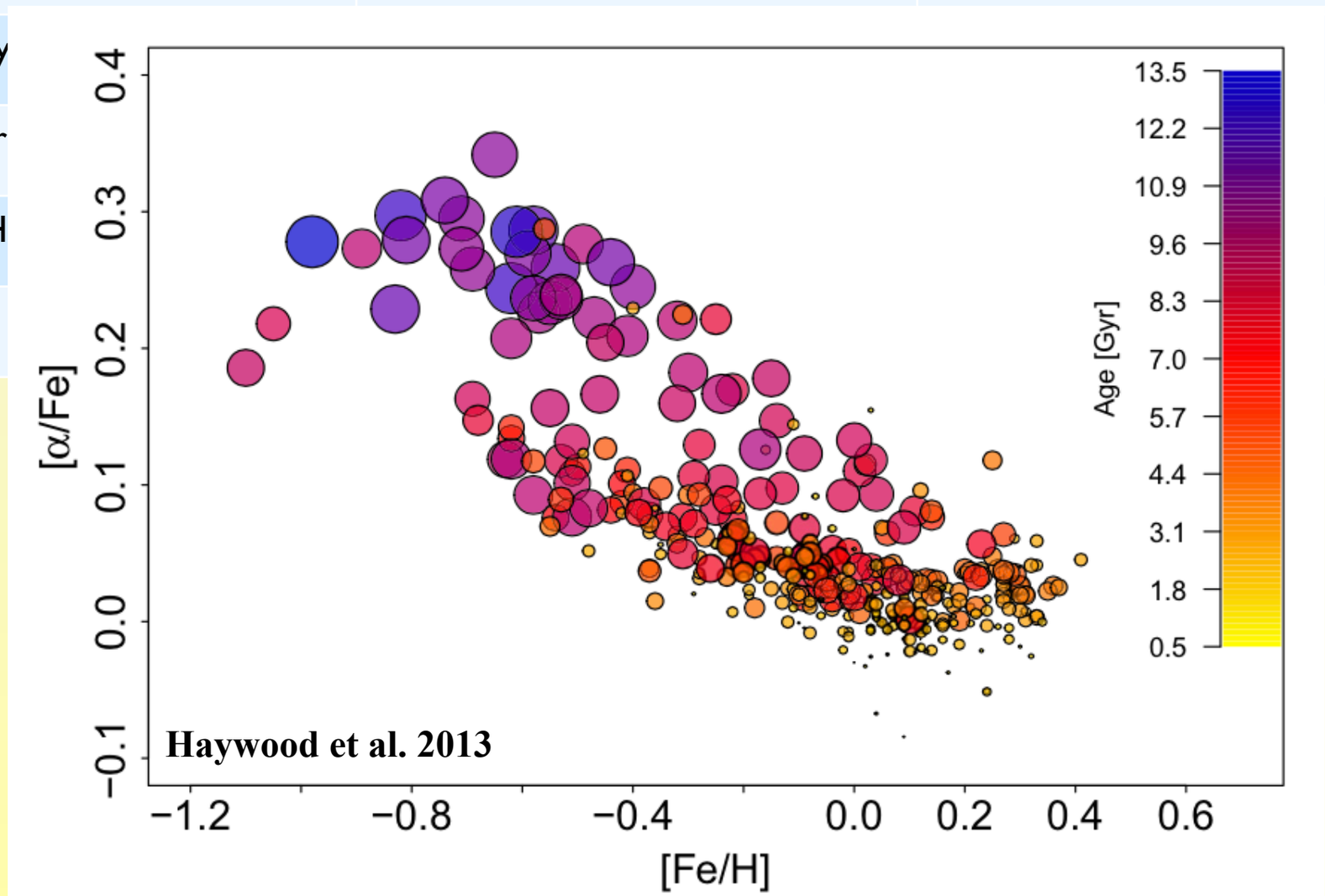

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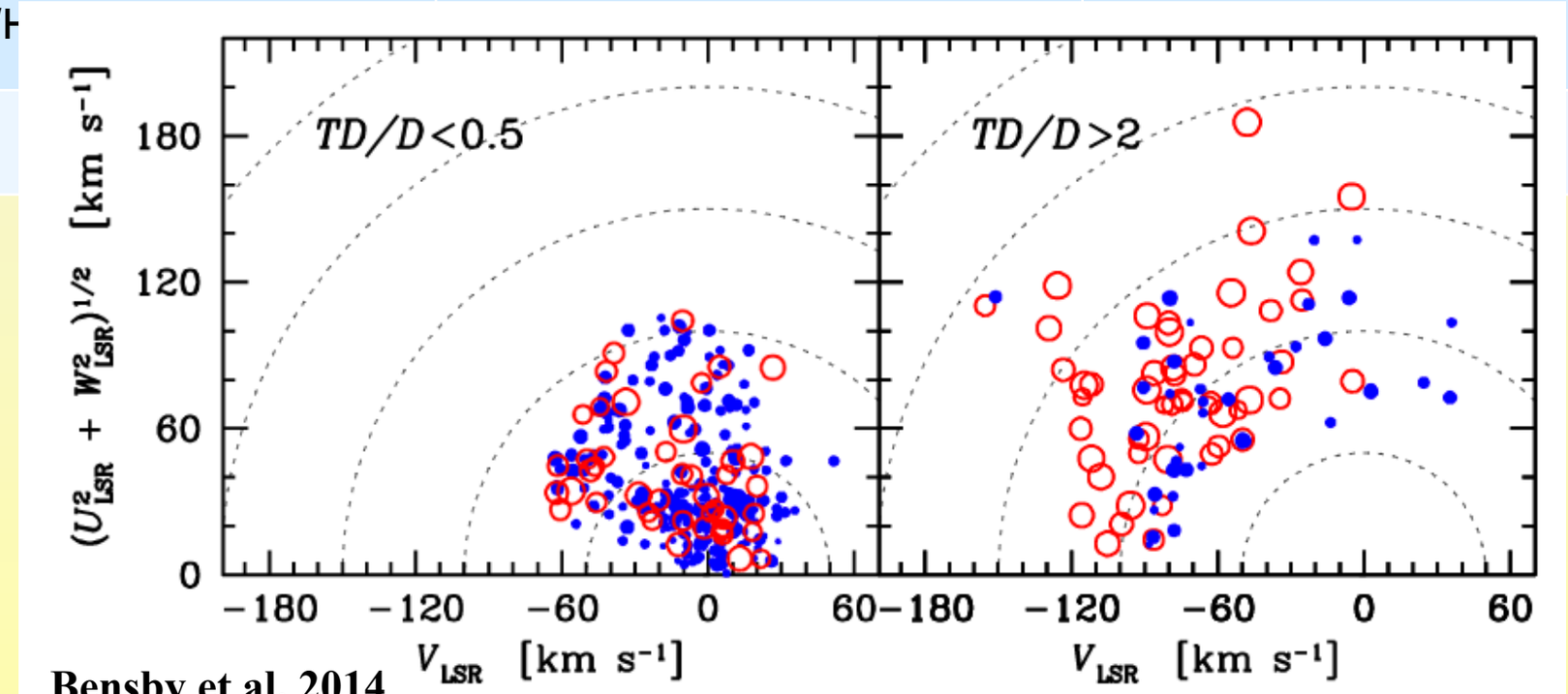

Bensby et al. 2014

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Chemo-dynamics	V-[Fe/H]	Negative	Positive
Age	Age	Young	Old

Most of the previous studies, the sample size they employed is quite limited (hundred to thousand). It is **too difficulty to** study all the above properties of Galactic discs **simultaneously**.

One fundamental question: all these properties consistent with each other for thin and thick discs?

Galactic discs: observational view

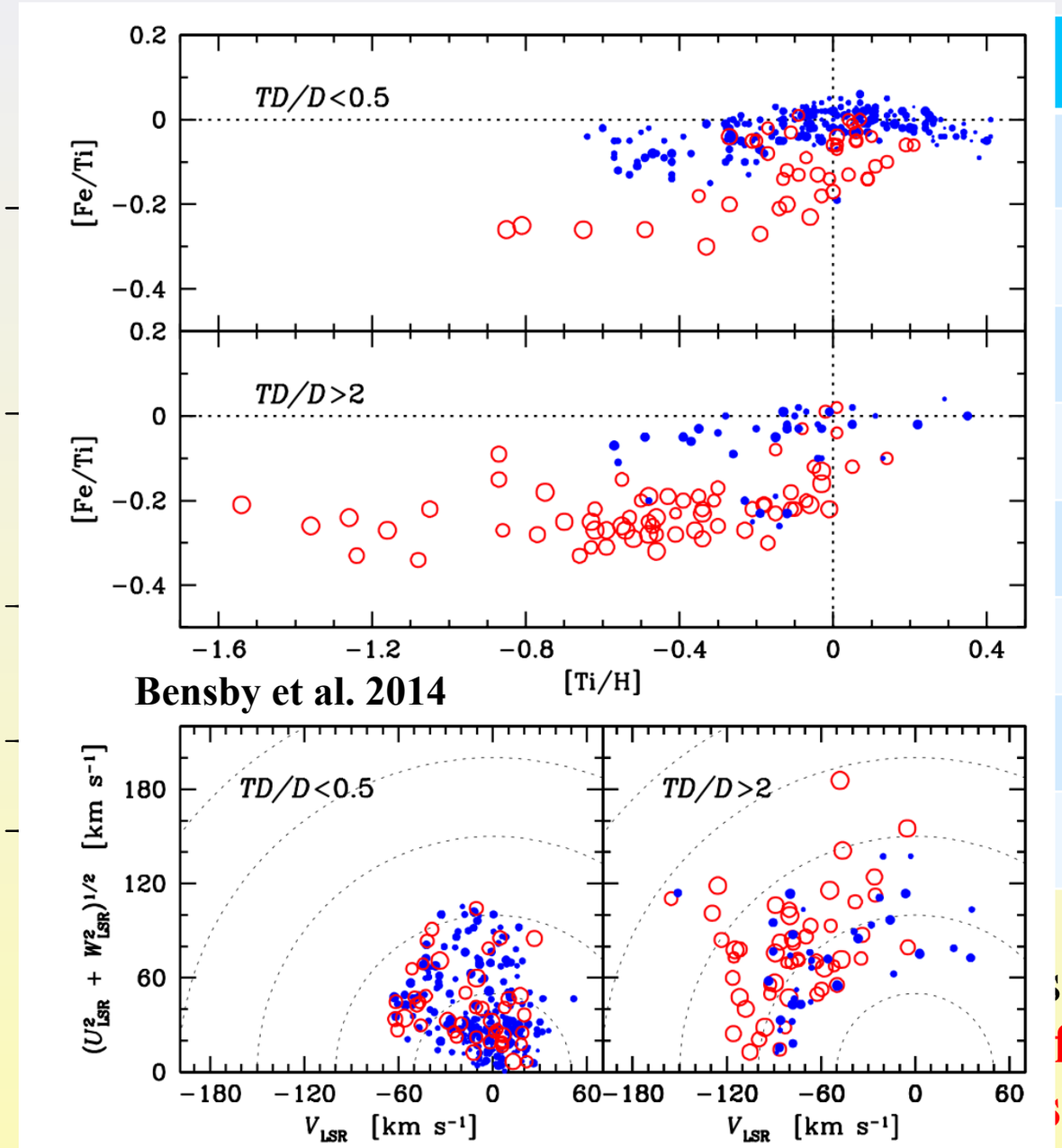
Structure

Chemistry

Kinematics

Chemo-dynamics

Age



	Thick disk
	Large
	Short/large (count)
	Iron-poor, high alpha
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	Large
	Large
	Positive
	Old

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Galactic discs: observational view

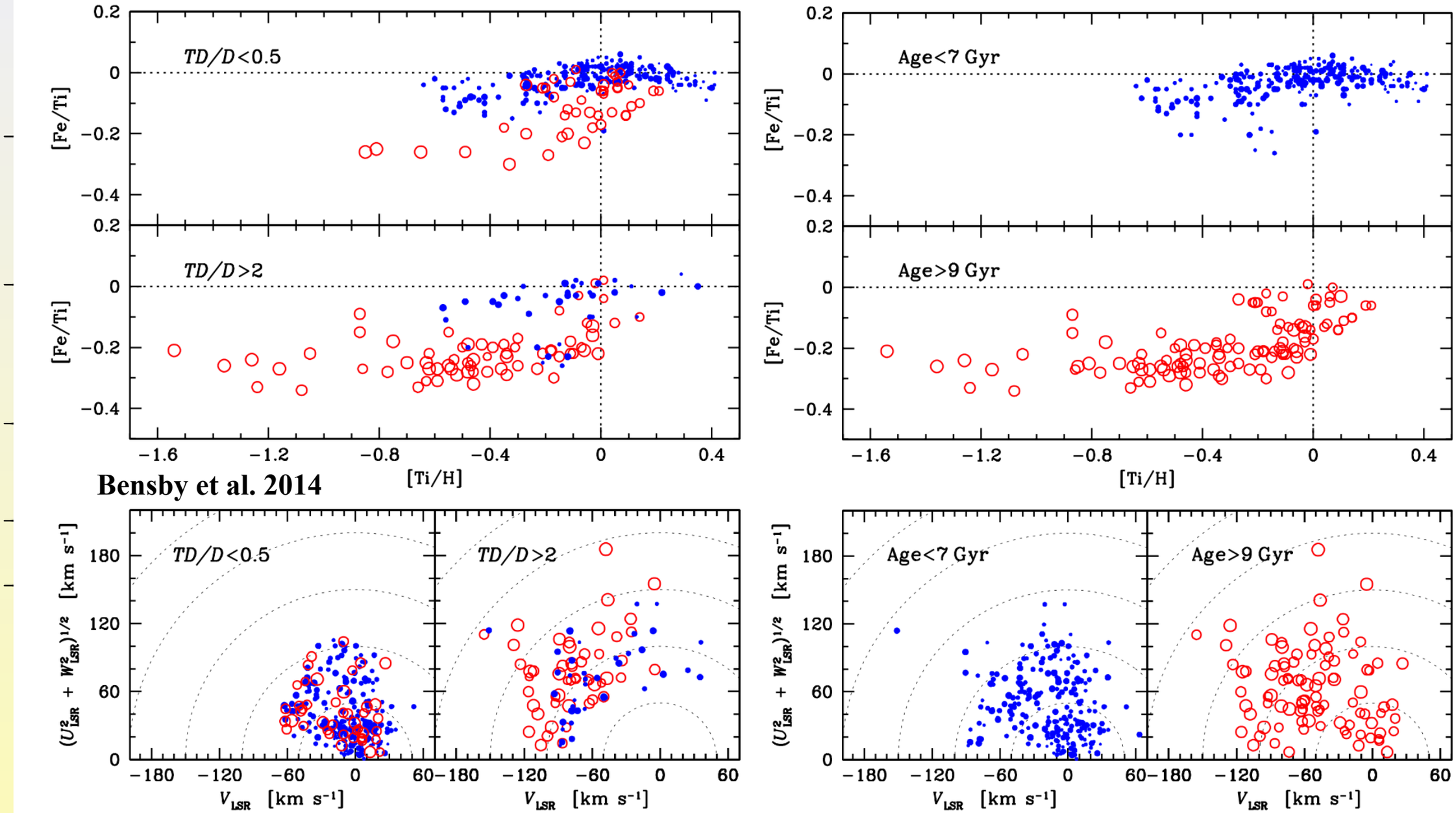
Structure

Chemistry

Kinematics

Chemo-dynamics

Age



One fundamental question: all these properties consistent with each other for thin and thick discs?

Galactic discs: theoretical view

Chemical enrichment history
Star formation history
Gas flows

} Galactic chemical evolution models (e.g. Chiappini et al. 1997, 2001)

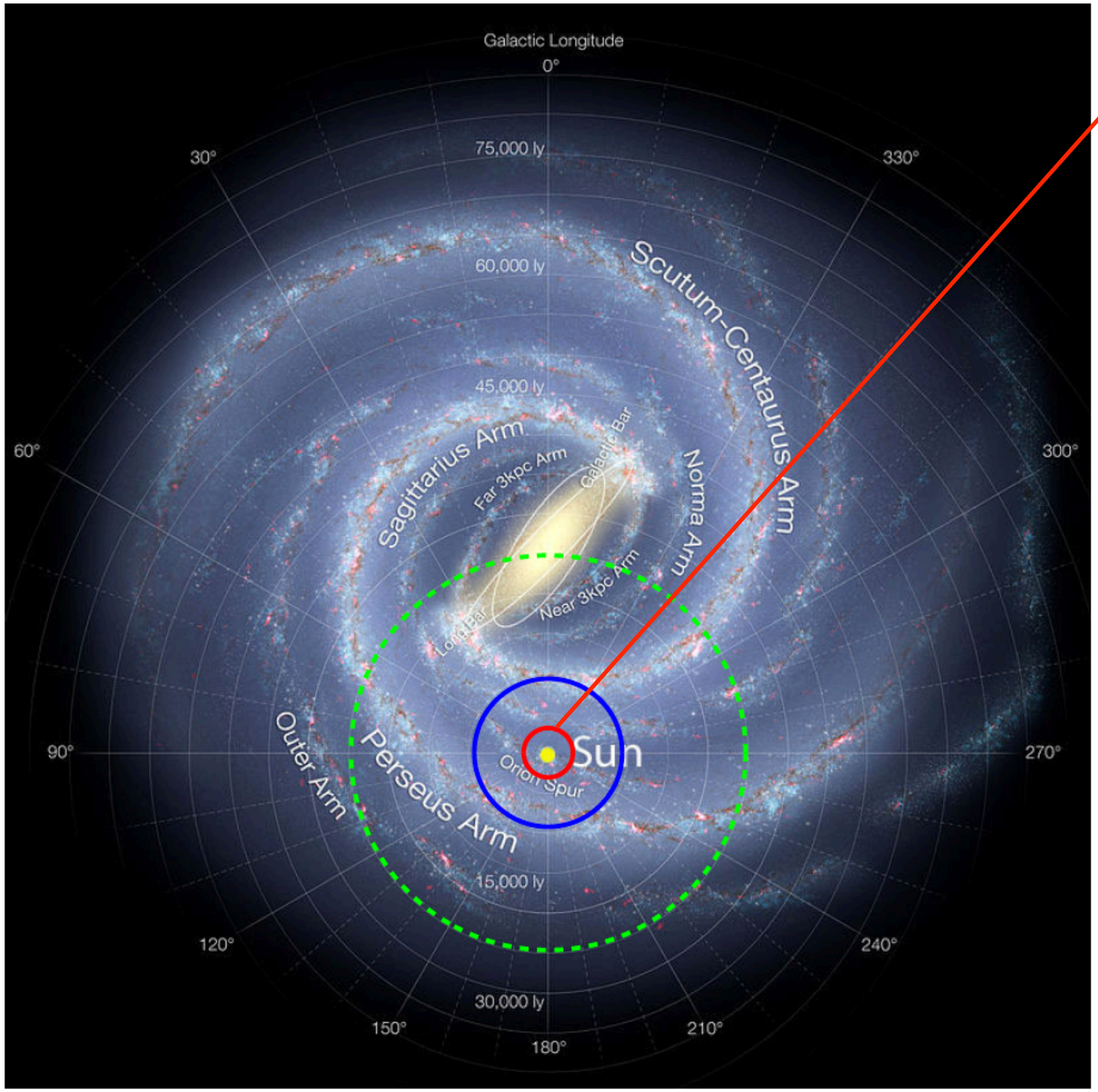
"Inside out" and "Upside-down" (Stinson et al. 2013; Bird et al. 2013): Older stars form in a relatively thick component, or are kinematically heated very quickly after their birth. Younger populations form in successively thinner disks.

Dynamical effects: spatial distribution & kinematics & chemistry
Major/Minor merge (e.g. satellite accretion; Abadi et al. 2003; Brook et al. 2004)
Radial migration (e.g. Sellwood & Binney 2002; Schonrich & Binney 2009):
disk flaring effect

Specially, for thick disc, at least 4 scenarios:

- Accretion and disruption of satellites (like in the stellar halo)
- Disk heating due to minor merger (also secular)
- Radial migration, via resonant scattering
- In-situ formation from thick gas disk (mergers, or clumpy galaxies)

Galactic discs: LAMOST plus Gaia



LAMOST-TGAS MSTO-SG:

- **Typical size: 500 pc**
- **6D phase space + abundance + age**
- **~ 0.1 million stars**

Huang et al. in prep. 2017a

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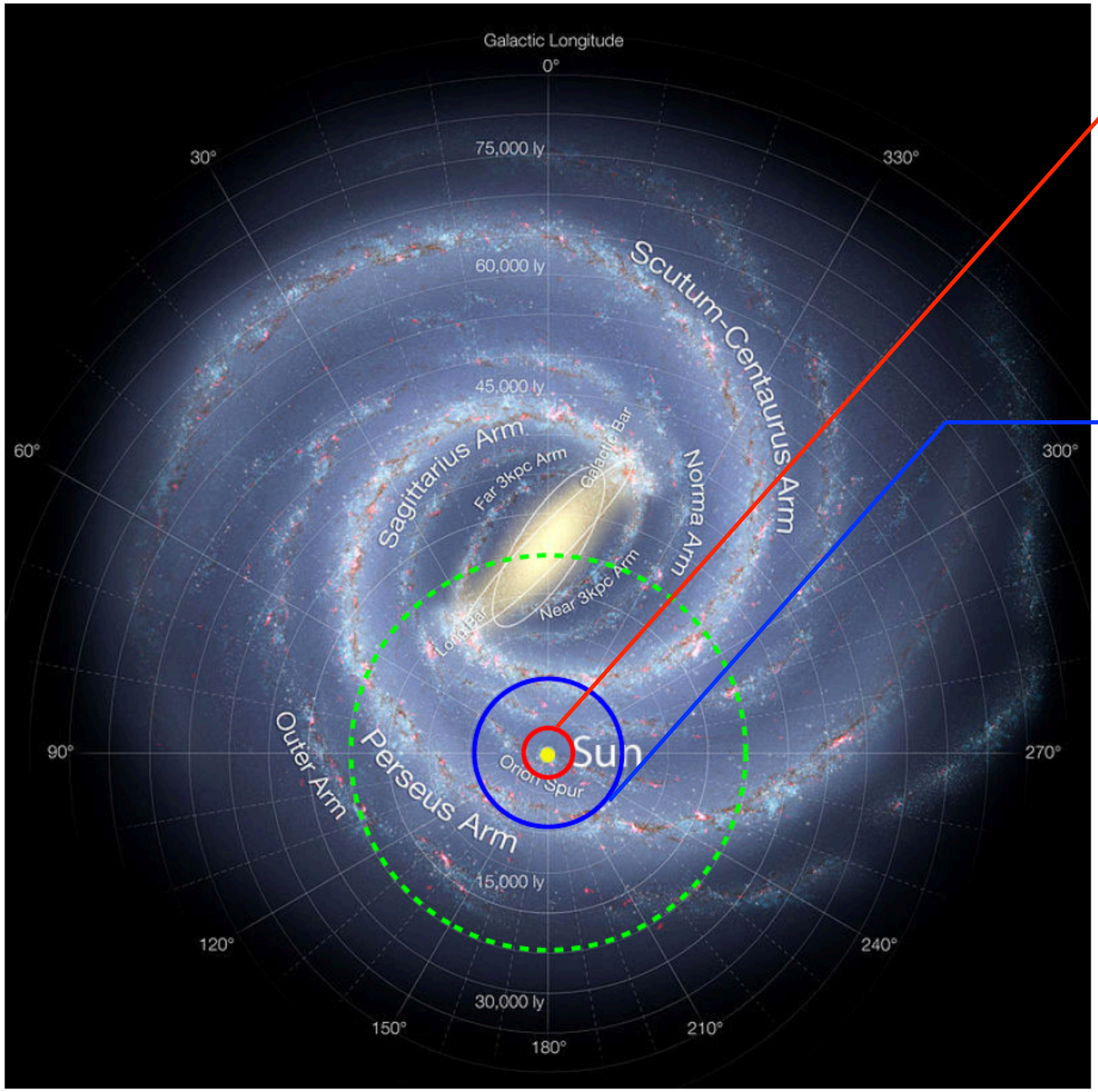

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LAMOST MSTO-SG + GAIA DR+:

- **Typical size: 2 kpc**
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Xiang et al. in prep. 2017

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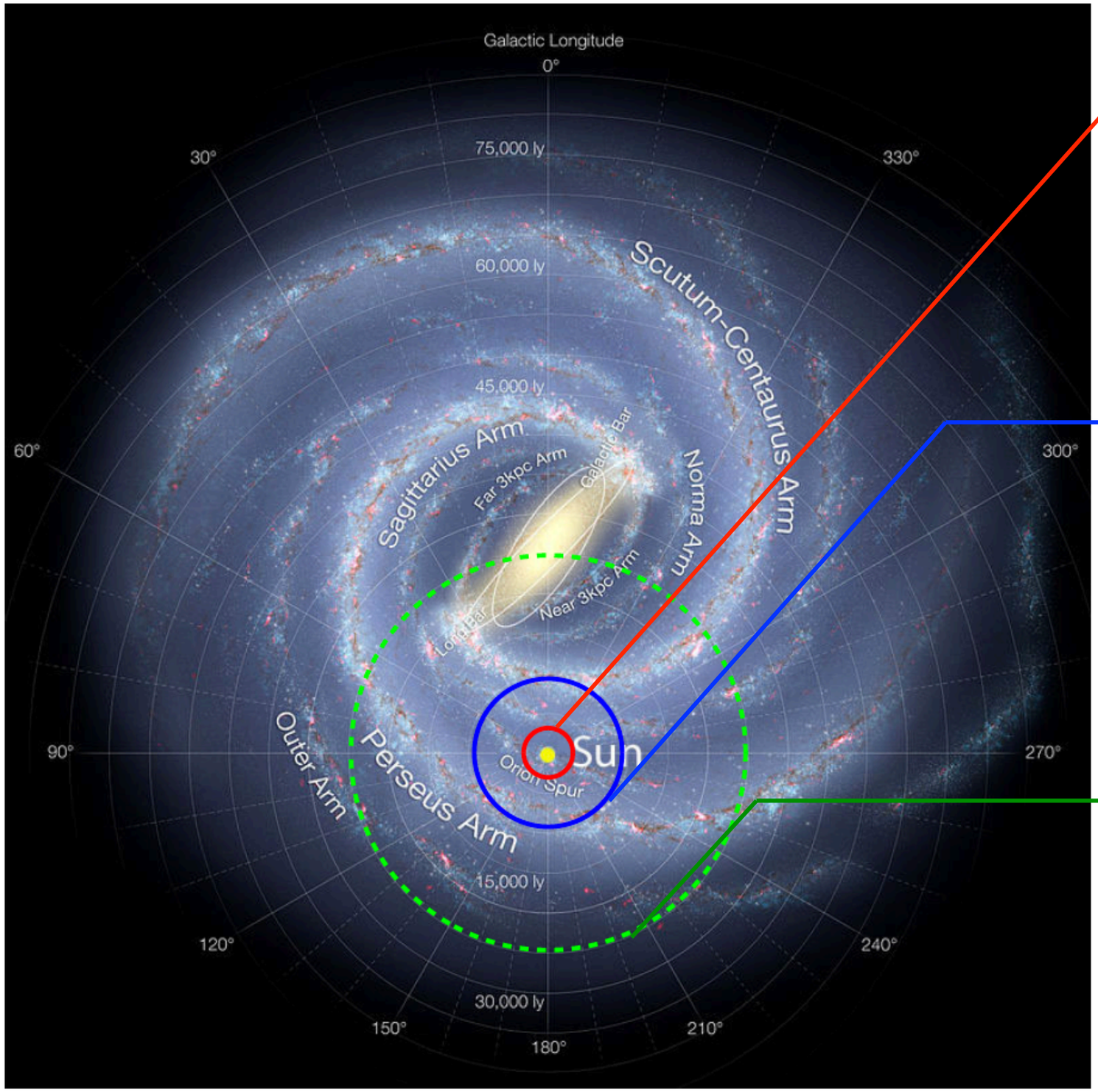

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Xiang et al. in prep. 2017

LAMOST RG + GAIA DR+:

- **Typical size: 8 kpc**
- **6D phase space + abundance + age**
- **~ 0.5 million stars**

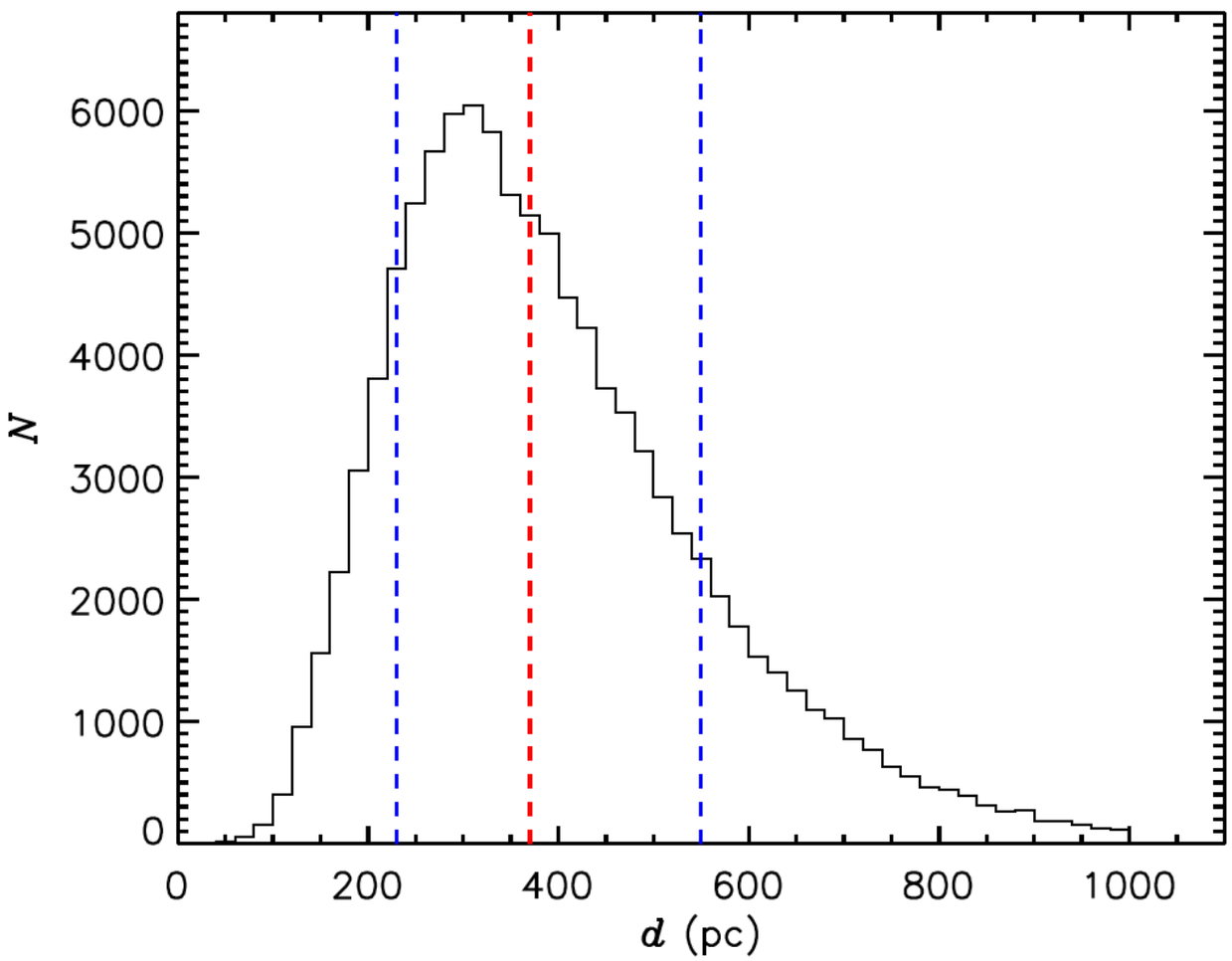
Huang et al. in prep. 2017b

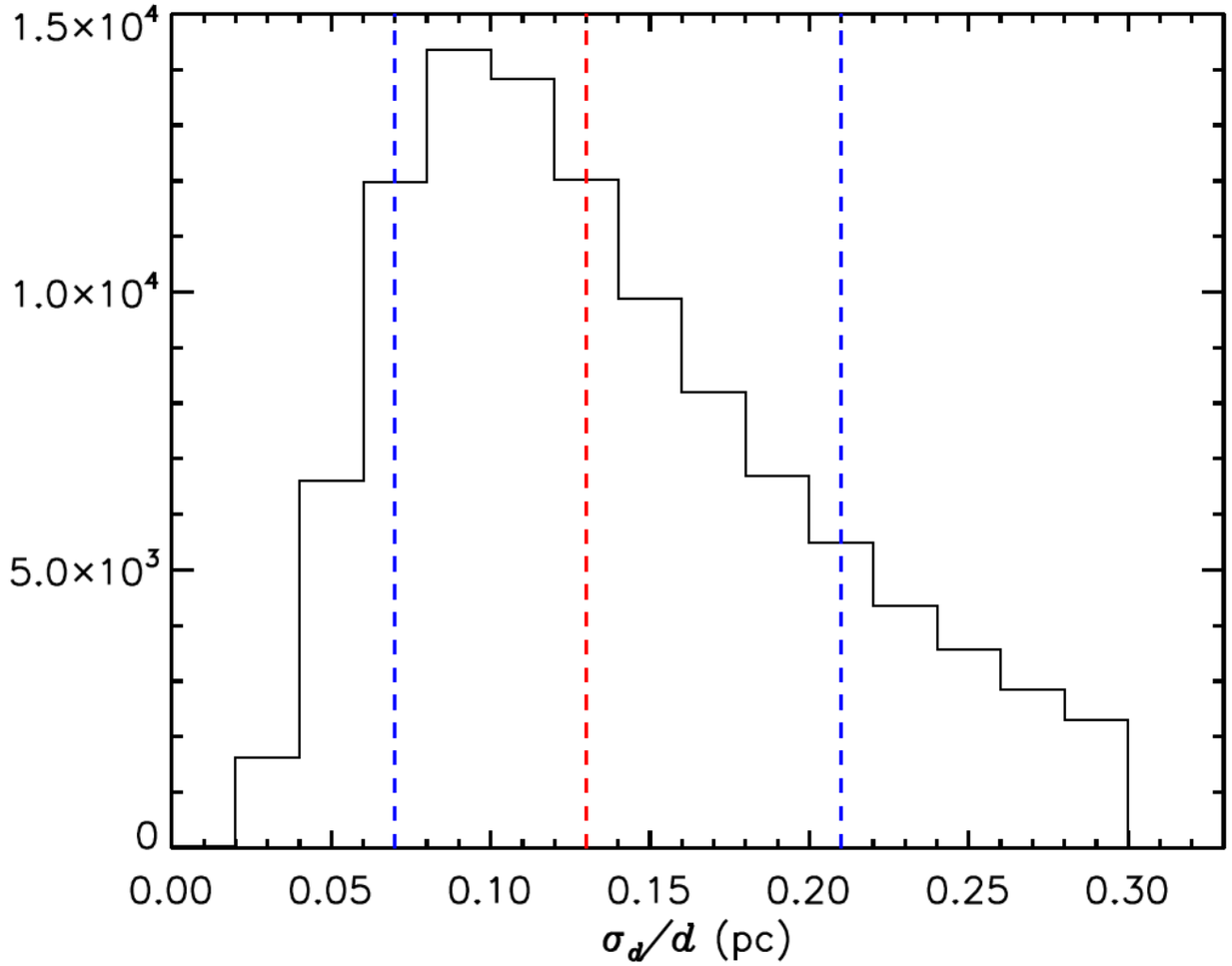
LAMOST-TGAS MSTO-SG sample

LAMOST-TGAS MSTO-SG sample

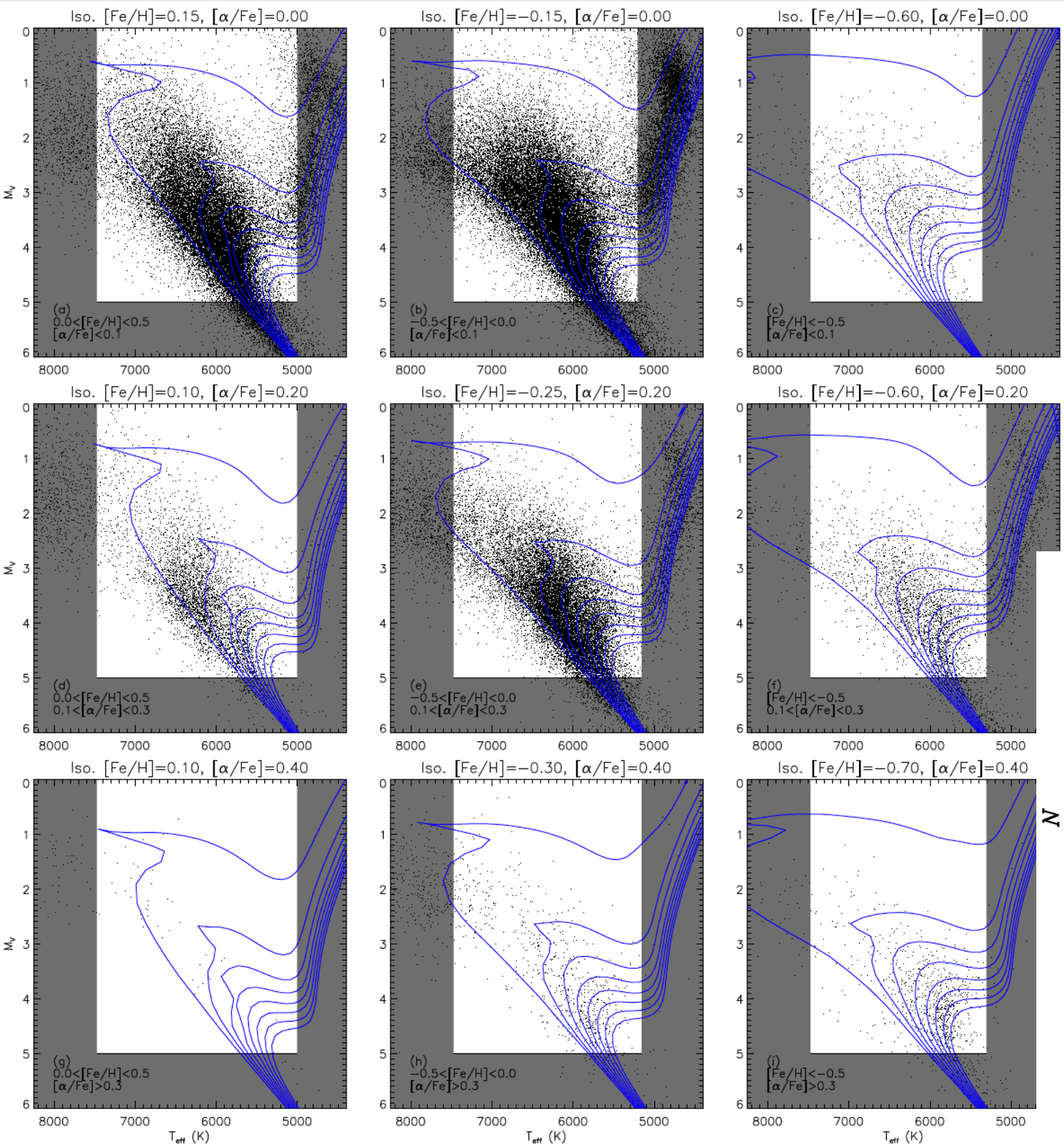
Cross match LAMOST data (6 million, 2011.06-2016.06) to TGAS (2 million), we obtain 0.25 million common sources.

We further cut distance error smaller than 30% and select MSTO-SG in HR diagram. Finally, we get 0.1 million sources.



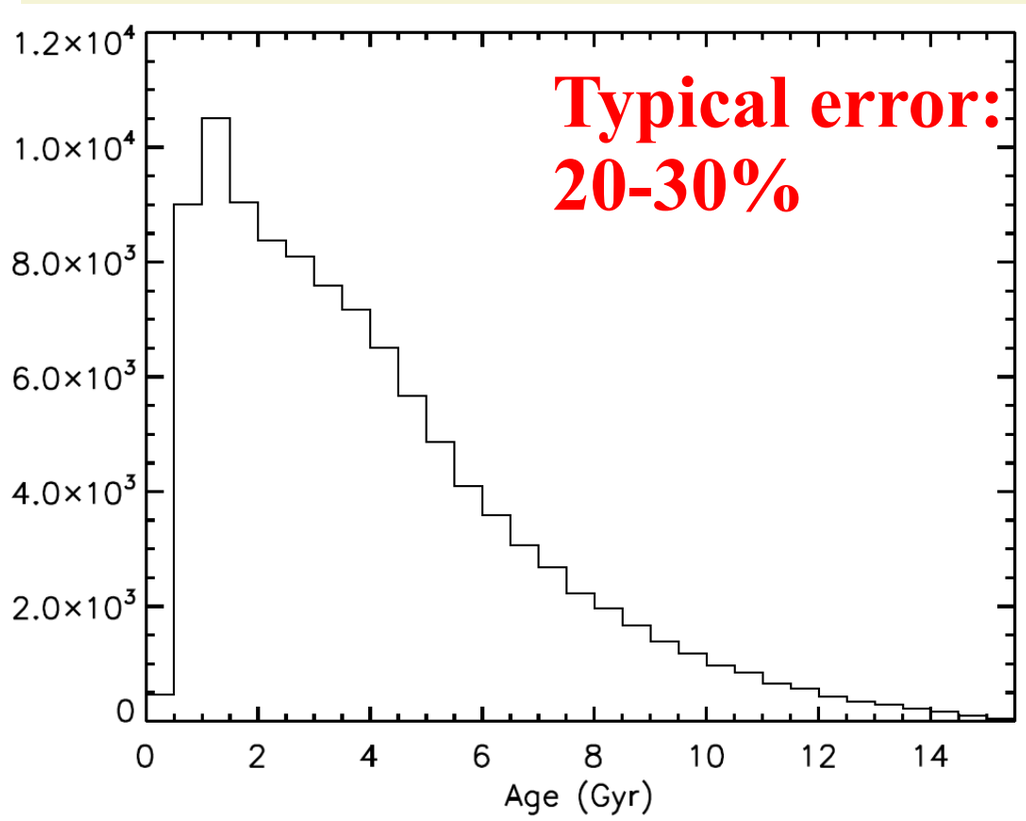


LAMOST-TGAS MSTO-SG sample



Using a similar method to Xiang et al. (2017), we have derived the age for those 0.1 million MSTO-SG stars using YY isochrones.

Below is the age distribution of our sample:



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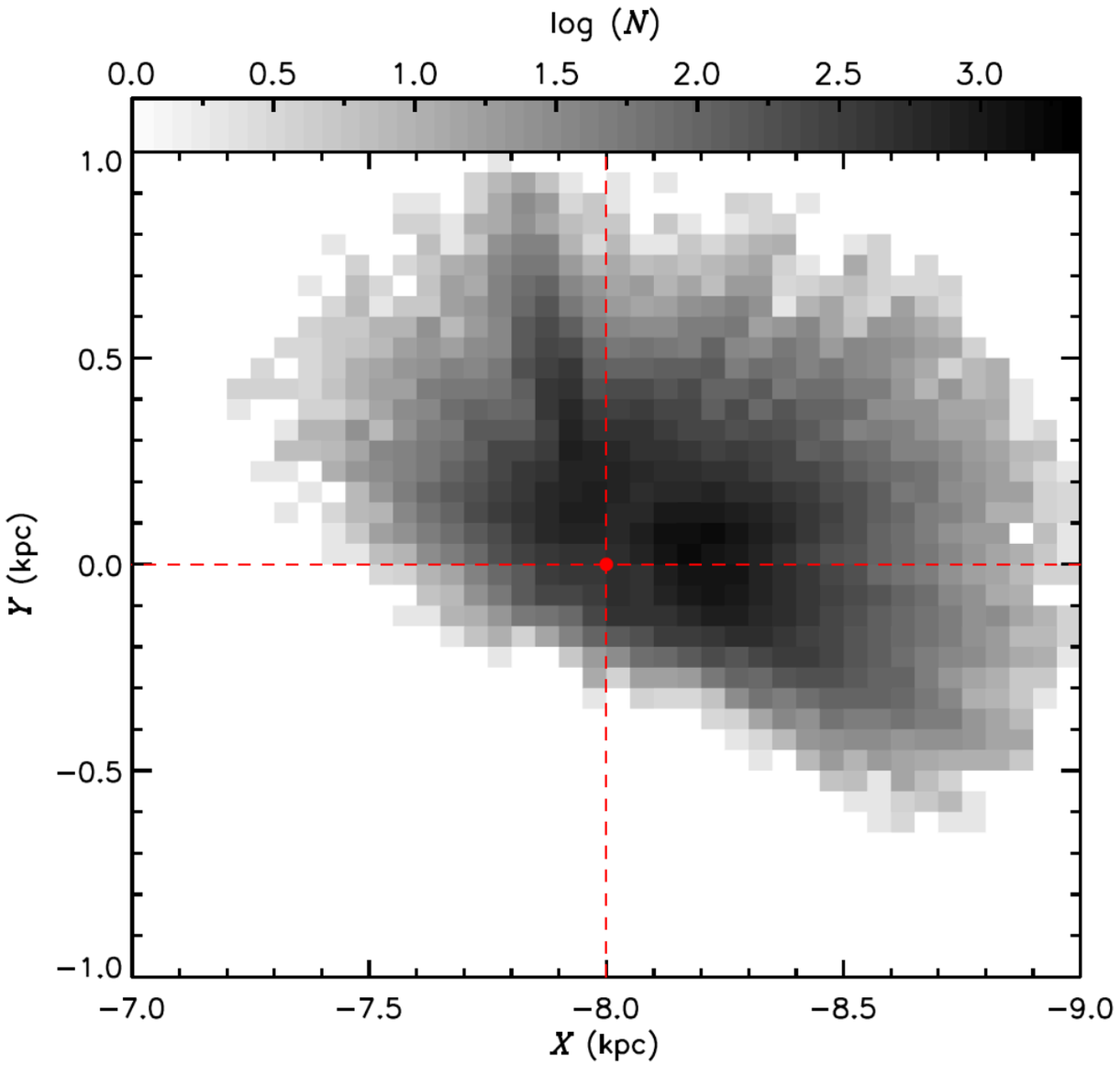

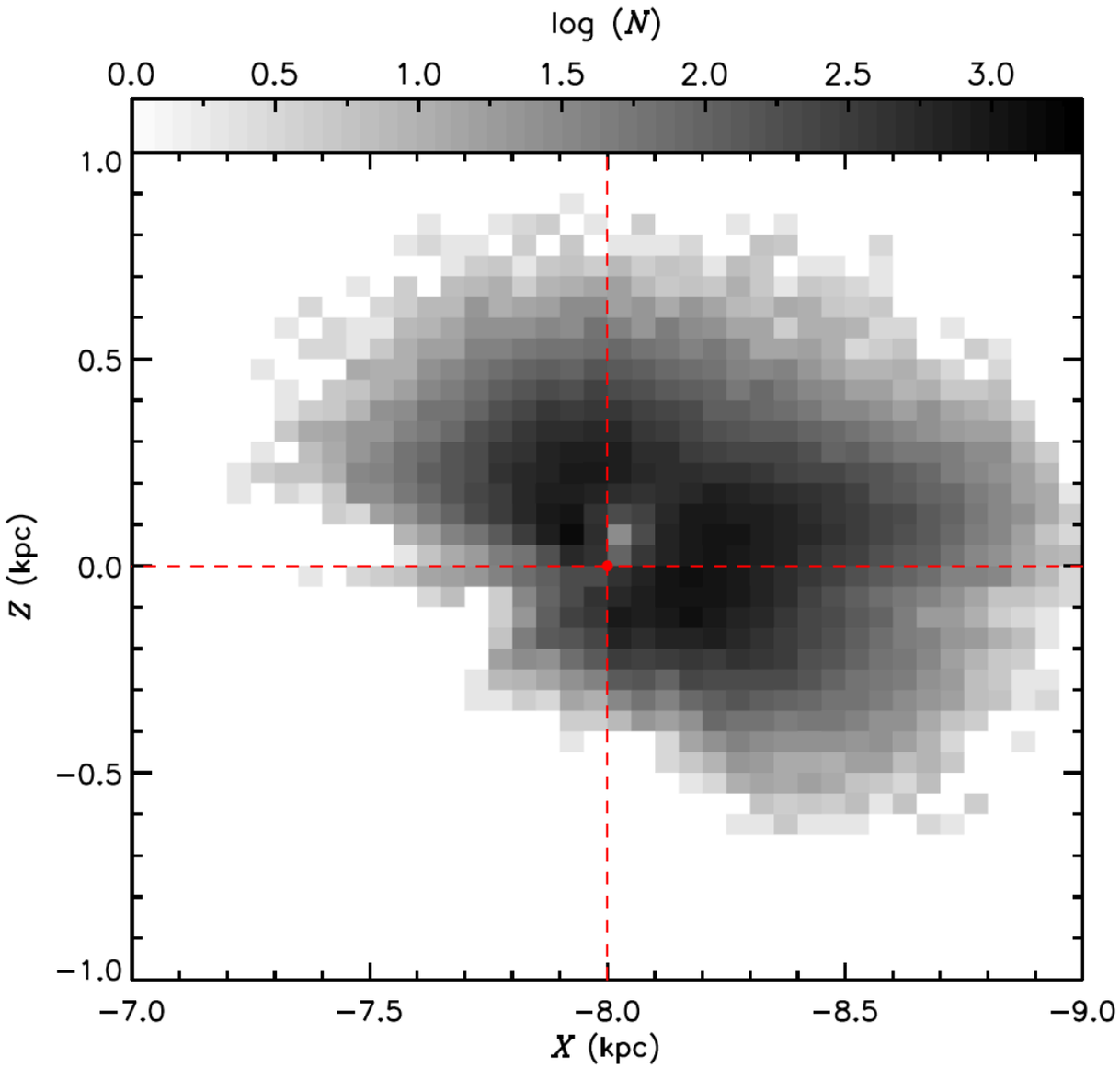

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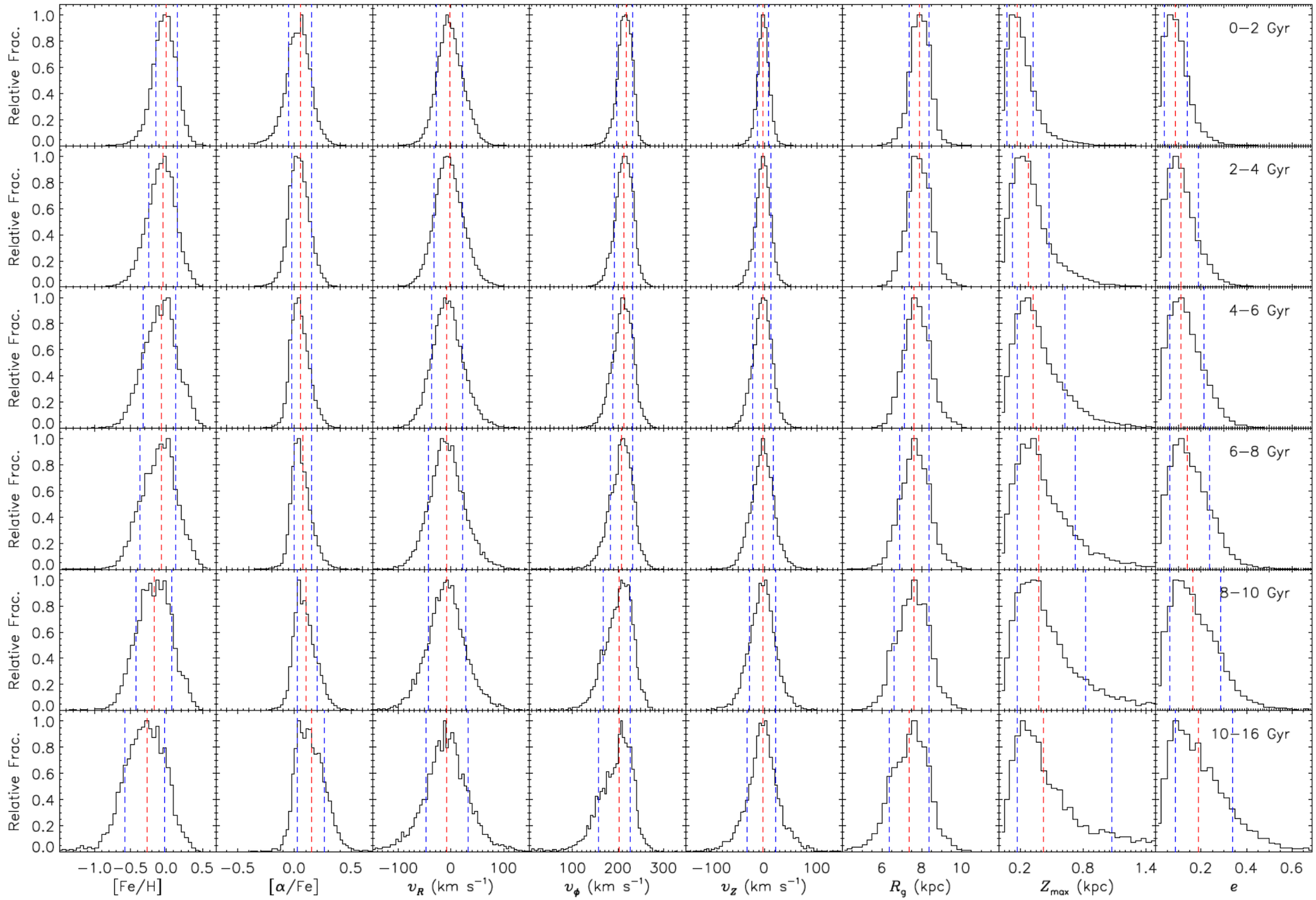
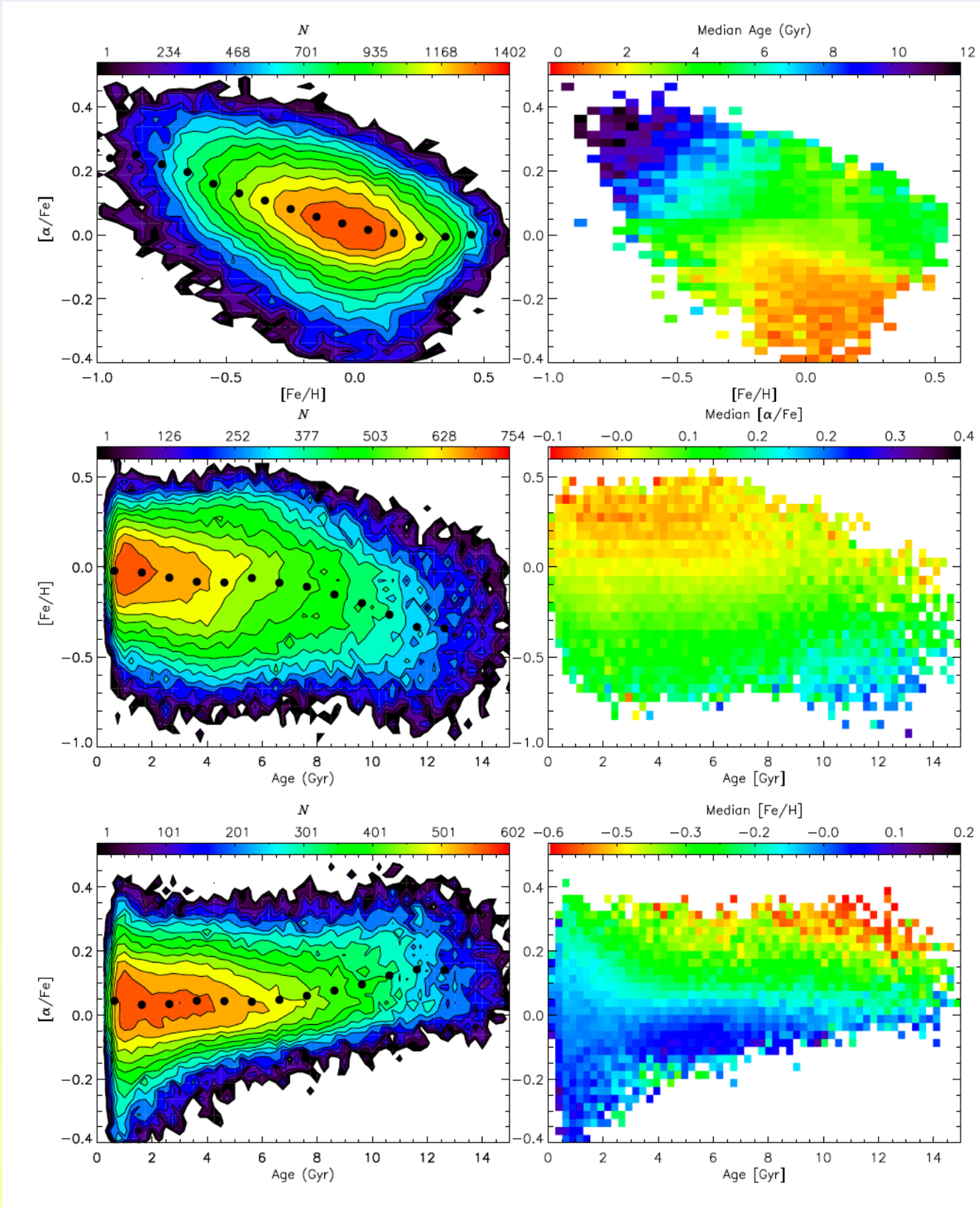


Abundance **Velocities** **Orbital parameters**

Study the Galactic disc(s) using Mono-Age Population Phase-spacE Distributions (MAPPED) analysis

MAPPED Analysis – Abundance

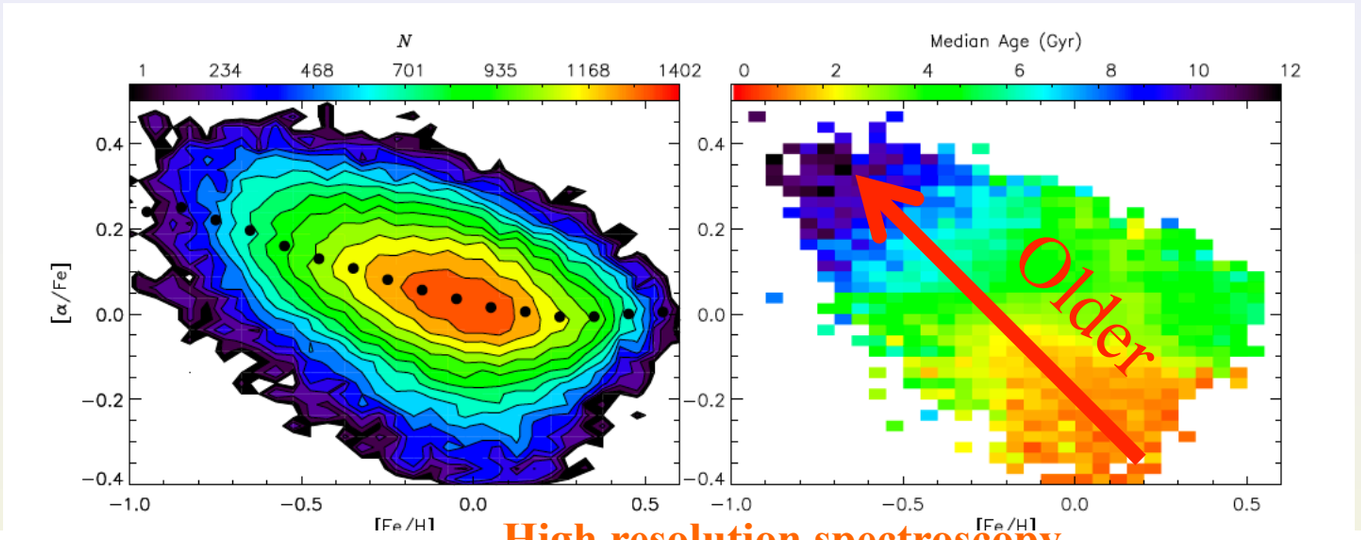


[Fe/H] – [α/Fe]

Age – [Fe/H]

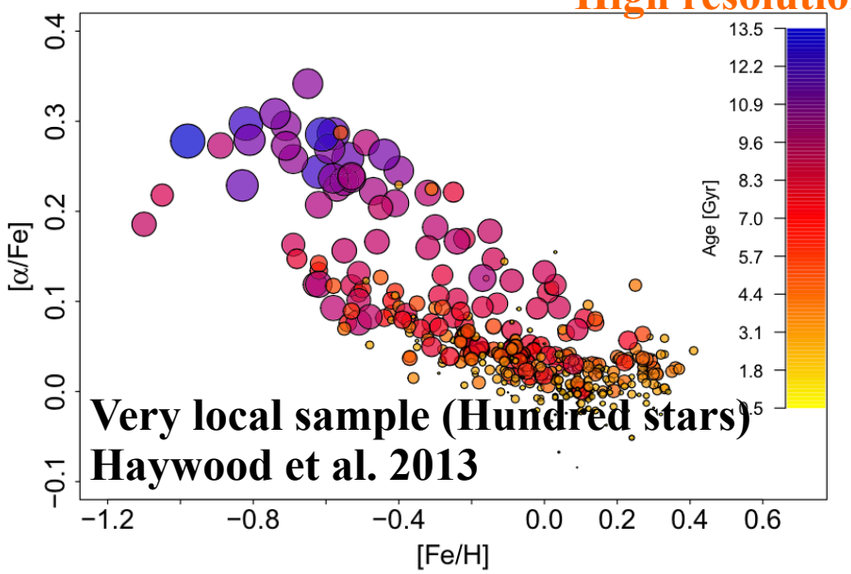
Age – [α/Fe]

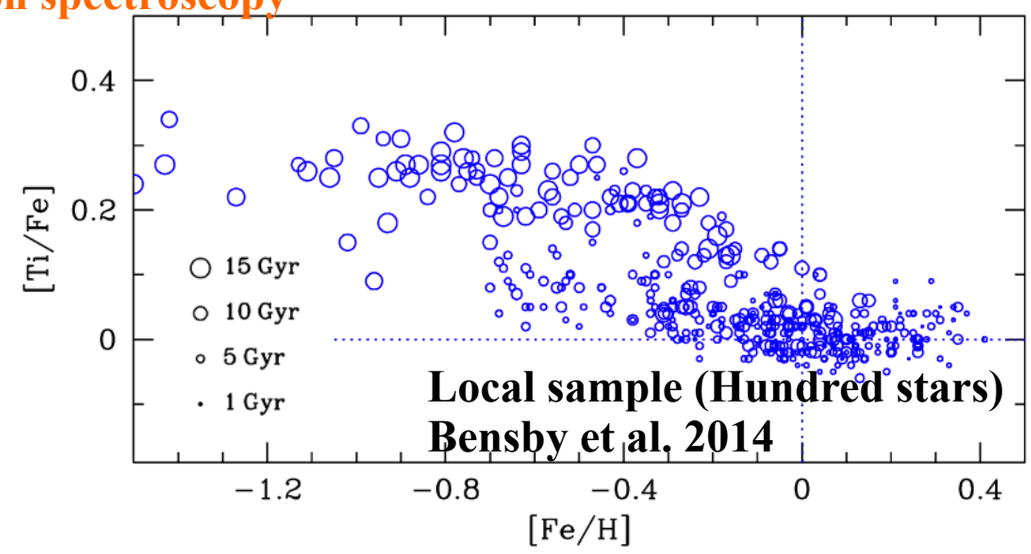
MAPPED Analysis – Abundance

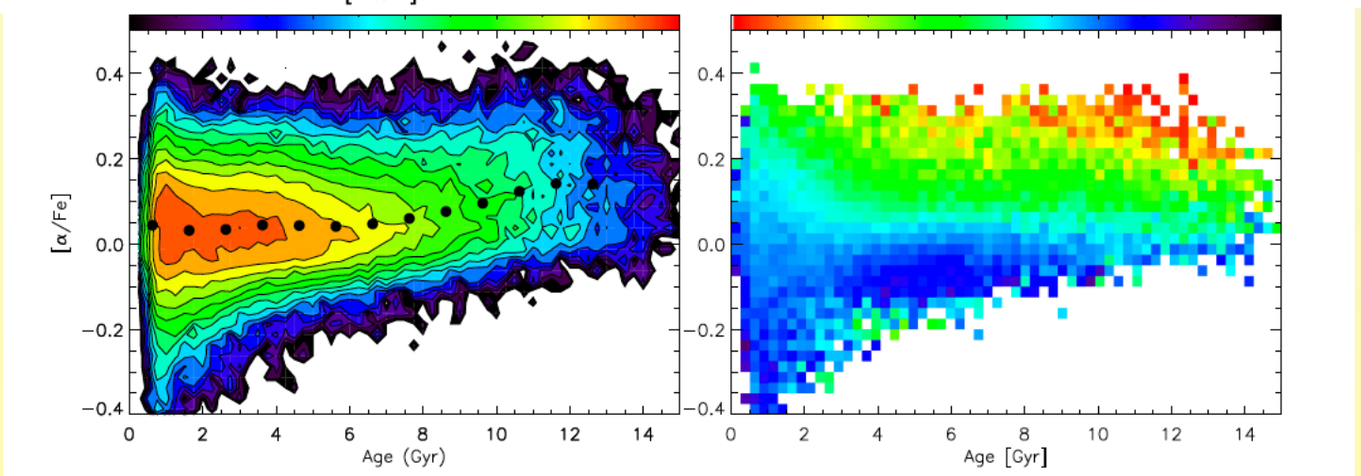


[Fe/H] – [α/Fe]

High resolution spectroscopy

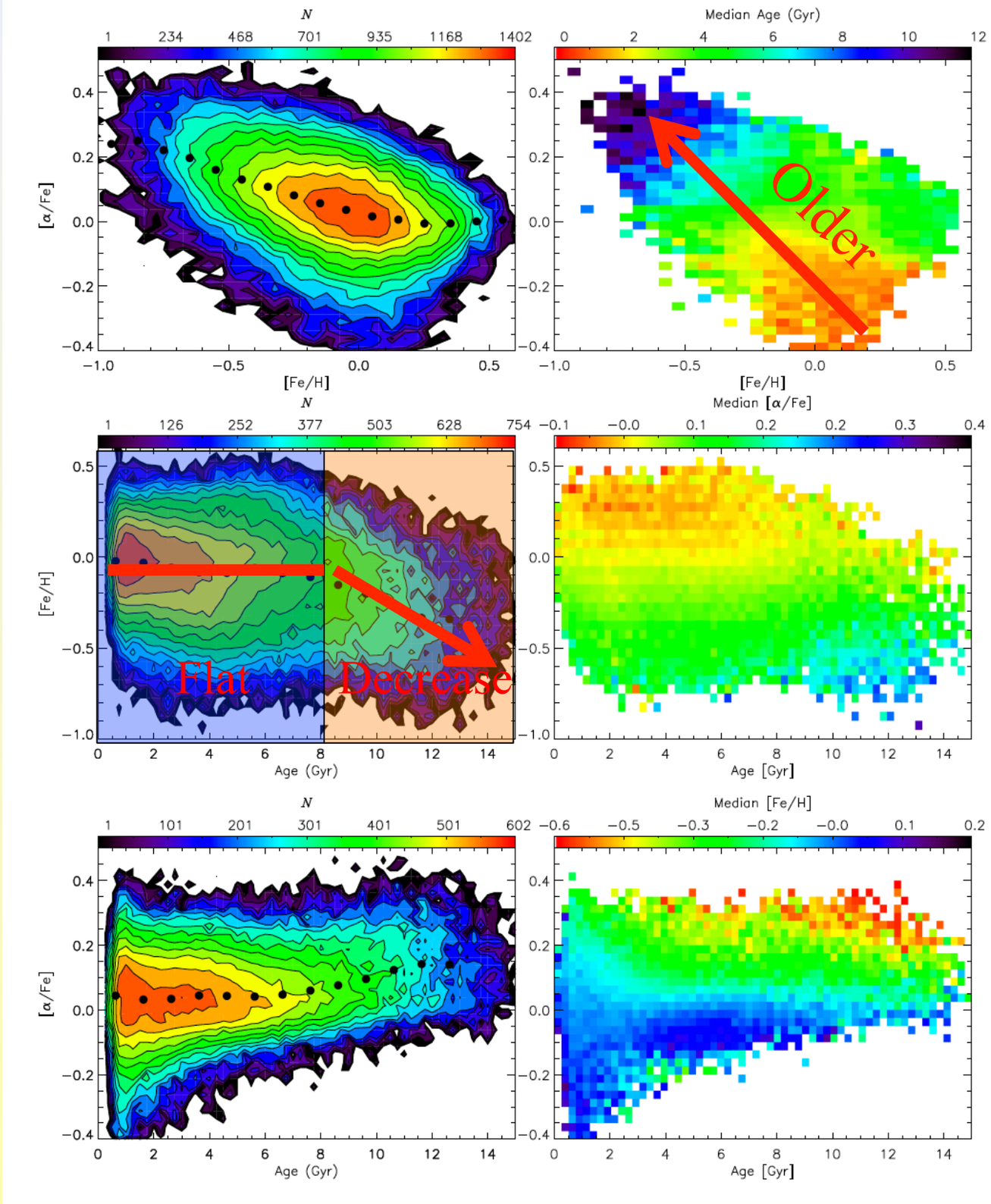






Age – [α/Fe]

MAPPED Analysis – Abundance



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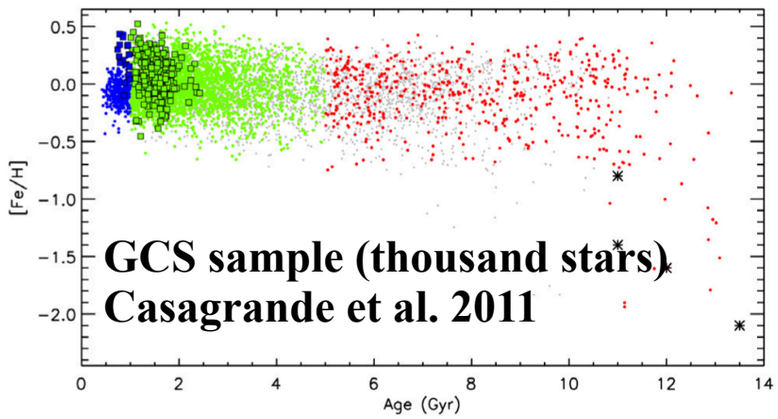
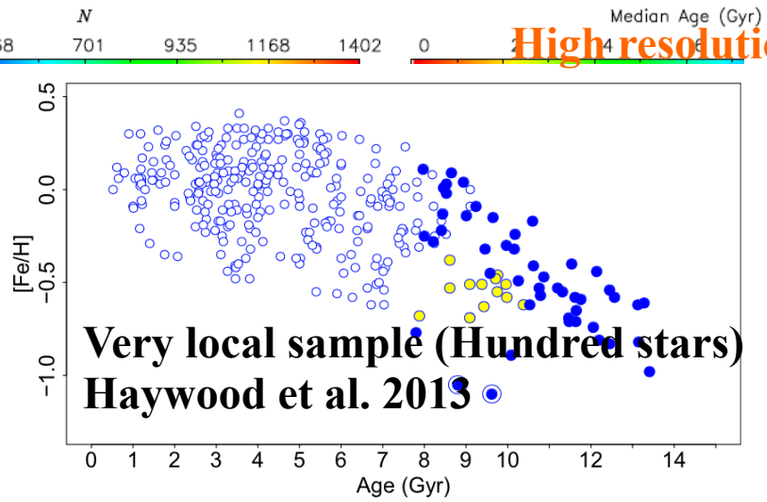
Age – [Fe/H]

Age – [α/Fe]

MAPPED Analysis – Abundance

Photometric [Fe/H]





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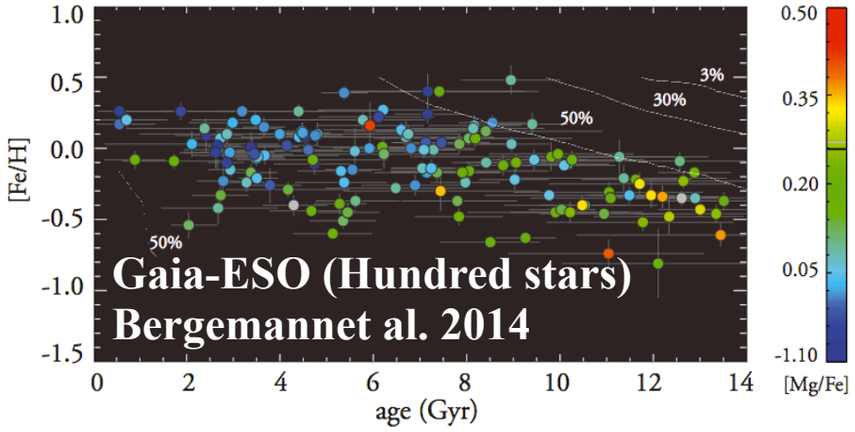

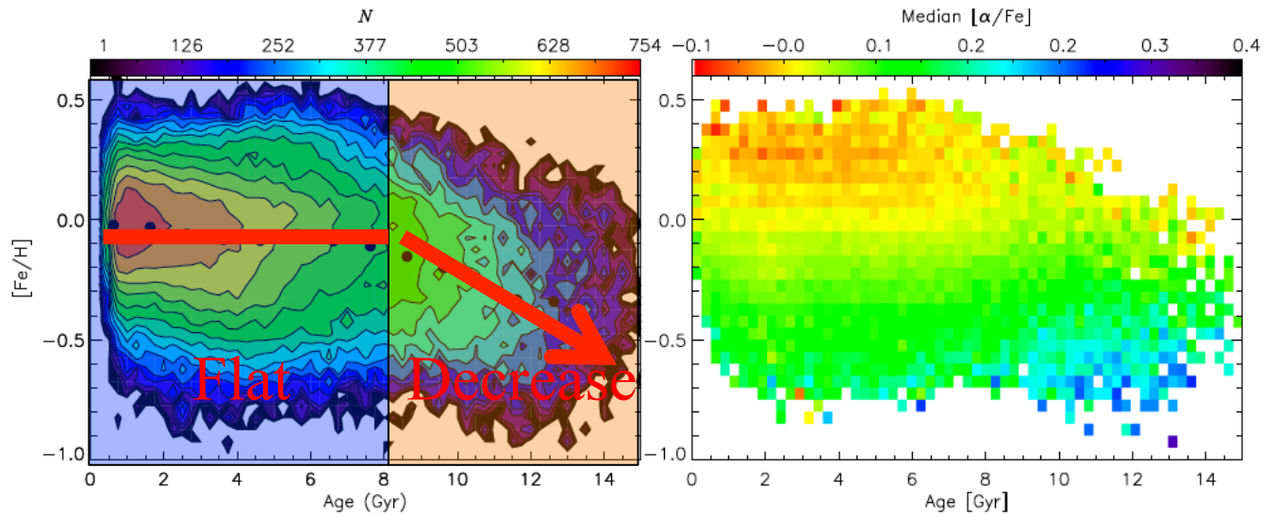

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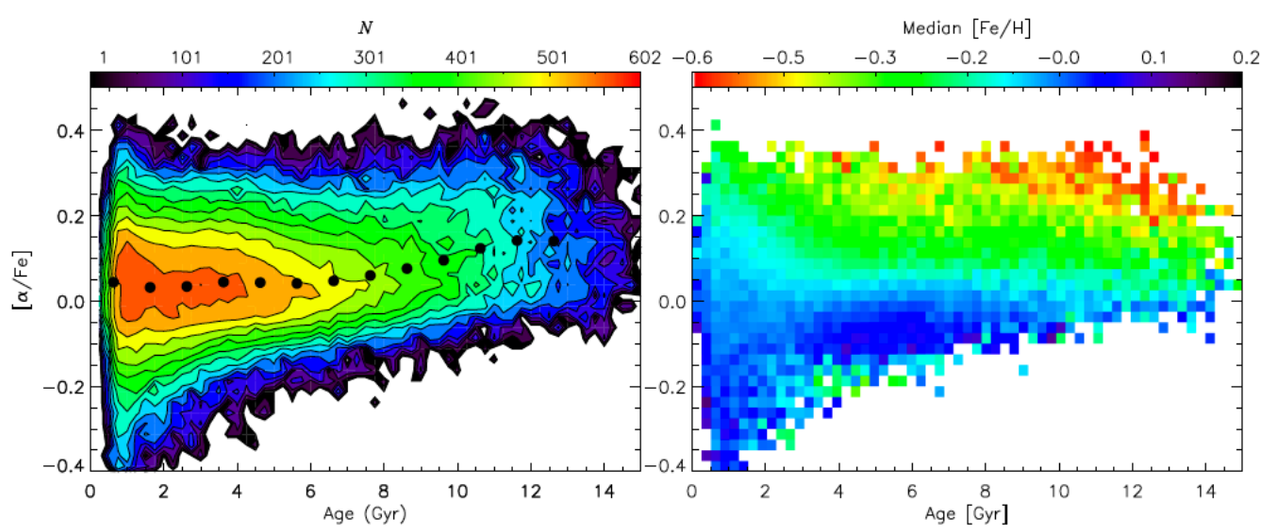

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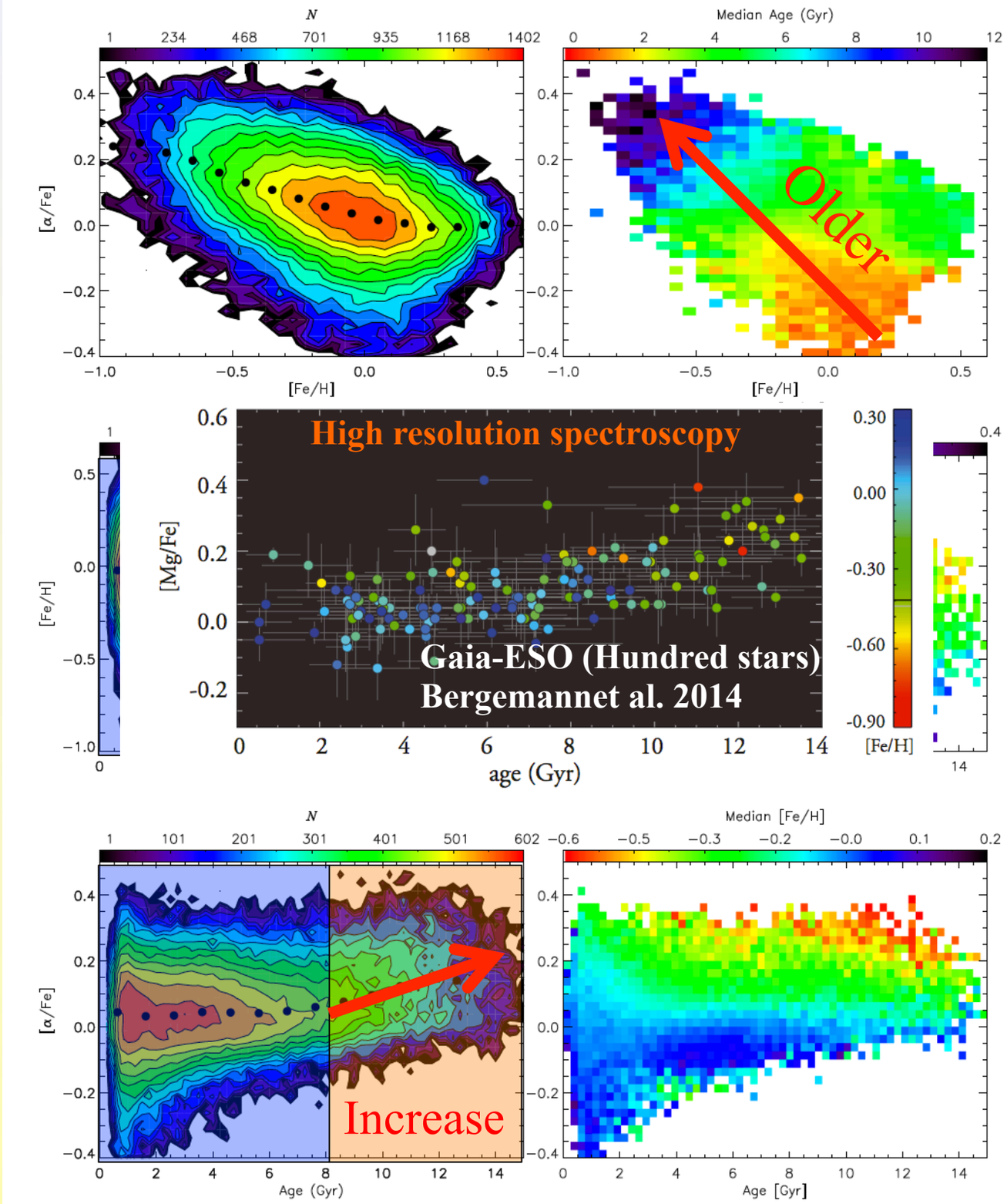

[Fe/H] – [α/Fe]

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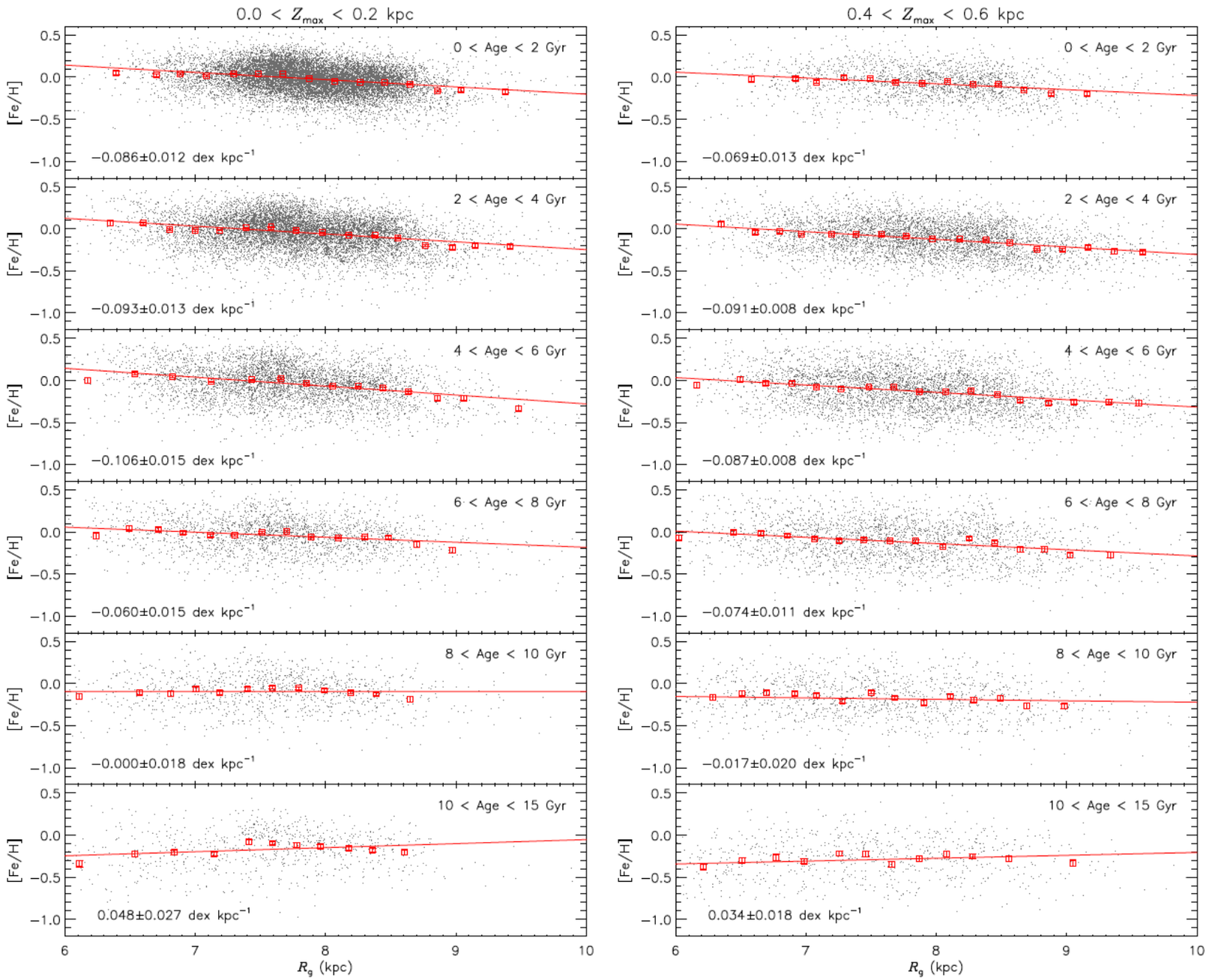
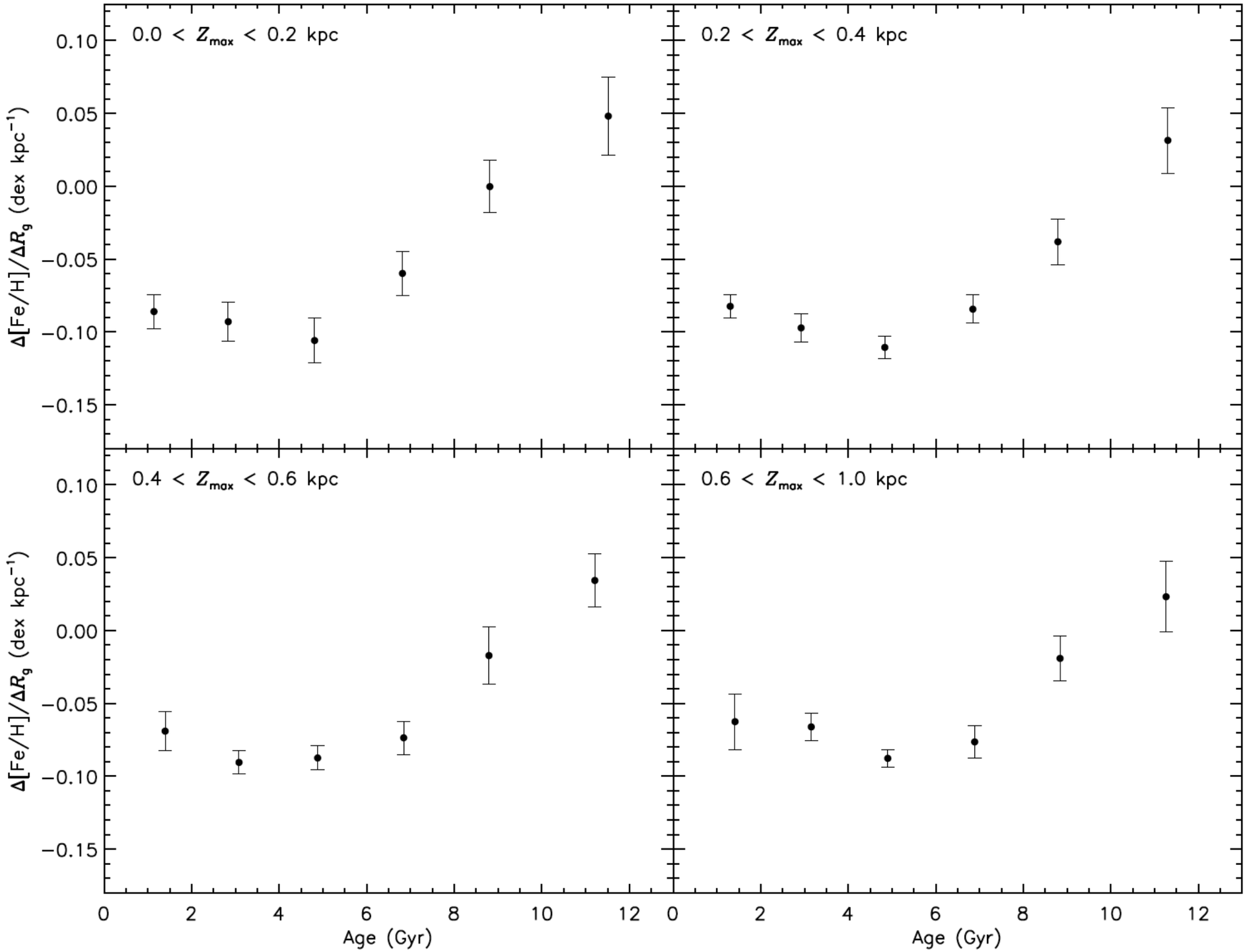
MAPPED Analysis – Metallicity gradient



[Fe/H]

R_g (kpc)

MAPPED Analysis – Metallicity gradient

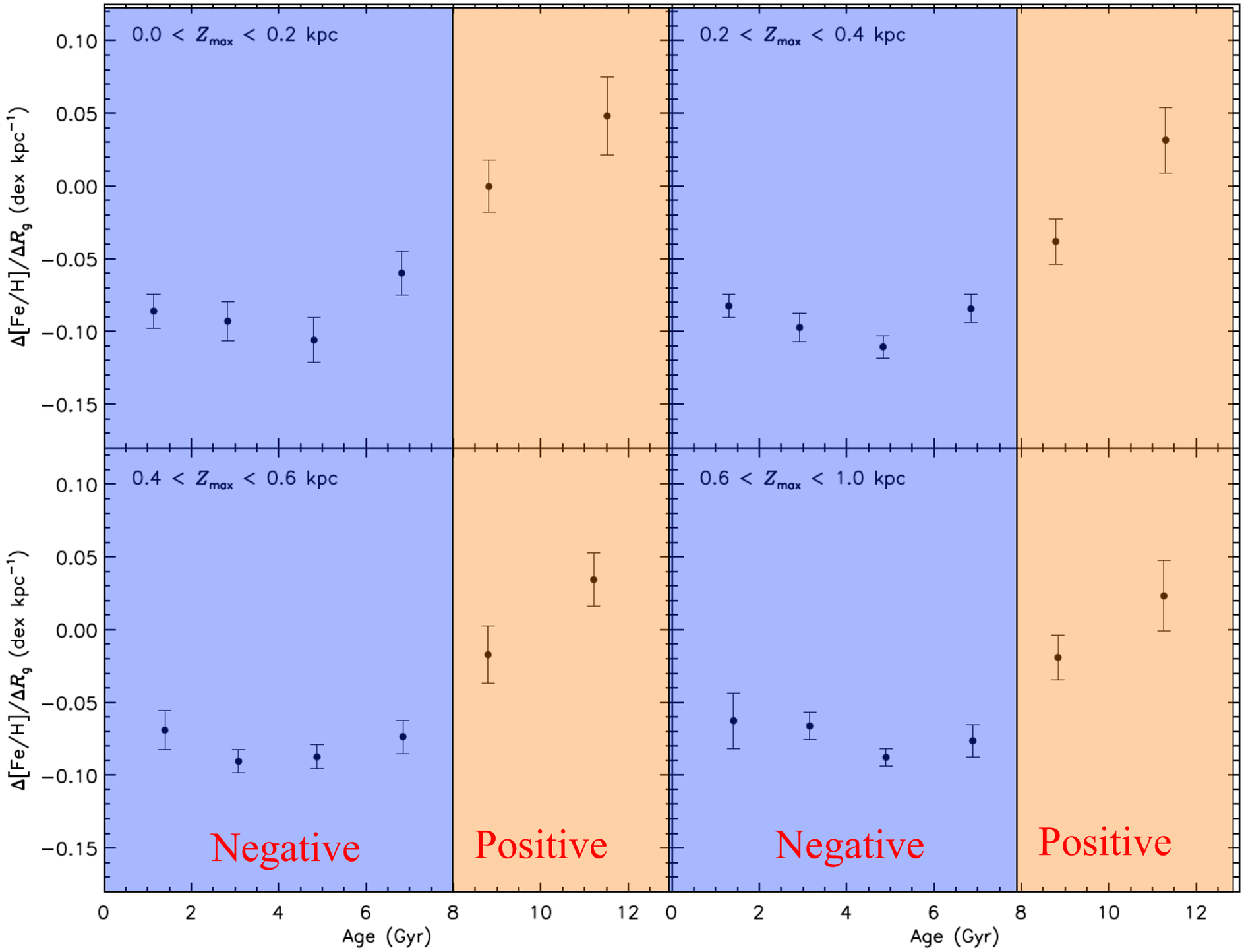


Radial metallicity gradient

Age (Gyr)

MAPPED Analysis – Metallicity gradient

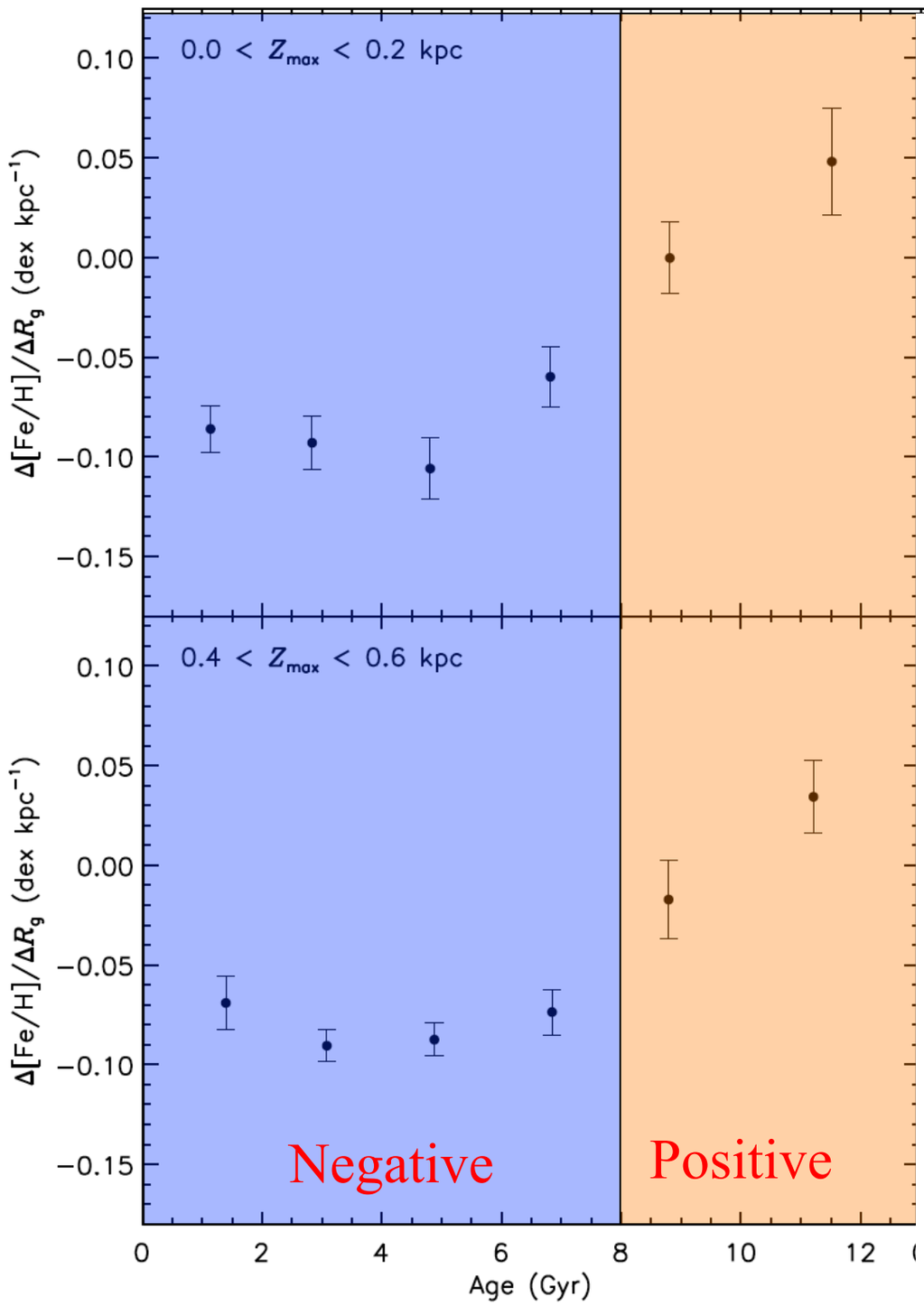
Radial metallicity gradient



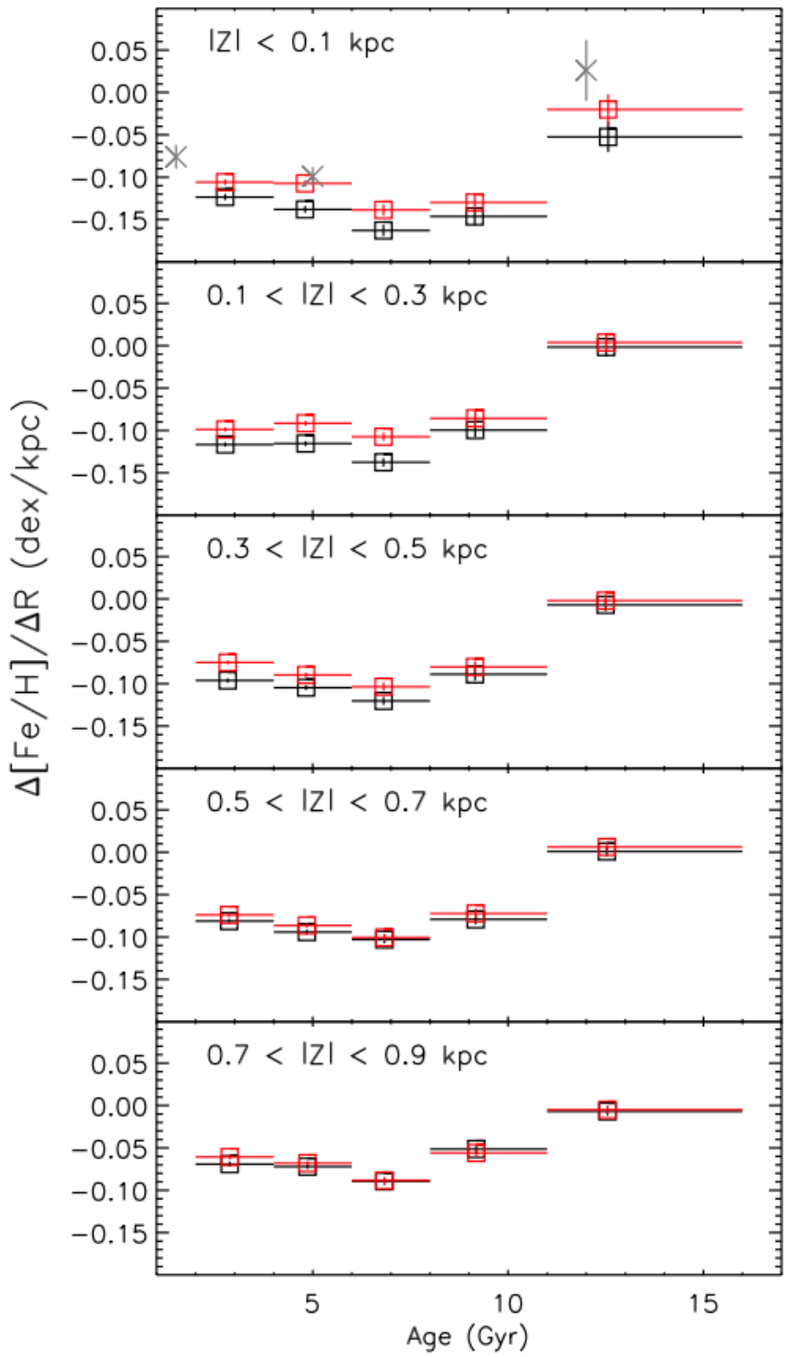
Age (Gyr)

MAPPED Analysis – Metallicity gradient

Radial metallicity gradient



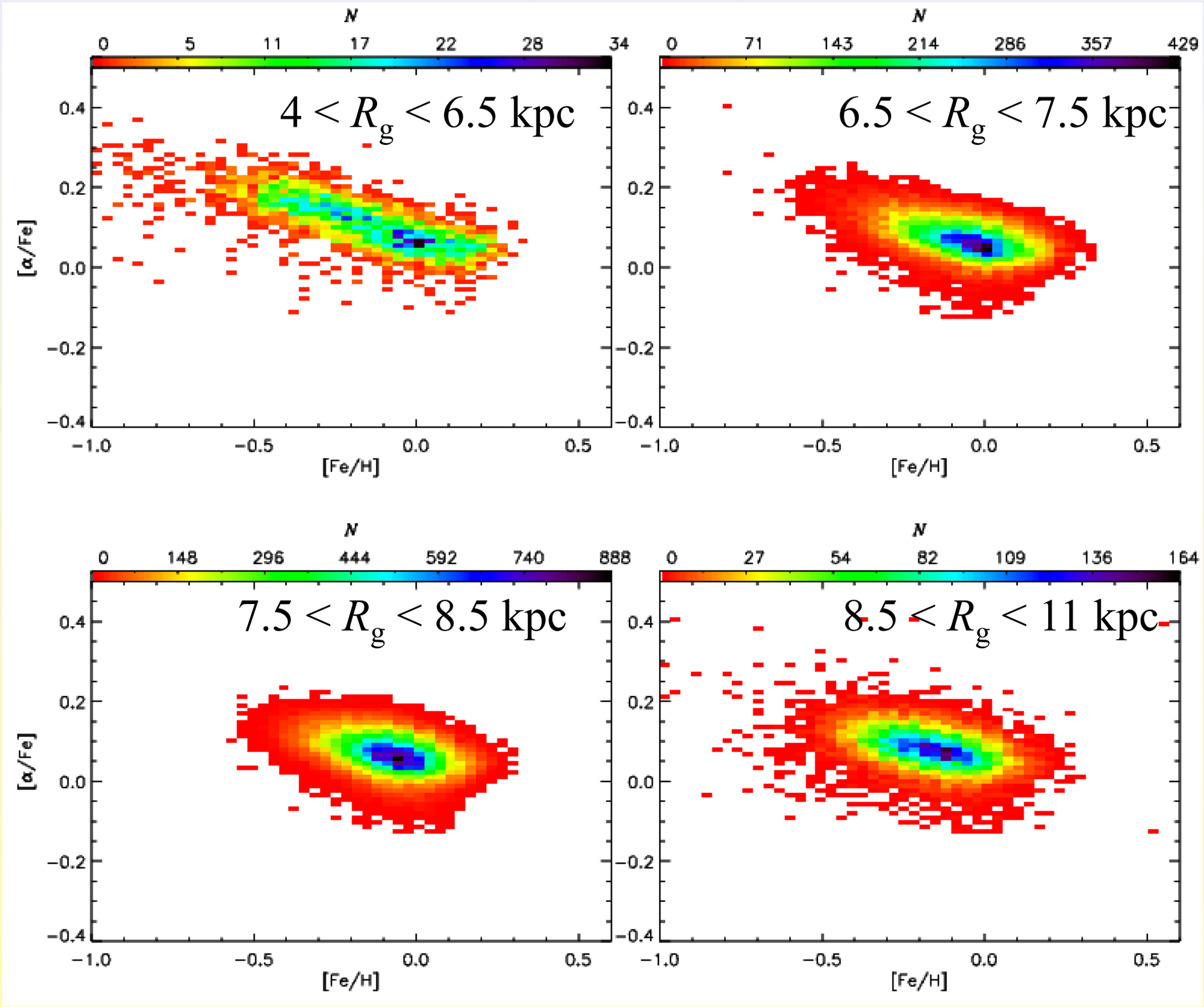
LSS-GAC DR2 MSTO



Xiang et al. 2015

Age (Gyr)

MAPPED Analysis – Spatial evolution of Abundance



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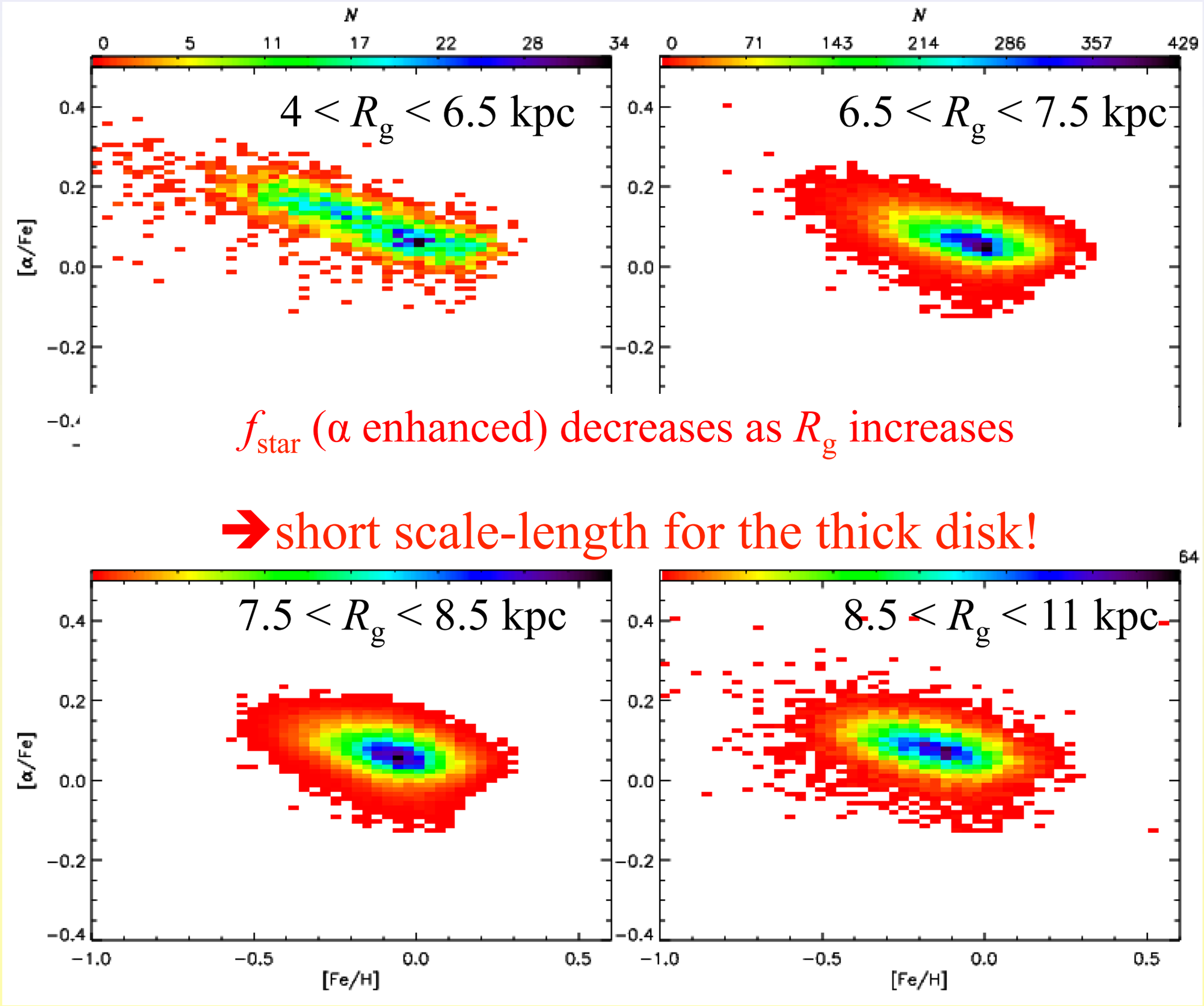
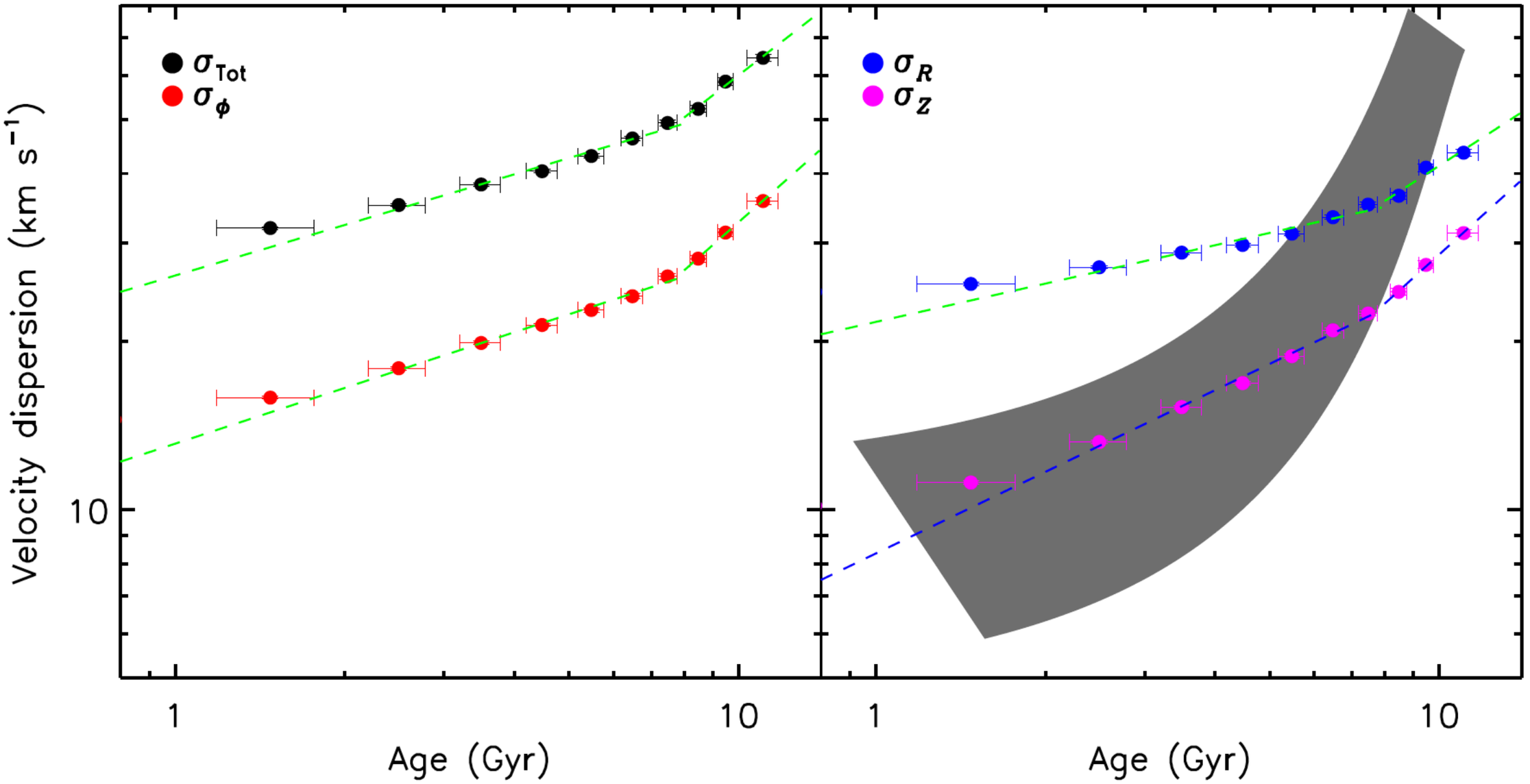


MAPPED Analysis – Kinematics



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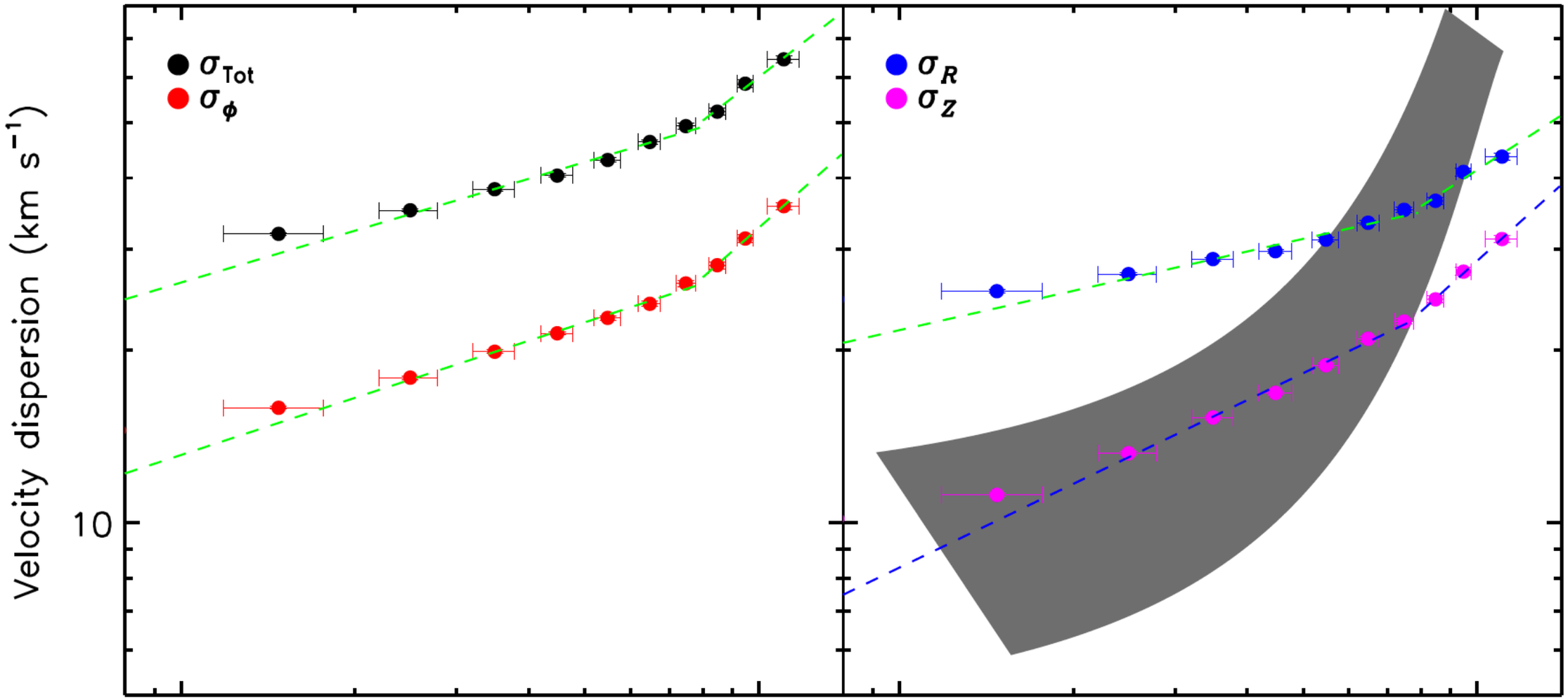
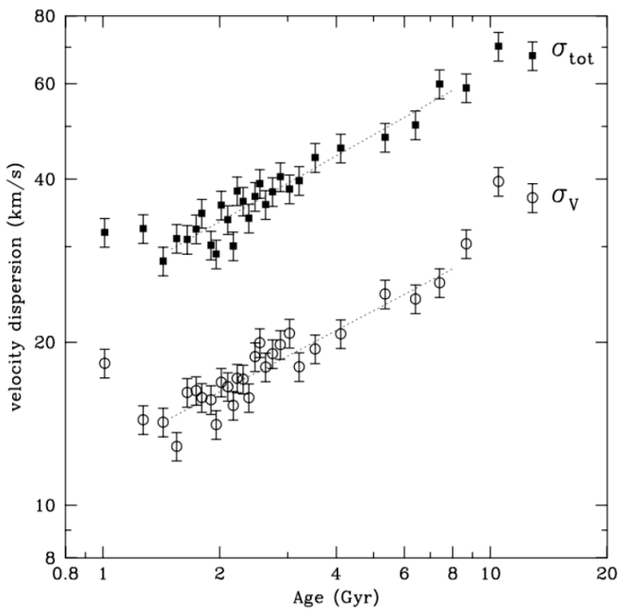
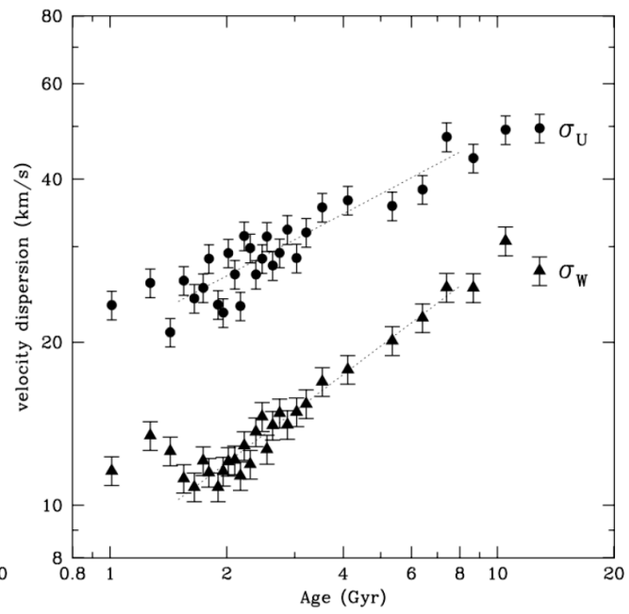
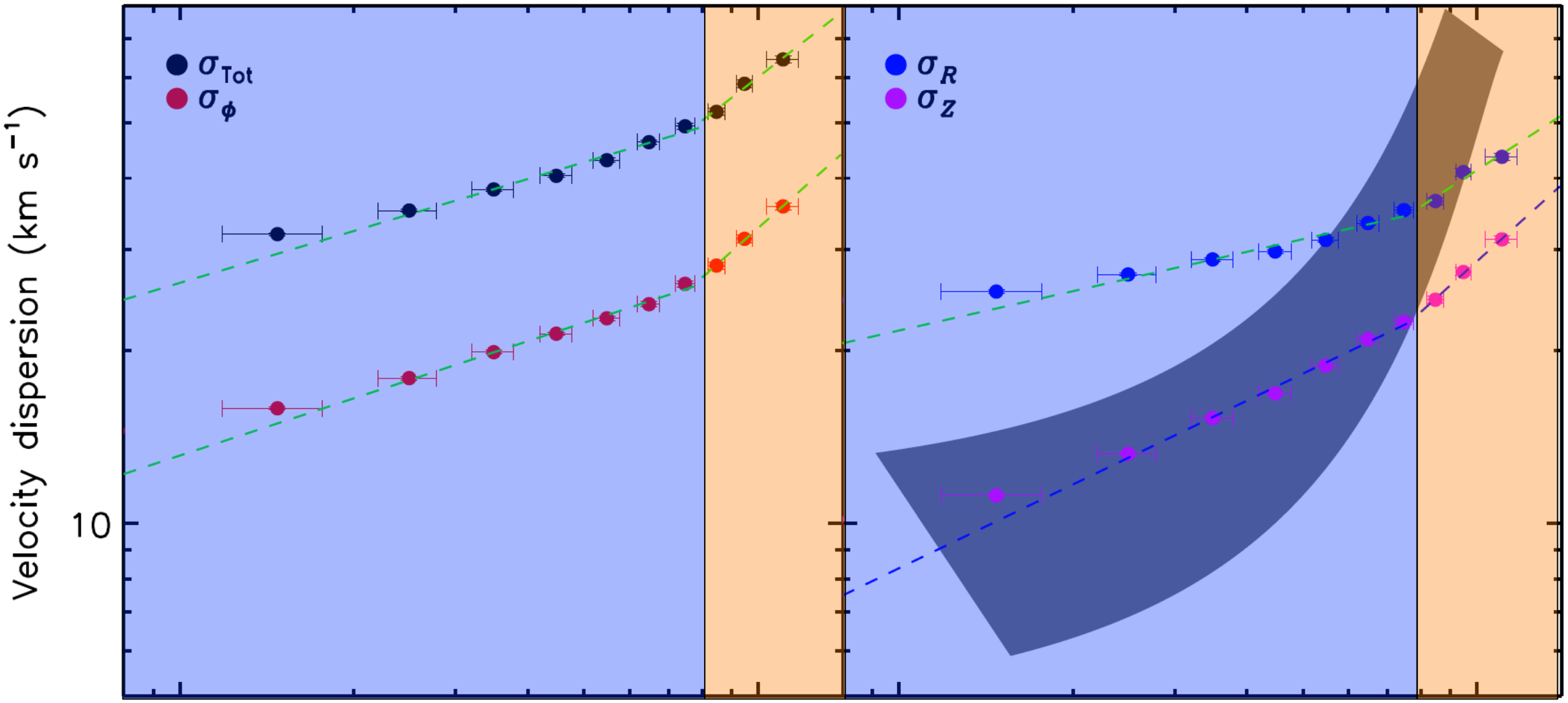


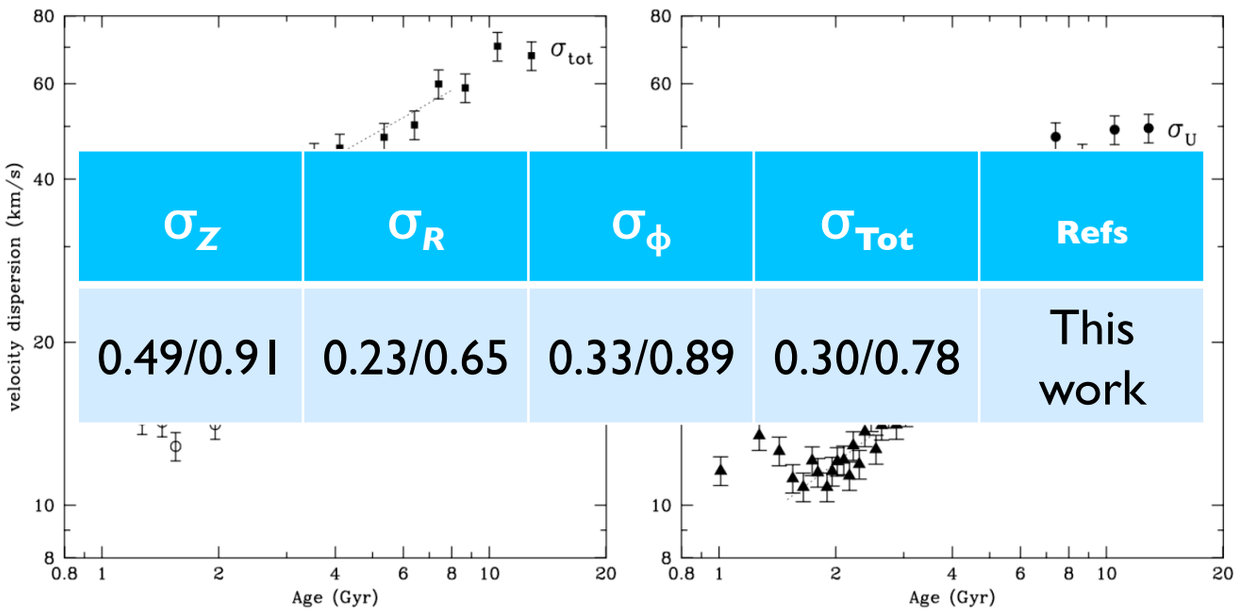




σ_Z	σ_R	σ_ϕ	σ_{Tot}	Refs
0.45	0.31	0.43	0.35	AB09
0.47	0.31	0.34	0.34	GCS
0.53	0.39	0.40	0.40	GCSIII

MAPPED Analysis – Kinematics

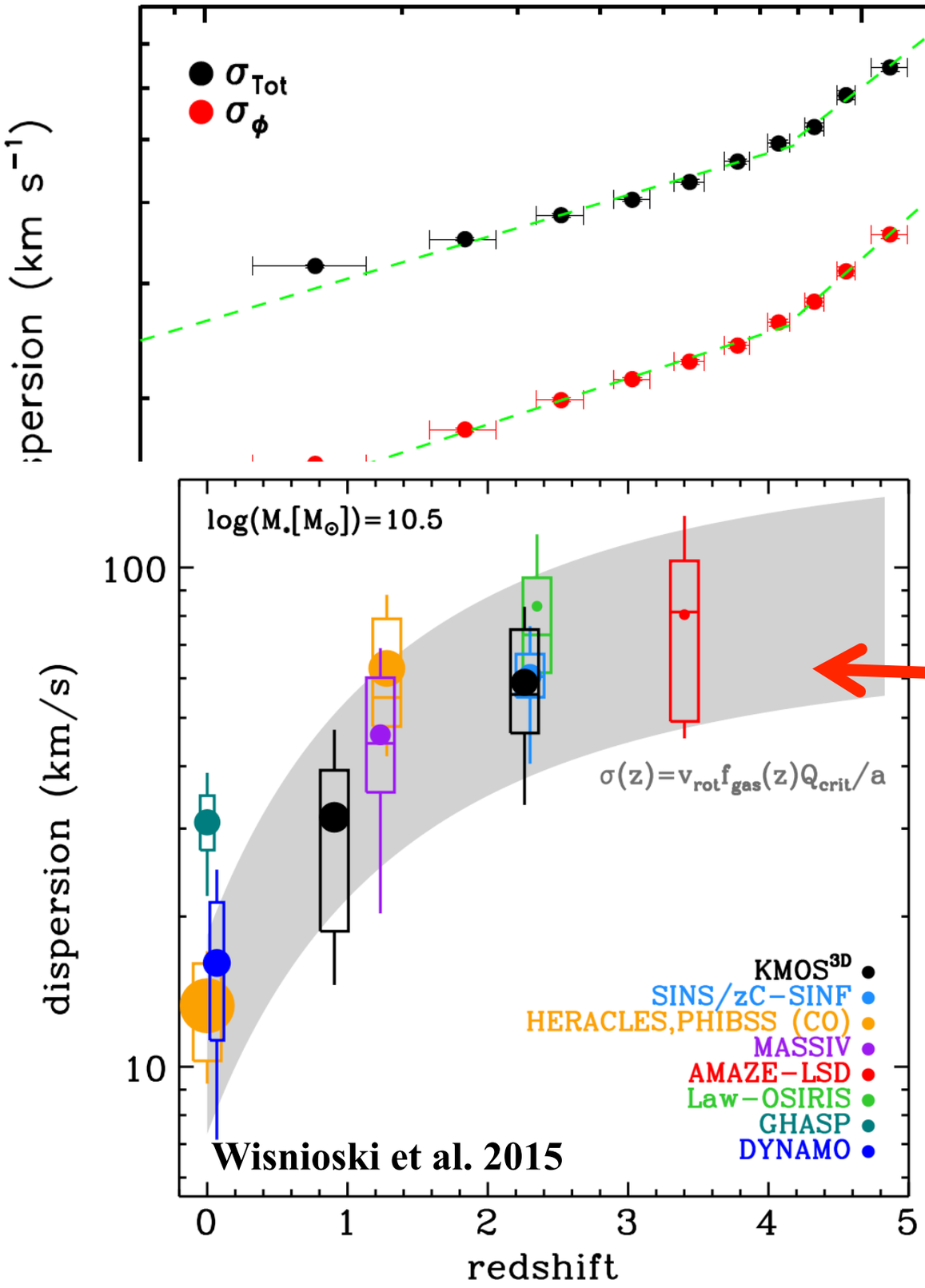


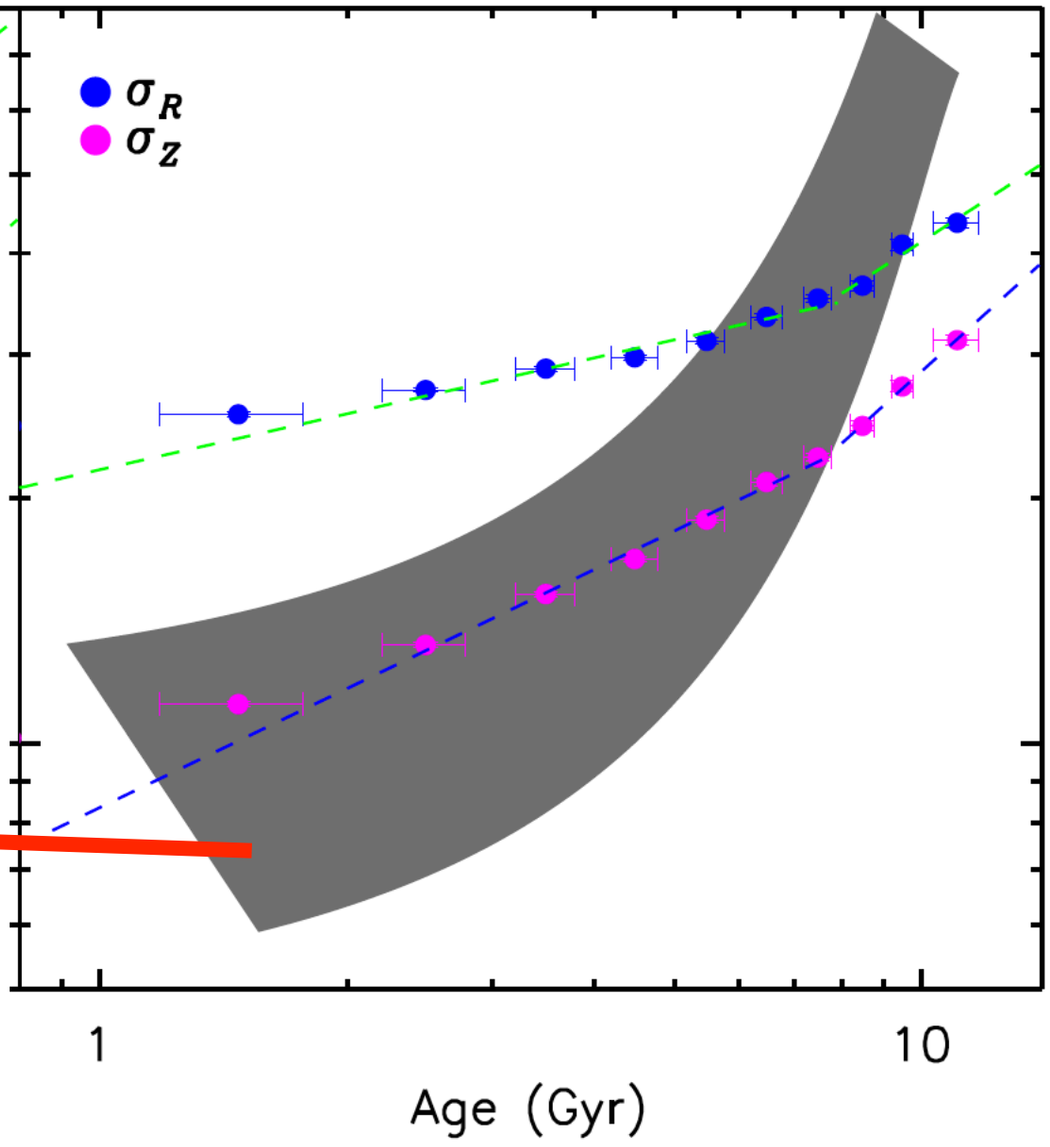


σ_Z	σ_R	σ_ϕ	σ_{Tot}	Refs
0.49/0.91	0.23/0.65	0.33/0.89	0.30/0.78	This work

σ_Z	σ_R	σ_ϕ	σ_{Tot}	Refs
0.45	0.31	0.43	0.35	AB09
0.47	0.31	0.34	0.34	GCS
0.53	0.39	0.40	0.40	GCSIII

MAPPED Analysis – Kinematics

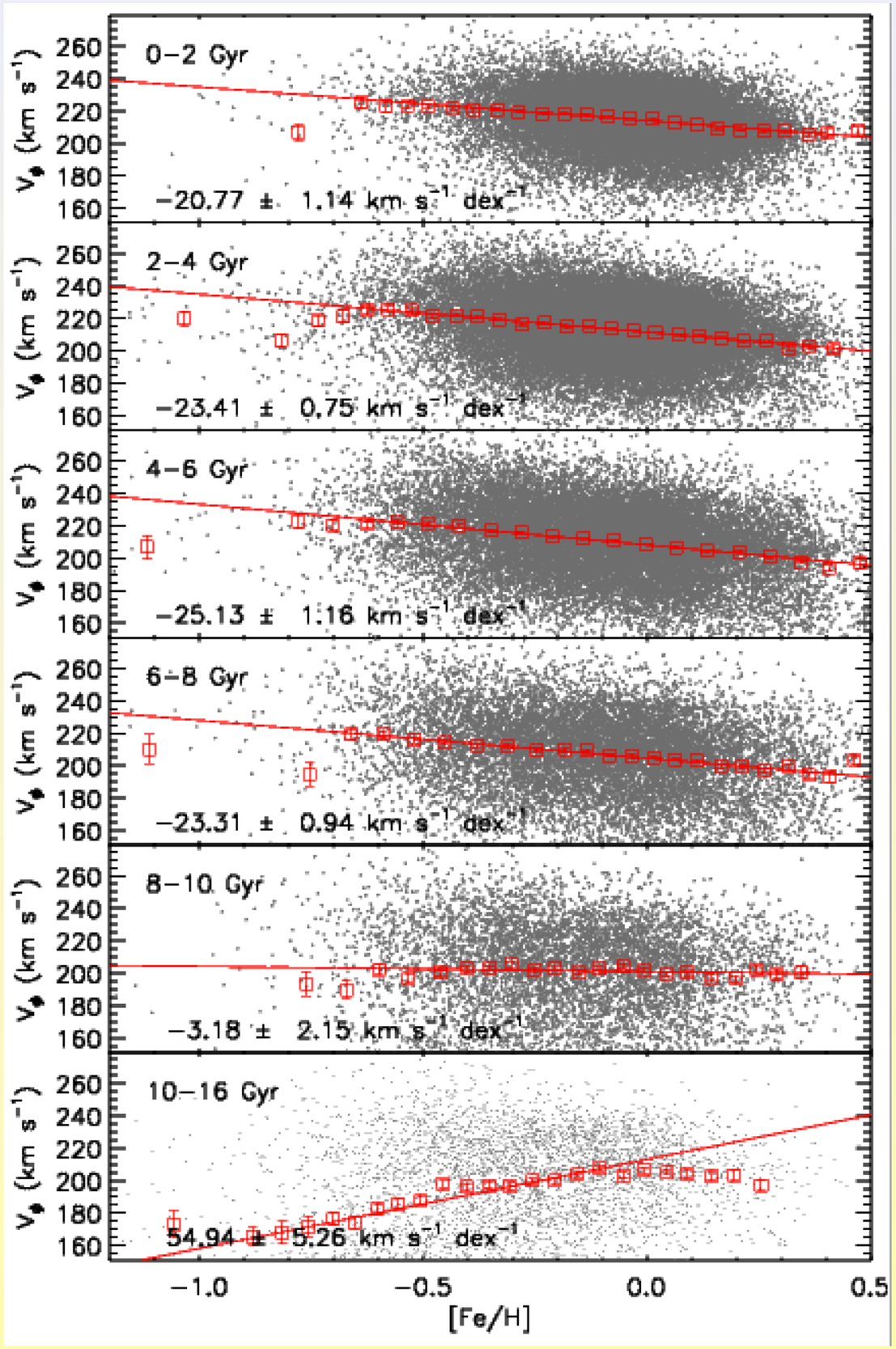




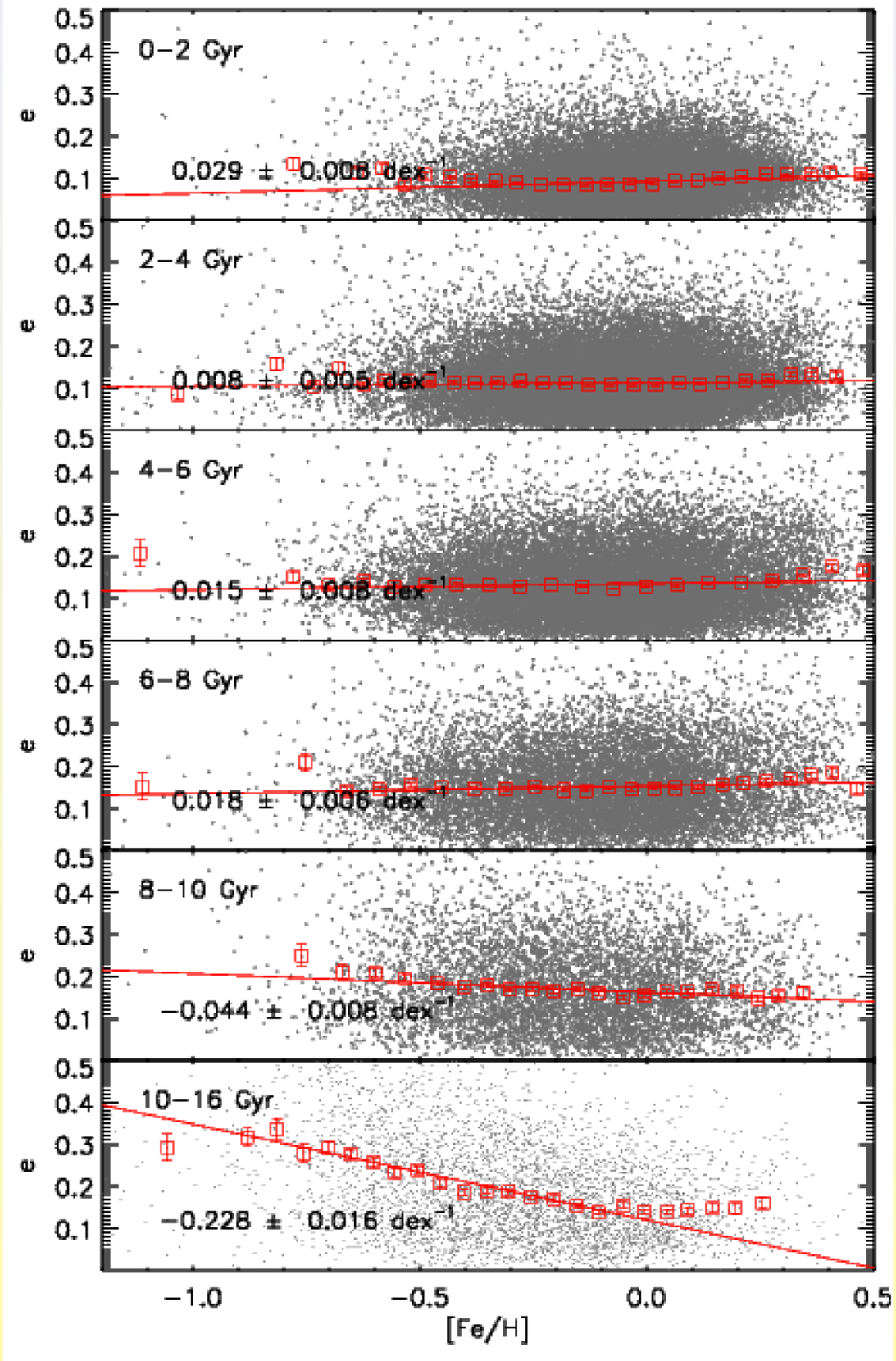
The AVR of older disk stars (thick disk, age > ~8Gyr) may reflect the decaying turbulence at high-z rather than disk heating.

MAPPED Analysis – Kinematics vs Metallicity

Azimuthal velocity

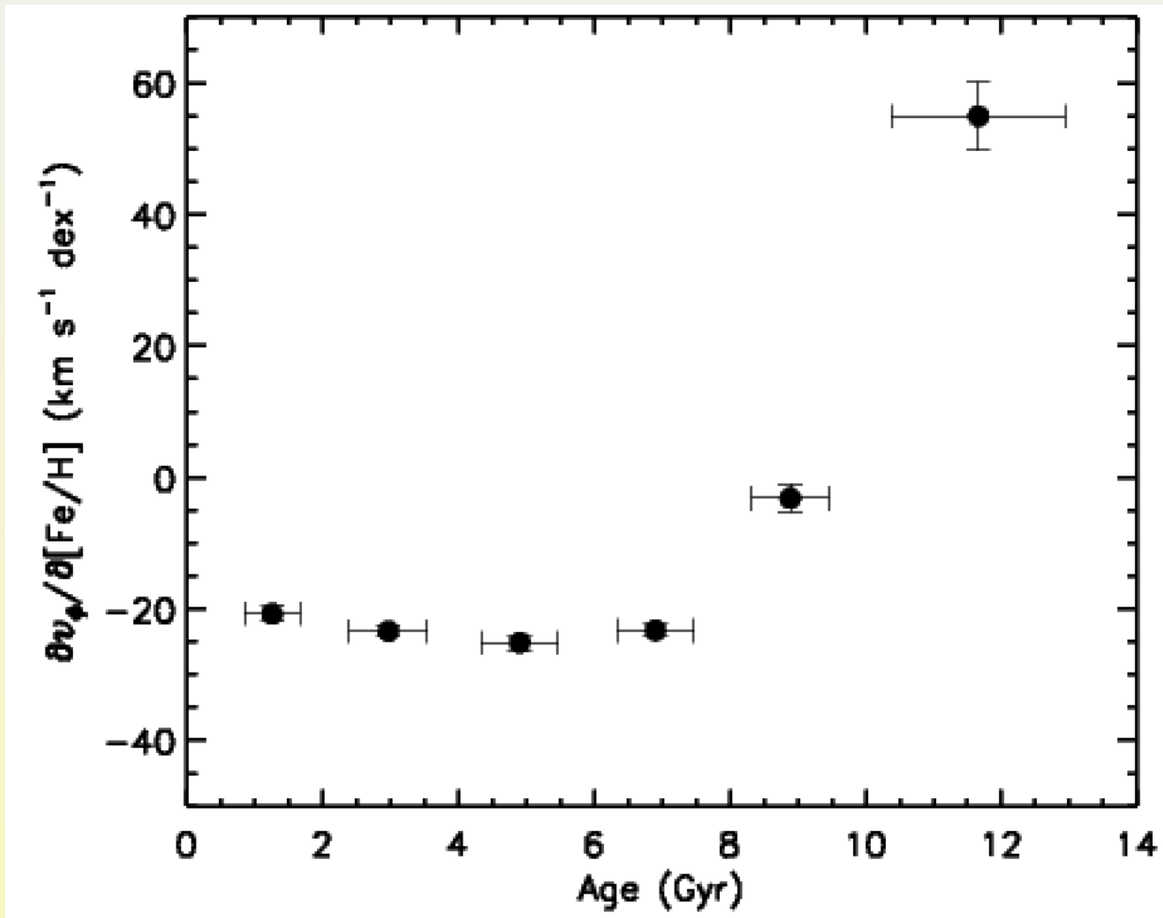


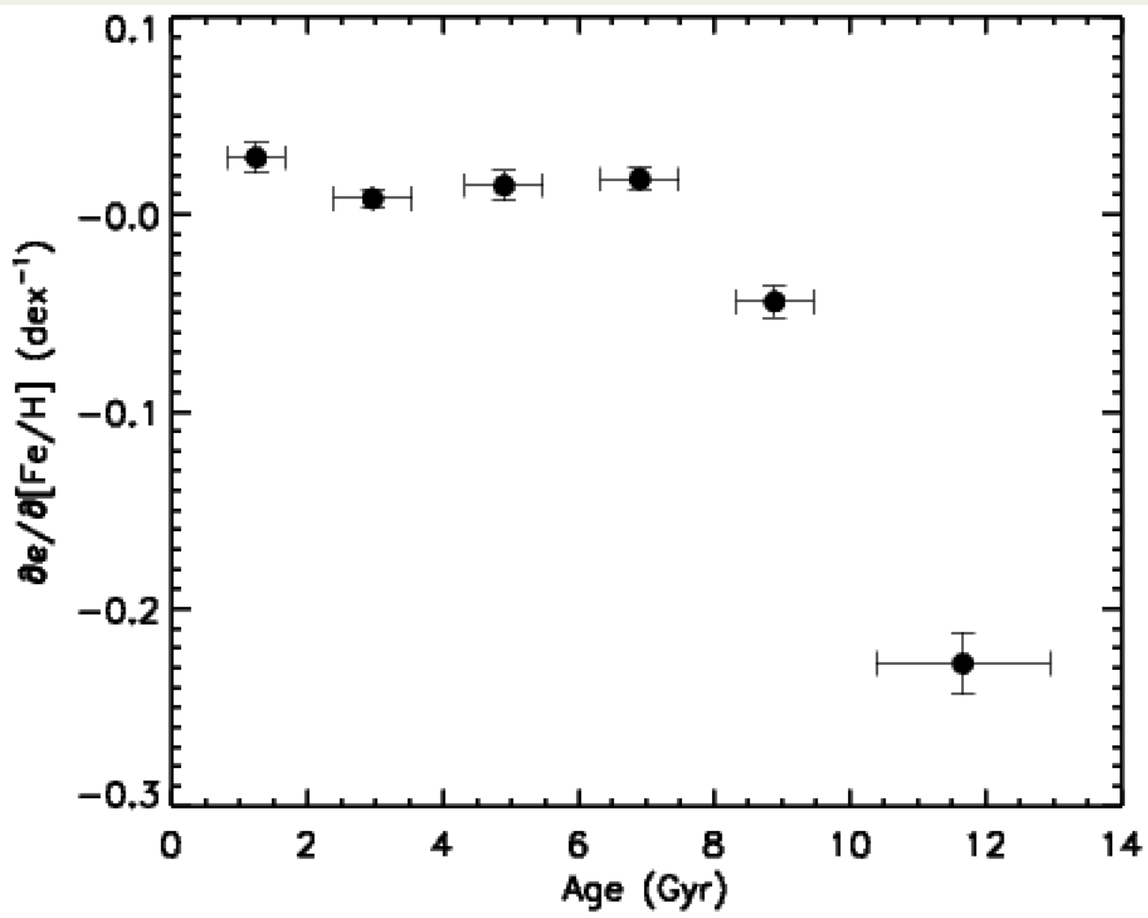
Eccentricity



[Fe/H]

MAPPED Analysis – Kinematics vs Metallicity





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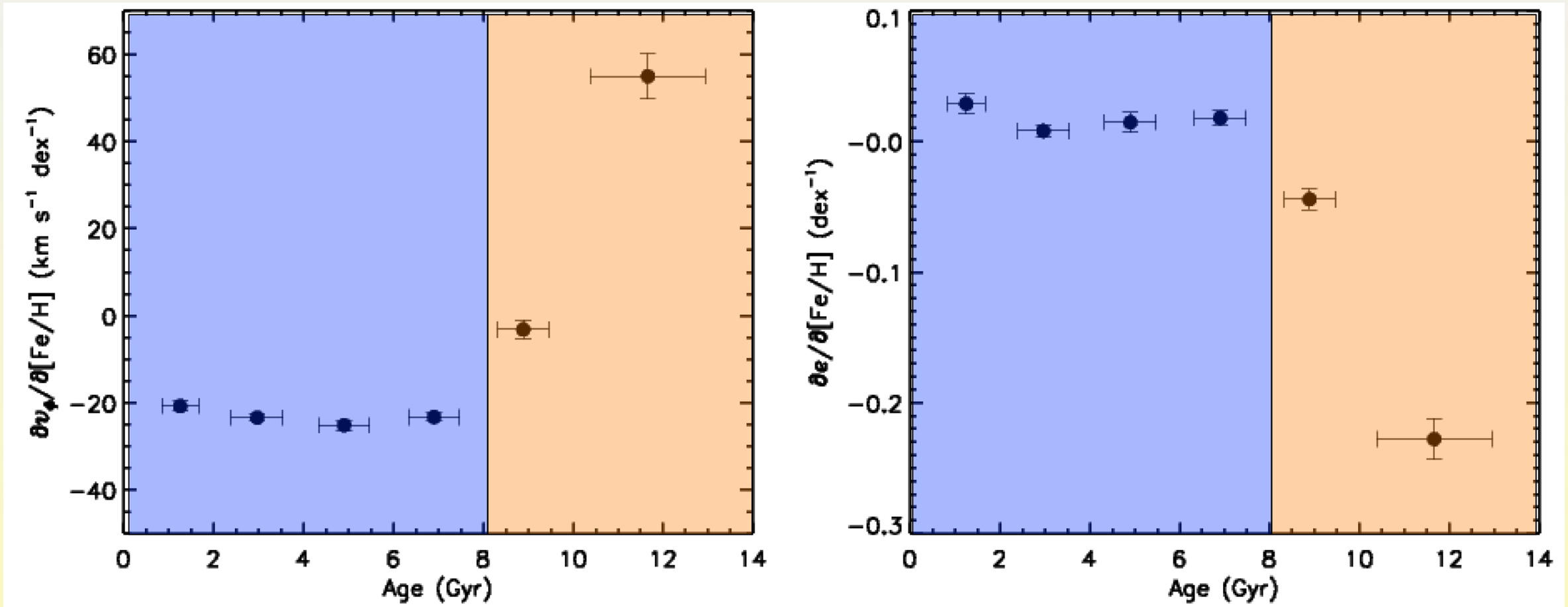
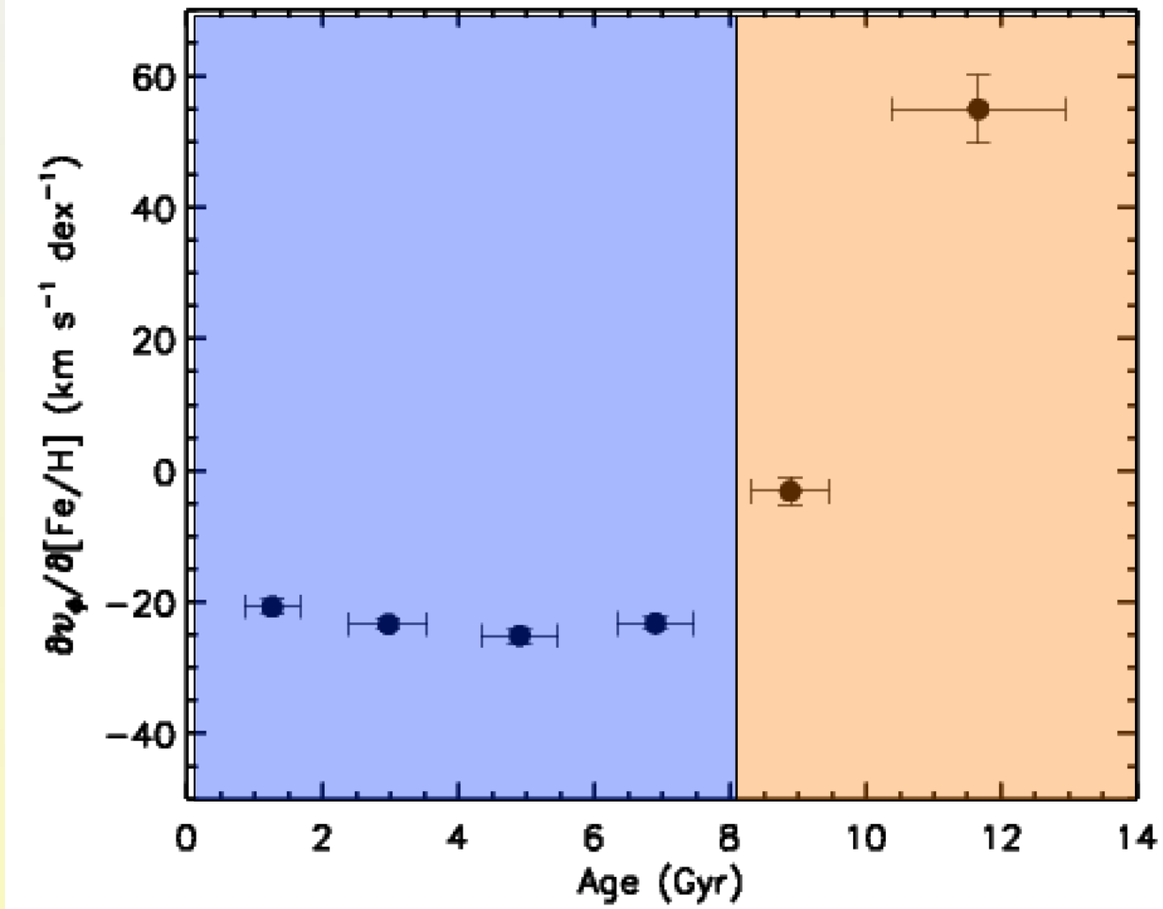
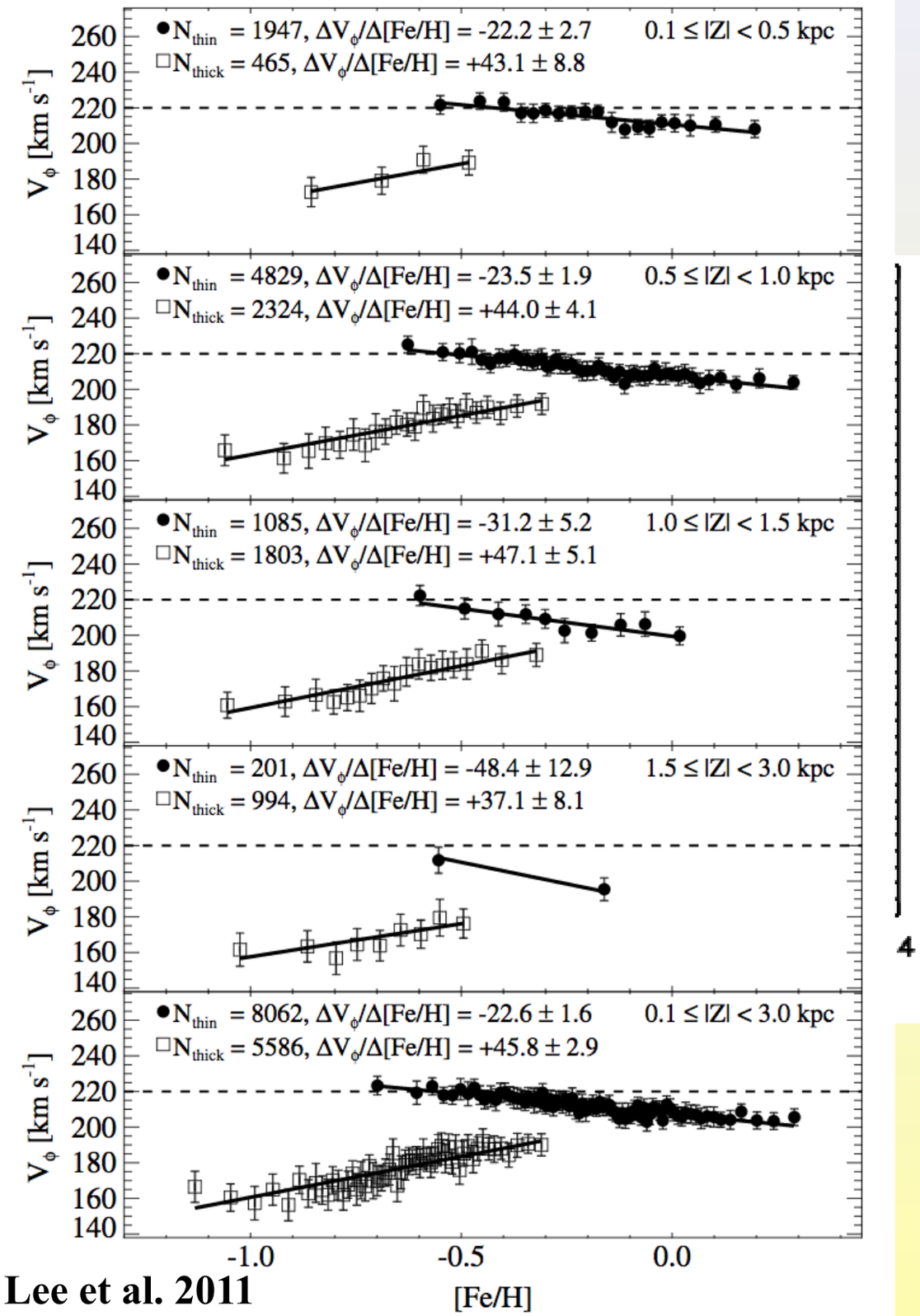


MAPPED Analysis – Kinematics vs Metallicity





Lee et al. 2011

Summary & Future plan

Summary

With a sample of nearly **0.1 million MSTO-SG stars** selected from LAMOST-TGAS, which have very accurate 3D positions + 3D velocities + orbital parameters (R_g, Z_{max}, eccentricity) + elements abundance ([Fe/H], [α/Fe]) + **age**, we have studied the Galactic disc(s) using **MAPPED analysis** and found the results listed below:

Properties	**Thin disc (Age < 8 Gyr)**	**Thick disk (Age > 8 Gyr)**
Scale length (indirect)	Large	Short
Abundance	Iron-rich, low alpha	Iron-poor, high alpha
Radial metallicity gradient	Negative	Near flat or slightly positive
AMR	flat	negative
Velocity dispersion & AVR	Lower & power law (~0.3)	Higher & power law (~0.8)
Eccentricity-[Fe/H]	Flat	Negative
Vphi-[Fe/H]	Negative	Positive
Age	Young	Old

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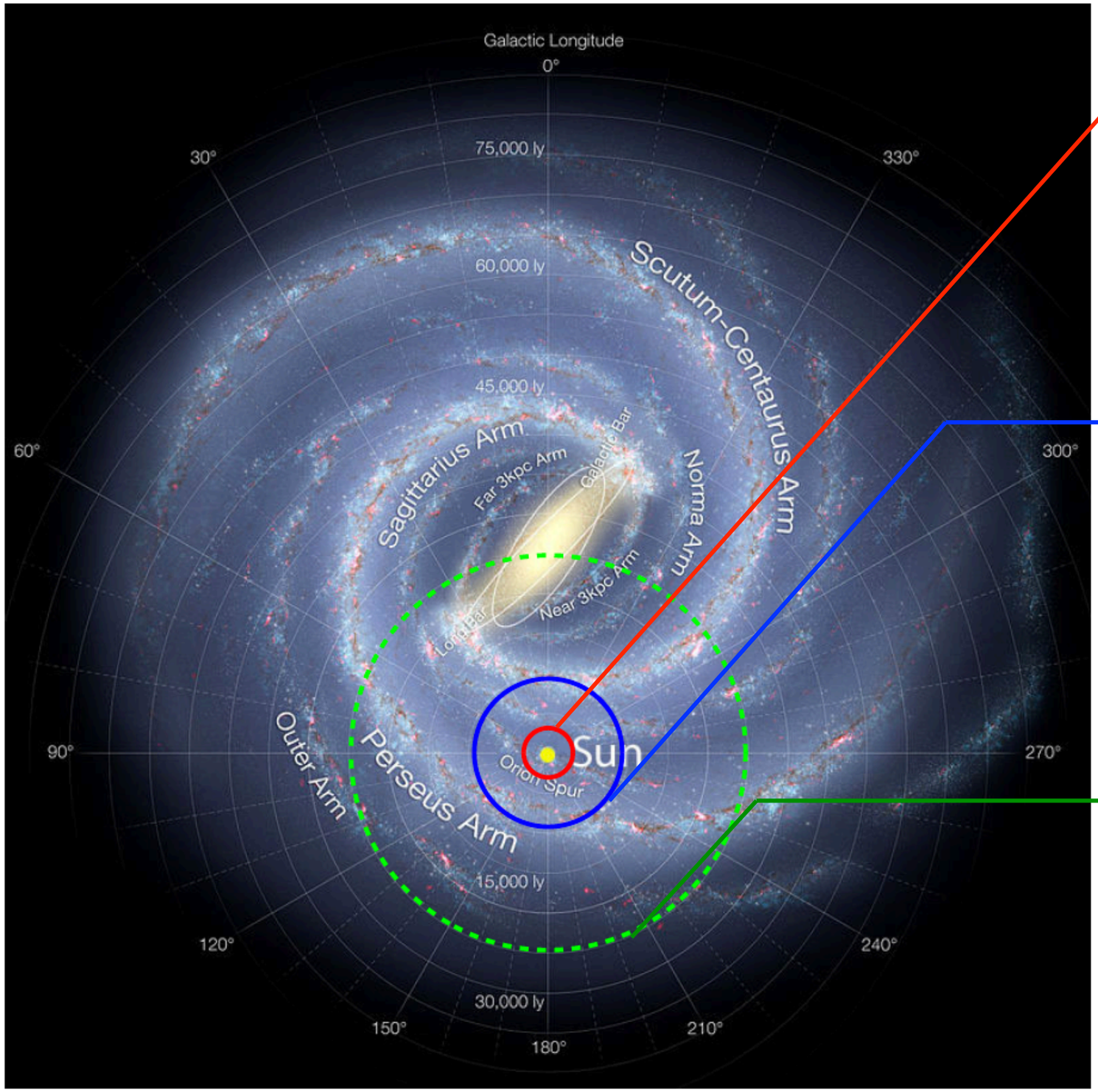
We do find two distinct discs: i.e. **thin (< 8 Gyr)** and **thick (> 8 Gyr) discs**, in **multiple phase spaces**.

Future plan



LAMOST-TGAS MSTO-SG:

- **Typical size: 500 pc**
- **6D phase space + abundance + age**
- **~ 0.1 million stars**

Huang et al. in prep. 2017a

LAMOST MSTO-SG + GAIA DR+:

- **Typical size: 2 kpc**
- **6D phase space + abundance + age**
- **~ 1 million stars**

Xiang et al. in prep. 2017

LAMOST RG + GAIA DR+:

- **Typical size: 8 kpc**
- **6D phase space + abundance + age**
- **~ 0.5 million stars**

Huang et al. in prep. 2017b


Thank You!
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