The metallicity distribution of the Galactic bulge

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The metallicity distribution in the Milky Way discs
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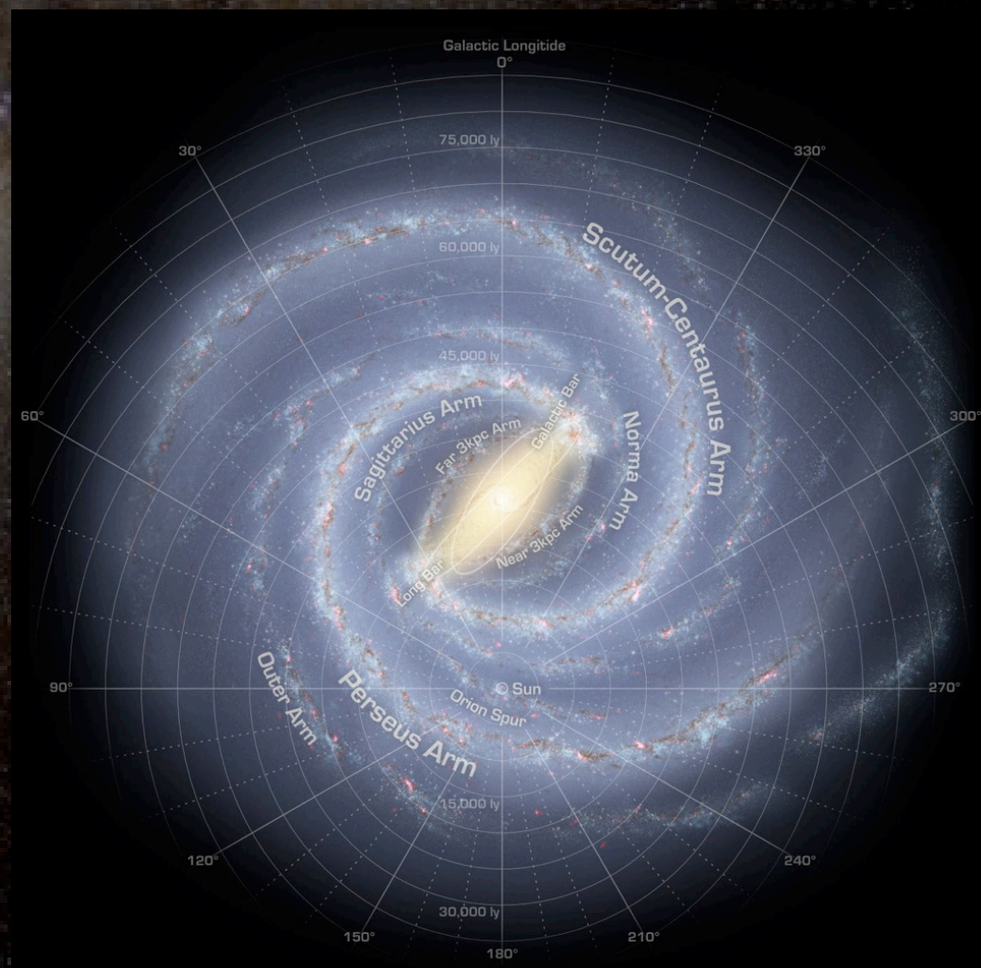
The Bulge-disk connection

- Red clump stars trace an inclined bar, 25 deg towards positive long.

- Boxy morphology, as expected from buckling instabilities of a bar (evidence of being X-shaped!)

- Bars are disk phenomena, should we observe the same populations?

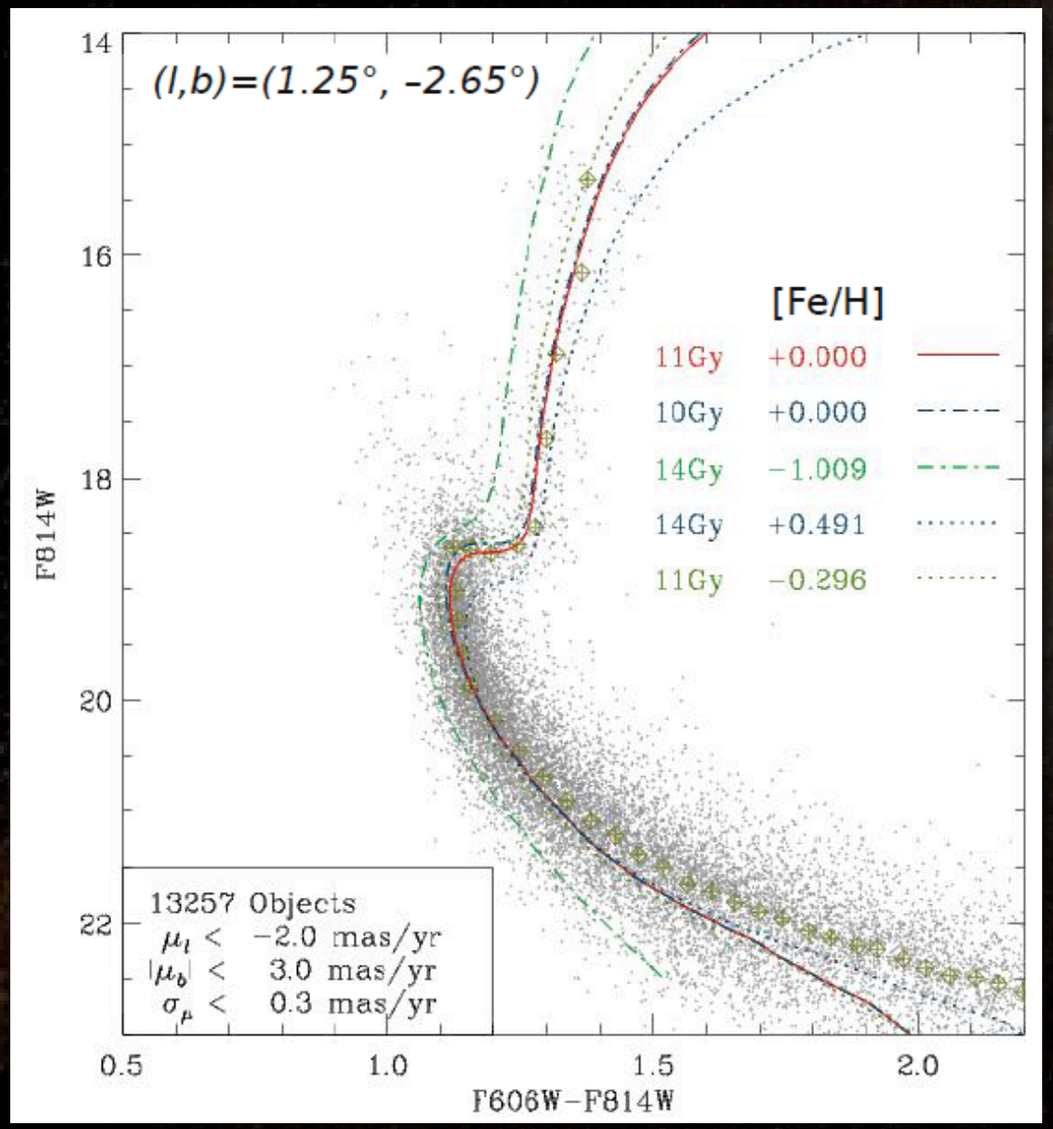
- Maybe there is also a “classical” spheroidal component?



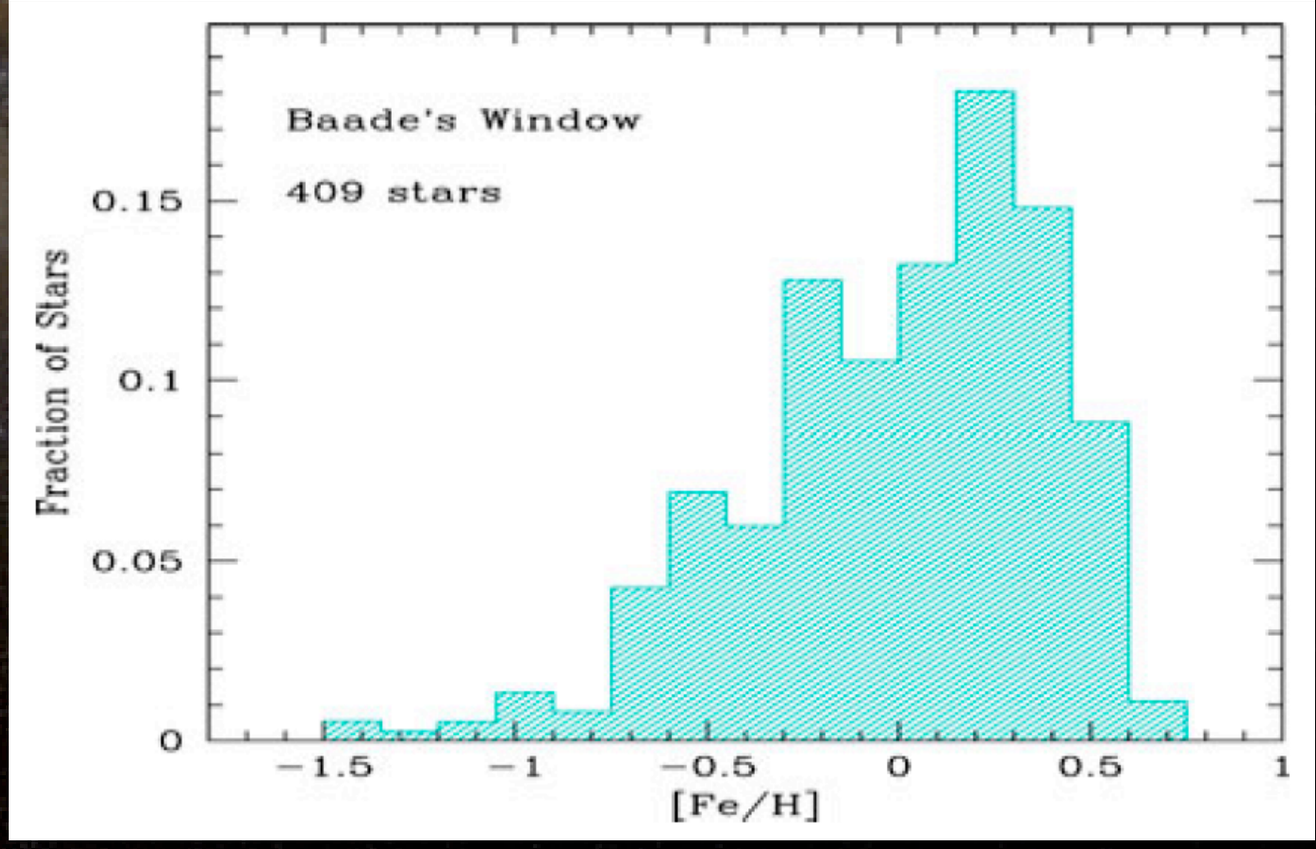
The simple view...

- The bulge is old and metal-rich

Turn off color-magnitude diagram from Clarkson et al. 2010



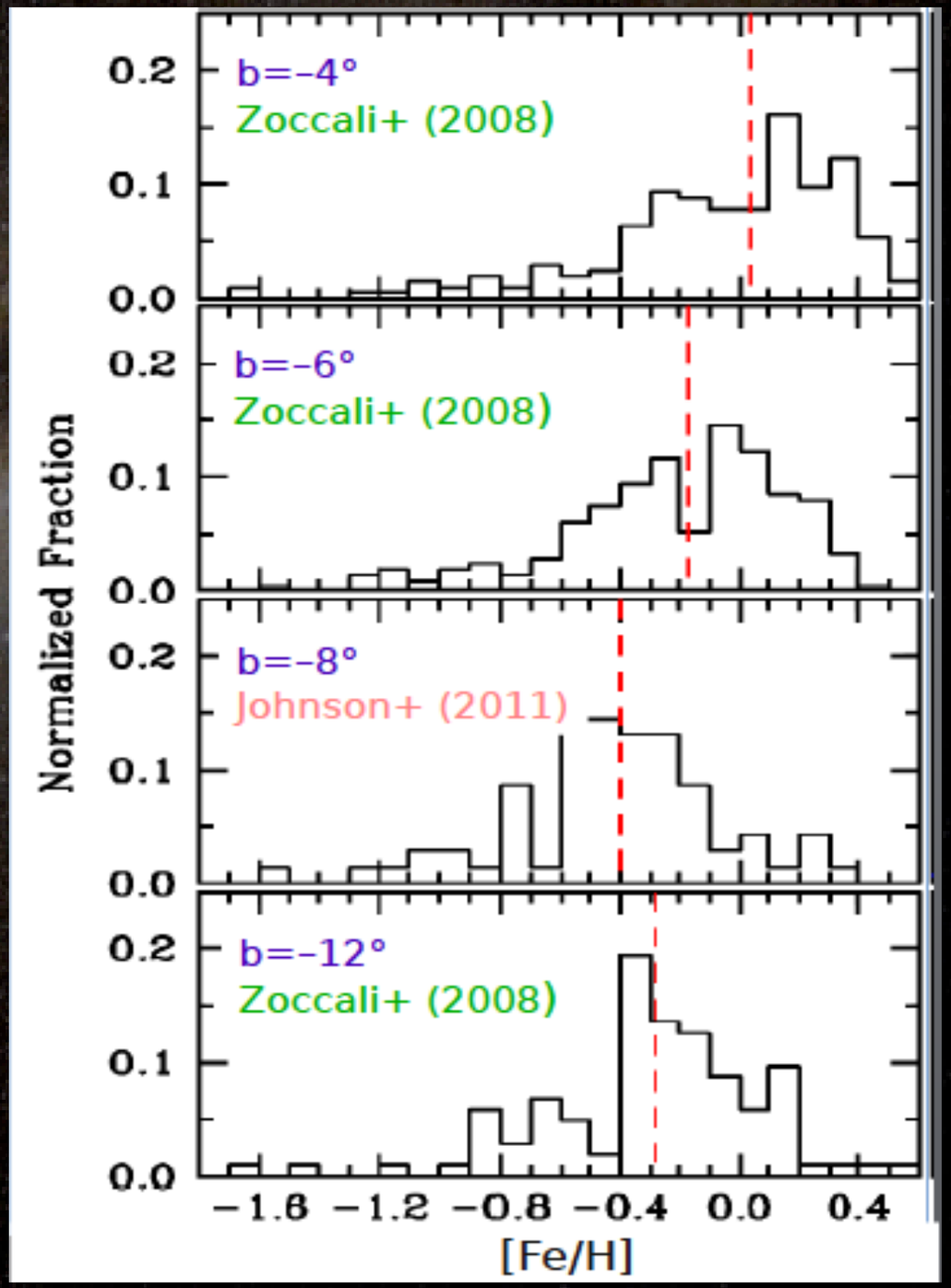
High-resolution spectroscopic metallicity distribution from Zoccali et al. 2008



more fields: [Fe/H] gradient

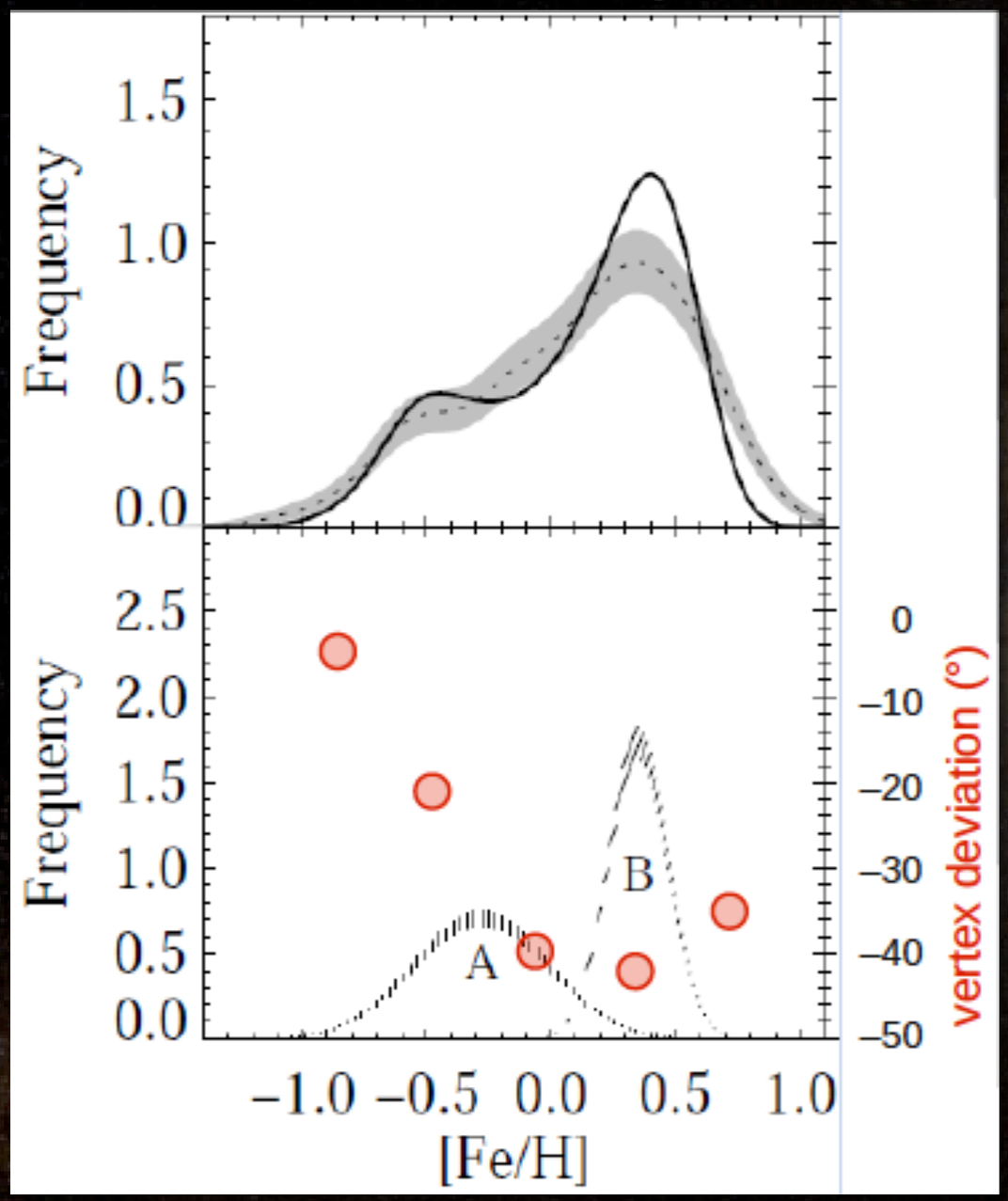
- The bulge is old and metal-rich
- AND it has a minor axis metallicity gradient
  - *Expected view of a merger-build bulge*
  - *Are these gradients possible in boxy-bulges (thickened bars)?*

Minor axis metallicity distributions
from Zoccali+ 2008 and Johnson+ 2011



Two bulge populations?

Error deconvolved metallicity distribution for b=-4
from Hill et al. 2011



Vertex deviation from the velocity ellipsoid for b=-4
from Babusiaux et al. 2010

- Metallicity distribution in Baade's window
  - *Consistent with two component gaussian distributions*
- Components A (metal-poor) and B (metal-rich) have different kinematics
  - A *spheroidal kinematics*
  - B *Bar-like kinematics*

Two bulge populations?

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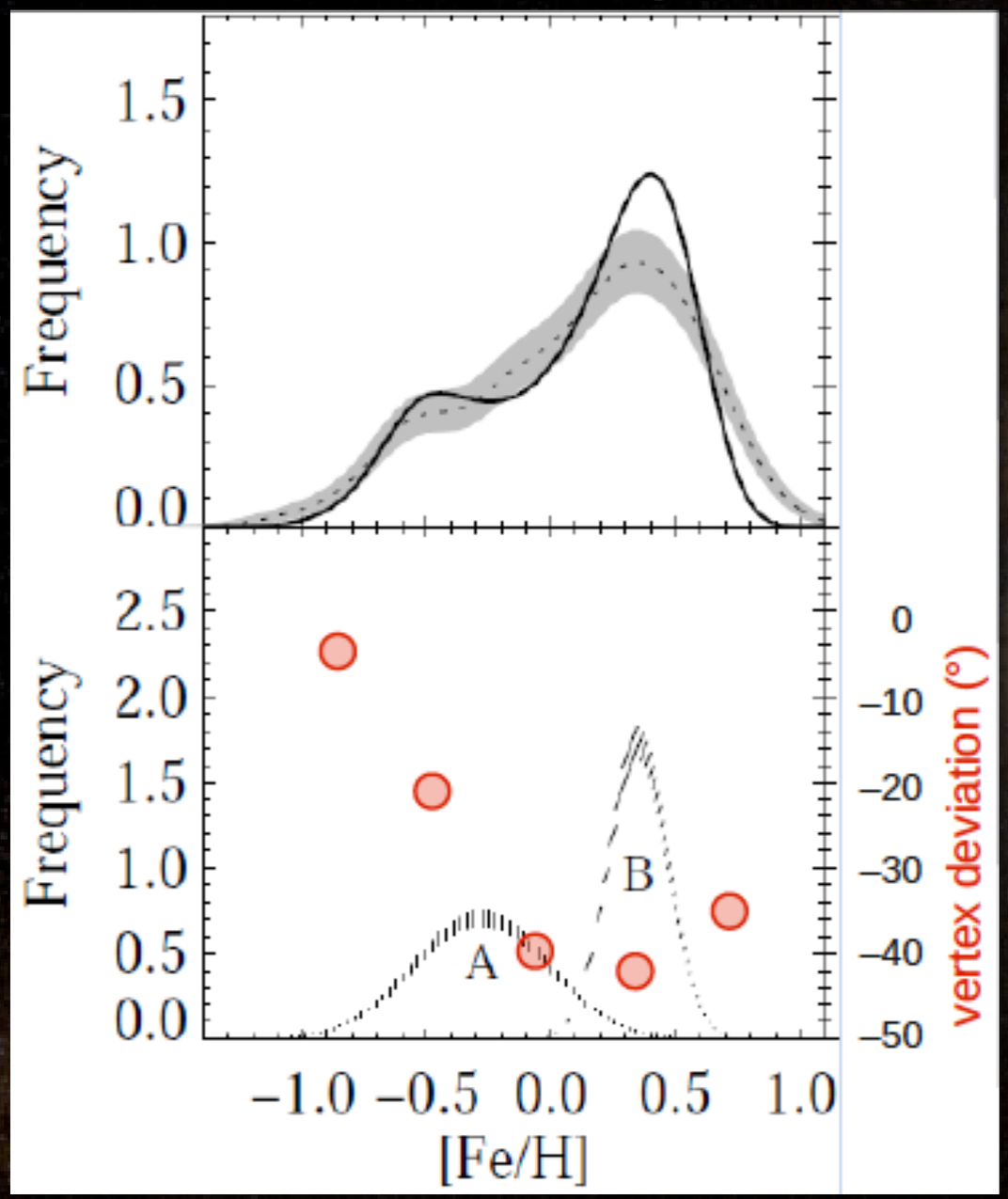
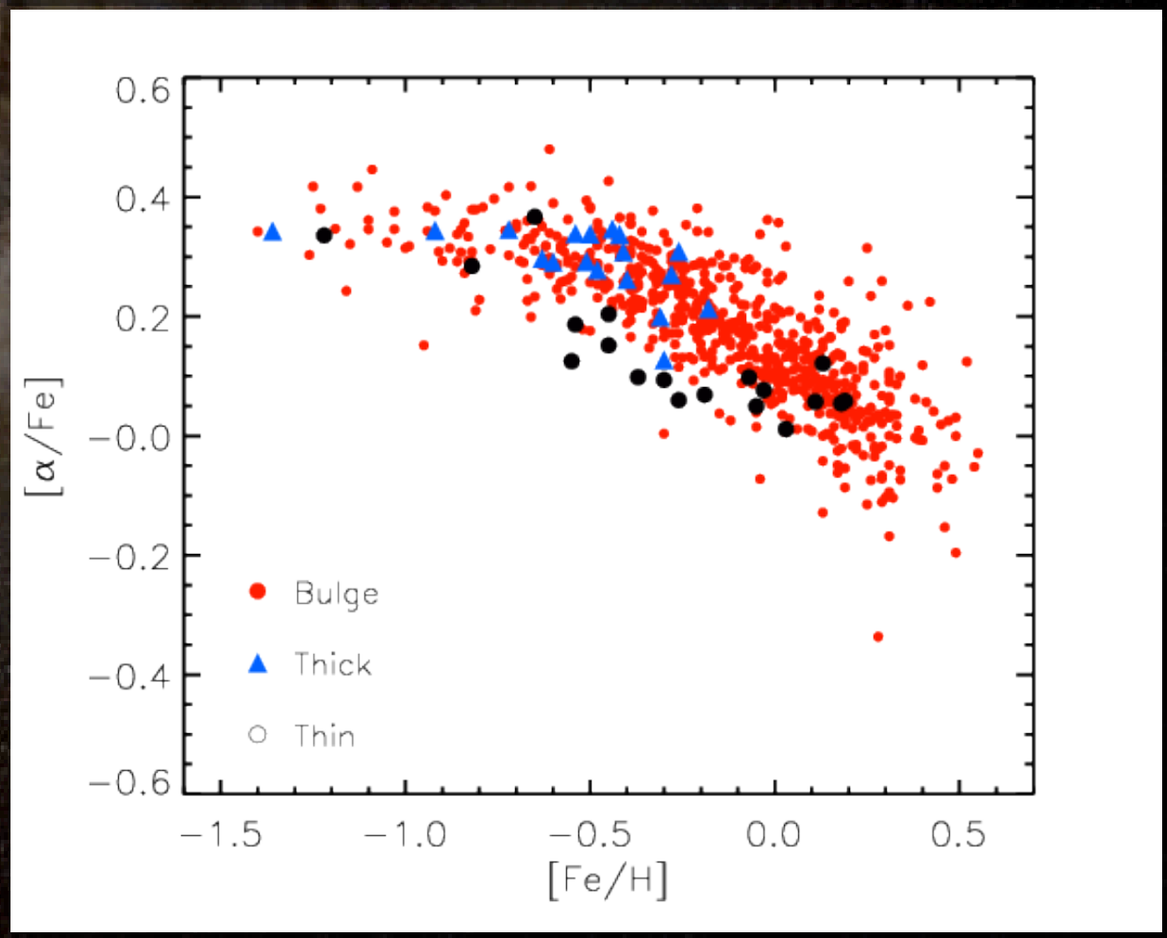


Vertex deviation from the velocity ellipsoid for b=-4
from Babusiaux et al. 2010

- A metal-poor alpha-rich
- B metal-rich alpha-poor

Alpha element over Iron ratio for 650 bulge giants
from Gonzalez et al. 2011



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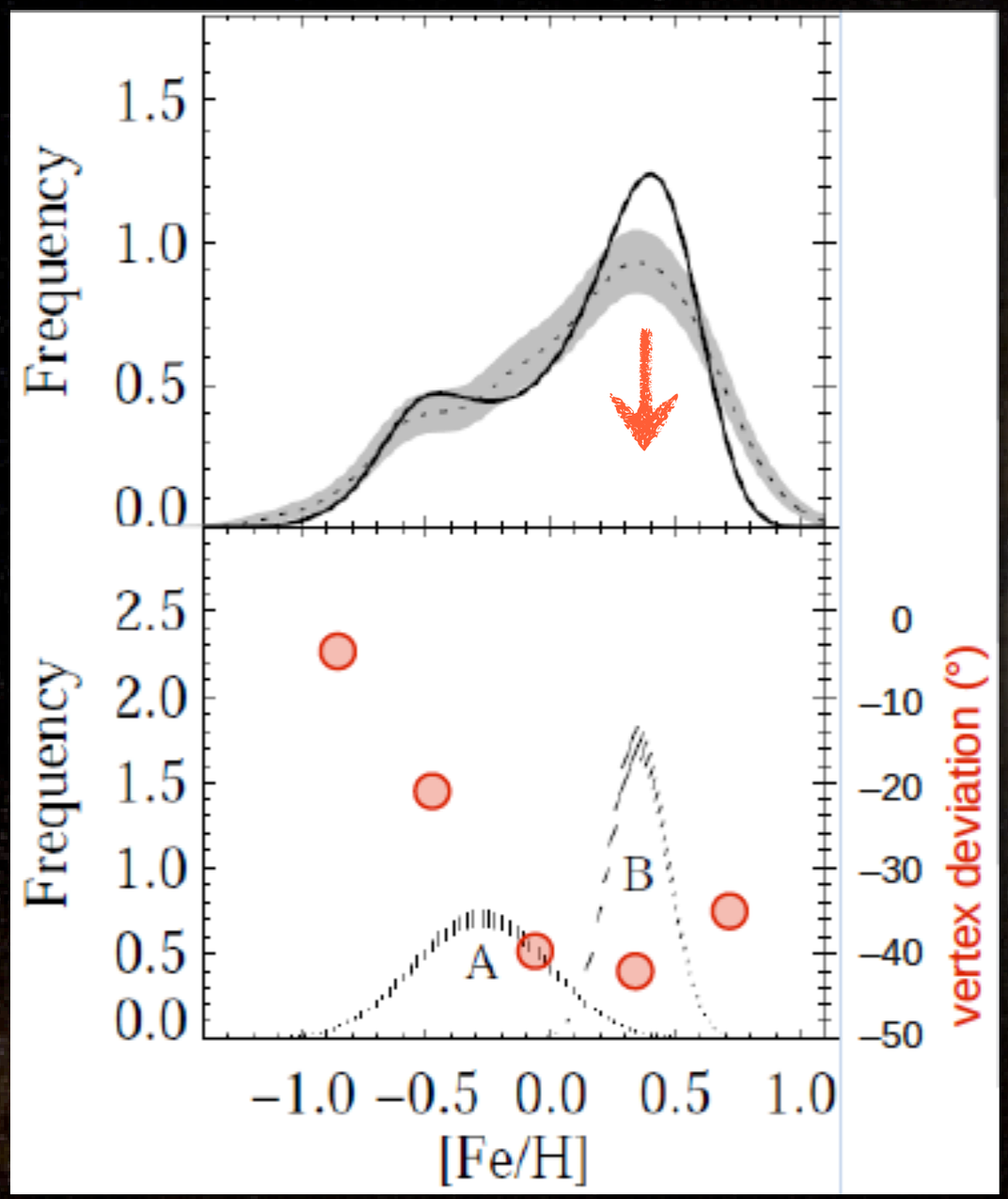
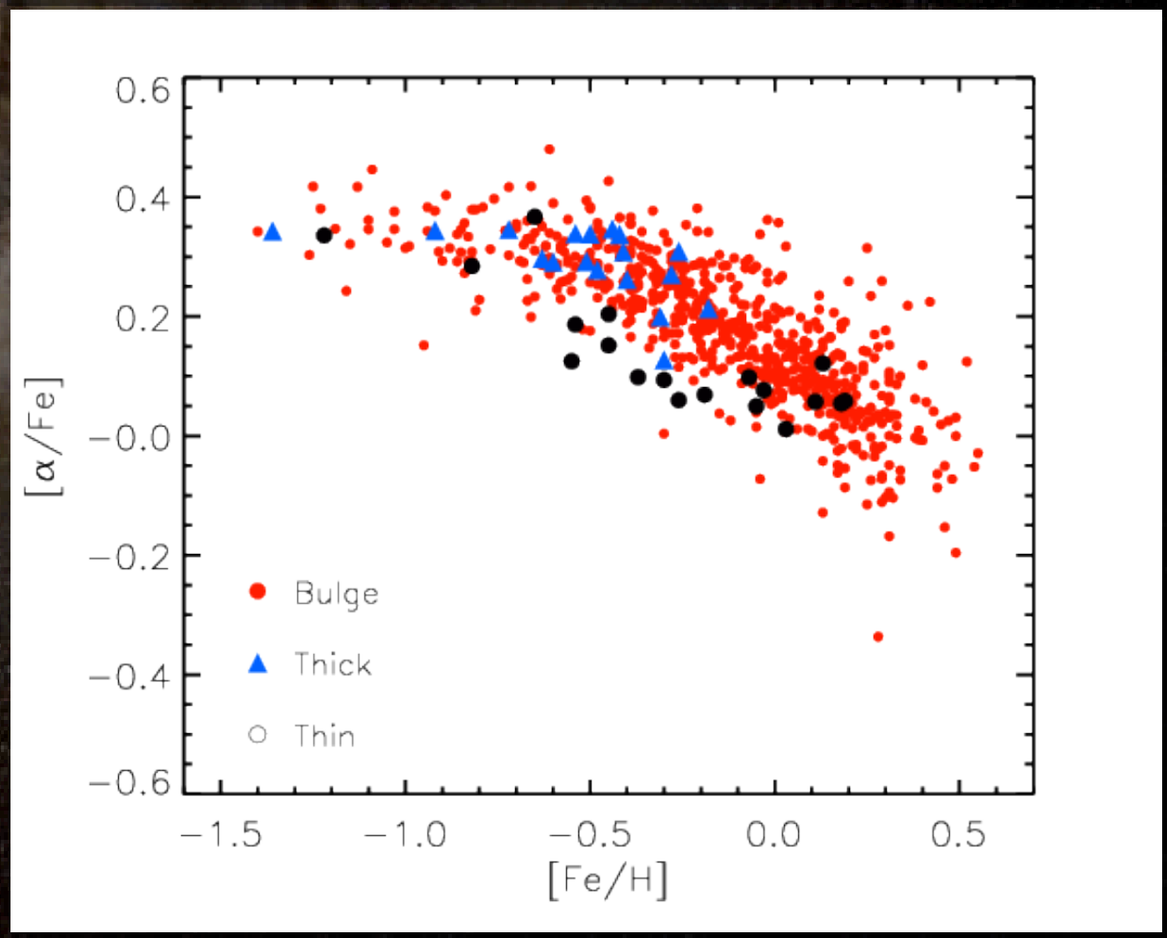


Vertex deviation from the velocity ellipsoid for b=-4
from Babusiaux et al. 2010

- Metallicity gradient arises from lower contribution of metal-rich bar at larger latitude

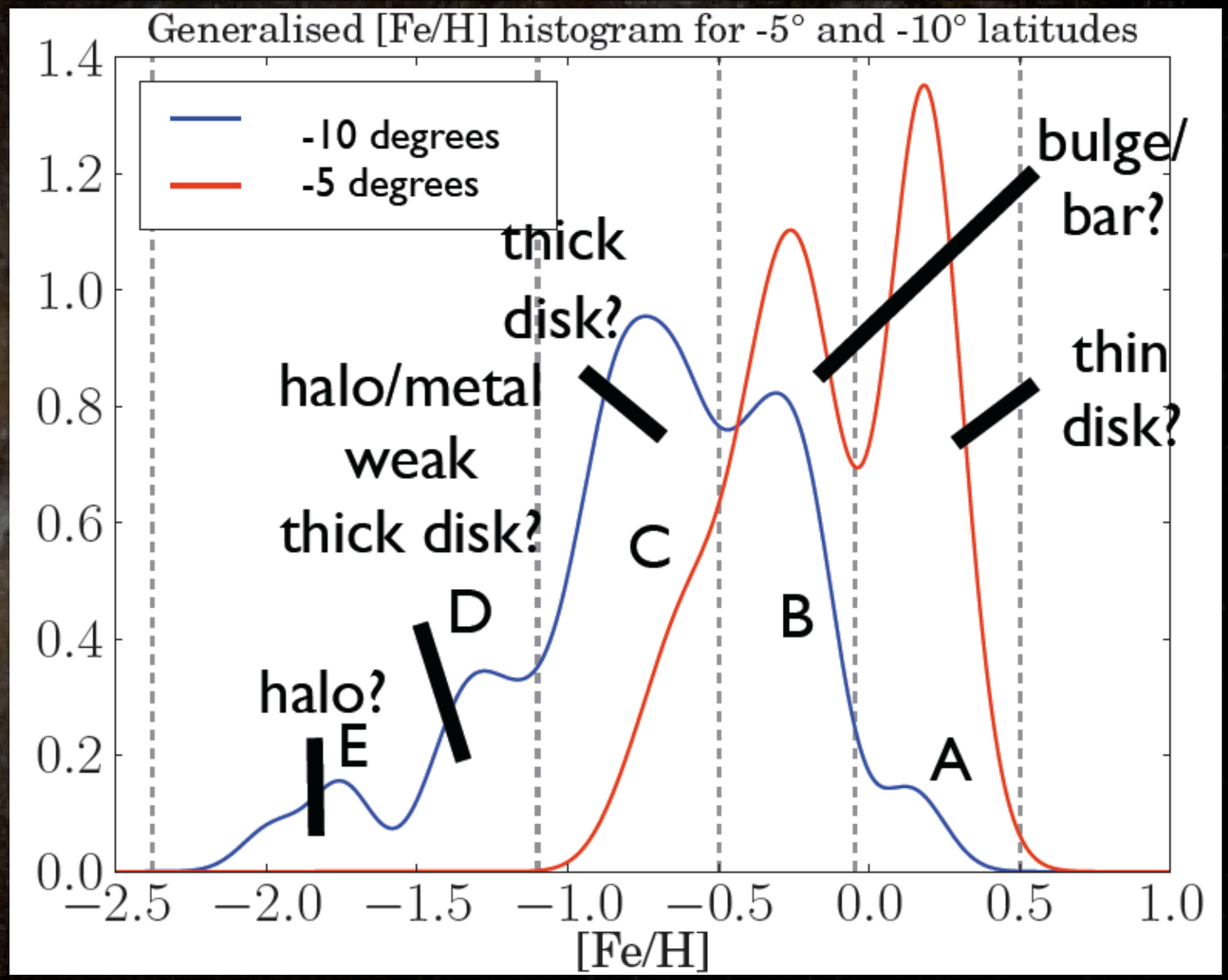
Alpha element over Iron ratio for 650 bulge giants
from Gonzalez et al. 2011



More than two populations?

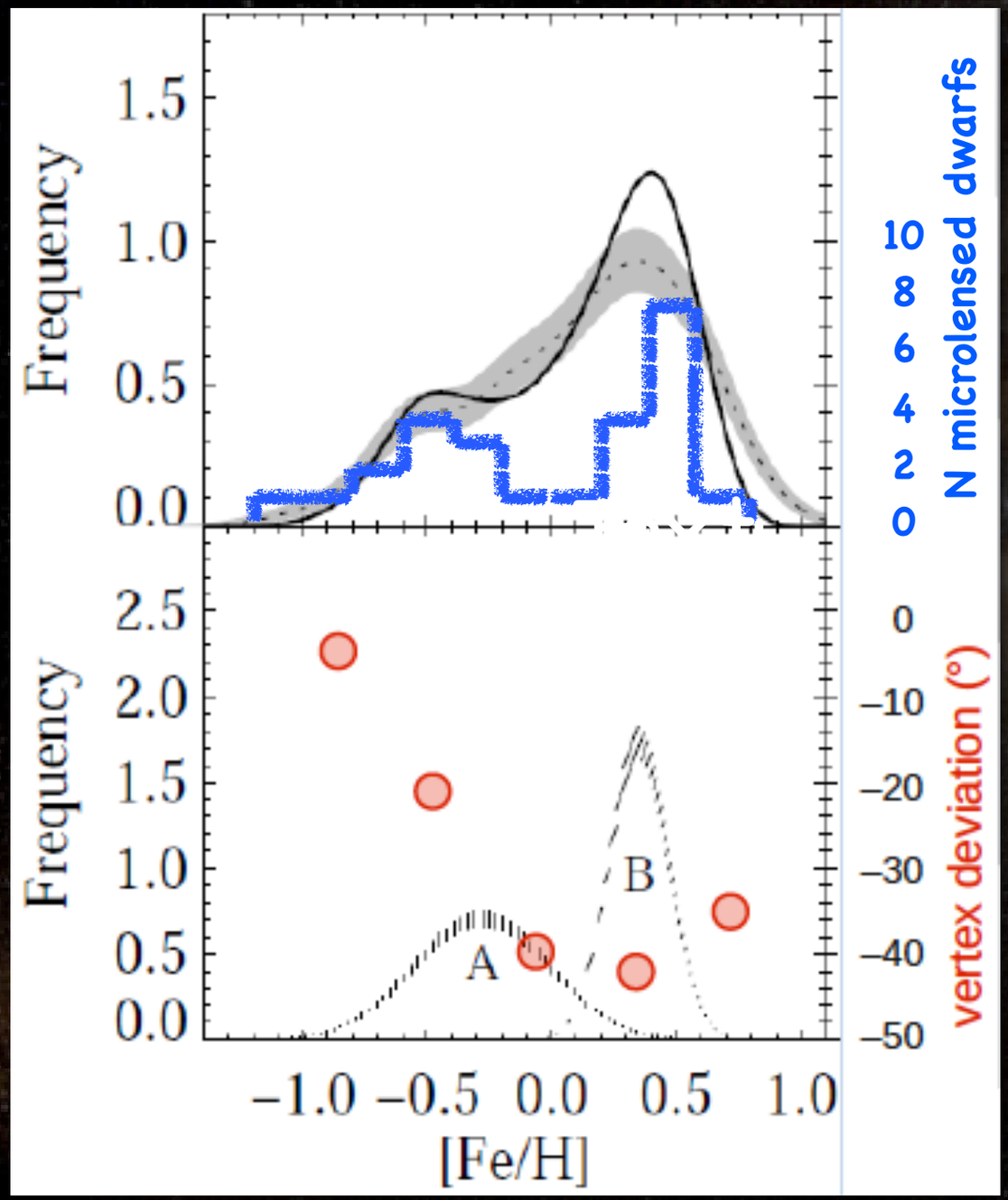
- Metallicity distribution at different latitudes:
  - *5 gaussian components with different contributions at different latitudes*
  - *Metallicity gradient from different contribution of "contaminating" components*

Different components interpreted in the Low-resolution metallicity distribution from Ness et al. 2011



Bulge microlensed dwarfs

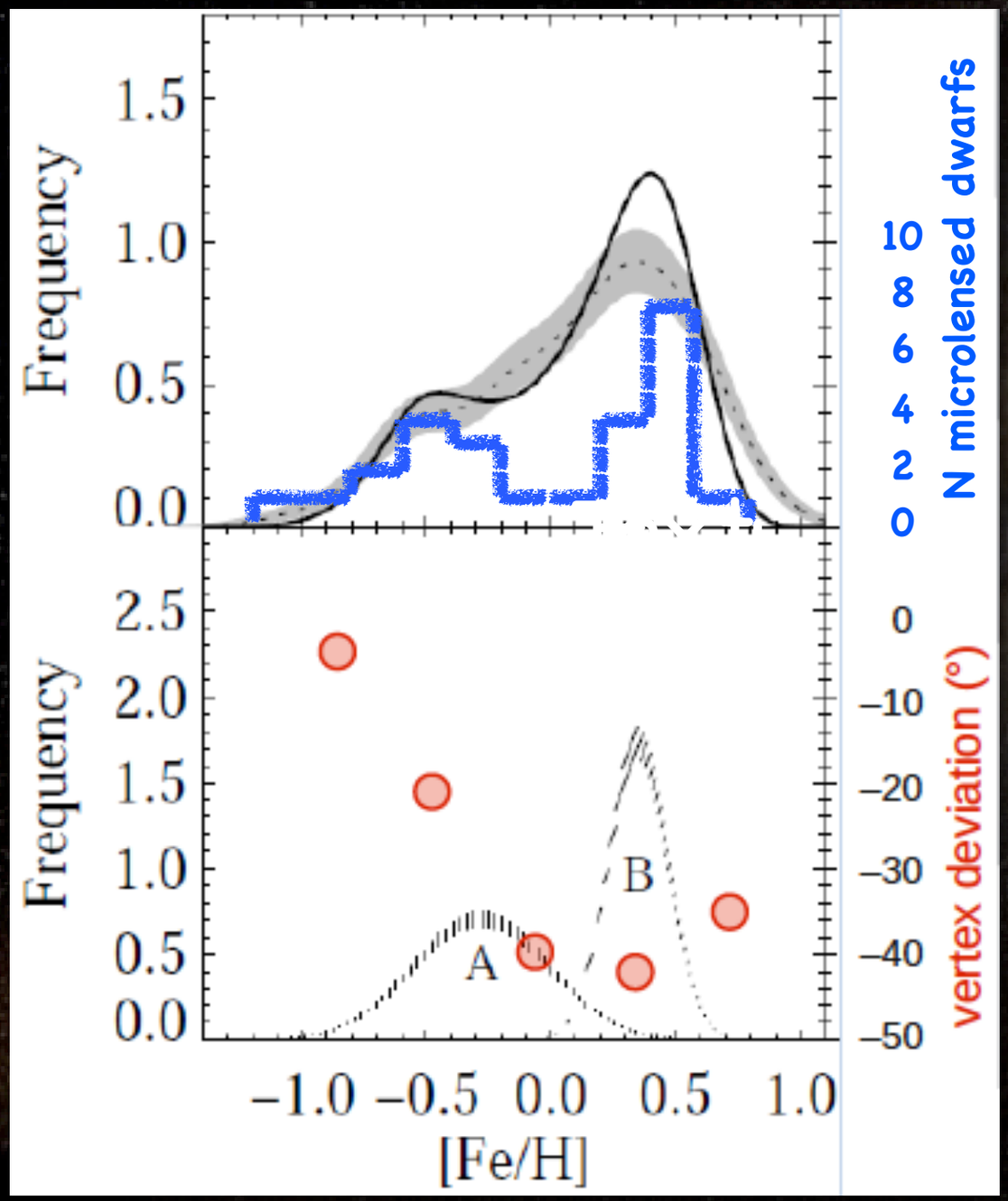
Metallicity distribution from 26 microlensed dwarfs from Bensby et al. 2011



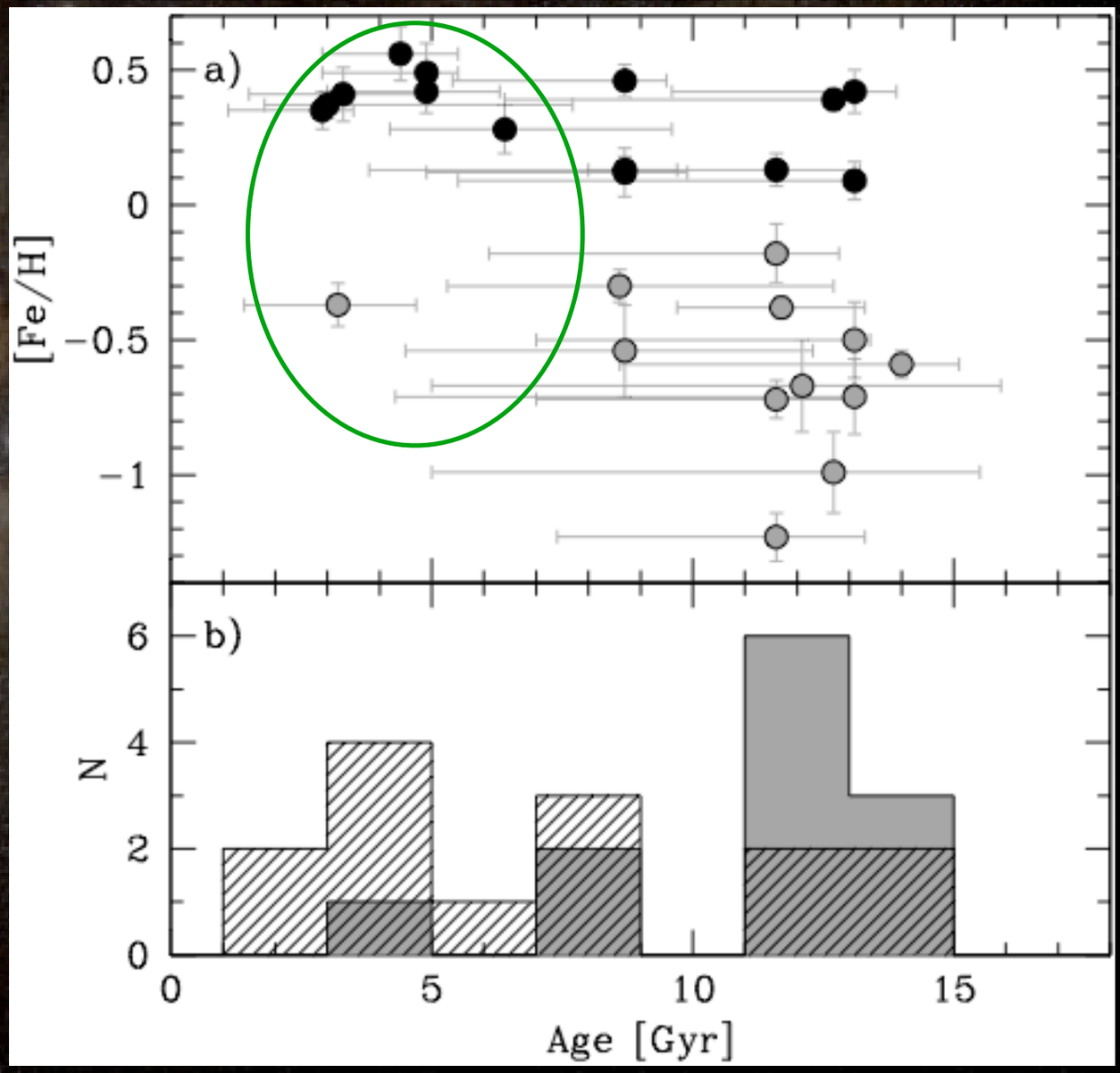
- Microlensing allows to study abundances in dwarf bulge stars
  - *Also consistent with the bimodal metallicity distribution*
  - *They allow to study more in detail the properties of each component*

Bulge microlensed dwarfs

Metallicity distribution from 26 microlensed dwarfs from Bensby et al. 2011



Age distribution for the 26 microlensed dwarfs from Bensby et al. 2011



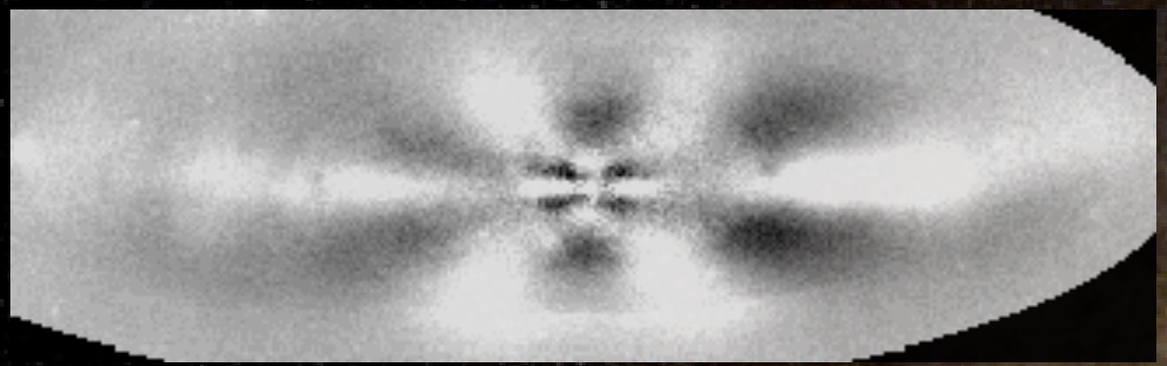
Summary

- Metal-rich, alpha-poor bulge stars:
  - trace a bar, thickened into a boxy / X-shape bulge
  - might have a wide range of ages
- Metal-poor, alpha-enhanced stars:
  - Trace a component with kinematics that deviate from a bar
  - Mainly old stars

Open questions

- Is the formation of the disk "connected" to the Bulge
  - Chemical similarities and ages could favor this scenario
  - Is there a classical component besides the bar?
- Bulge metallicity gradient:
  - Is there a vertical/radial gradient?
  - or is it due to contribution of different components?

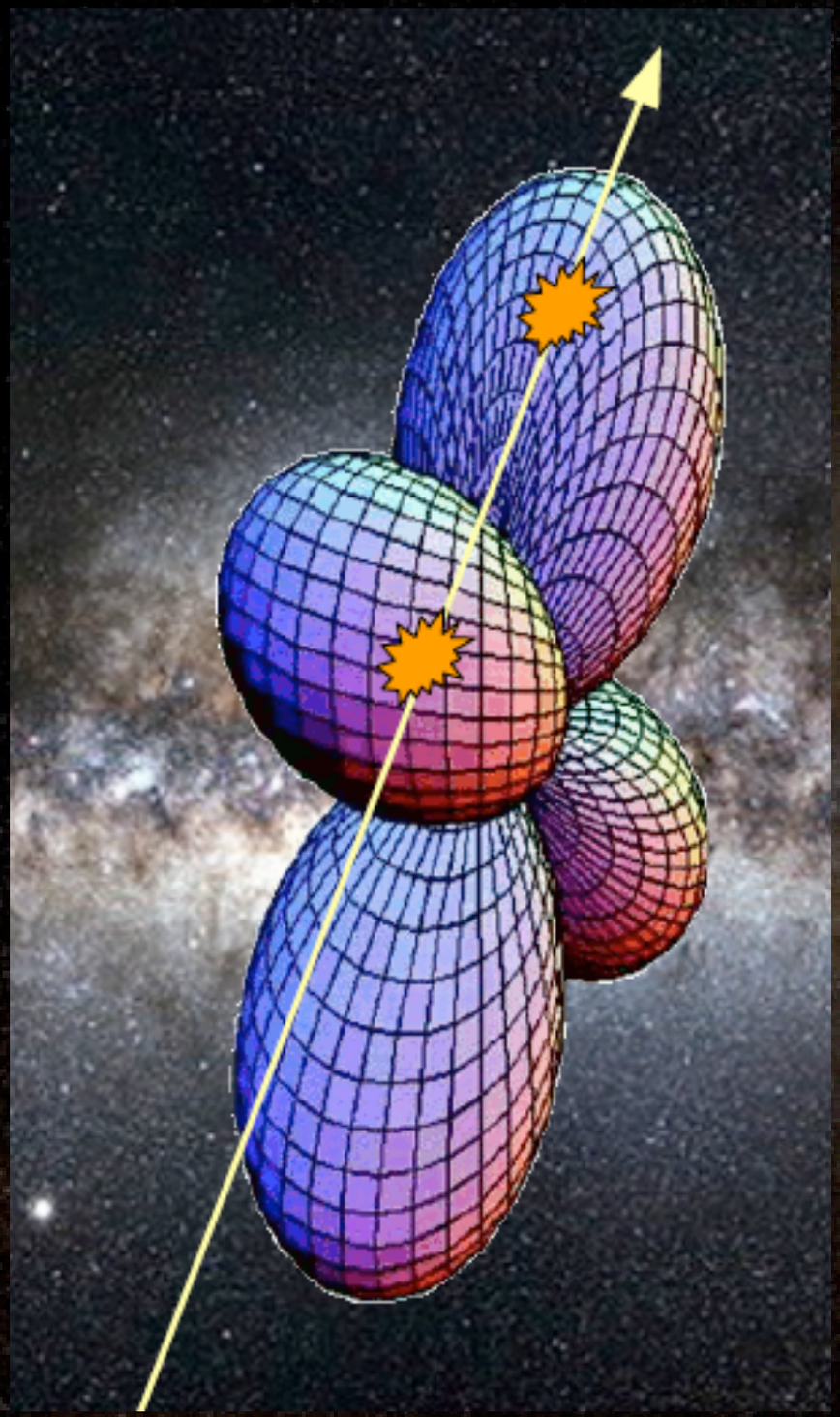
A problem to keep in mind



X shape bulge of the disk galaxy NGC 128 after subtraction of a model bulge fitting elliptical isophotes from D'Onofrio et al. 1999

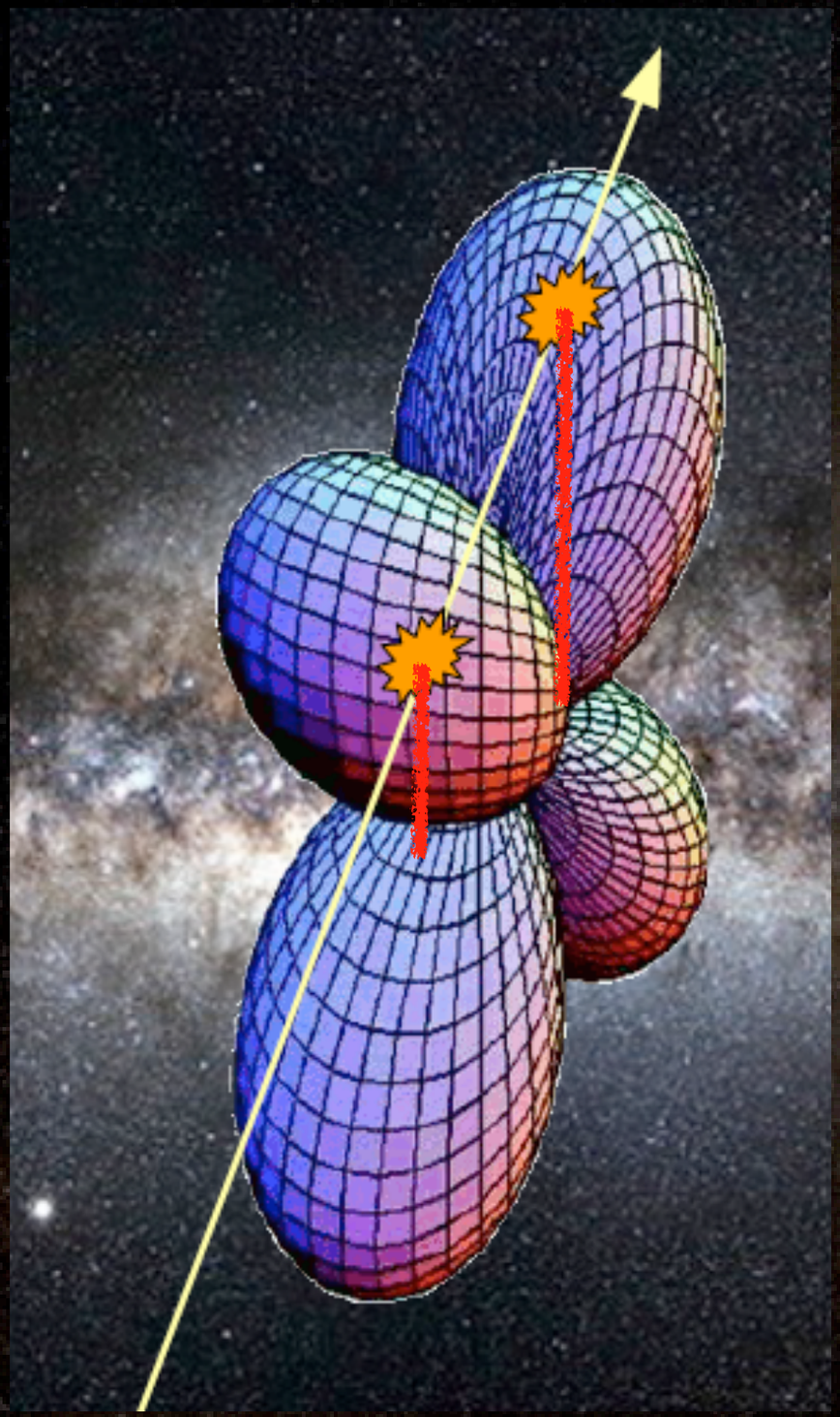
- The Bulge is peanut / X shaped
  (McWilliam+10, Nataf+10, Saito+11)

A problem to keep in mind



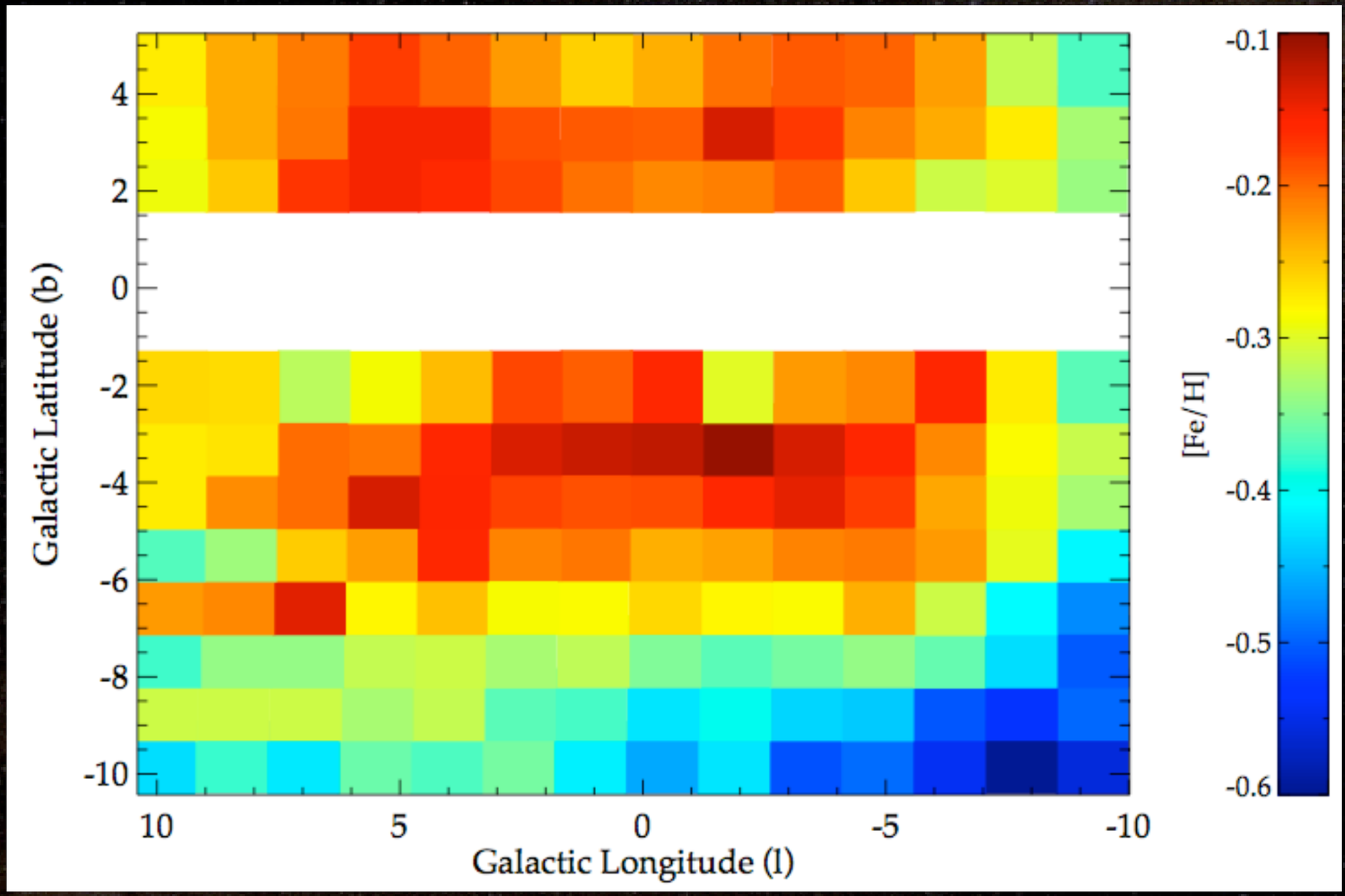
- The Bulge is peanut / X shaped
  - *Two red-clumps for latitudes* $|b| > 5$
  - *Two overdensities of stars at different distances*

A problem to keep in mind



- The Bulge is peanut / X shaped
  - *Two red-clumps for latitudes* $|b| > 5$
  - *Two overdensities of stars at different distances*
  - *Effect in the metallicity gradient along the minor axis?*

The complete metallicity map of the Bulge



The global picture is required!

Thank you