Dynamical and chemical evolution of the Milky Way from Optical and IR spectroscopic surveys

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~~Dynamical and~~ Chemical evolution of the Milky Way from Optical and IR spectroscopic surveys (focus on the disks)

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The Milky Way

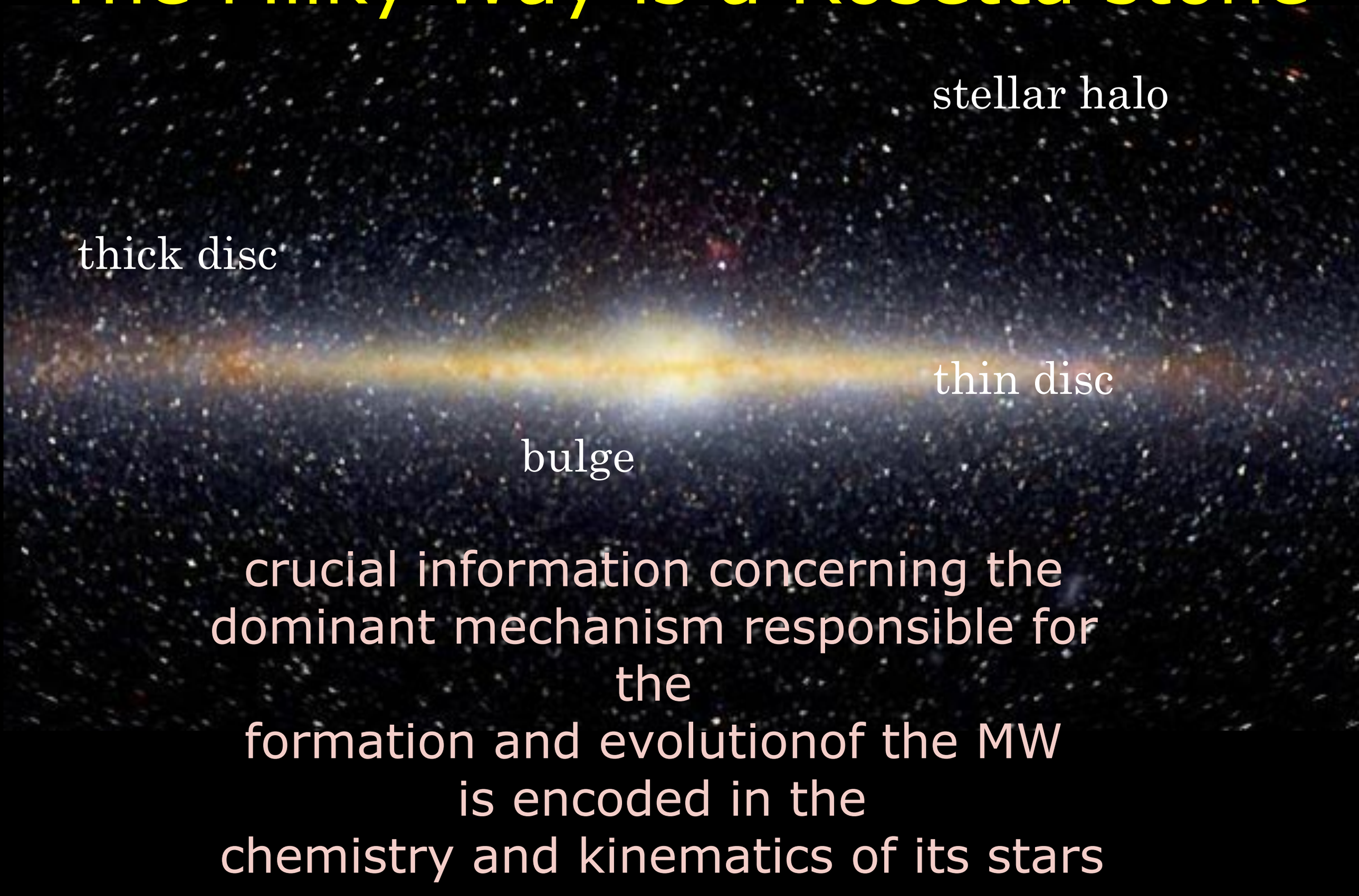
How did the Galaxy come to be like this?

What is the origin/formation epoch/mechanism and relation between the various components?

The Milky Way is a Rosetta stone

We can observe individual stars and clusters and measure their properties

The Milky Way is a Rosetta stone



crucial information concerning the
dominant mechanism responsible for
the
formation and evolutionof the MW
is encoded in the
chemistry and kinematics of its stars

We have *Gaia*!

Exquisite astrometry and photometry for almost 2 billion stars, plus some spectroscopy

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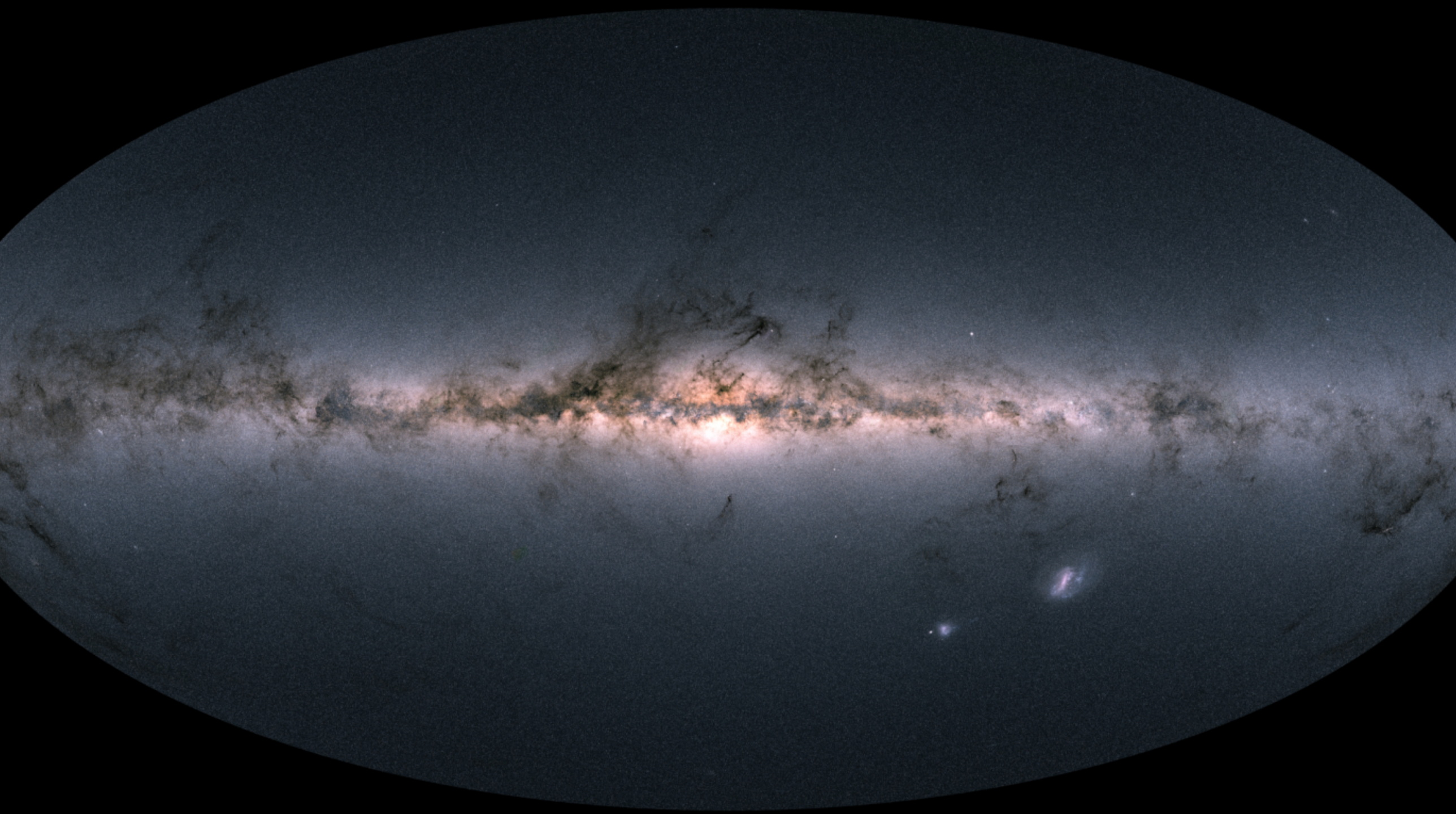
9/2016 – DR1
25/4/2018 – DR2
A revolution in MW science

GAIA'S SKY IN COLOUR



esa.int

Credit: ESA/Gaia/DPAC

European Space Ag

GAIA'S SKY IN COLOUR

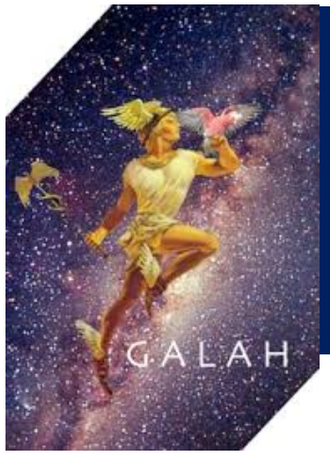
Gaia on its own is not enough. We need ground based spectroscopy (down to faint stars) to get the 3D motions and the elemental abundances that are crucial for a complete understanding of the MW

Ground based spectroscopic surveys

APOGEE

2.5 m
10^5+10^5 stars
mainly giants

1&2



4m
A few x10^6 stars
mainly thin disc

RAVE

1.2 m
A few x10^5 stars
dwarfs & giants

GaiaESO

Lamost

4m
A few x 10^6 stars
All MW components

VLT
10^5 stars
Discs and bulge
All stellar ypes
Star clusters

http://www.sdss3.org/surveys/apogee.php
https://galah-survey.org/
https://www.gaia-eso.eu/
https://www.rave-survey.org/project/
http://www.lamost.org

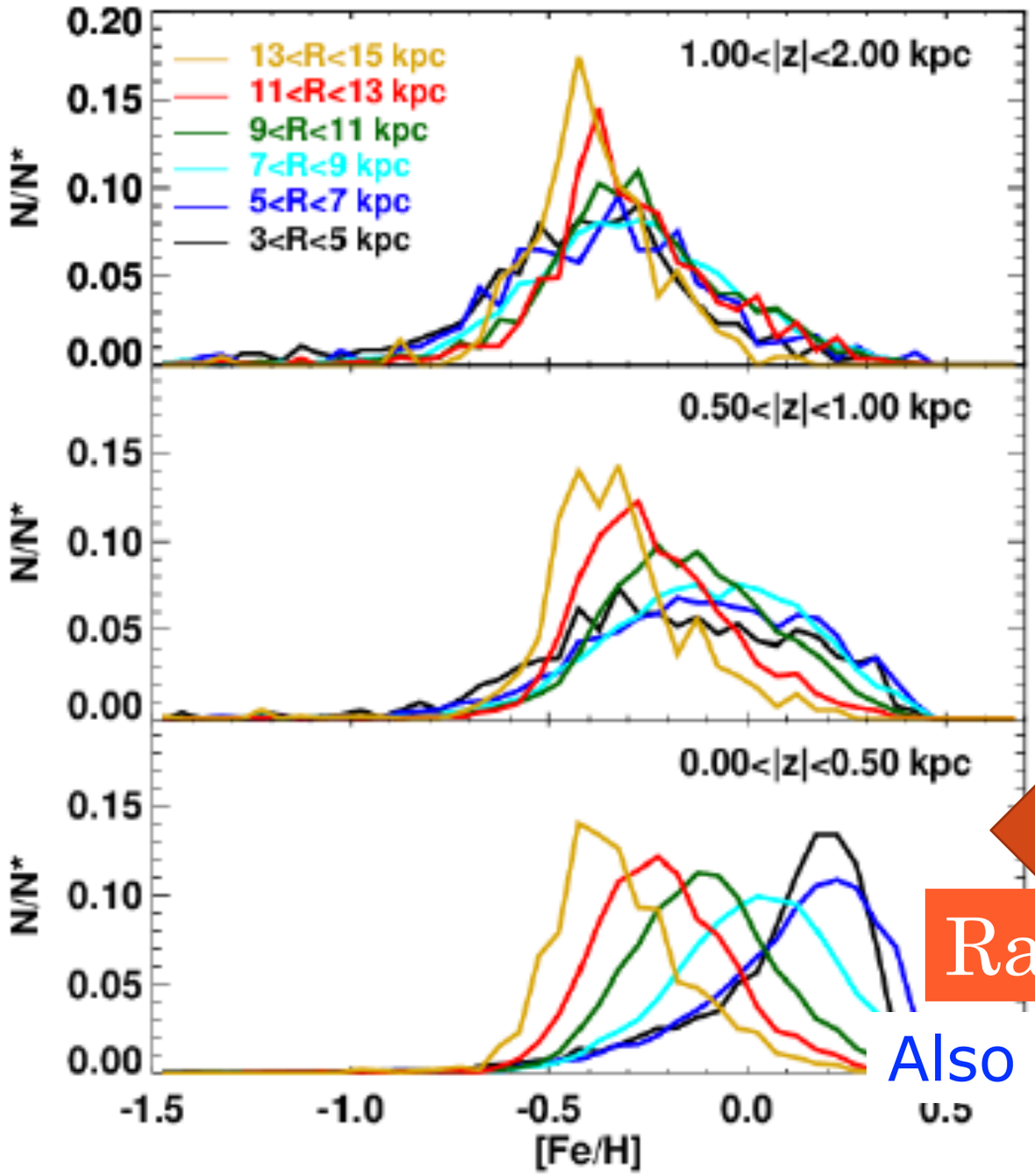
The products

- Radial velocities
- Astrophysical parameters (Teff, logg) → ages
- Metallicity
- Elemental abundances (for > 30 elements tracing all nucleosynthetic channels

A few highlights (from hundreds of papers)

- Metallicity ([Fe/H])
- alpha-elements
- n-capture elements

The metallicity distribution function across the Galaxy

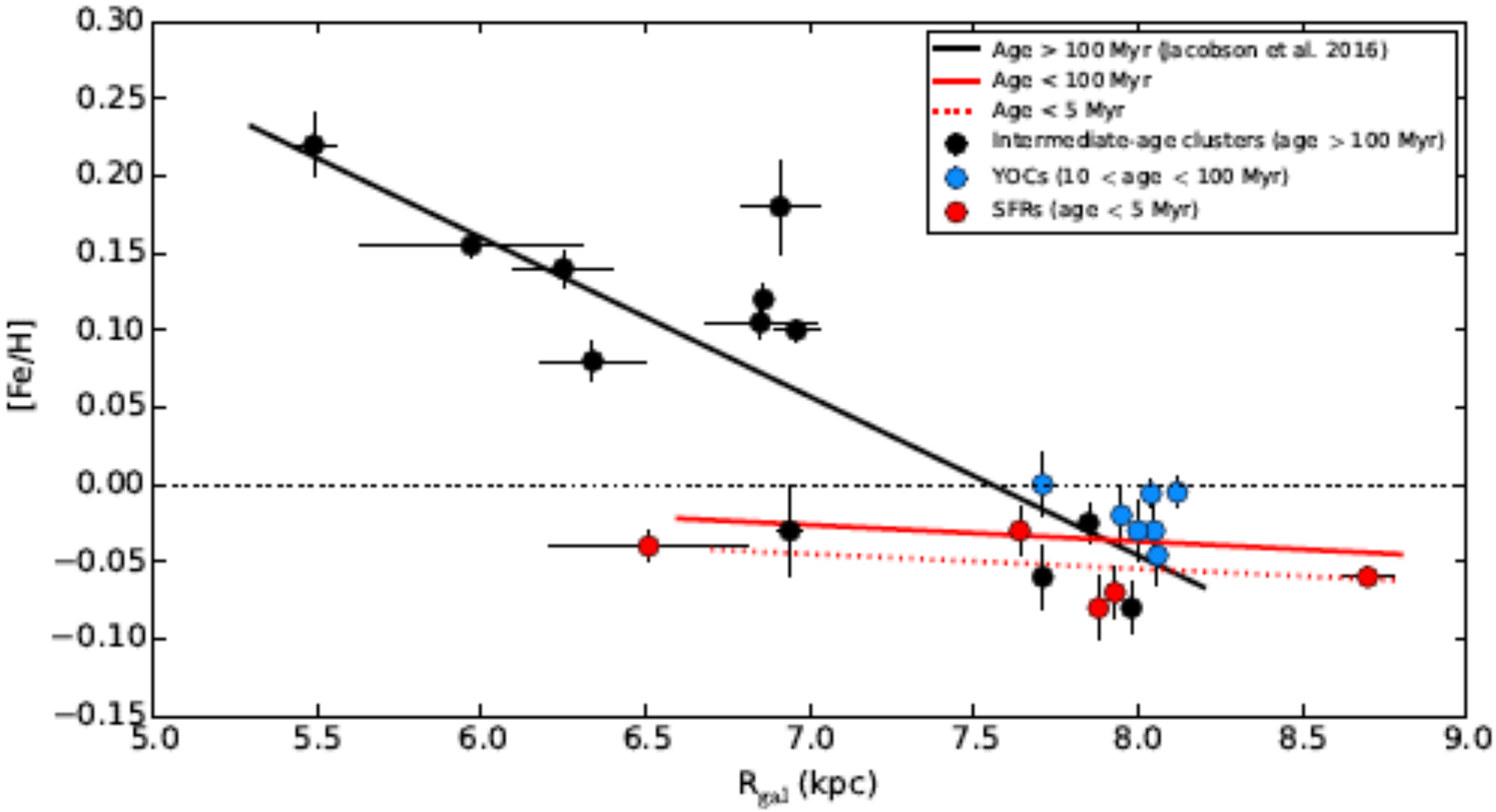


Radial Gradient

Also note the different shapes

Hayden et al. (2015) - APOGEE

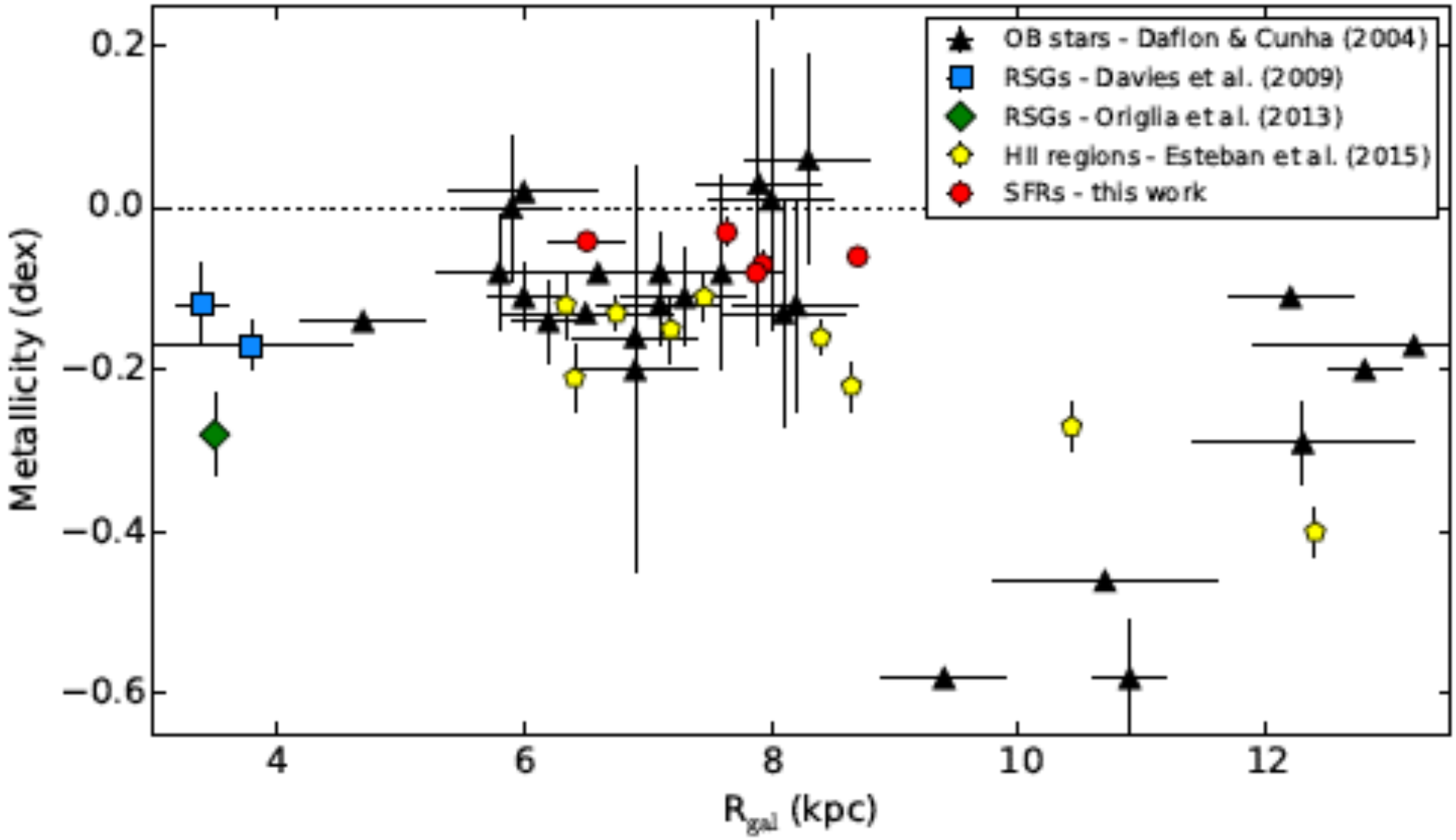
The metallicity gradient from open clusters: the surprise from young clusters



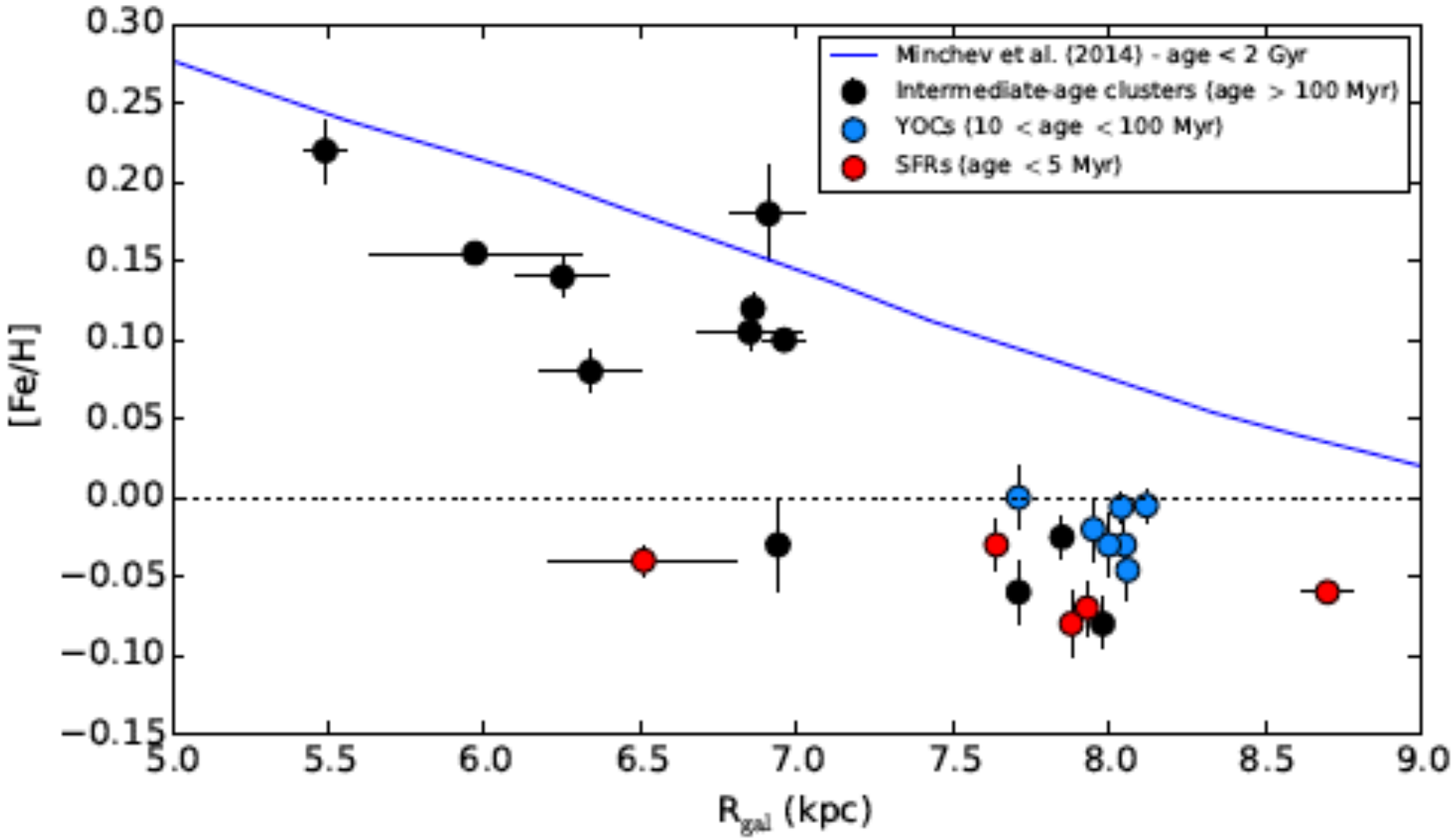
Spina, Randich, et al. (2017) – Gaia ESO

First determination of metallicity in low-mass members of SFR and young OCs (<30 Myr) in the inner Galaxy – **present day distribution solar metallicity, lower than for older clusters**

The metallicity gradient from open clusters – comparison with other populations

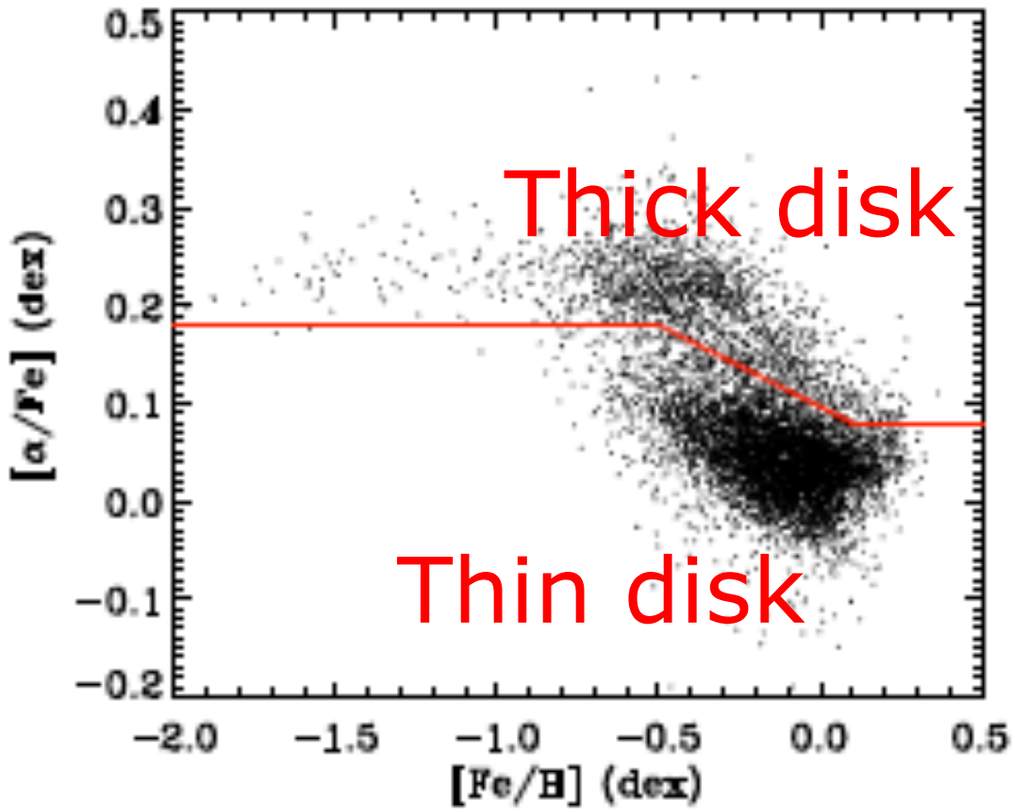


The metallicity gradient from open clusters – comparison with the models

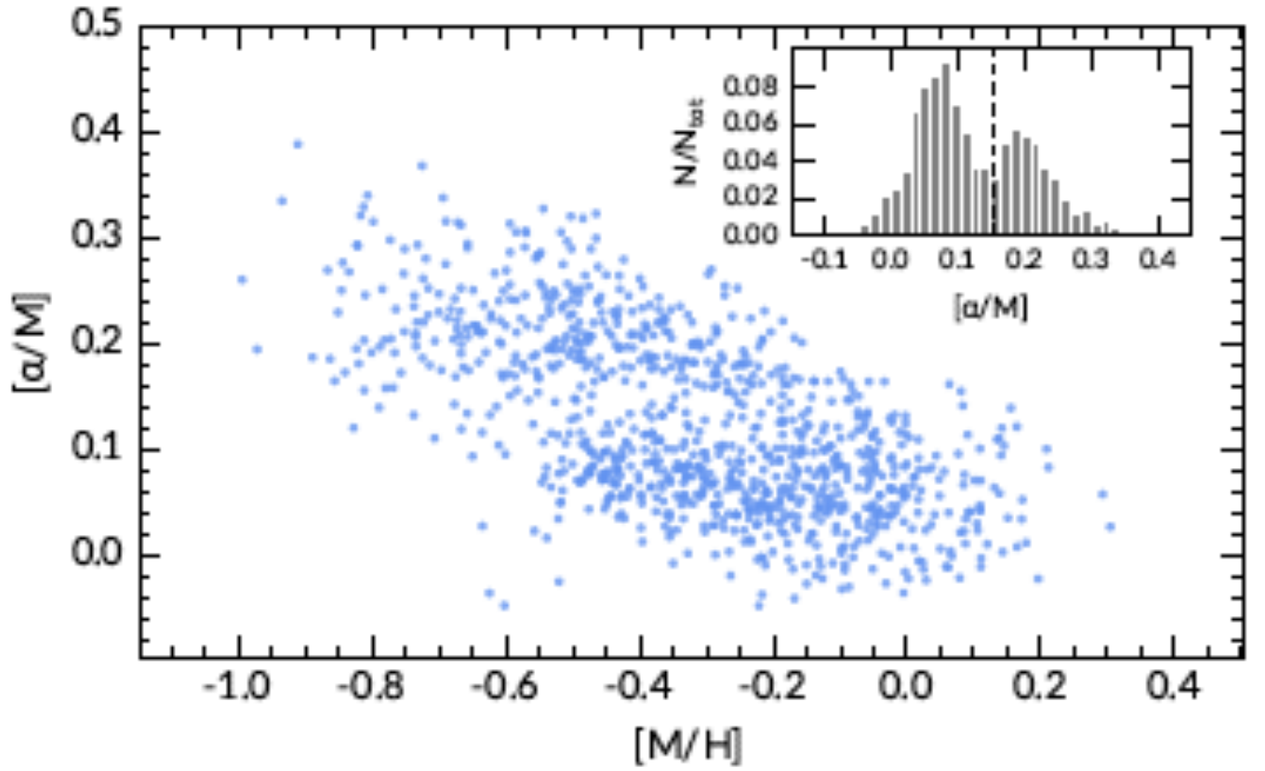


Latest stages of evolution: complex interplay of several processes (star formation activity, accretion history, etc.)

The alpha sequences and age-metallicity relations



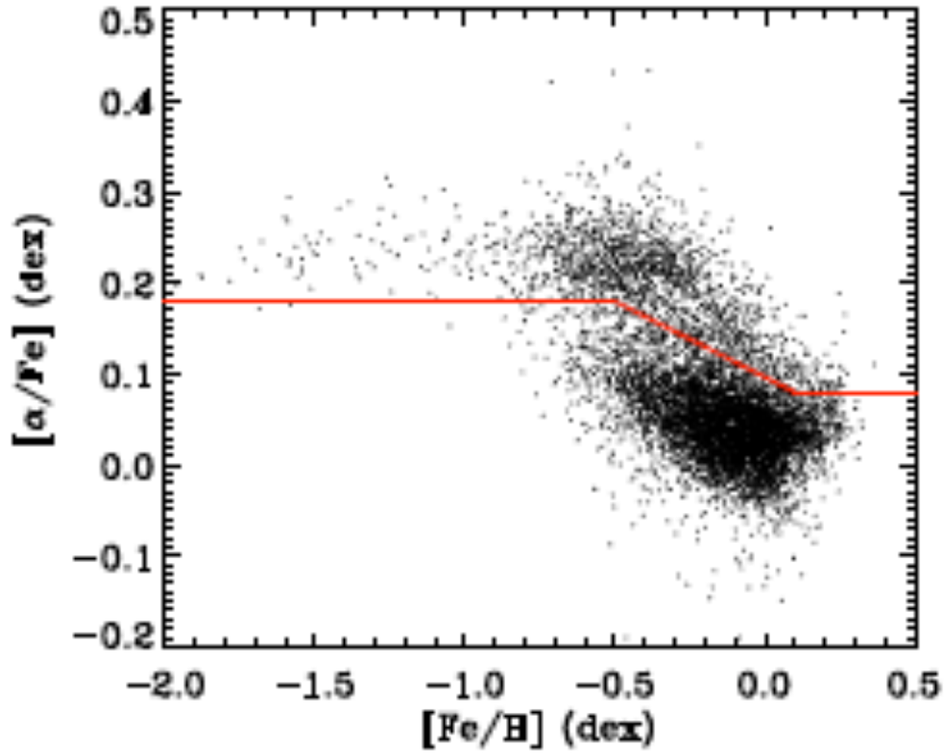
Wu et al. (2018) – LAMOST
(Similar results from APOGEE and GES)

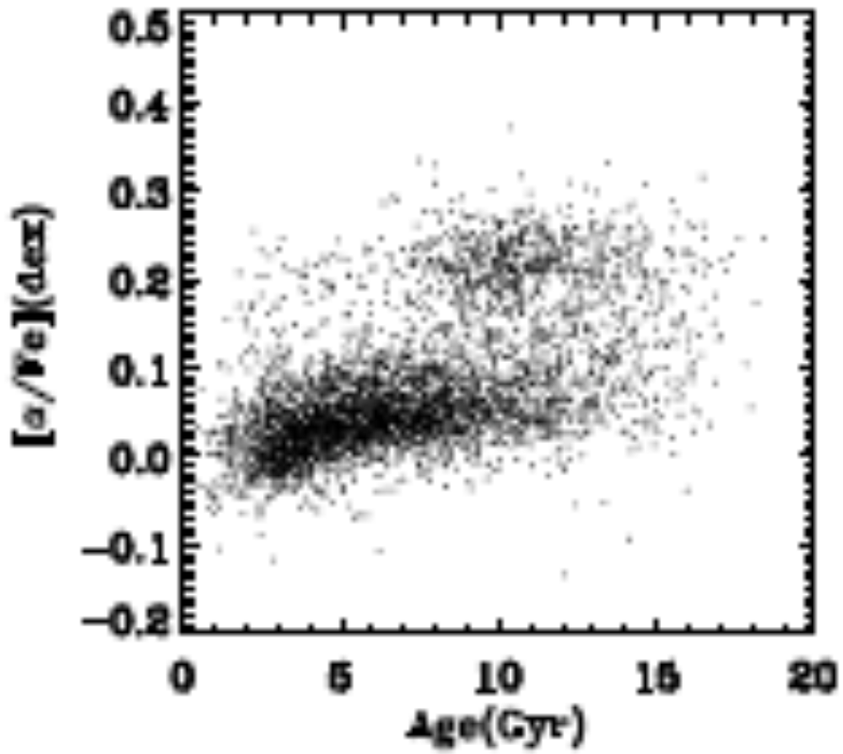


Duong et al. 2018 - Galah

Low alpha – thin disc
High alpha – thick disk

The alpha sequences and age-metallicity relations

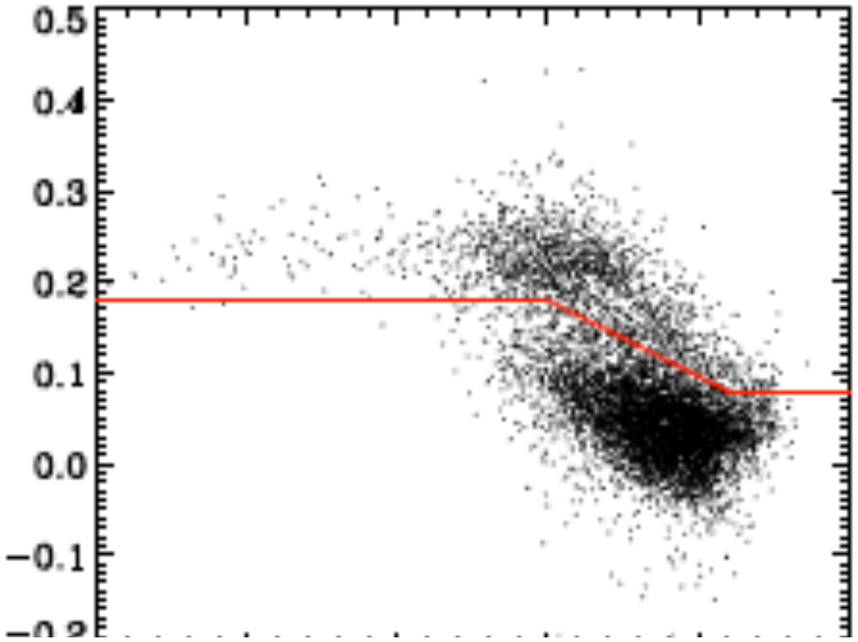


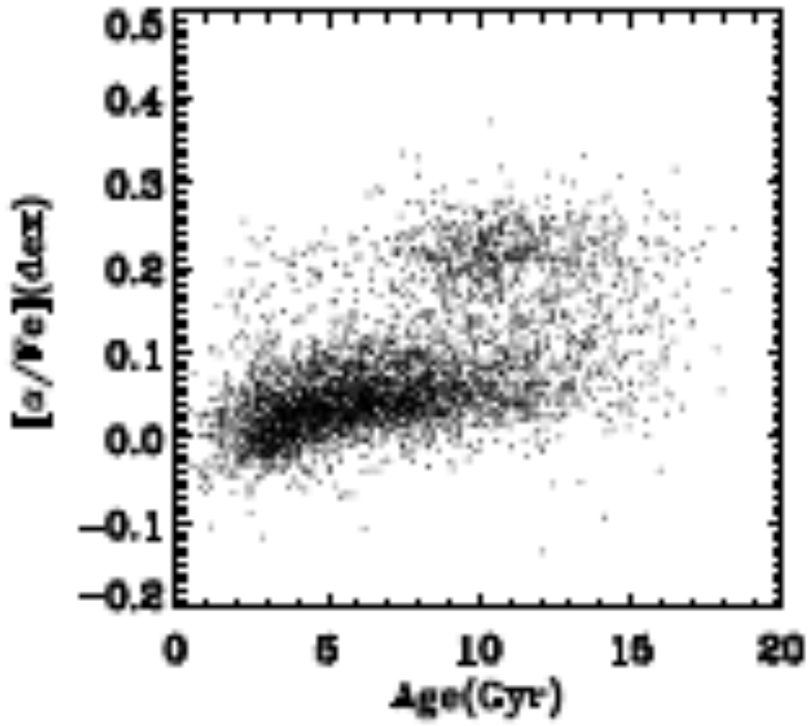


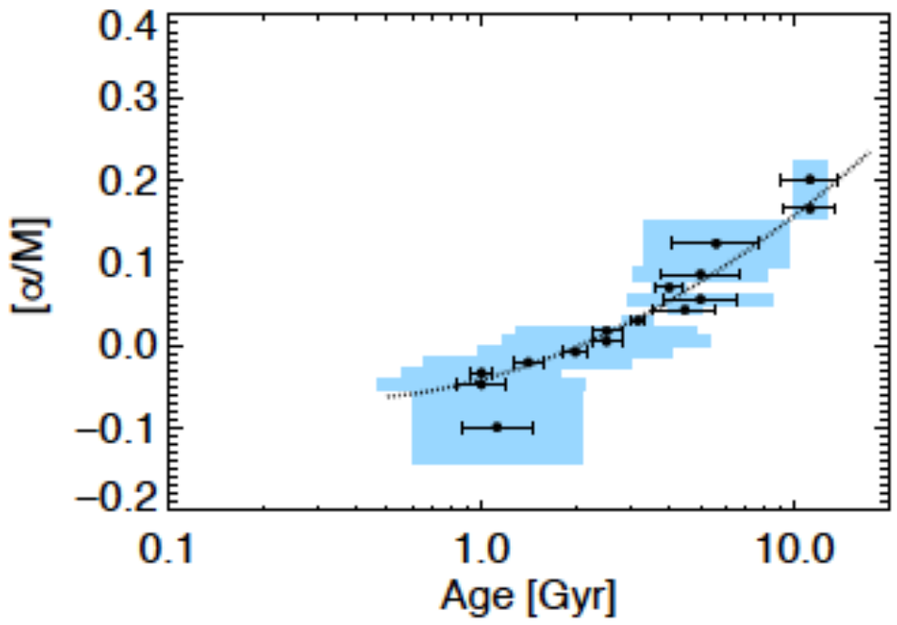
Age →

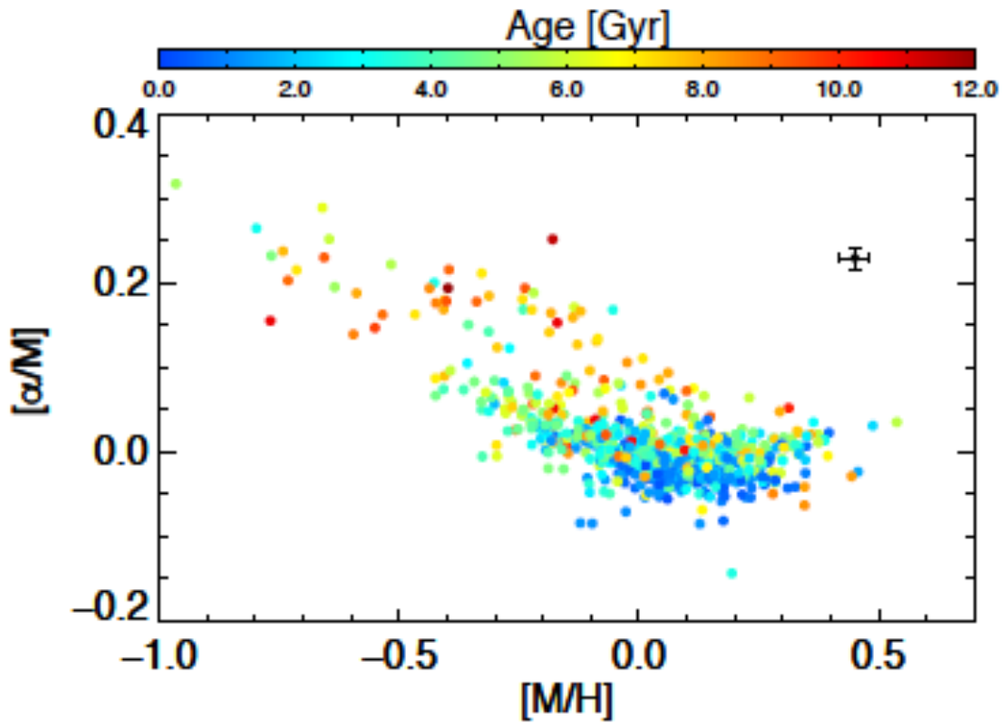
Wu et al. (2018) – LAMOST
(Similar results from APOGEE and GES)

The alpha sequences and age-metallicity relations





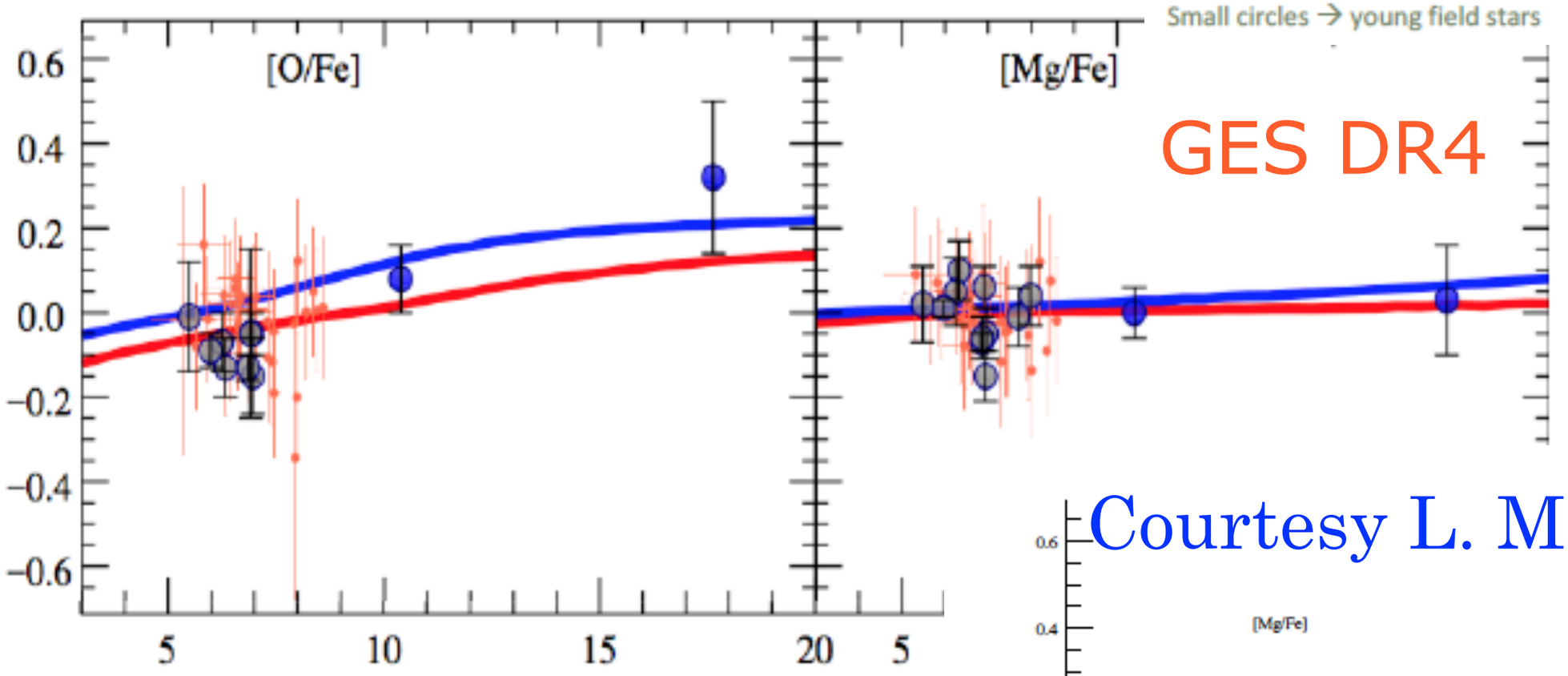




Feuillet et al. (2018) - APOGEE

Individual α elements: O and Mg

Magrini, Randich, et al. (2017) - GES

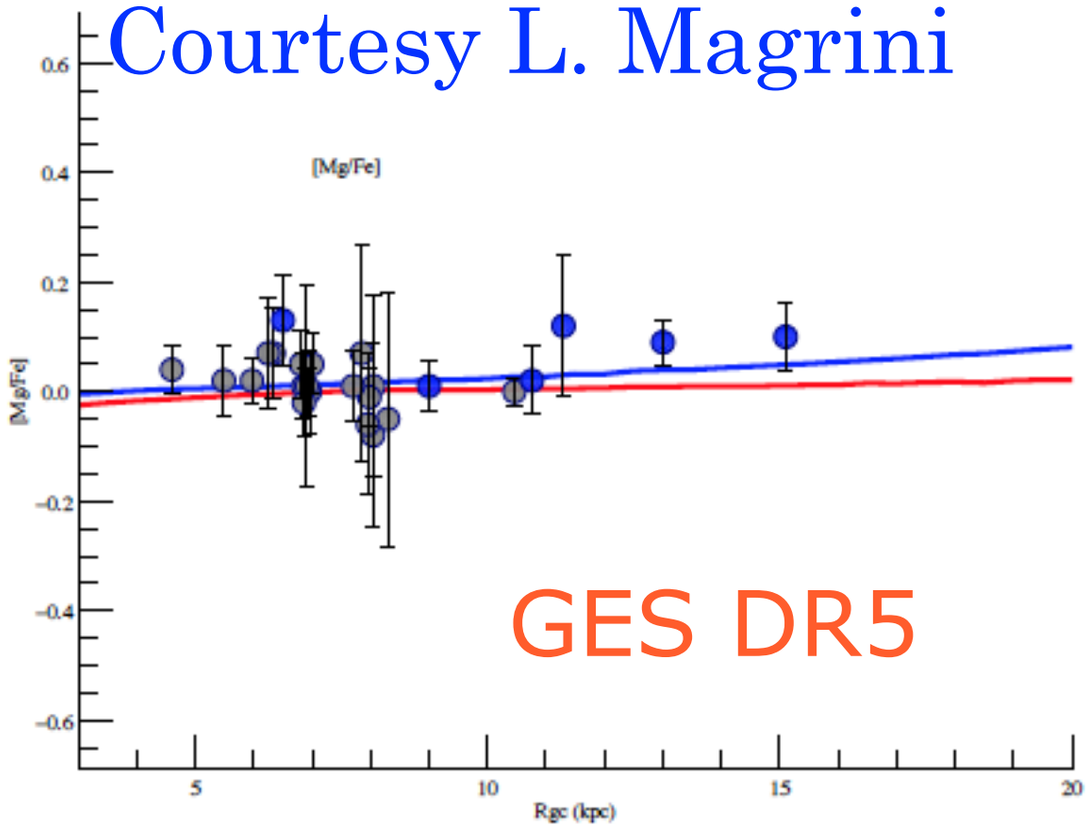


Model by Kubrik+15, with updated stellar yields as in M17
Red → present time
Blue → 5 Gyr ago
Large circles → open clusters (older/younger)
Small circles → young field stars

GES DR4

Oxygen and magnesium are expected to have the same distribution → new models/yields with rotation and metallicity dependence (see Prantzos talk)

Courtesy L. Magrini

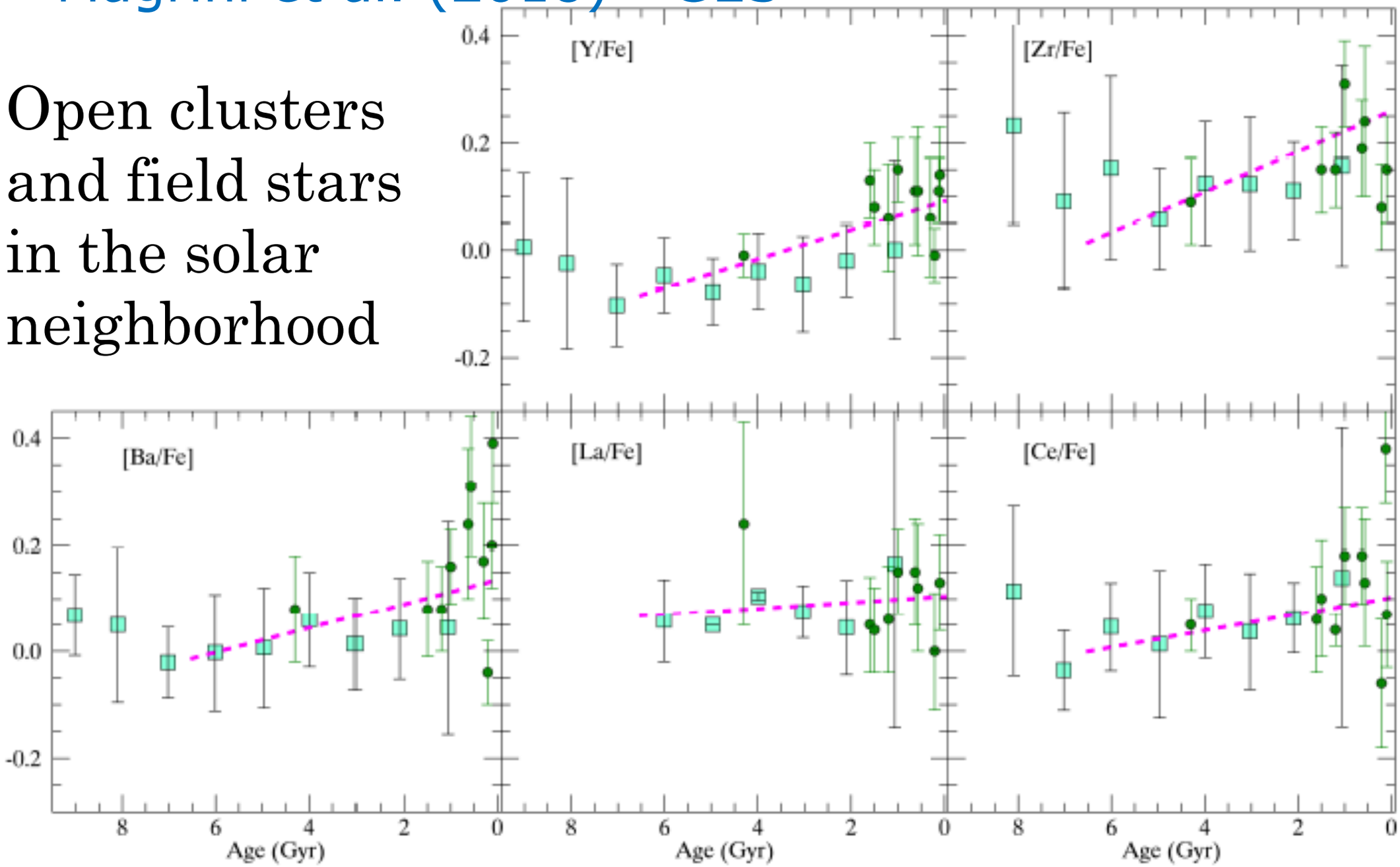


GES DR5

Neutron capture elements

Magrini et al. (2018) - GES

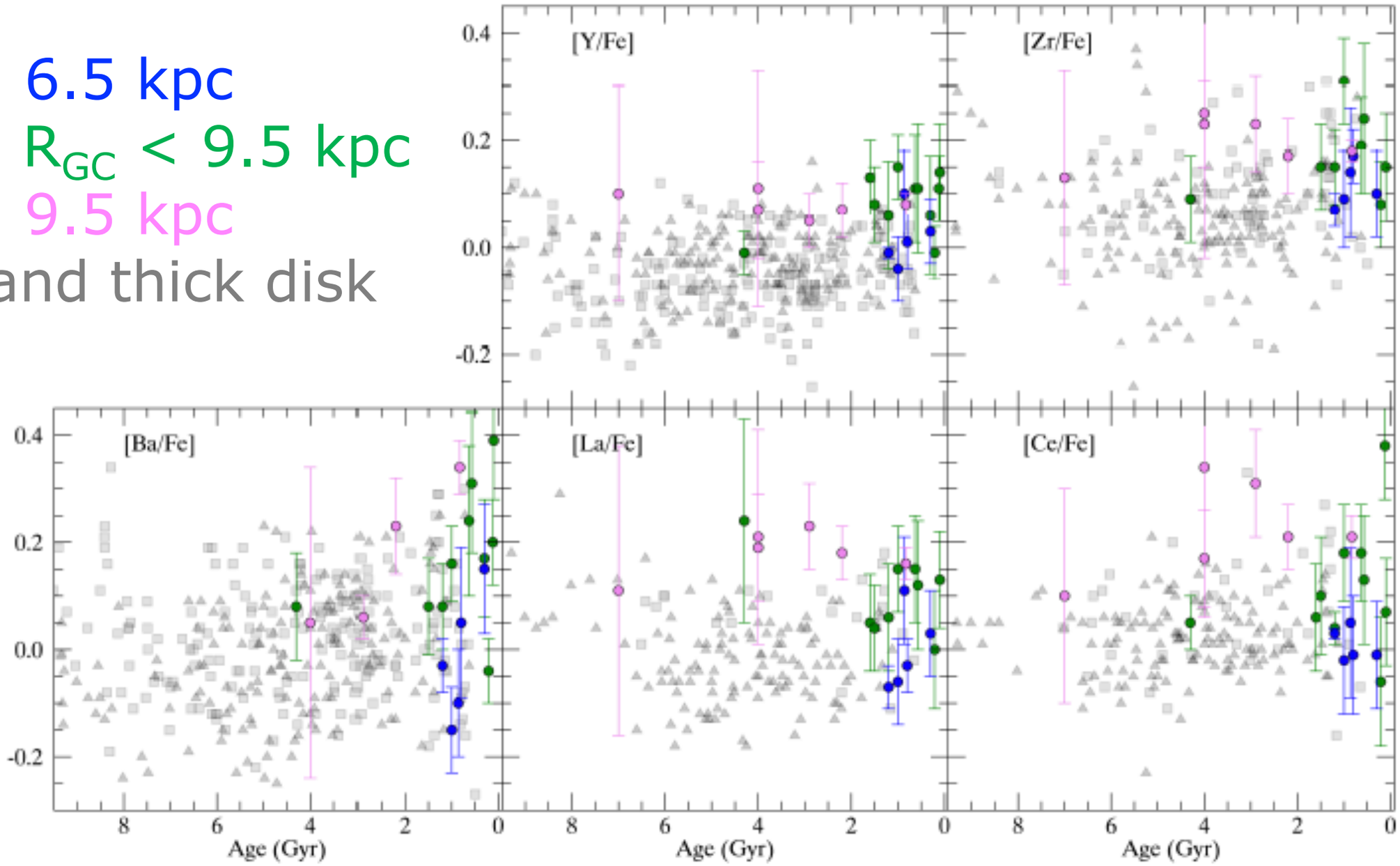
Open clusters and field stars in the solar neighborhood



Maiorca et al. (2011) results confirmed with more solid statistics
Late enrichment due to long-lived low mass stars

Neutron capture elements

R_{GC} < 6.5 kpc
6.5 < R_{GC} < 9.5 kpc
R_{GC} > 9.5 kpc
Thin and thick disk



Dependence on SFH and metallicity

Summary

- Ground based spectroscopic surveys observe a few x 10^5 – 10^6 stars belonging to all populations of the MW
- They provide detailed critical information to complement Gaia astrometry
- While confirming some “known” results, they are revoluzioning our empirical description of the distribution of metals in the MW and their age evolution, opening new questions to be addressed by theoreticians

Stay tuned!

In the next few years new large spectroscopic surveys will start

- WEAVE on WHT: > 10^6 stars LR; > 10^5 stars HR; optical
- 4MOST on 4m: 1-2 x10^7 LR; 1-2 x 10^6 HR; optical
- MOONS on VLT – surveys being defined; LR and HR; NIR
- DESI, 4m Kitt Peak; >10^7 stars; optical