Mapping radial abundance gradients with Gaia-ESO open clusters: Evidence of recent gas accretion in the Milky Way disk

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Introduction

A fundamental constraint to study the formation and chemical evolution of the Galaxy

abundance gradients along the Galactic disk.

The samples used to study the Galactic radial abundance gradient:

a. Open Clusters;
b. Classical Cepheids;
c. field stars with precise stellar ages ;
d. planetary nebulae;
e. young massive O and B stars;
f. HII regions;
……

In order to reproduce the Galactic radial abundance gradient, this paper revises the old chemical evolution model and proposes a new chemical evolution model.

Two-infall model

There-infall model

Sample

1) OCs (open clusters):

The sample of OCs used in this work was the sample of OCs used by Magrini et al. (2023)

These samples provide 25 chemical element abundances for 62 Gaia-ESO OCs older than 100 Myr.

2) Additional data sets:

Gaia-ESO field stars; (About 3,800 were selected)

CCs (classical cepheids);

The sample of CCs used in this work was the sample of CCs used by da Silva et al. (2023)

Model

The basic equation for the chemical evolution of a given element i is:

the abundance fraction in mass of a given element i

SFR

Rate of element i supplied by radial inflow of gas

$$\dot{G}_i(\mathrm{R},t) = -\psi(\mathrm{R},t)\,X_i(\mathrm{R},t) + R_i(\mathrm{R},t) + \dot{G}_{i,inf}(\mathrm{R},t) + \dot{G}_{i,\mathrm{R_f}}$$

The rate at which an element i is removed from the ISM due to star formation

Nucleosynthesis in low and intermediate mass stars, Type Ia and Type II SNe, provides rates of element i.

Rate of element i provided by gas falling

Model

Nucleosynthesis prescriptions:

for LIMS, this work used the yield set from Ventura et al. (2013,2018, 2020)

for massive stars, this work used the stellar yields from Limongi &Chieffi (2018)

for Type Ia SNe, this work adopted the stellar yields from Iwamoto et al. (1999)

stellar radial migration:

This work considers the radial migration of stars in a model given by Frankel et al.(2018)

Model

The two-infall model assumes two consecutive gas accretion episodes feeding the MW disk

This model advantage of the model prescriptions adopted in Palla et al. (2020b) and later revised in da Silva et al. (2023)

	$t_{max,1}$ (Gyr)	τ_1 (Gyr)	τ_2 (Gyr)	ν_1 (Gyr^{-1})	ν_2 (Gyr^{-1})	Σ_1	Σ_2	v_{flows} (km s^{-1})
2INF	3.25	1	1.033×R(kpc)−1.26	2	5 (4 kpc) - 0.4 (>12 kpc)	$\propto e^{-R/2.3}$	$\propto e^{-R/3.5}$	-1

The there-infall model assumes three consecutive gas accretion episodes feeding the MW disk

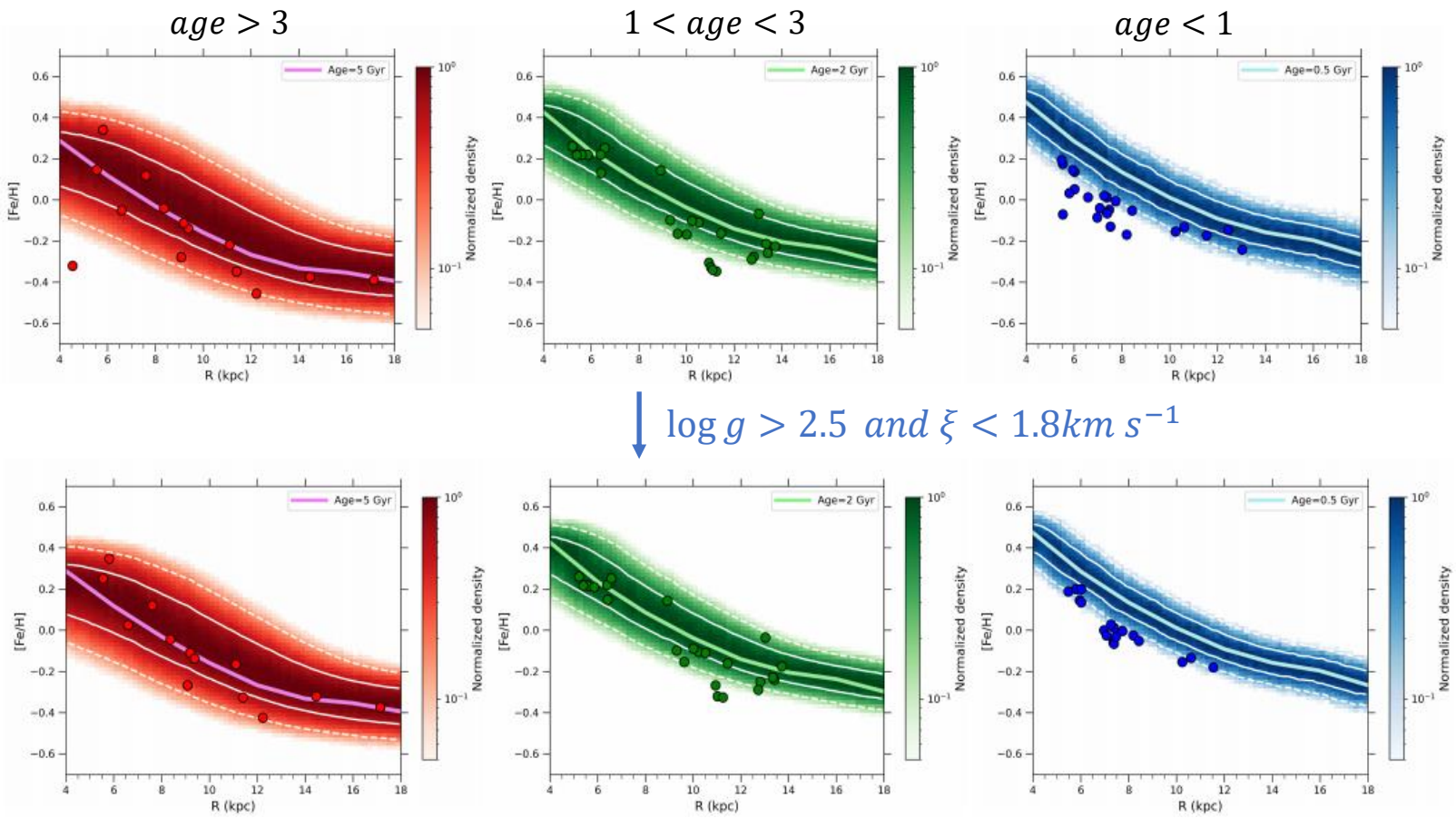
This model adds a third gas falling event to the two-infall model.

	$t_{max,2}$ (Gyr)	τ_3 (Gyr)	ν_3	Σ_2/Σ_3
3INF-1	11	0.15	$(1/3)\times\nu_2$	2.33
3INF-2	11	1	$(2/3)\times\nu_2$	10(4 kpc)-3.5(>12 kpc)

This model considers two different third gas accretion events: **Stronger and milder gas accretion**

Results

two-infall model

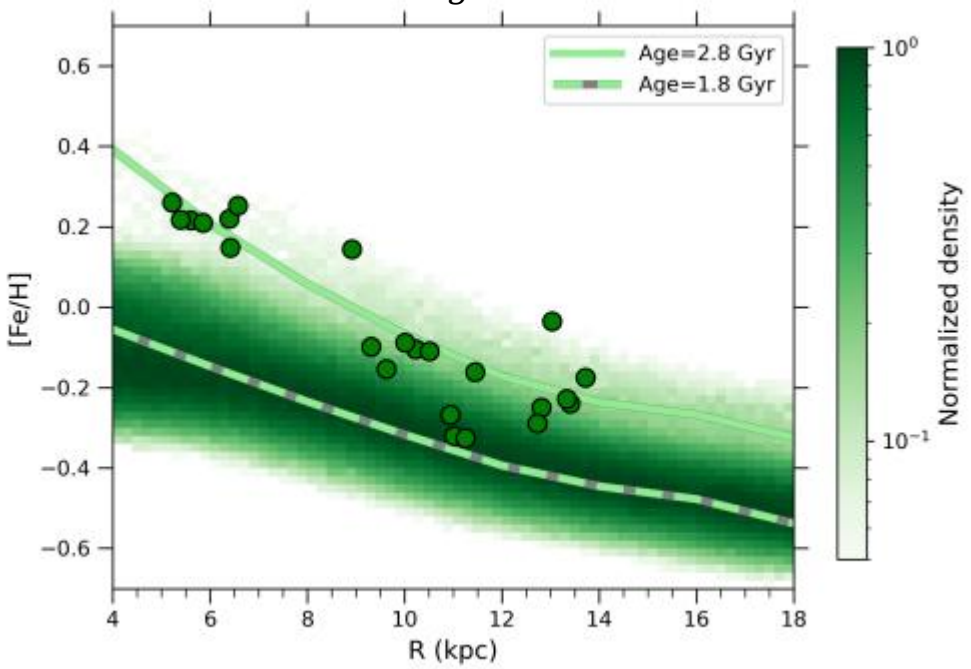


- **Filled circles** are the OC sample.
- **Density plots** show the normalized density (in log scale) of stars as predicted by the model in given Galactocentric bin of 0.2 kpc width.
- **White contour lines** show the limits within are contained the 68% (solid) and the 95% (dashed) of the predicted stellar distribution in a given radial bin.
- **Solid lines** show the results for the [Fe/H] gradient as predicted by the genuine chemical tracks

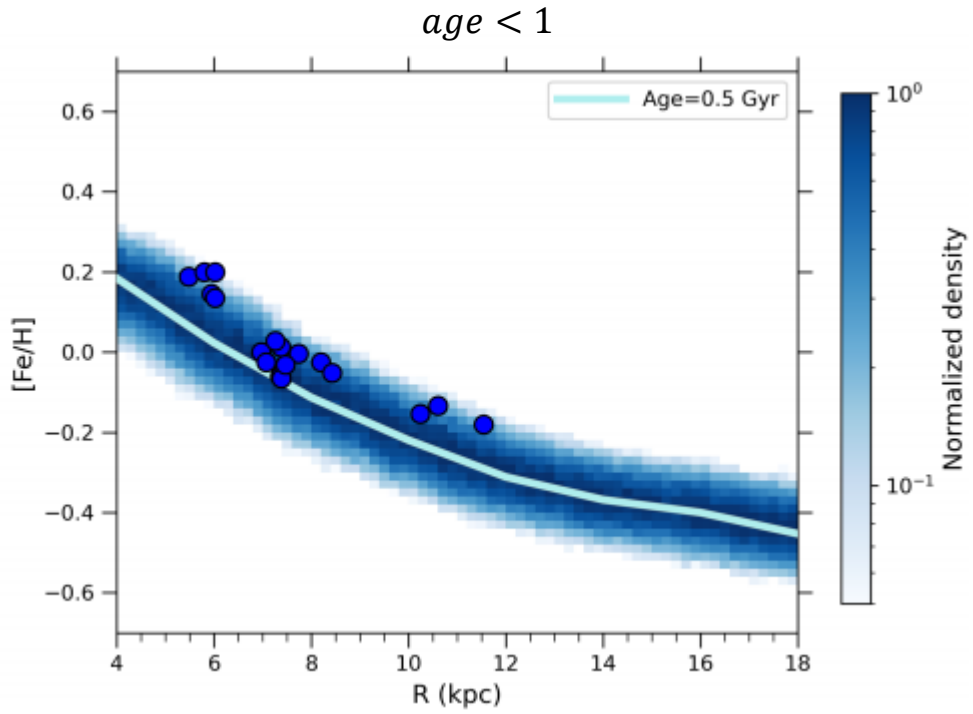
Results

three-infall model — 3INF-1

$1 < age < 3$

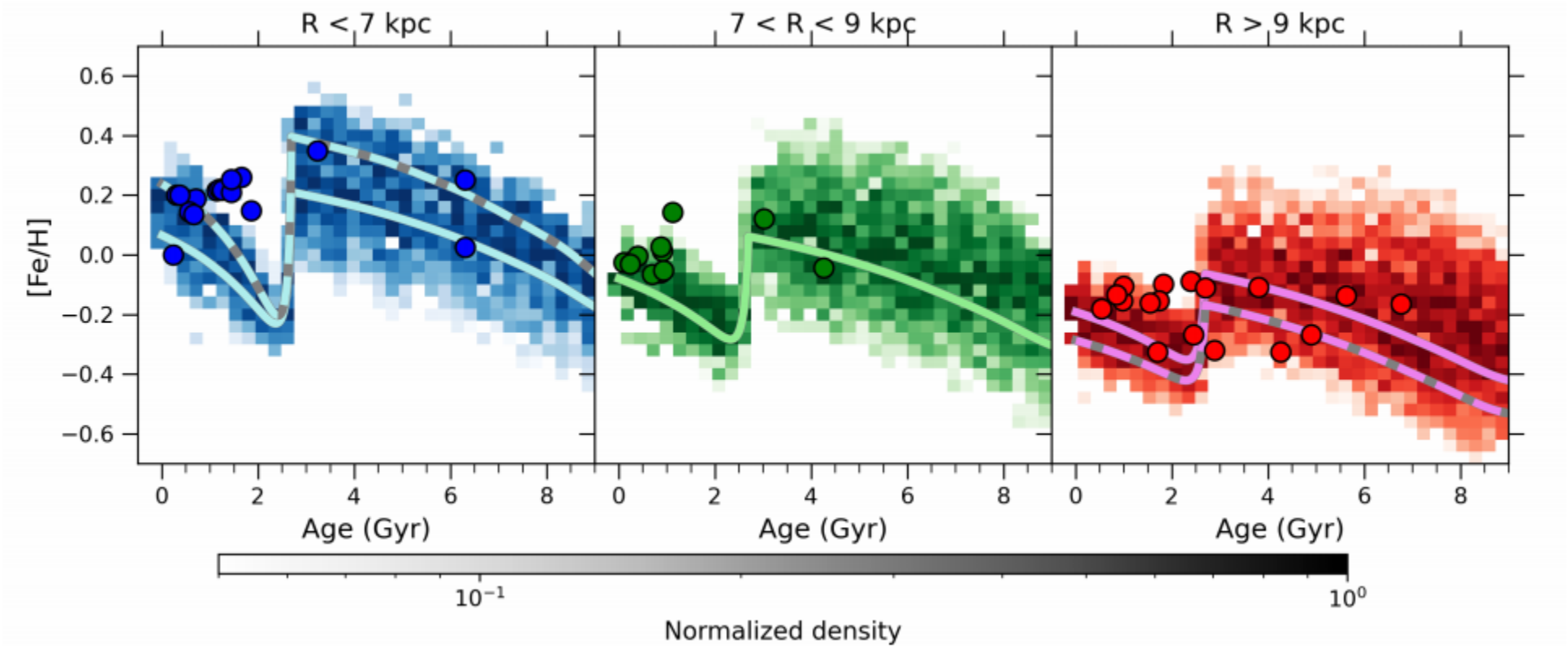


$age < 1$



Results

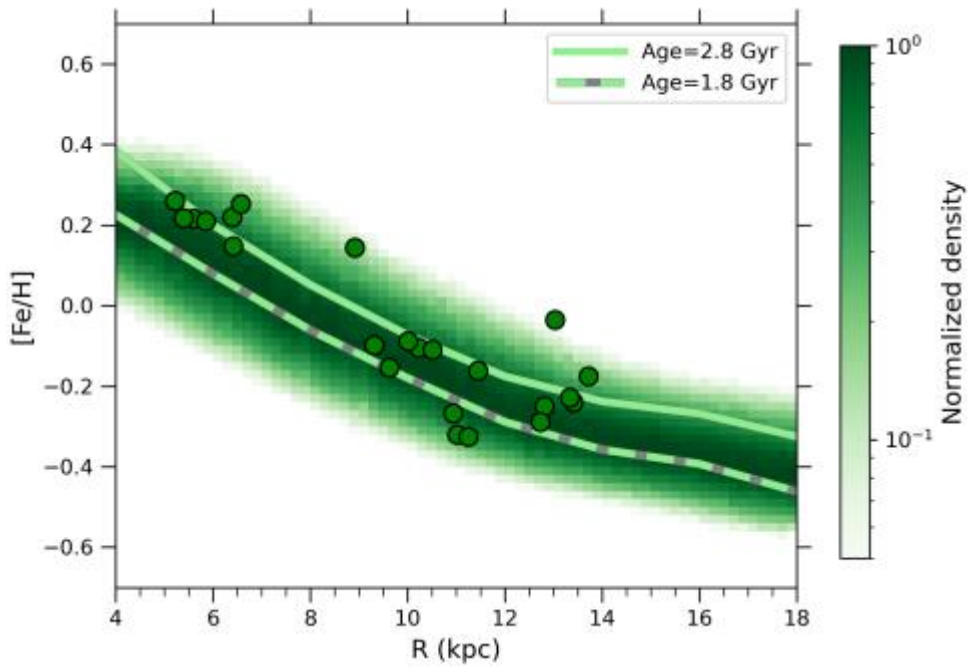
three-infall model — 3INF-1

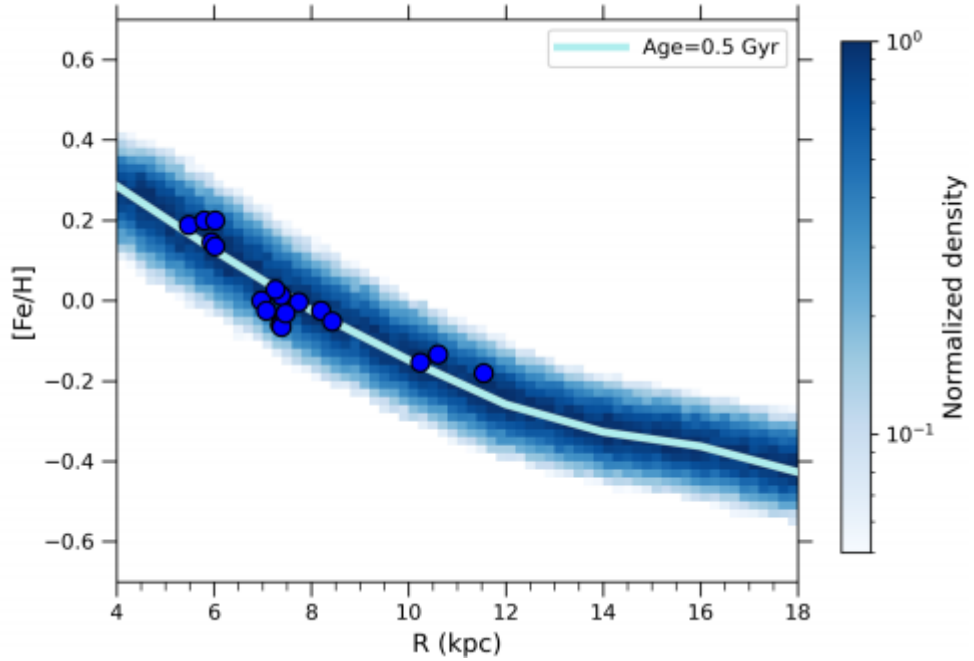


- **Density plot** show the normalized density of stars (in log scale) as predicted by the model in a given age bin of 0.25 Gyr width.
- **Lines** are genuine chemical tracks at 6, 8 and 10 kpc (solid) and 4 and 12 kpc (dashed).

Results

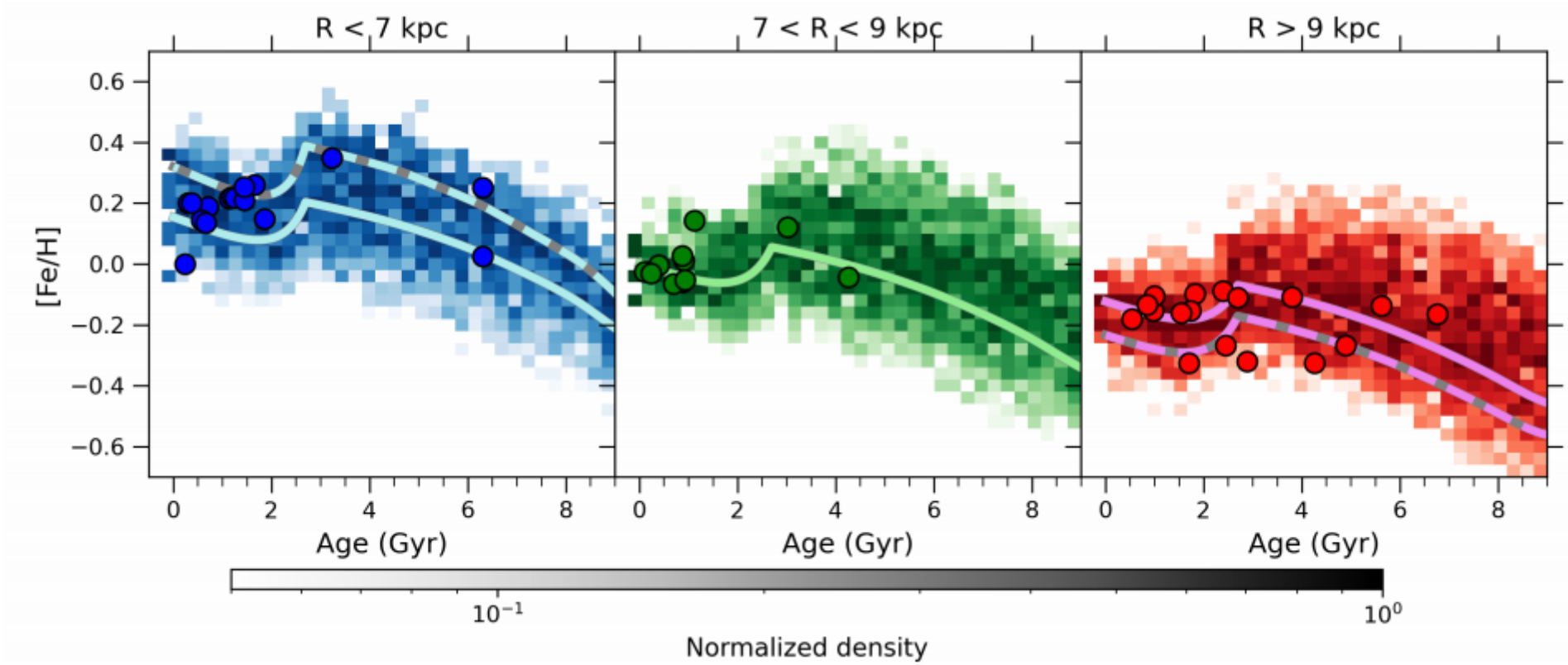
three-infall model —— 3INF-2





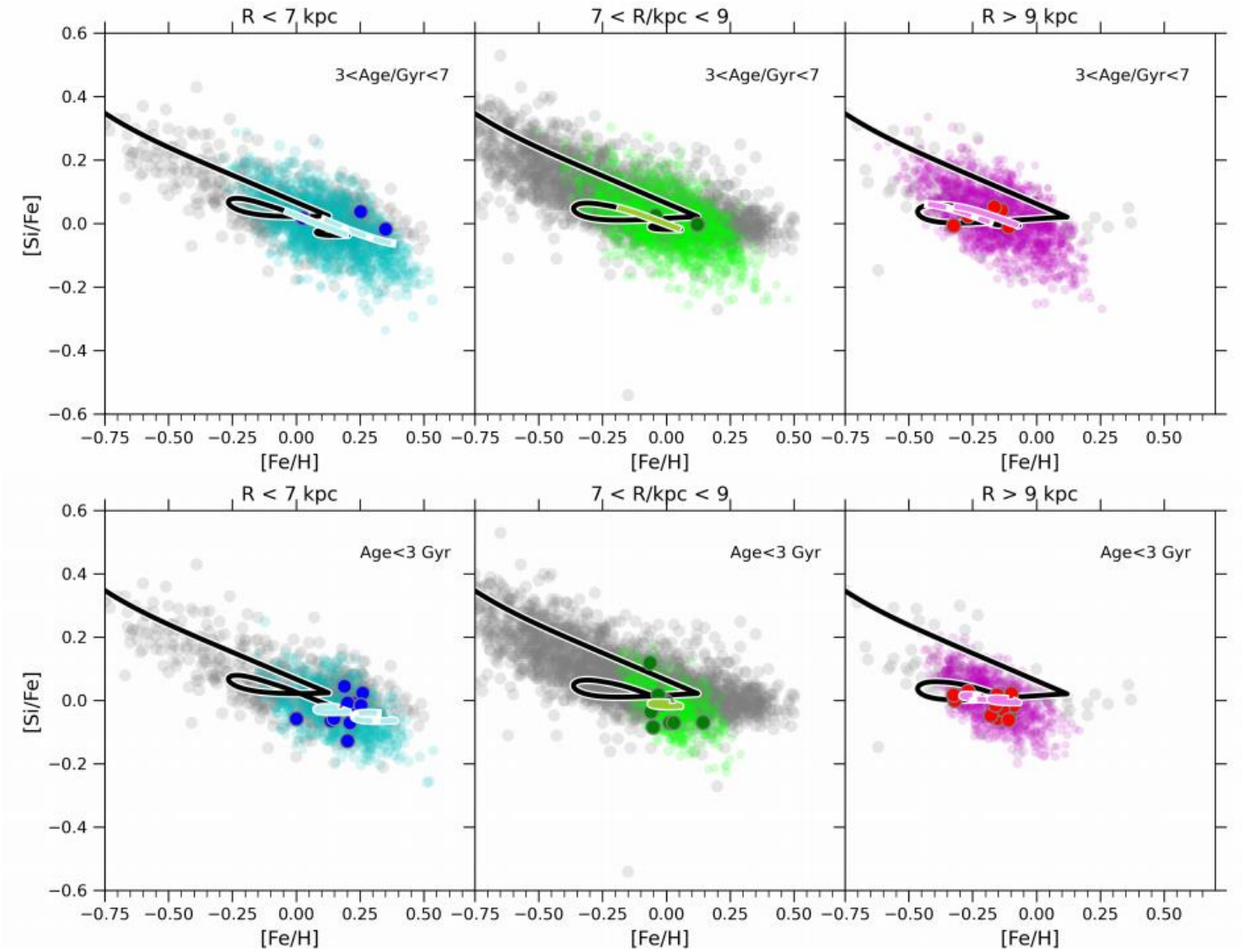
Results

three-infall model —— 3INF-2



Results

three-infall model — 3INF-2



- **The shaded cyan, light green and magenta areas** are the model prediction in a certain radial range.
- **Solid lines** represent genuine chemical evolution tracks at 6, 8 and 10 kpc and are colored in the age range considered in the respective panel.
- **Colored dashed** lines are the same as colored solid lines but for the radii of 4 kpc (left panels) and 12 kpc (right panel).
- **Colored filled circles** represent the sample within OCs.
- **Grey points** are selected field stars.

Conclusion

- This work excluded stars whose spectral analysis can generate metallicity bias. This choice reduces the trends between stellar parameters and metallicity within the same cluster. But this solution does not solve the problem of analyzing massive and/or low-gravity giants.
- The radial metallicity gradient as traced by young OCs is overestimated by the predictions of the two-infall scenario, even by accounting for the effect of stellar migration in the model.
- This work propose that a late gas accretion episode triggering a metal dilution should have taken place, and the first time they extend the three infall scenario to the whole MW disk
- This work invoke a milder metal dilution for this late gas infall episode. The model better explains the sample.

Thanks