The radial metallicity gradient as traced by open clusters

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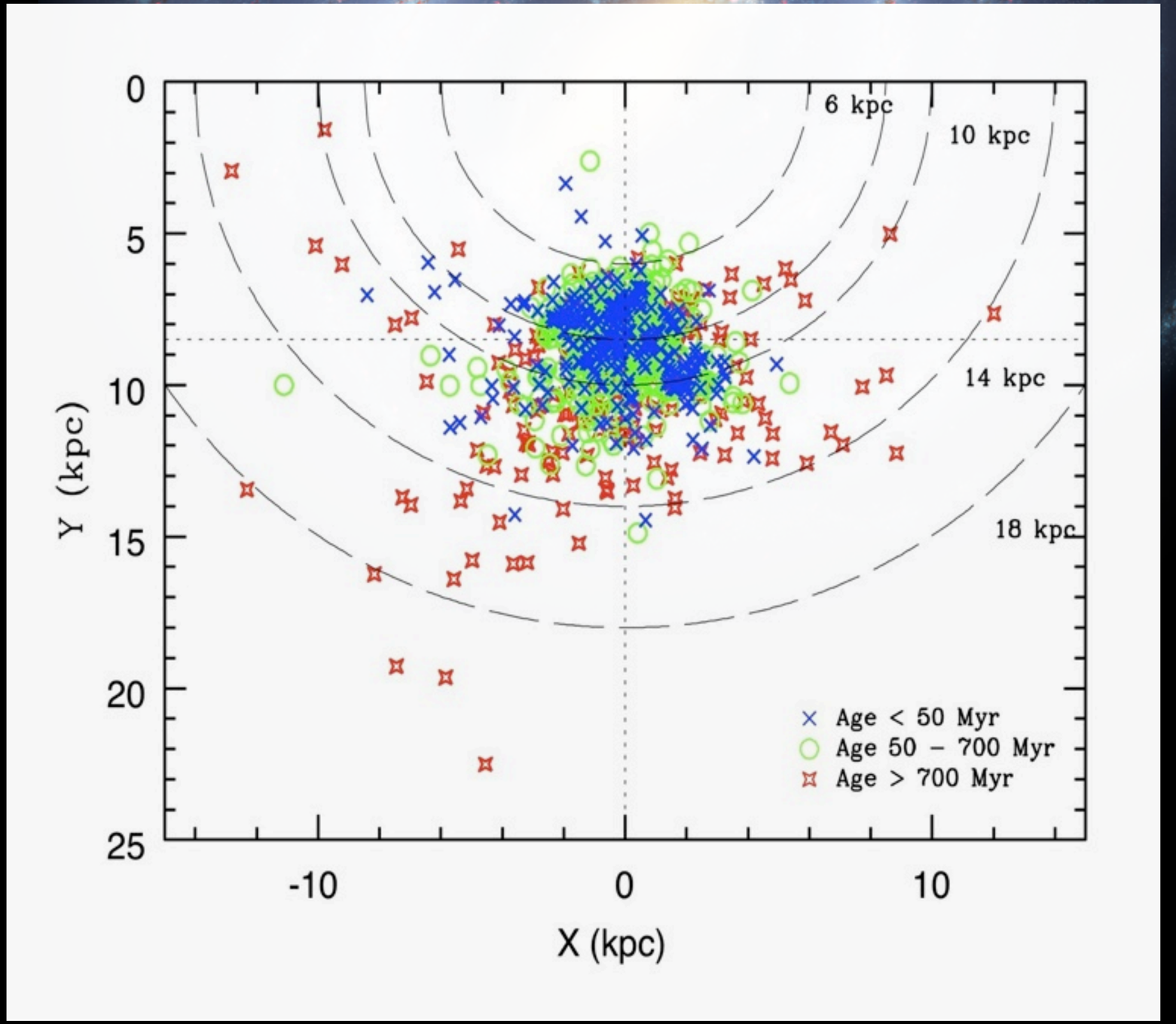
Open cluster spatial distributions



Clusters in Dias catalog with ages and distances (1118)

Open cluster spatial distributions

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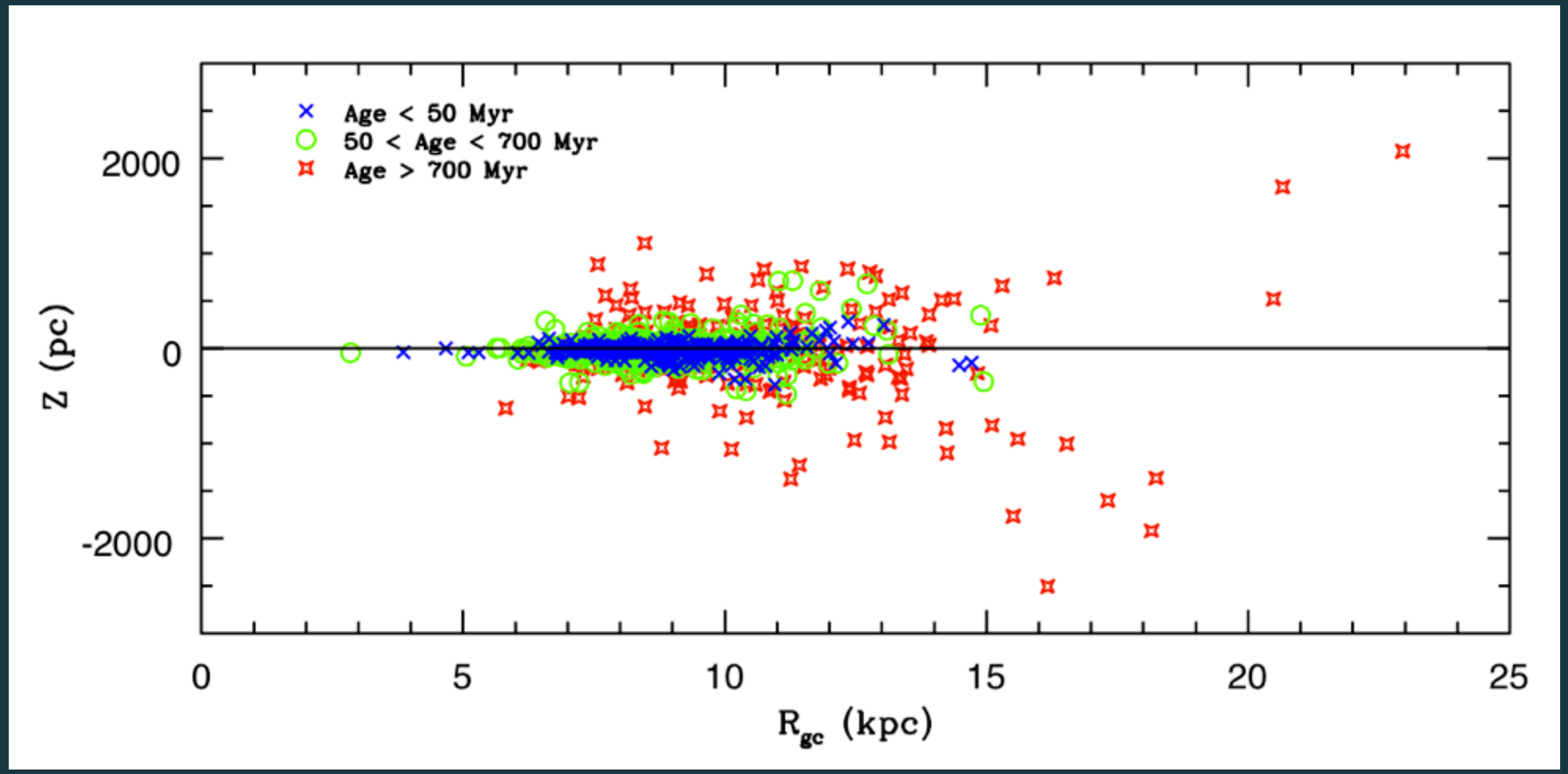


Open cluster age distribution

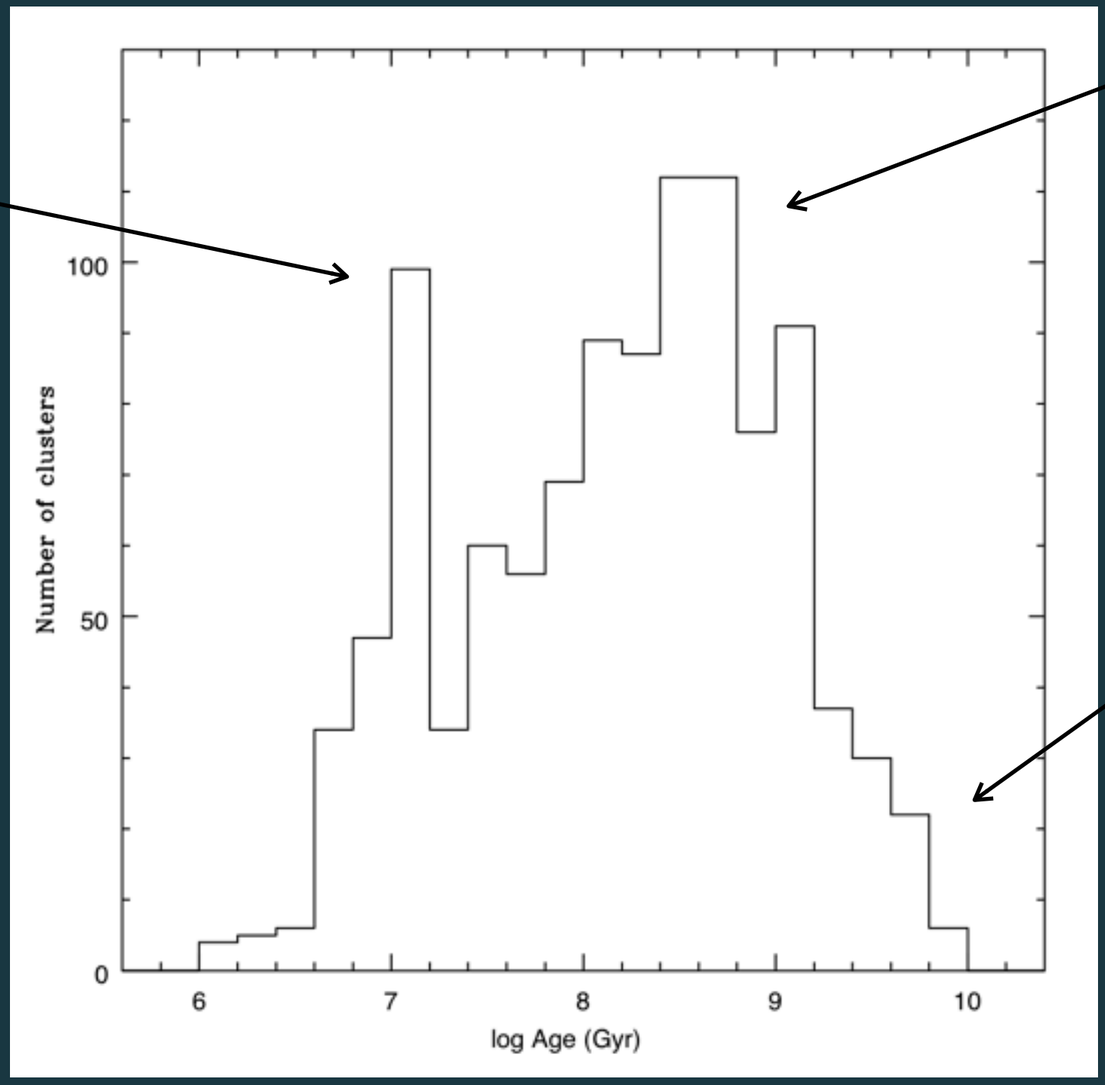
Clusters in Dias catalog with ages and distances (1118)

10 Myr | 100 Myr | 1 Gyr | 10 Gyr

Associations, unbound ~10 Myr

‘Typical’ open cluster ~ 300 Myr

Tail of old open clusters > 1 Gyr



Open clusters serve as probes of the conditions of the Milky Way Galaxy at all ages and a wide range of locations in the disk.

What do they tell us about the metallicity gradient and its evolution over time?

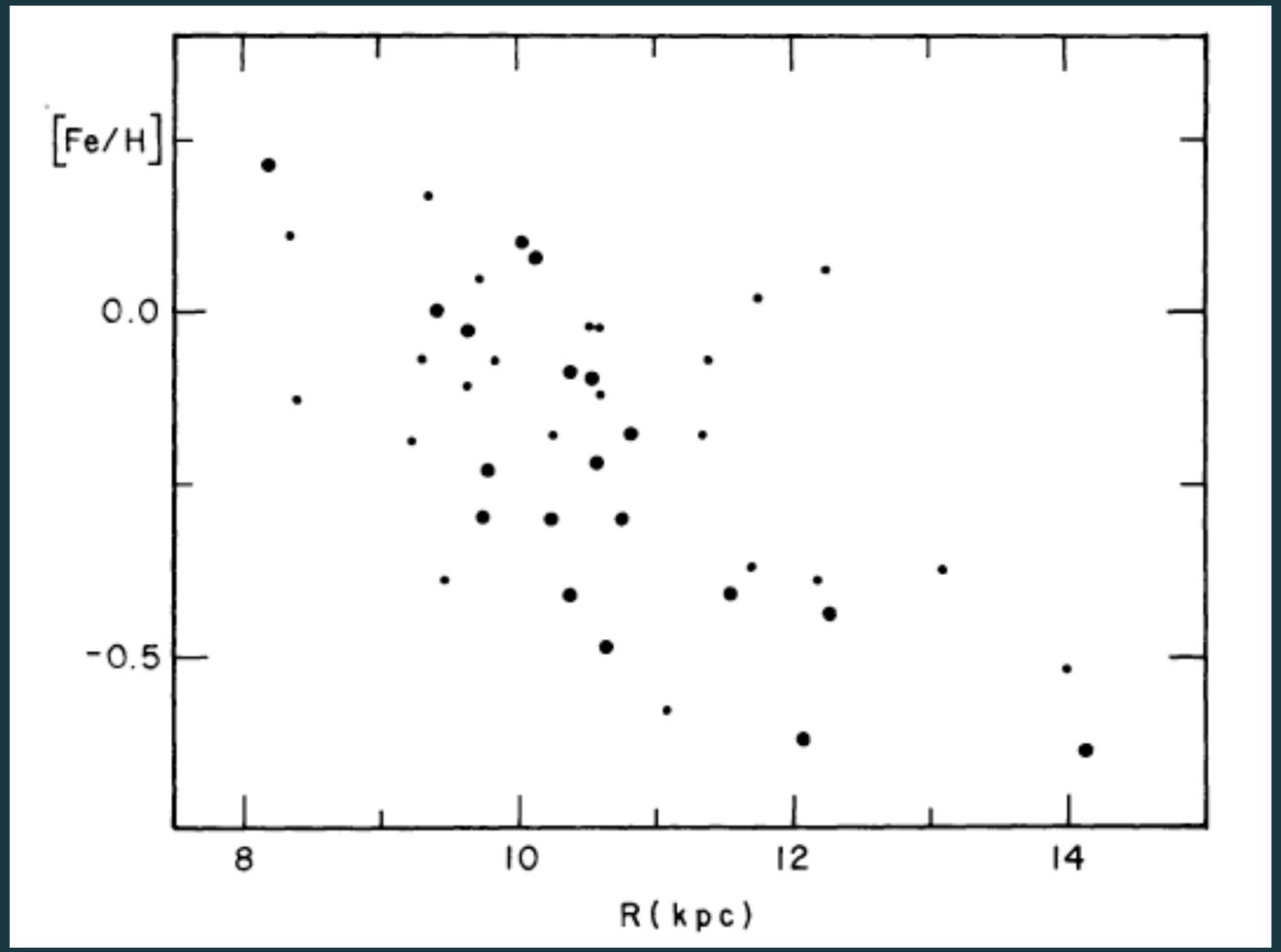
Janes 1979

Janes 1979

- Metallicity based on DDO and UBV photometry of 41 clusters.

(with $R_\odot$ = 10 kpc, over 6 kpc)

d[Fe/H]/dR = -0.05 ± 0.01 dex/kpc

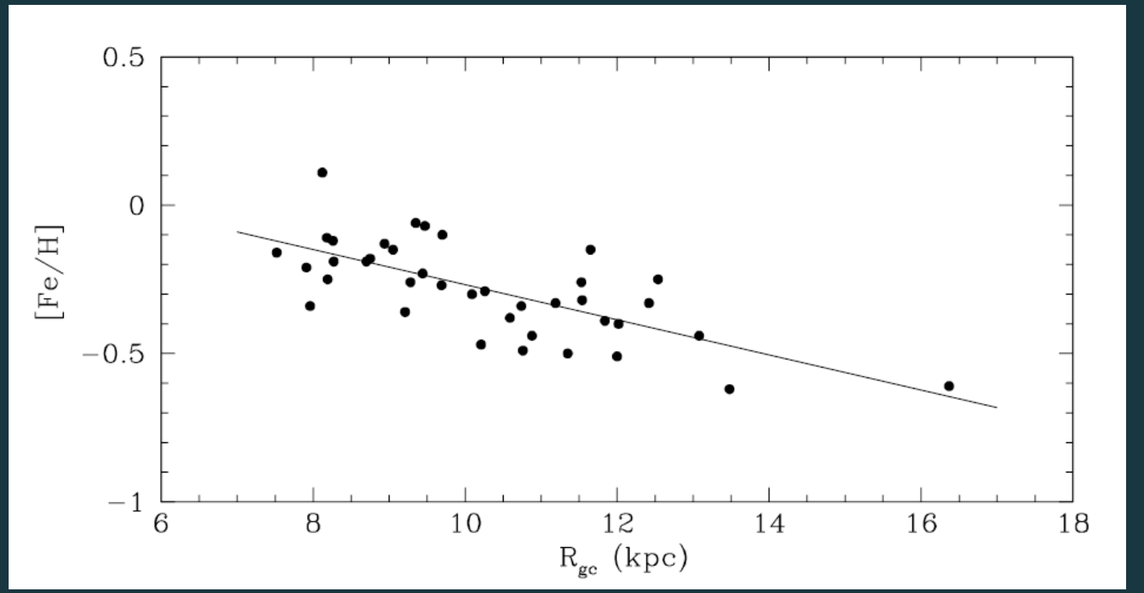


Spectroscopic samples (low resolution)

- advantages of membership information from radial velocities (459 stars, 39 clusters)

d[Fe/H]/dR = -0.06 ± 0.01 dex/kpc

Friel et al 2002



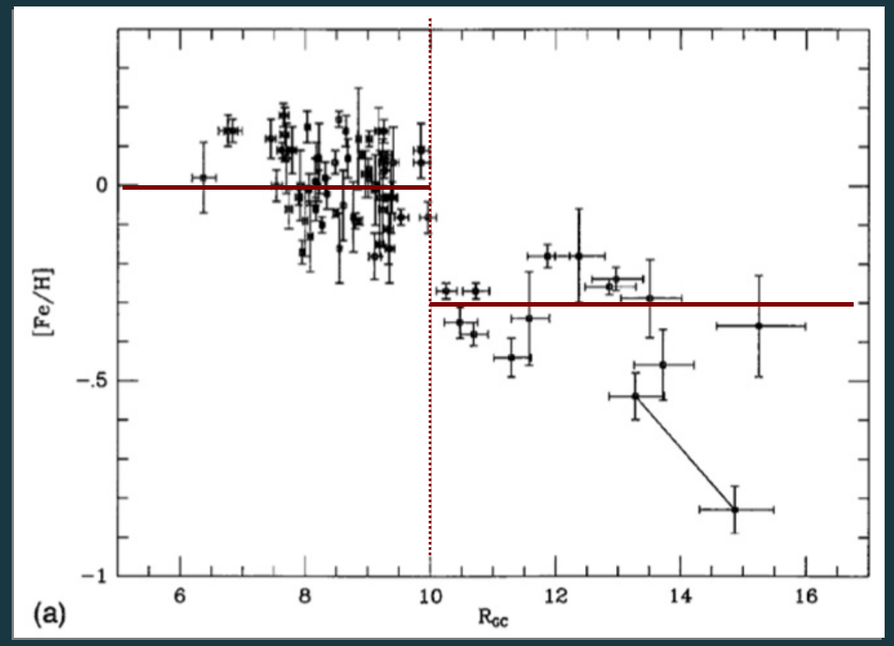
Combined photometric and spectroscopic samples

No smooth gradient, but discontinuity at R=10 kpc (with $R_\odot$ = 8.5 kpc)

[Fe/H] ~ 0 inside R_{gc}=10 kpc

[Fe/H] ~ -0.3 outside R_{gc} ~ 10 kpc

Twarog et al 1997



Since ~ 2004 activity in many areas:

- discovery and study of some very distant clusters (R_{gc} ~ 20 kpc)

- numerous high resolution studies provided elemental abundances, not just overall metallicity

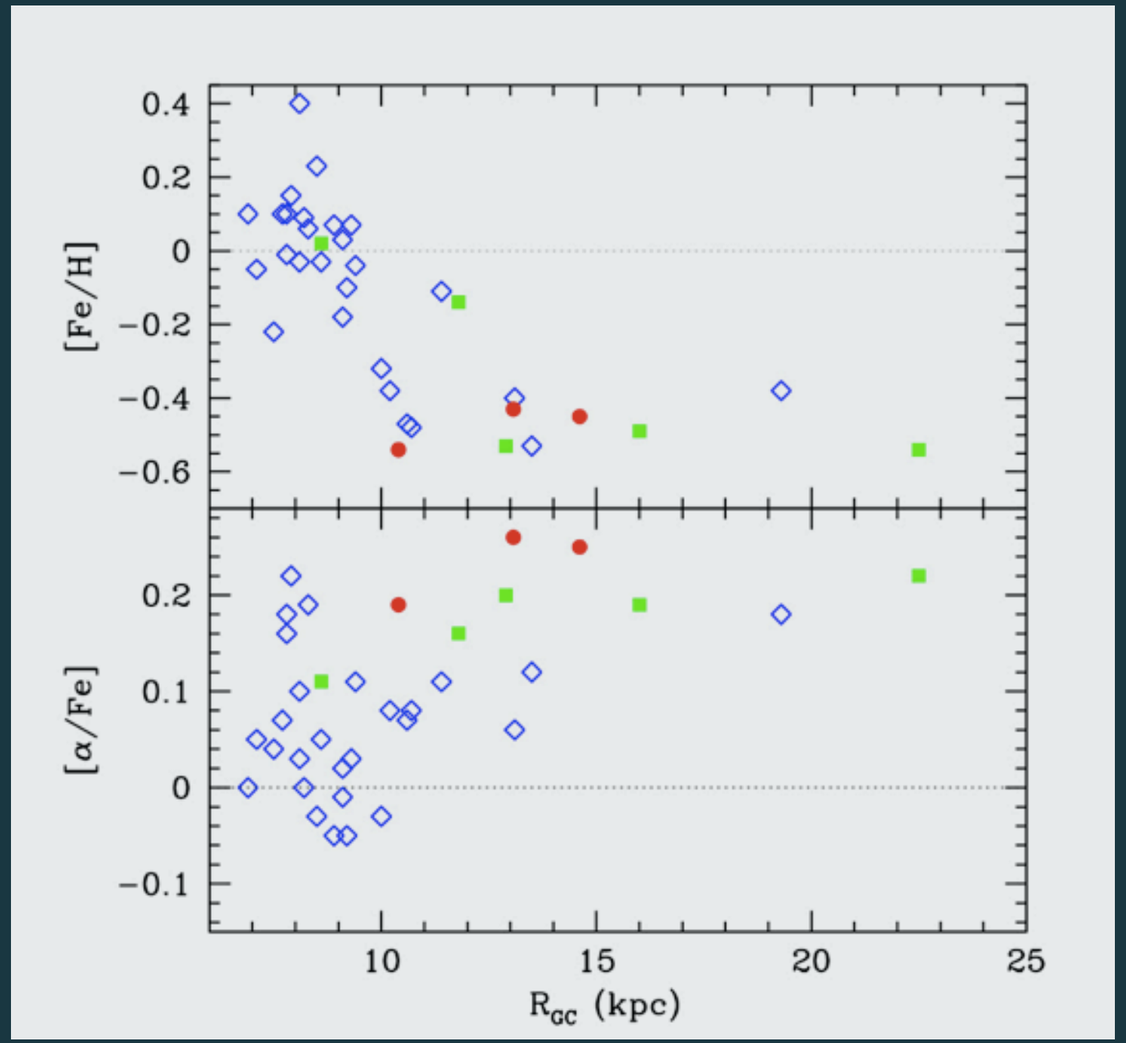
- recognition of the importance of large samples and uniform analysis techniques.

Abundance gradient from open clusters

Yong et al. 2005,
Carraro et al, 2004 –
new outer disk clusters

The metallicity gradient flattens in the outer regions.

Does [α/Fe] rise at the same time?

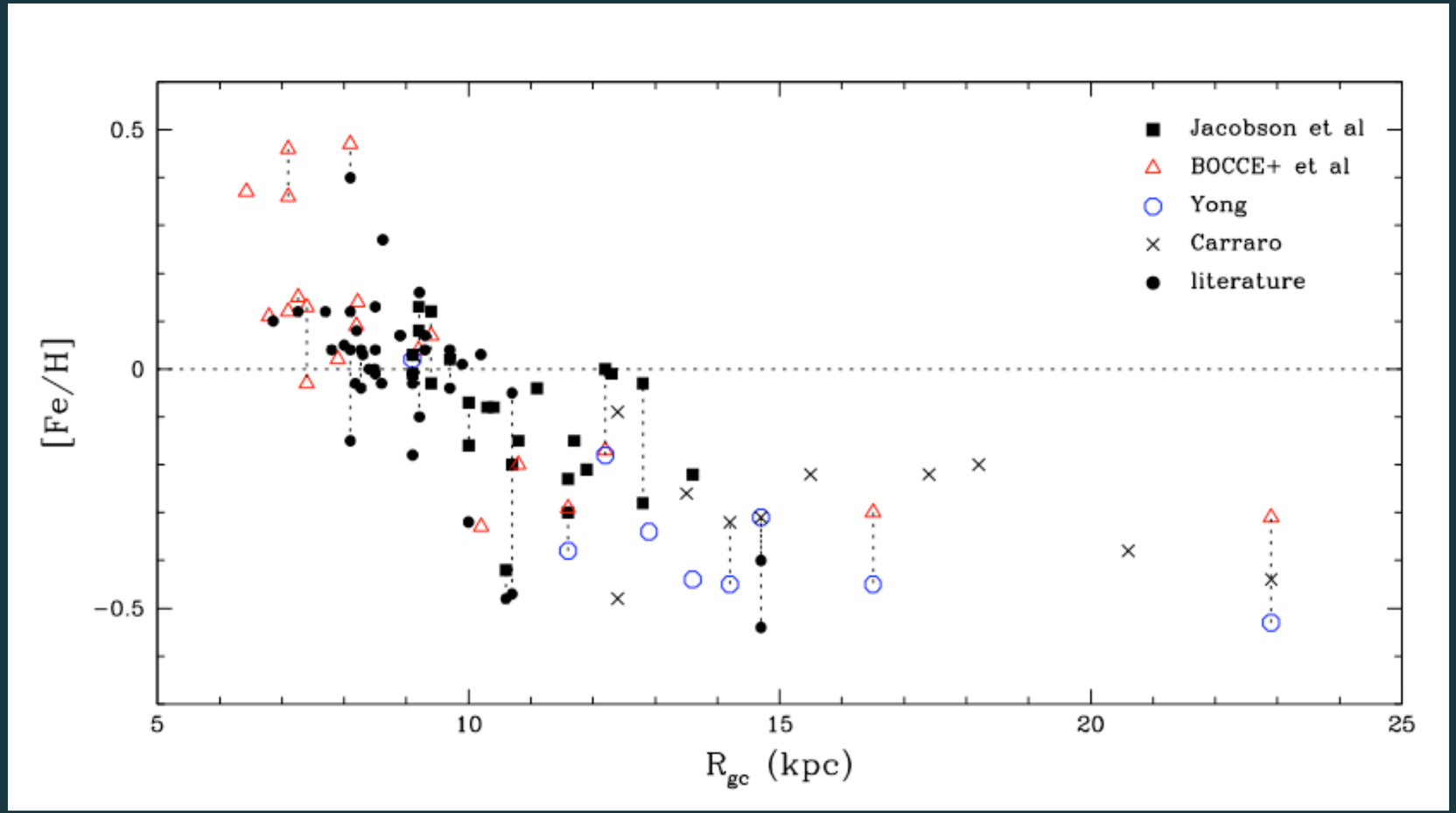


Yong et al. 2005, AJ

Abundance gradient from high resolution studies

Compilation of literature values, limited to high resolution studies

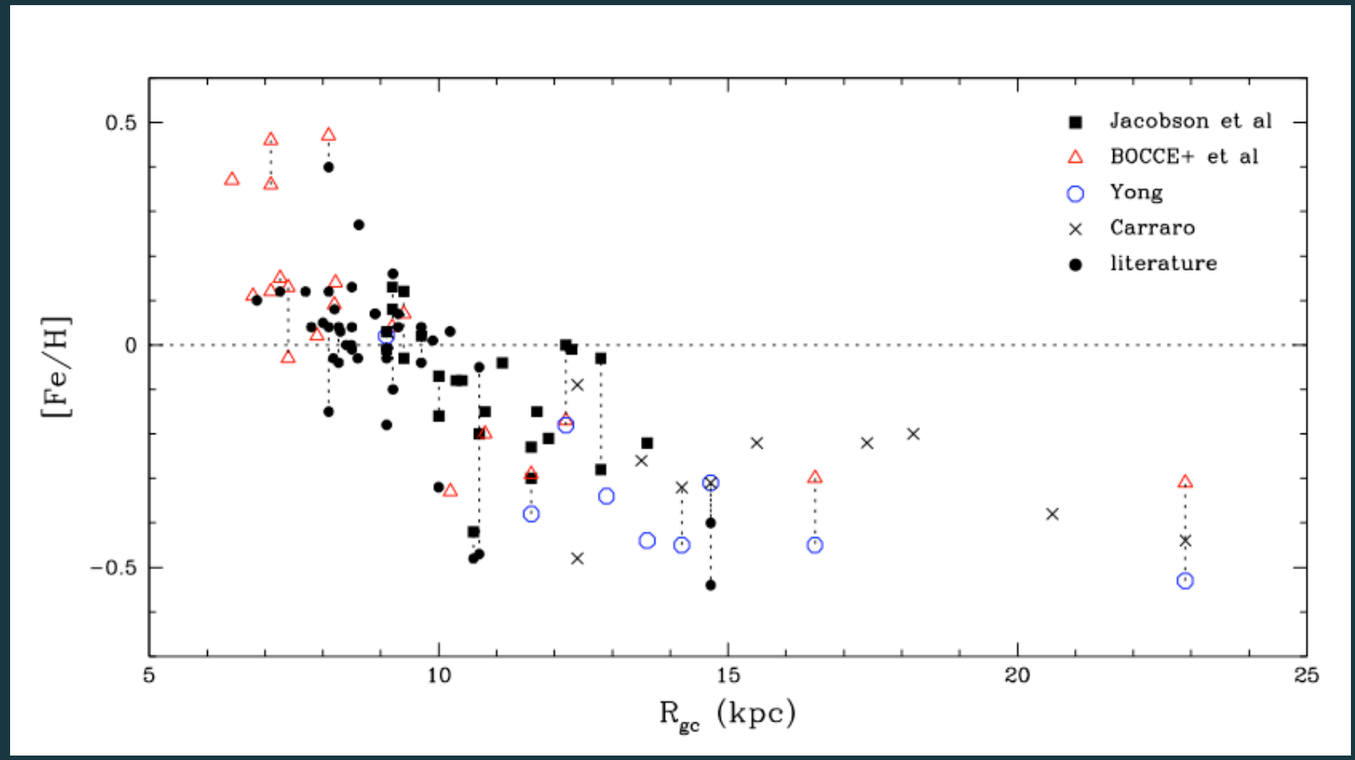
74 clusters
104 measurements
(dotted lines join values for the same cluster)



Sestito et al 2008; Magrini et al 2009; Jacobson et al 2011; Pancino et al 2011; Yong et al 2012

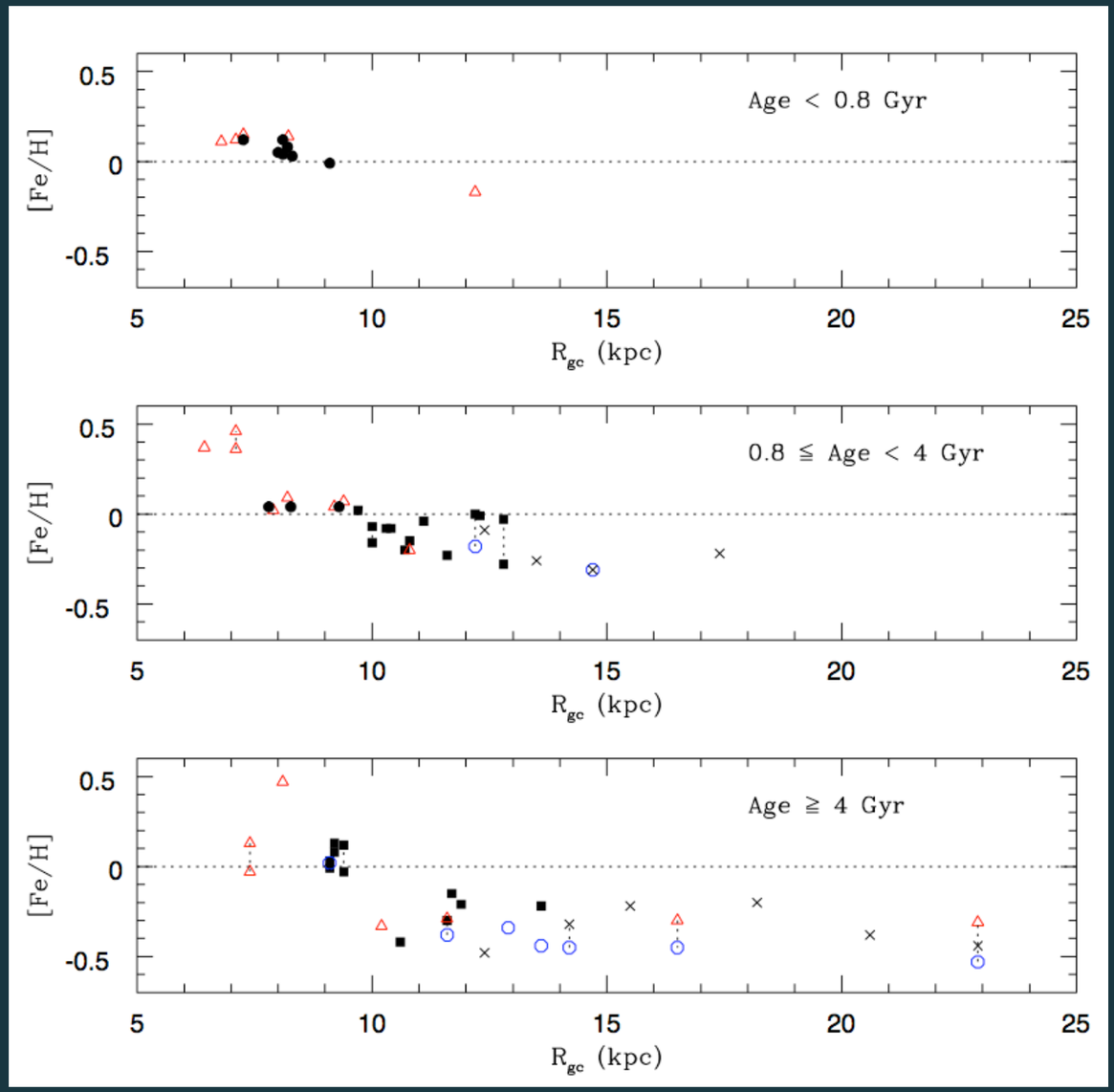
Some observations

- Decreasing metallicity to Galactocentric radii of ~ 10–12 kpc.
- Plateau at metallicity [Fe/H] ~ –0.3 to –0.5 in outer disk extending as far as we can probe.
- Wide dispersion in metallicity at any Galactocentric distance.
- The outer disk looks different.



Does the gradient change with age?

- Suggestions that younger clusters follow a shallower gradient in the solar neighborhood
  - d[Fe/H]/dR = −0.06 for < 0.8 Gyr
  - d[Fe/H]/dR = −0.15 for > 4 Gyr
  - But slope is sensitive to distance range fit, especially at intermediate ages
- Does the transition to the outer disk plateau move outward with time?



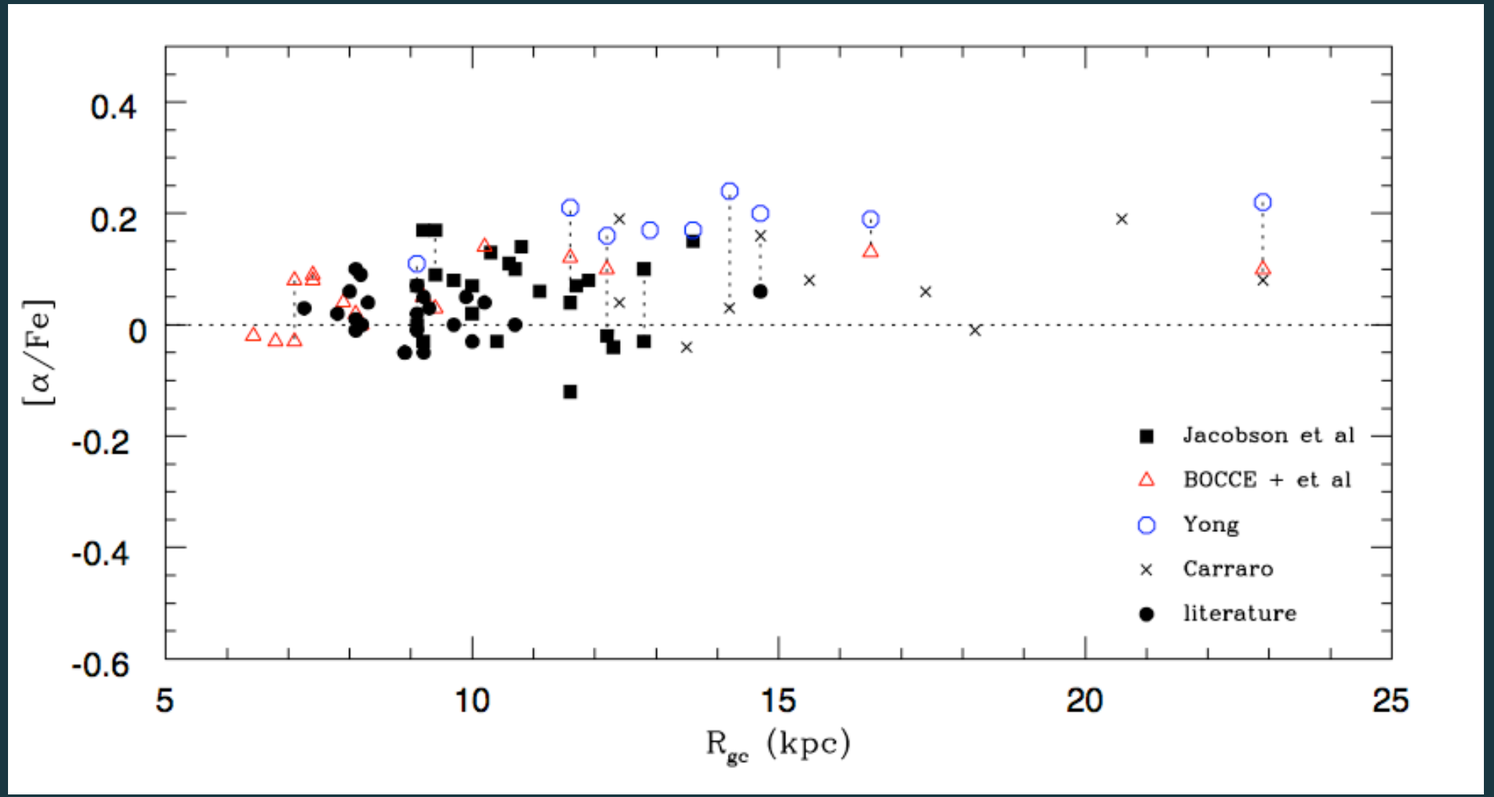
After Magrini et al 2009; Jacobson et al, 2011; Andreuzzi et al, 2011

Gradients in α-elements

Evidence for [α/Fe] enhancement in the outer disk?

Conclusions vary by author.

Dominated by potential systematic differences between studies....



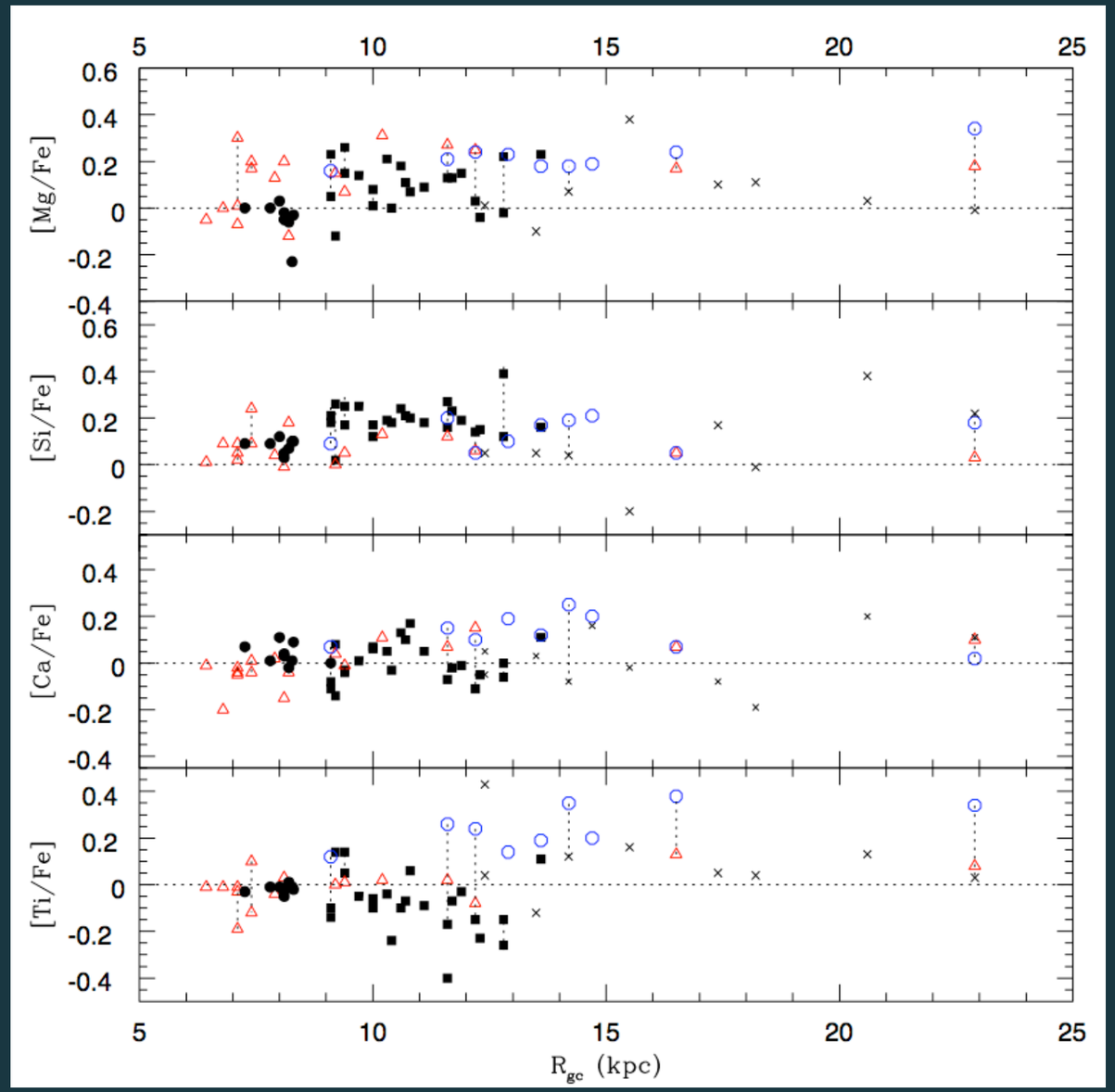
Gradients in α-elements

Not all α-elements behave similarly.

Maybe in [Mg/Fe], [Ti/Fe]?
Not in [Si/Fe], [Ca/Fe]?

Dispersions vary with element

Systematic differences an issue



Summary

- Abundance gradient decreases from R_{gc} ~6 to 10 kpc in the solar neighborhood, but levels off to a plateau at R_{gc} ~ 10–12 kpc
    - Gradient in solar neighborhood shallower for younger clusters
    - Transition point perhaps dependent on age?
- [α/Fe] overall shows no strong dependence on distance, but conclusions vary with individual element and with data set

Some Issues and Observations

We may be at the limit of what current data can tell us until we deal with several issues:

- Systematic differences between studies –
  - Can't quantify dispersions or detailed distributions when we have 0.1 to 0.2 dex offsets from study to study (especially for interpreting α-abundances)
  - They are not due to a single easily identified (and corrected) cause.

- Need large, uniformly analyzed samples and/or careful treatment to homogenize existing samples
  - Improving the internal precision with more closely differential studies
  - Look to upcoming surveys Gaia-ESO, APOGEE, ...