The ARGOS bulge survey

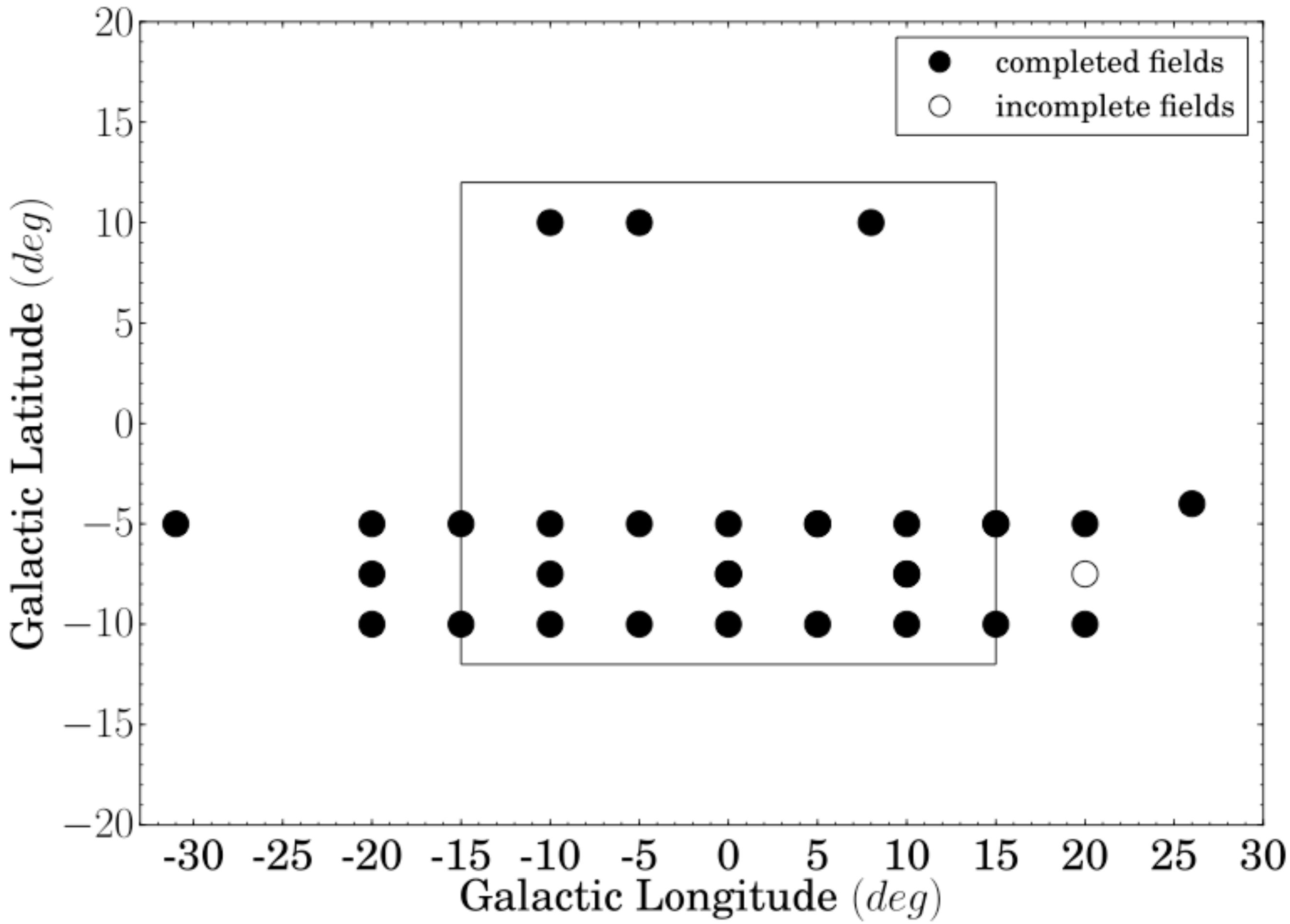
Melissa Ness, Ken Freeman and the ARGOS team

The Galactic bulge is believed to be a boxy/peanut bulge formed via bar-forming and bar-buckling instabilities of the disk. Simulations suggest that this event occurred a few Gyr after the formation of the disk: the bulge structure is likely to be younger than some of its stars. Our goal is to interpret the observed kinematics and chemical properties of the ARGOS survey stars in the context of the dynamical and chemical evolution of the early disk and bulge.

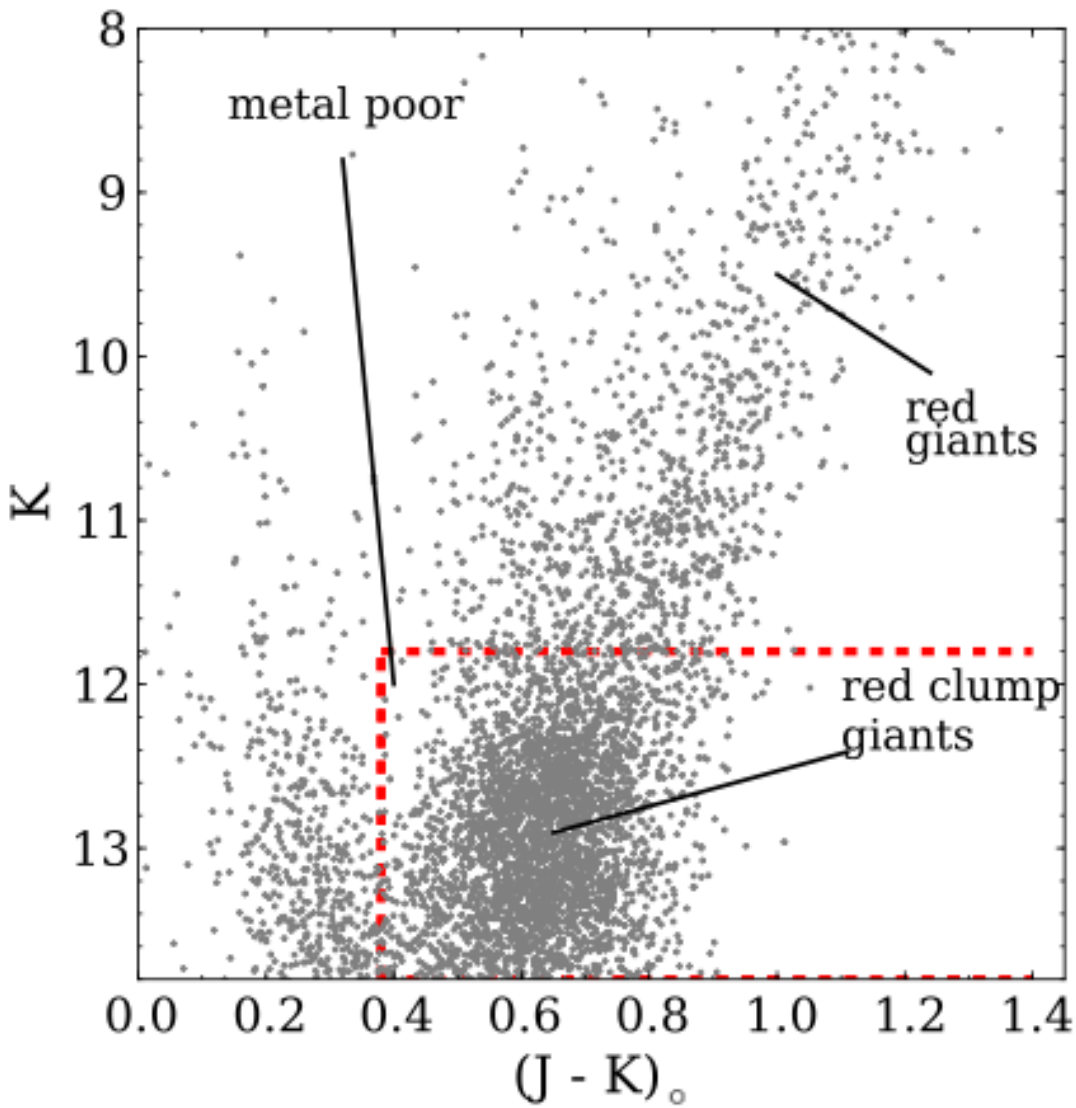
In the inner Galaxy, we expect to see the the bulge stars, and stars from the other components of the Galaxy: bulge, thin disk, thick disk, halo. Some stars from the other components will have become incorporated in the bulge. Other stars may have formed after the bulge forming event(s).

Aim to relate the chemical and kinematical properties of what we see now to the chemical evolution that occurred before during and after bulge formation.

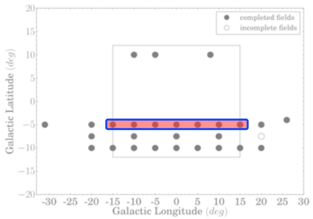
What can we learn about the mapping of the disk into the bulge via the instability processes ? The mapping is likely to depend on position, velocity and therefore metallicity of the initial disk stars.

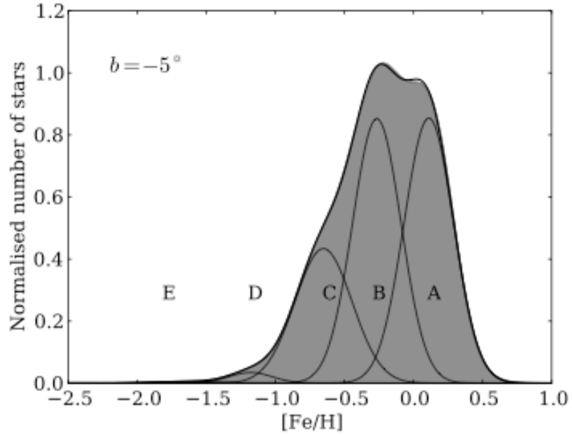


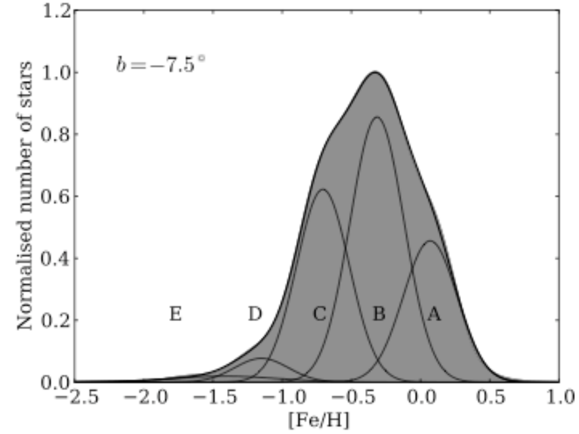
The ARGOS survey fields: 28,000 stars, R = 11,000, SN ~ 75, $\sigma_{[Fe/H]} = 0.13$, $\sigma_{[\alpha/Fe]} = 0.10$, $\sigma_{Vrad} = 1.2$ km/s.
Mostly clump giants, selection does not exclude metal-poor giants

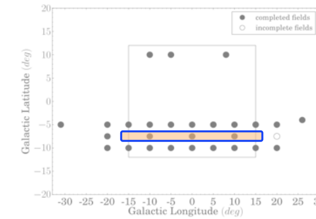


ARGOS selection criteria



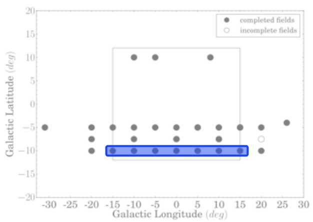


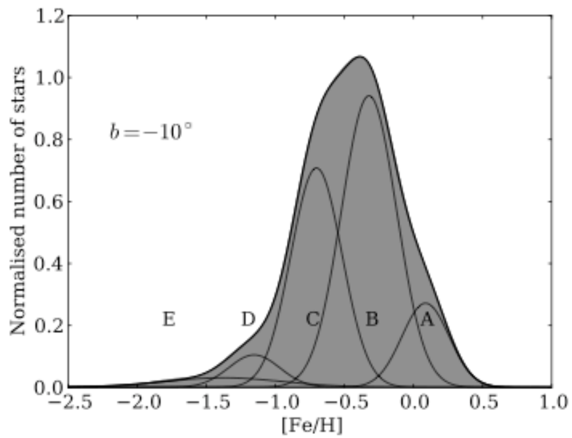


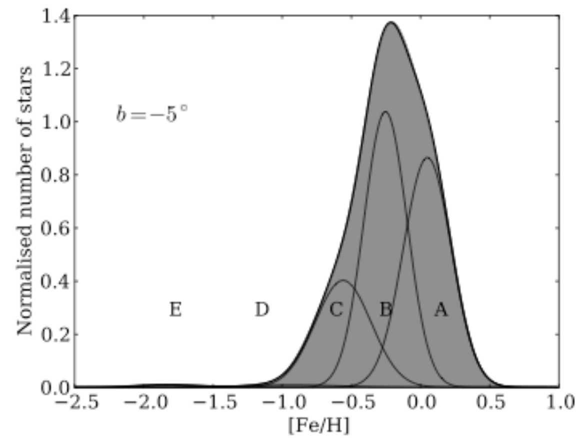


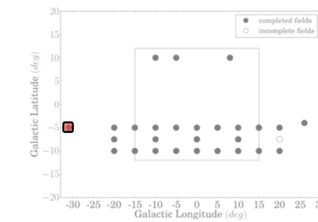
(a) $l \pm 15°$, $b = -5°$

(b) $l \pm 15°$, $b = -7.5°$









(c) $l \pm 15°$, $b = -10°$

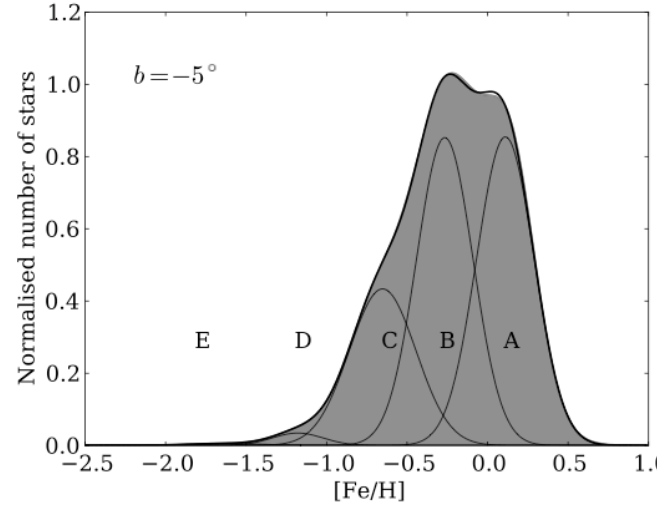
(d) $l = -31°, b = -5°$

Bulge MDFs at different locations (stars with R < 3.5 kpc)

Ness et al 2012b

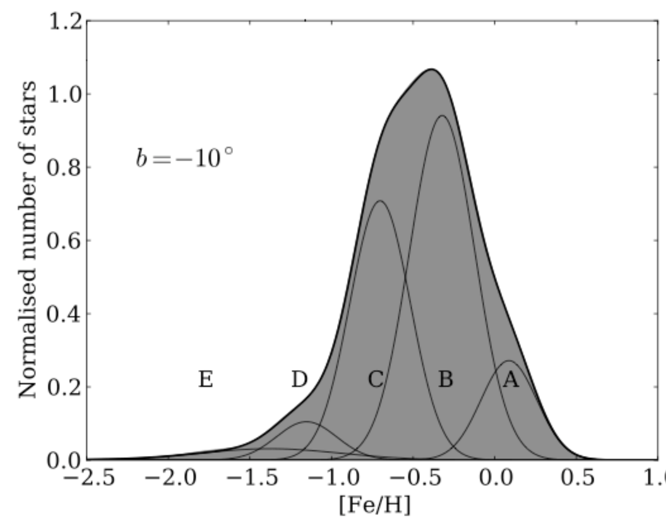
$b°$	A	B	C
-5	0.12	-0.24	-0.65
-7.5	0.07	-0.31	-0.71
-10	0.09	-0.32	-0.70

Mean [Fe/H]



Weight

$b°$	A	B	C
-5	0.39	0.37	0.22
-7.5	0.22	0.43	0.30
-10	0.11	0.50	0.31



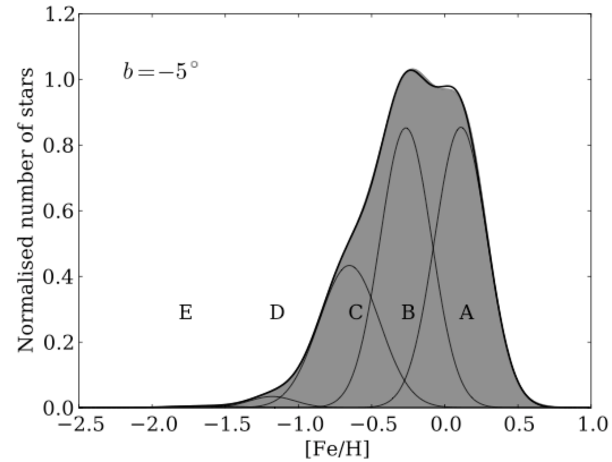
Ness et al 2012b

Initial interpretation of the MDF components

A [Fe/H] = +0.1 thin disk surrounding bulge

B [Fe/H] = -0.3 true boxy/peanut bulge

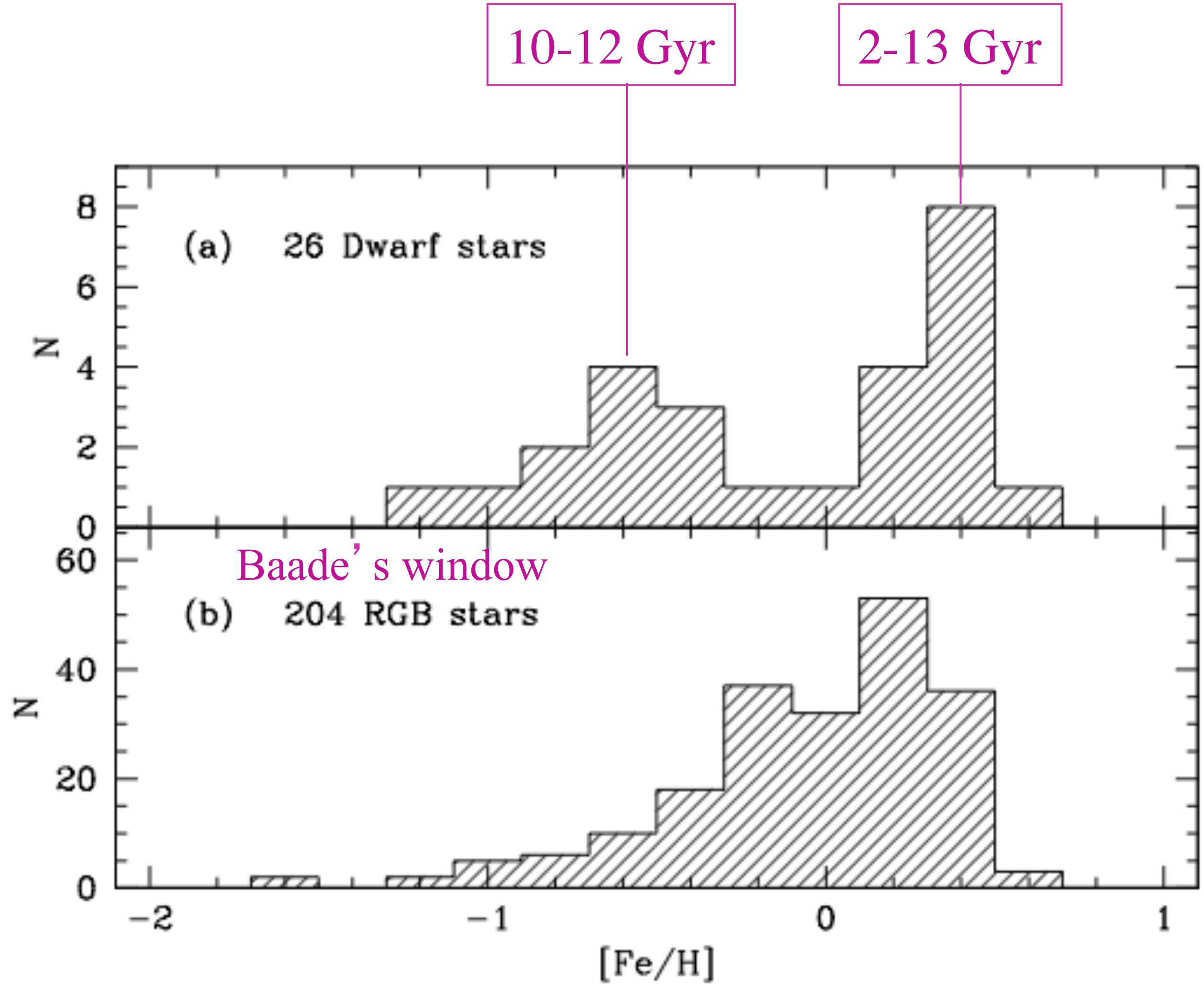
C [Fe/H] = -0.7 old thick disk, maybe part of bulge



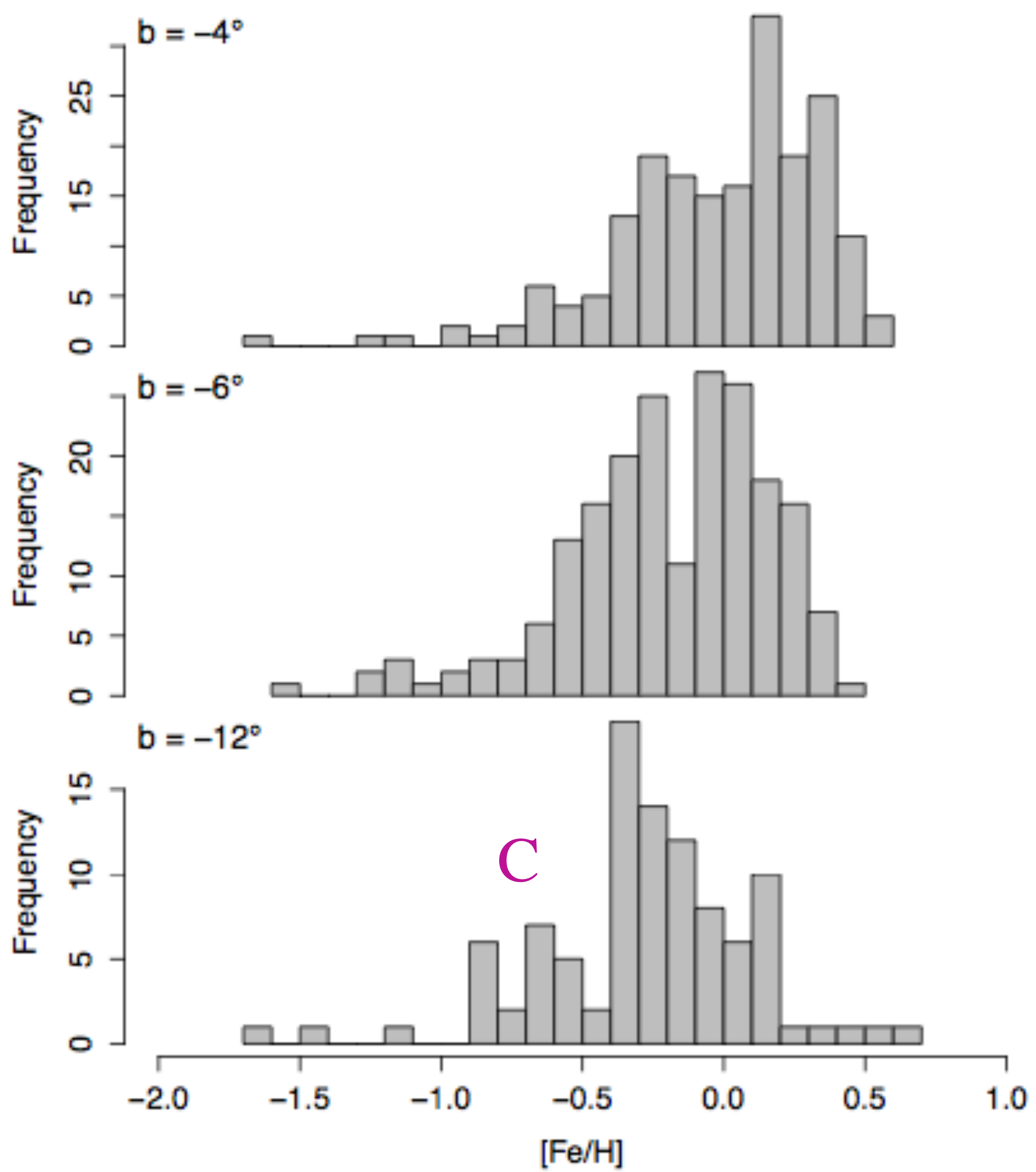
Bensby et al (2011) see components A and C in microlensed dwarfs.
Component A has a wide age range.

Babusiaux et al (2010) bulge giants: see components A, B, C :
Component A shows vertex deviation in the plane.

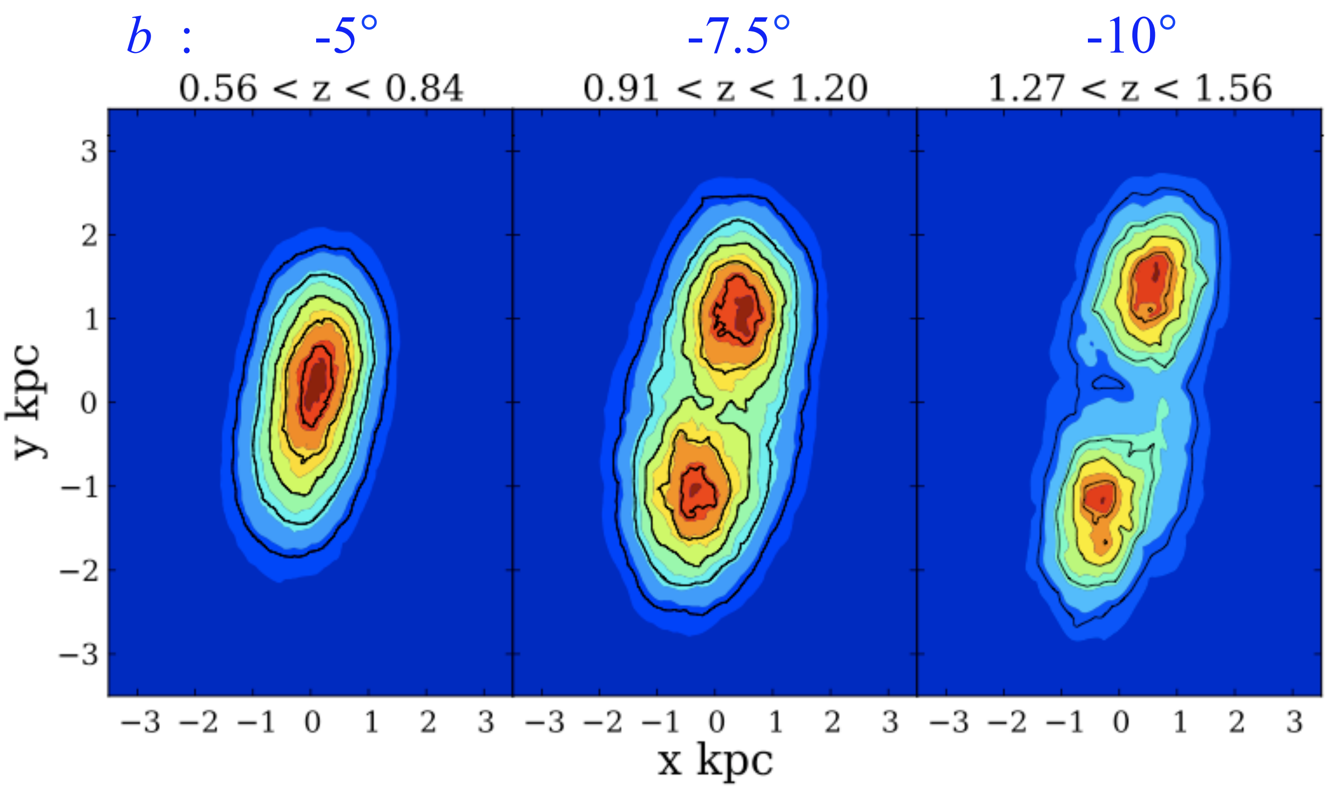
Bensby et al (2011): 26 microlensed dwarfs and subgiants with $|l| < 5.2$, b = -1.6 to -5.2. See modes A and C only



Babusiaux et al (2010): Red clump giants towards bulge. Identify modes A, B, D from gaussian decomposition at b = -4 and -6 (see indication of mode C at b = -12))



Our interpretation of the MDF components was modified by a study we did of the split red clump, comparing the observed split with the split seen in an N-body model from Athanassoula. The density distribution of the boxy/peanut bulge has a depression near its minor axis. Along lines of sight near the minor axis at $|b| > 5°$, this depression leads to a bimodal distribution of stars with distance.

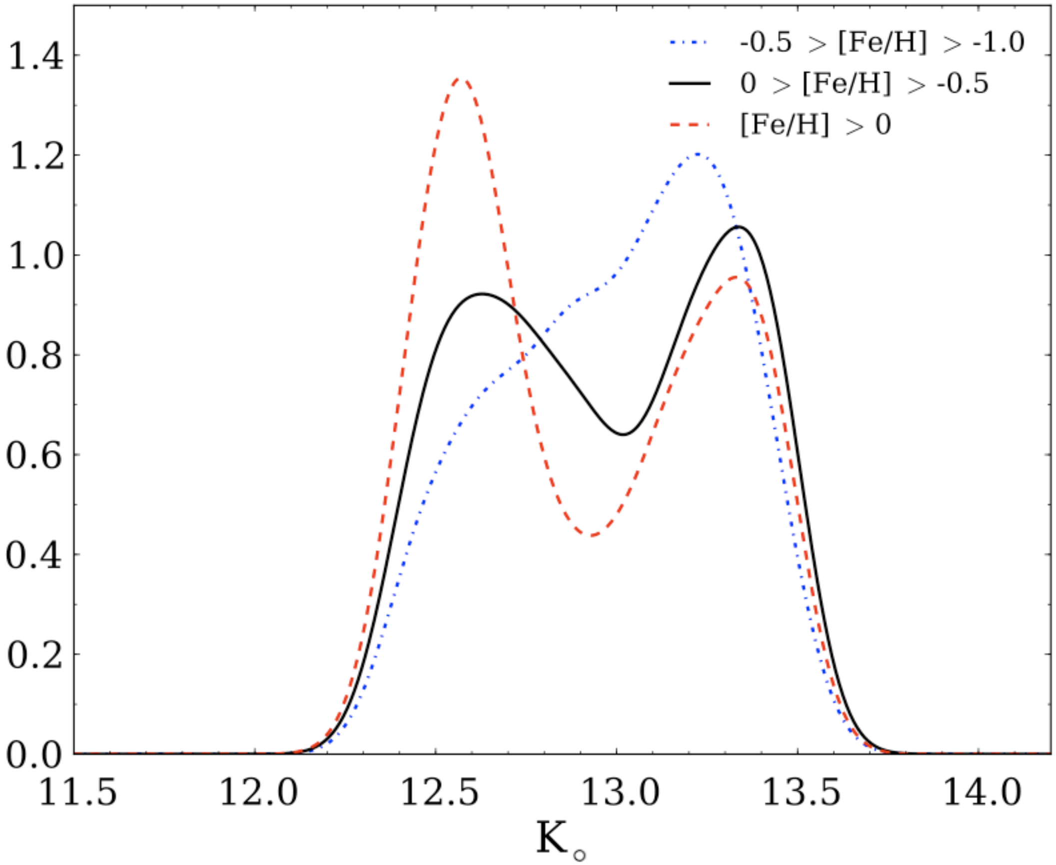


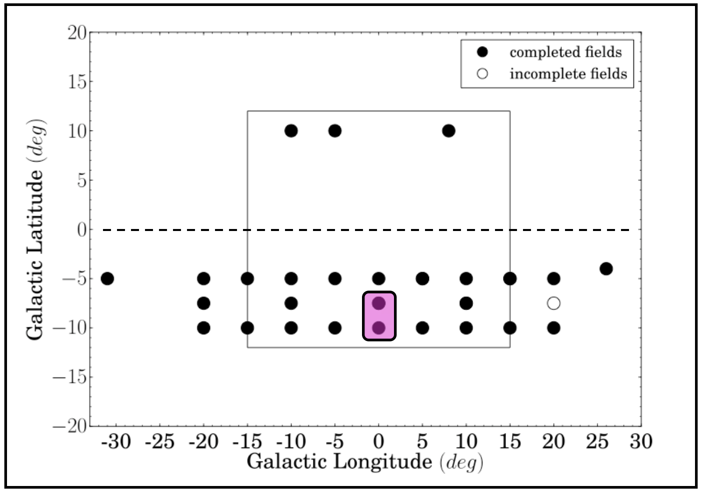
Density distribution of **model bulge** at different heights z above plane

Ness et al 2012a

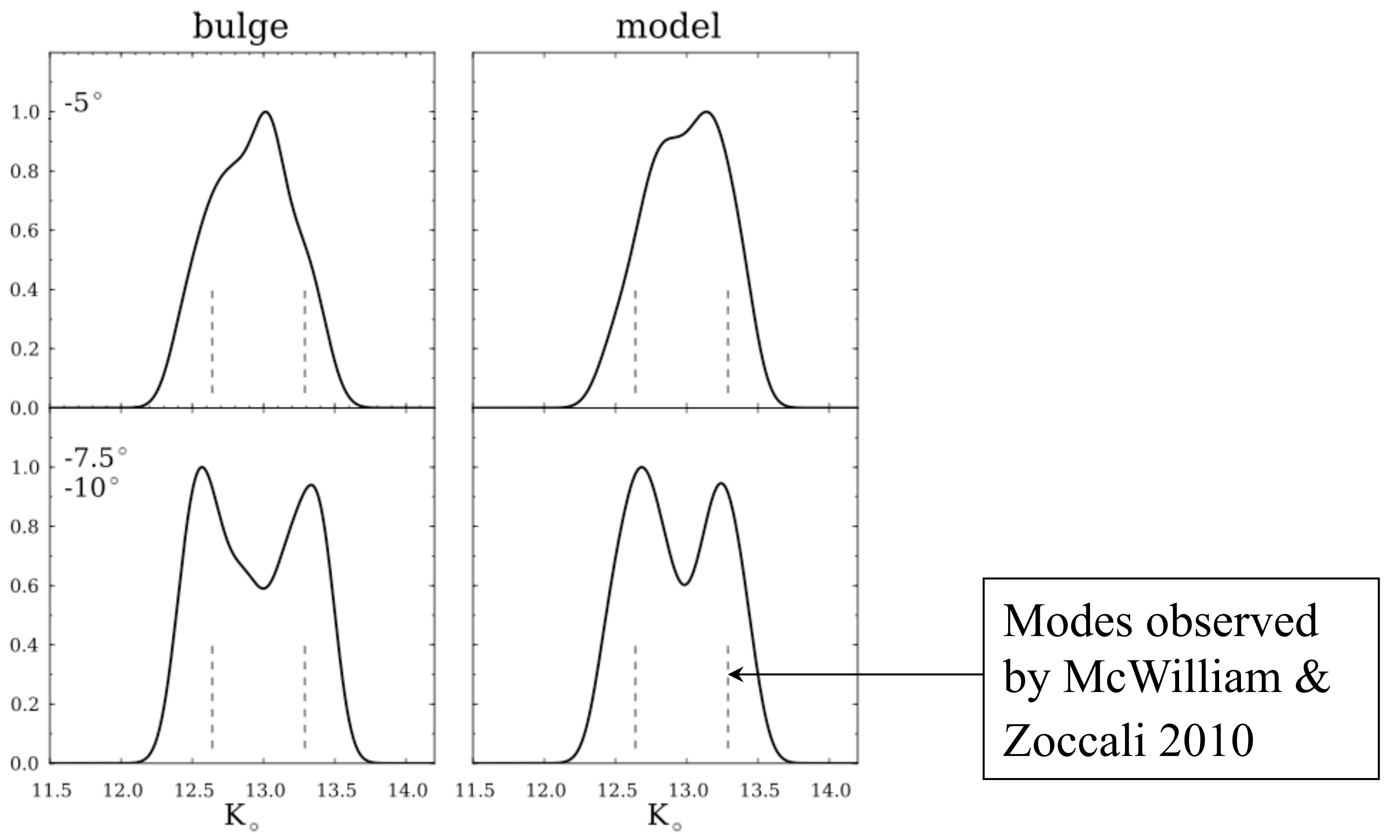
In our minor axis fields at b = - 5 to - 10°, we found that the split was present only for stars with [Fe/H] > -0.5 and was *strongest* for the most metal-rich stars (component A).

b = -7.5 + -10°





The split appears to be a generic feature of N-body models that generate boxy/ peanut bulges. The magnitude of the split depends on the particular model. The N-body model shows a similar split to the ARGOS data for [Fe/H] > - 0.5



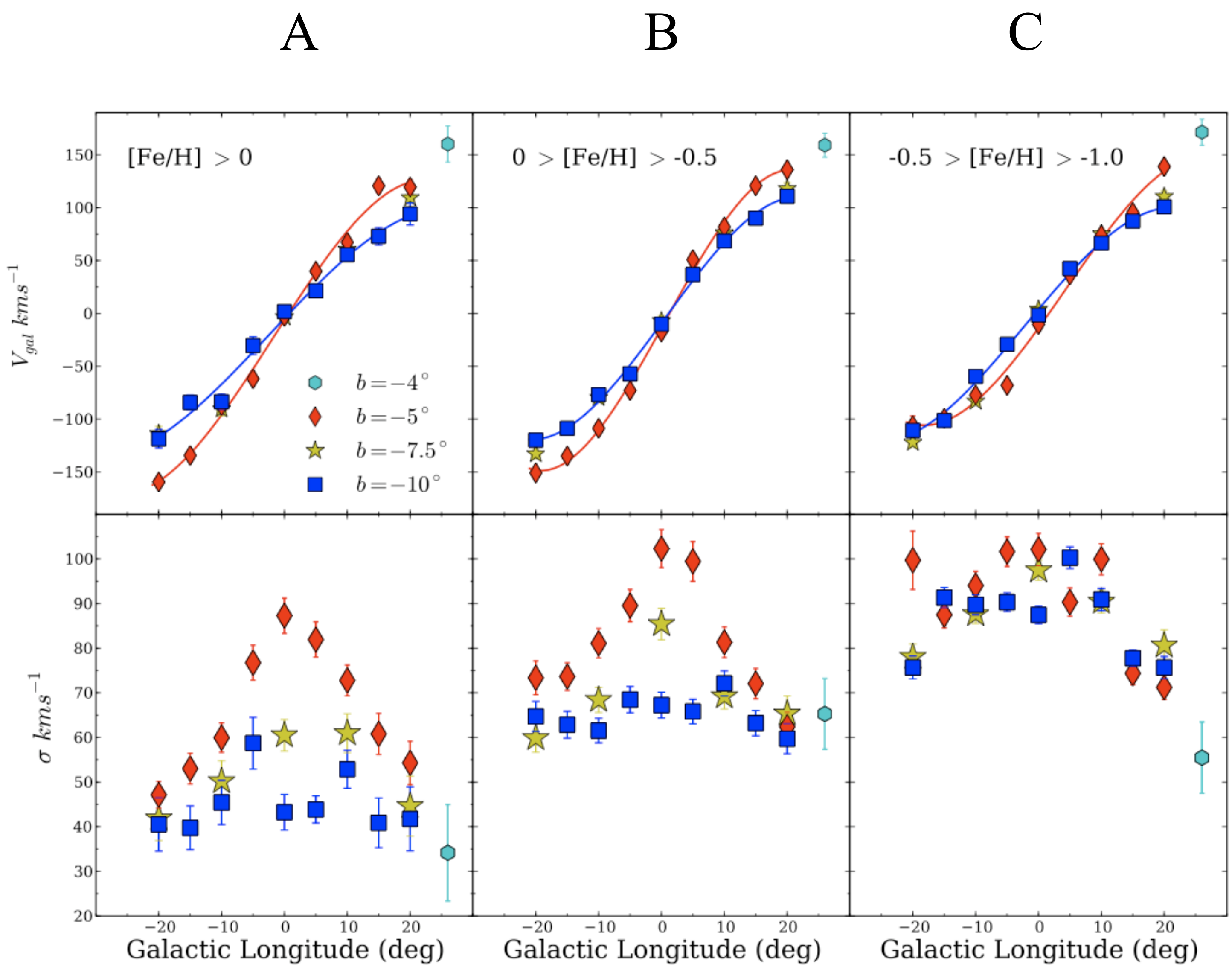
The peanut structure appears to be defined by stars with [Fe/H] > - 0.5, including the most metal-rich stars i.e. this is the abundance range of the stars which made up the disk at the time of the instability.

Stars with lower abundances do not appear to be strongly involved in this structure: our component C appears to be thick disk but is not part of the peanut structure. Why did this old thick disk component not become strongly involved in the bulge structure ? **Was it was too hot ?**

The velocity dispersion of stars in the inner Galaxy depends on the metallicity: at $b = -10°$ and averaged over the inner ± 5 deg in longitude, the dispersions are

A	[Fe/H] = +0.1	$\sigma = 67$ km/s
B	[Fe/H] = - 0.3	$\sigma = 80$
C	[Fe/H] = - 0.7	$\sigma = 96$

The coldest component A shows the strongest split (peanut signature)
Component C does not appear to be involved in the boxy/peanut structure

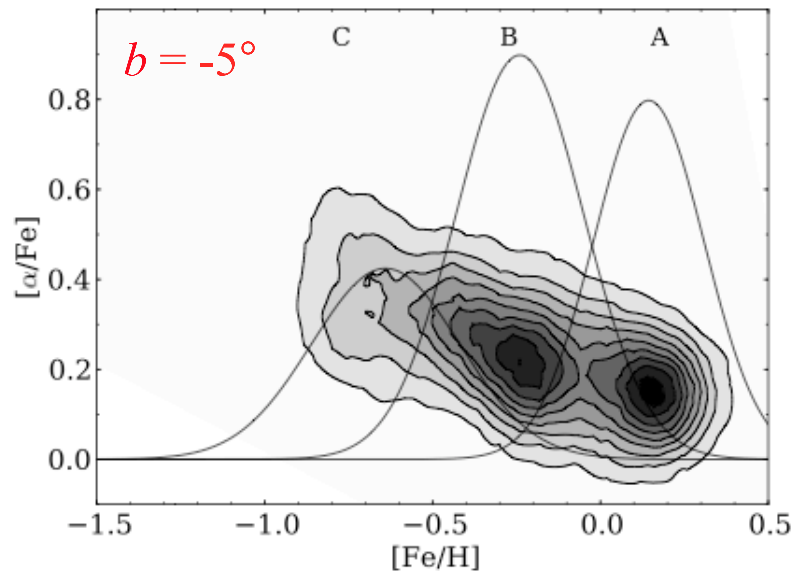


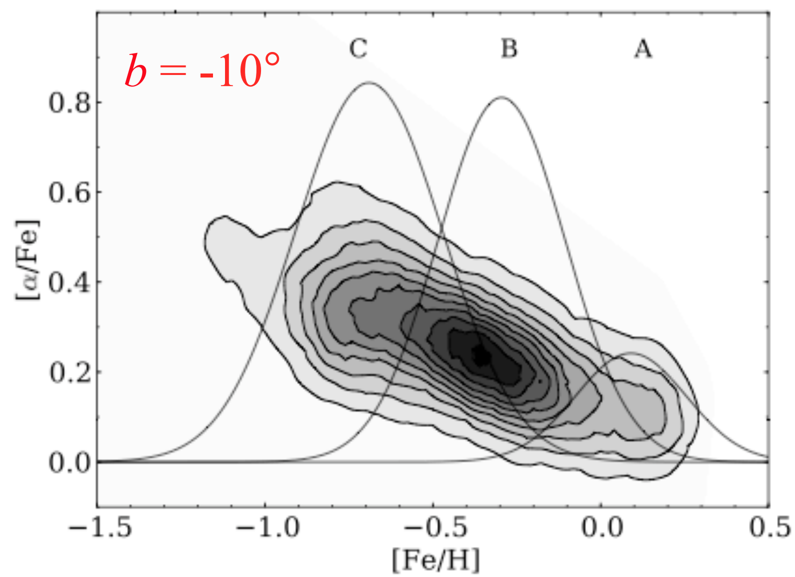
Rotation and velocity dispersion of components A,B,C

What does the [α/Fe] distribution say about the timing of bulge-forming events ? Just that the SNIa had made some contribution before the bar forming event.

The coldest population A appears to be most strongly involved in the peanut and is (weakly) α-enhanced.

The coldest metal-rich component A may have formed during the bar-buckling event, or maybe even in a second event. It replicates the kinematic and spatial properties of the thicker peanut bulge component B but at a lower height above the plane.

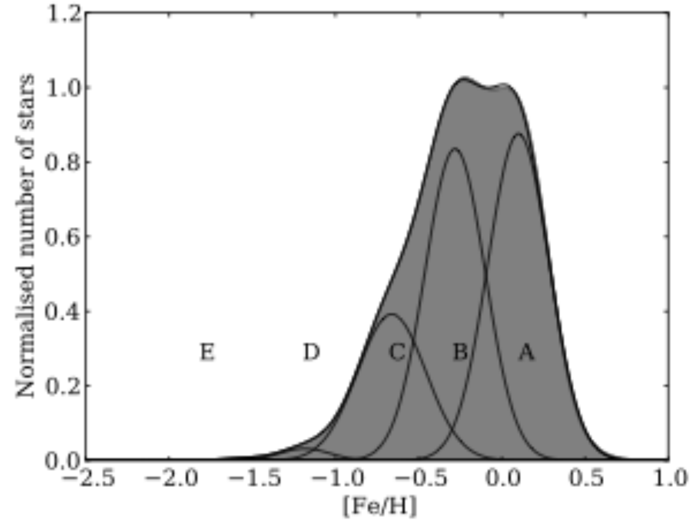




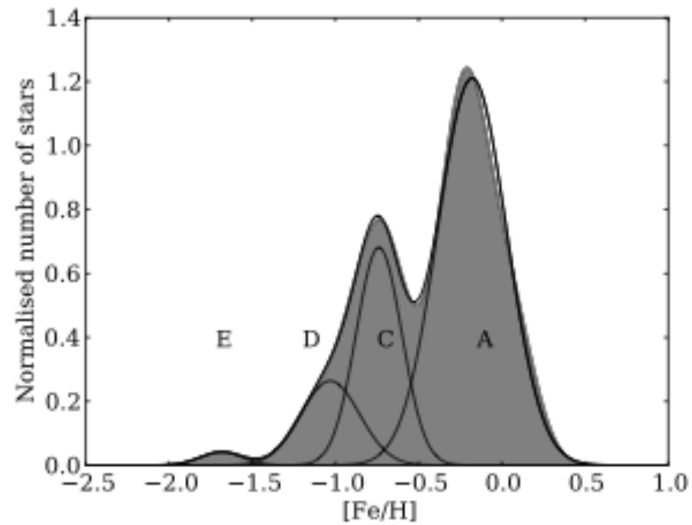
Component B disappears from the MDF outside the bulge region.

These histograms are at b = -5°

Component A appears to be the thin disk at larger R. In the inner region, it has been puffed up to be part of the peanut bulge



(d) $3.0kpc < R_{gal} < 4.5kpc$



(f) $6.0kpc < R_{gal} < 8kpc$

The instabilities that build the boxy/peanut bulge define a mapping of the early disk on to the bulge. If the star formation and chemical evolution in the inner disk was mostly over before the epoch of bar formation, then the chemical structures which we see in the inner Galaxy are defined by this mapping of disk → bulge.

The chemical structure of the early disk was probably simple - just a radial gradient. When we look at the details of the mapping from the models, it may be clear whether the mappings do define what we see, or if significant chemical evolution occurred during the growth of the bar and bulge.

Need models with multiple kinematic components in the initial disk, (eg thin and thick disk) to see how much the hotter components are involved in the growth of the boxy/peanut bulge.