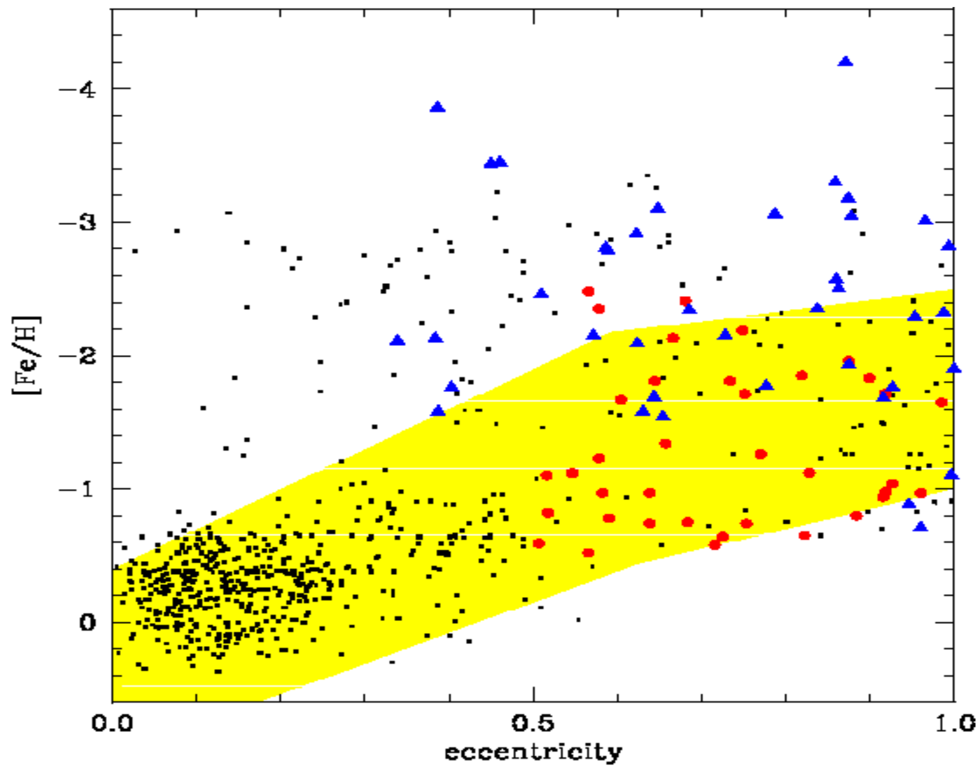
Vatican "Stellar Populations" was held May 1957, ELS was published in May 1962



That was a good decade

Now we are really in the decade of near-field cosmology!

Some of the big questions

- The expectations of merger histories from cosmology are not evident – why?
- The angular momentum challenge
- The G-dwarf challenge – MDFs are narrow
- The bulge challenge (not in Baade...)
- Abundance gradients!!
- Why do stellar populations look so discrete?
- Why do we see metal-rich high-alpha stars?

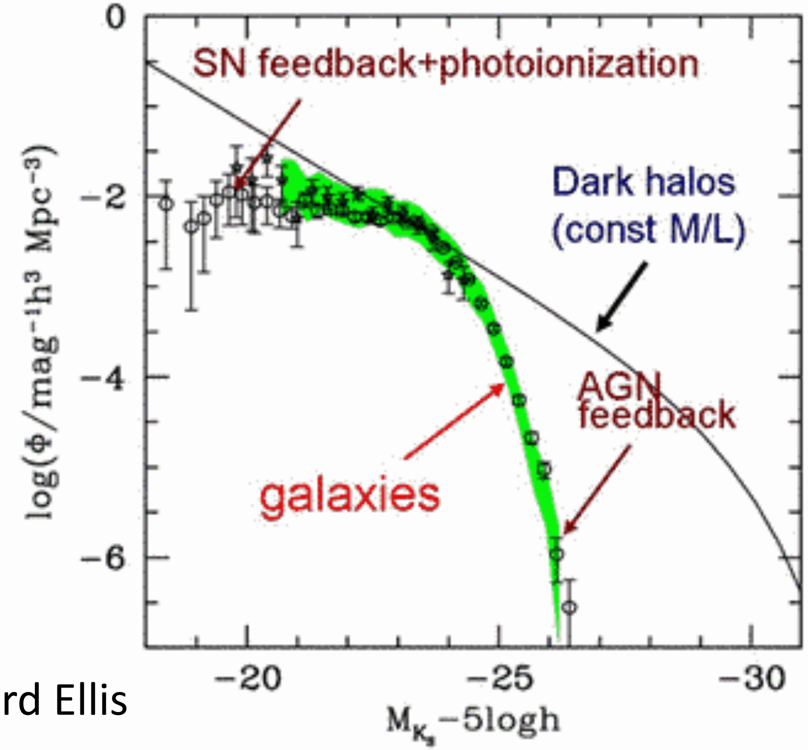
Cosmological context is important – even if/especially if it makes no sense:

galaxies look far too much like "Island Universes" – why?????

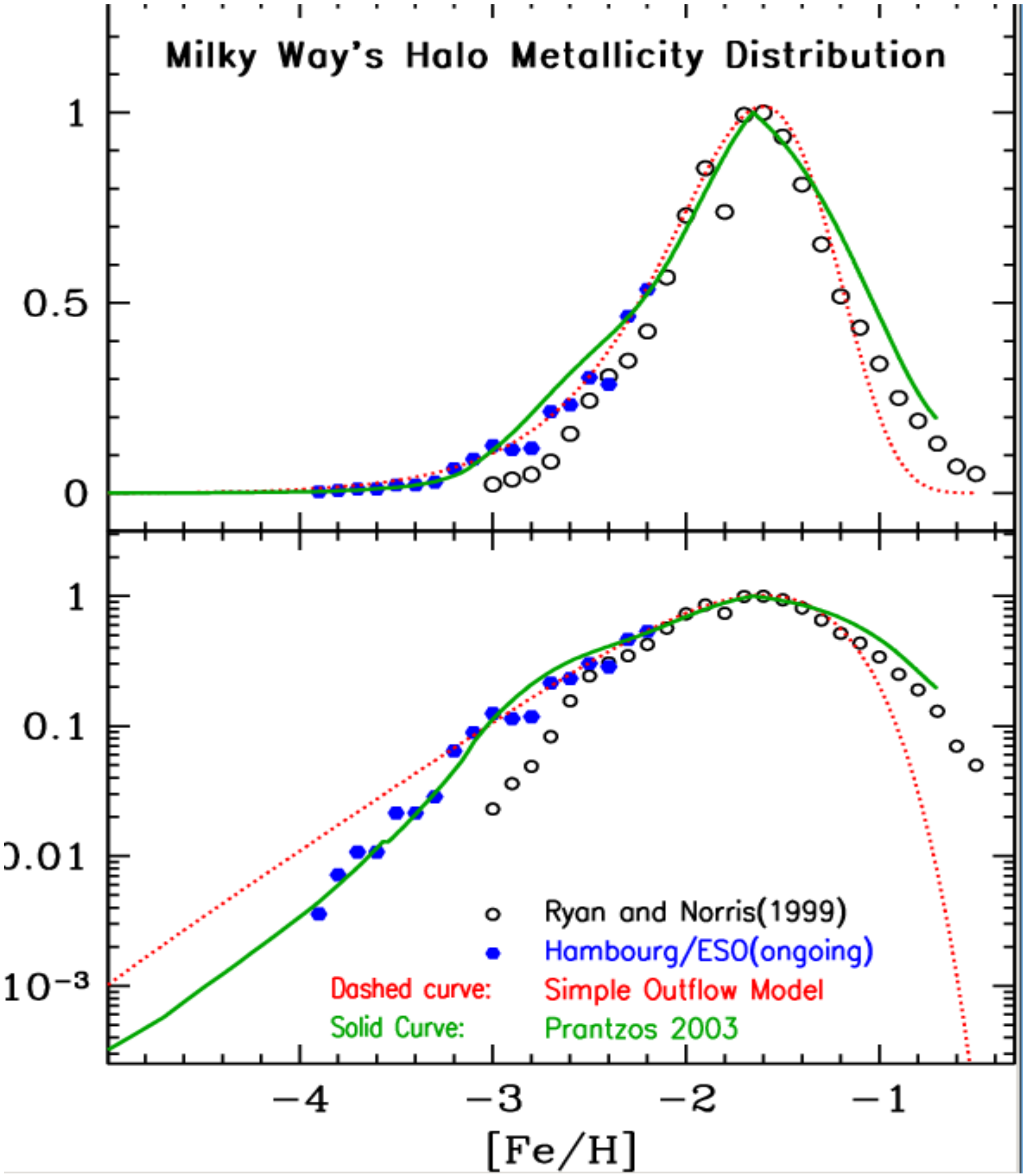
100% of large disk galaxies have major mergers since Z<2. – while too hard to calculate, these major mergers must leave signatures in chemistry/kinematics – lets look!!!

Suppression of star formation due to reionization and SN feedback is a semi-analytic fit to the galaxy luminosity function: <u>it is a hypothesis and not a proof</u>

Thus, Carlos, we <u>do</u> have to find the <u>dark satellites</u>



Slide courtesy of Richard Ellis



Stellar metallicity distributions are sequential:
Halo ➔ thick disk ➔ thin disk

Why?

AMUSING:

Halo MDF consistent with monolithic formation in situ, with gas loss into early disk. [ELS]

But this is not modern LCDM expectation.

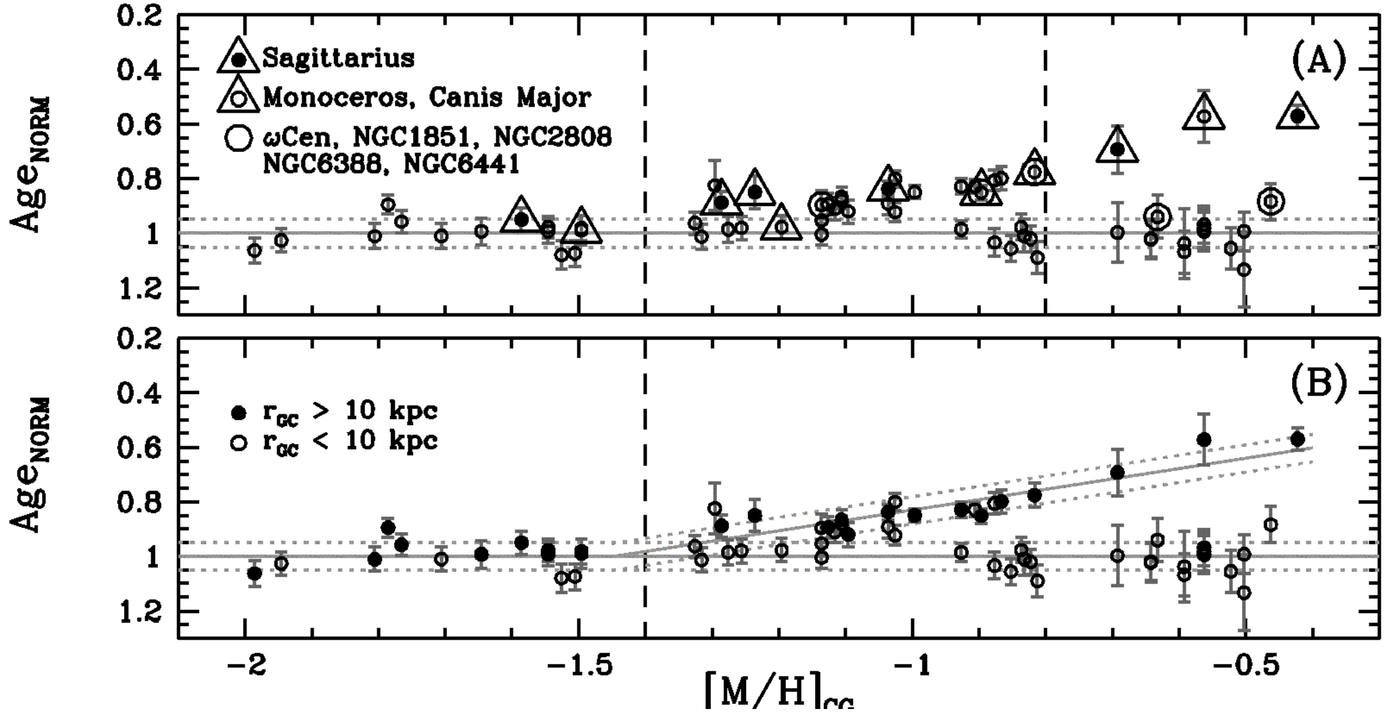
Coincidence or information?

MOST INNER HALO AND THICK DISK FORMATION COMPLETE EARLY??

Remarkably narrow old age range for halo and thick disk globulars, as for field stars.

Alpha elements well-matched to the fast timescale early in the Galaxy

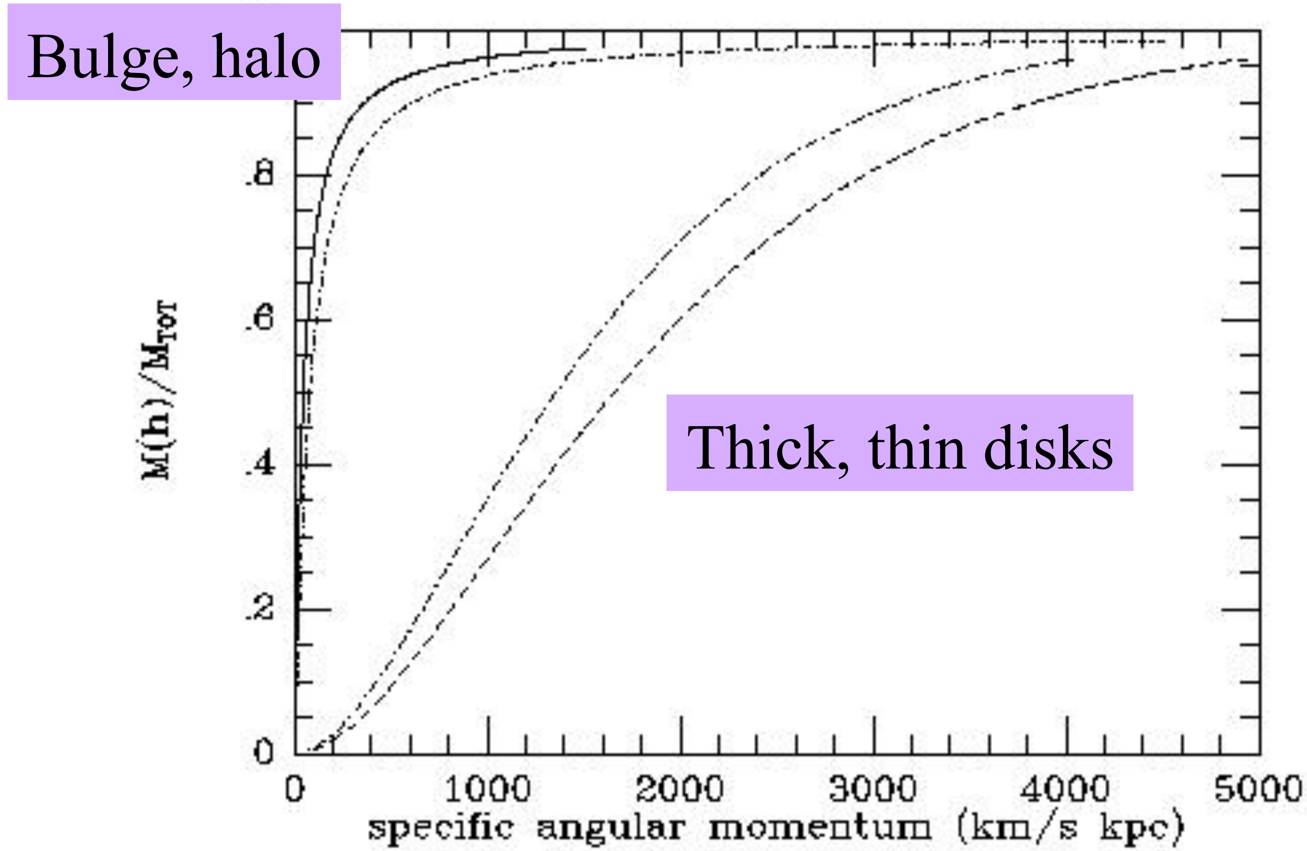
Are the heavy r/s elements best suited to resolve later Galactic evolution?



Younger clusters plausibly associated with satellite galaxies?

Marin-Franch et al 09

Bulge—halo —disk connection? Which first?



Wyse & gg 1992

The first zero [Fe] stars should be in the bulge: are they?

SMBH connection??

Bulge angular momentum distribution consistent with dissipational collapse of gaseous ejecta from stellar halo star-forming regions -- mass ratios also agree with low metallicity of stellar halo Hartwick 1979:

old thick disk requires very early large disk formation/survival

no "classic" bulge is consistent, but even harder for cosmology

Disk Evolution: Migration

- is stellar radial migration significant?
  - Driven by resonance with transient structures within the disk, e.g. spiral arms (Sellwood and Binney 2006),
  - expected to be most efficient for stars in close-to-circular orbits, with low amplitude random motions: hence younger stars, beyond inner disk/bar where velocity dispersion higher
  - Or is probability independent of amplitude of random motions (e.g. Schönrich and Binney 2009)?
    - Is it consistent with age-dispersion relation, which shows spiral structure affects only young stars?

the case for migration proving to be important is still open

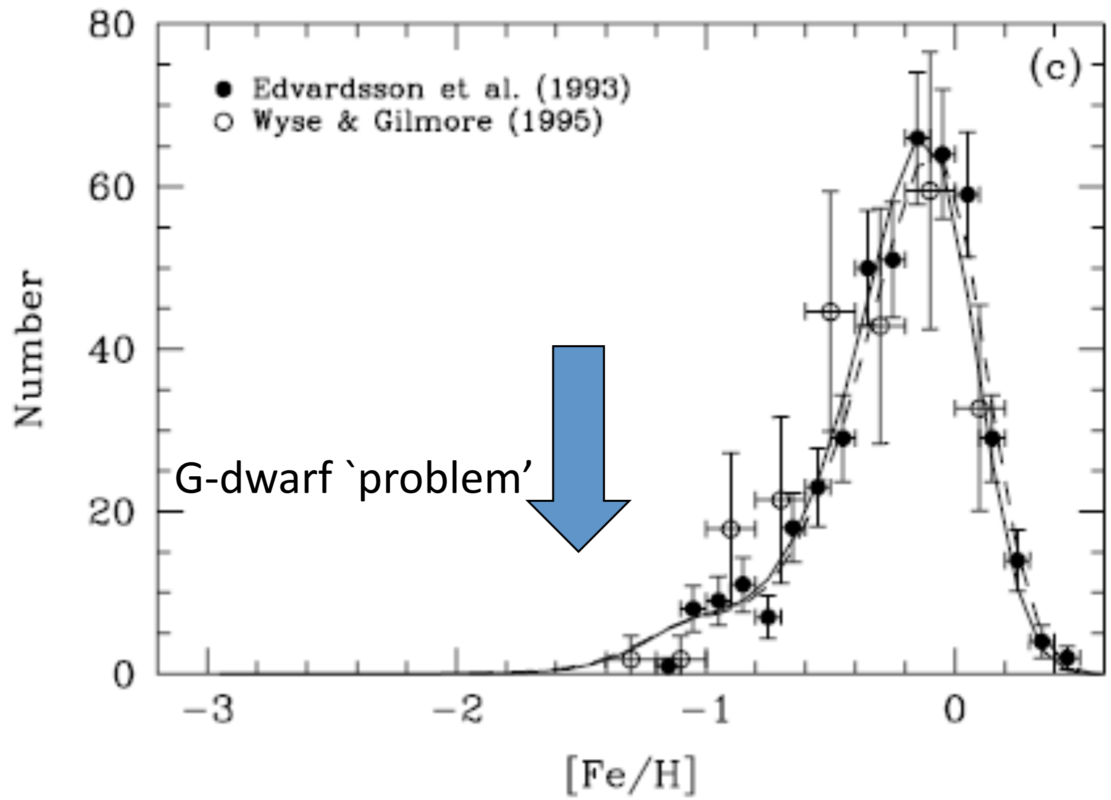
What came before the thin disk? The thick disk? The halo? Both? Neither?

Big challenge:
Understand the DF
of metal-poor stars

What created the
elements at low
abundances?

Where are the
ancestors?

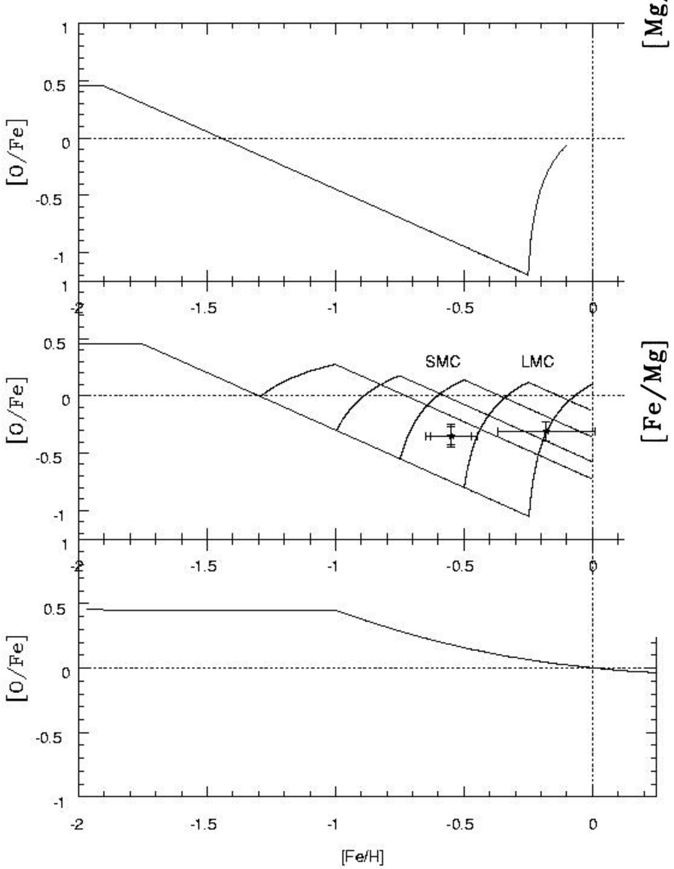
Solar cylinder metallicity DF

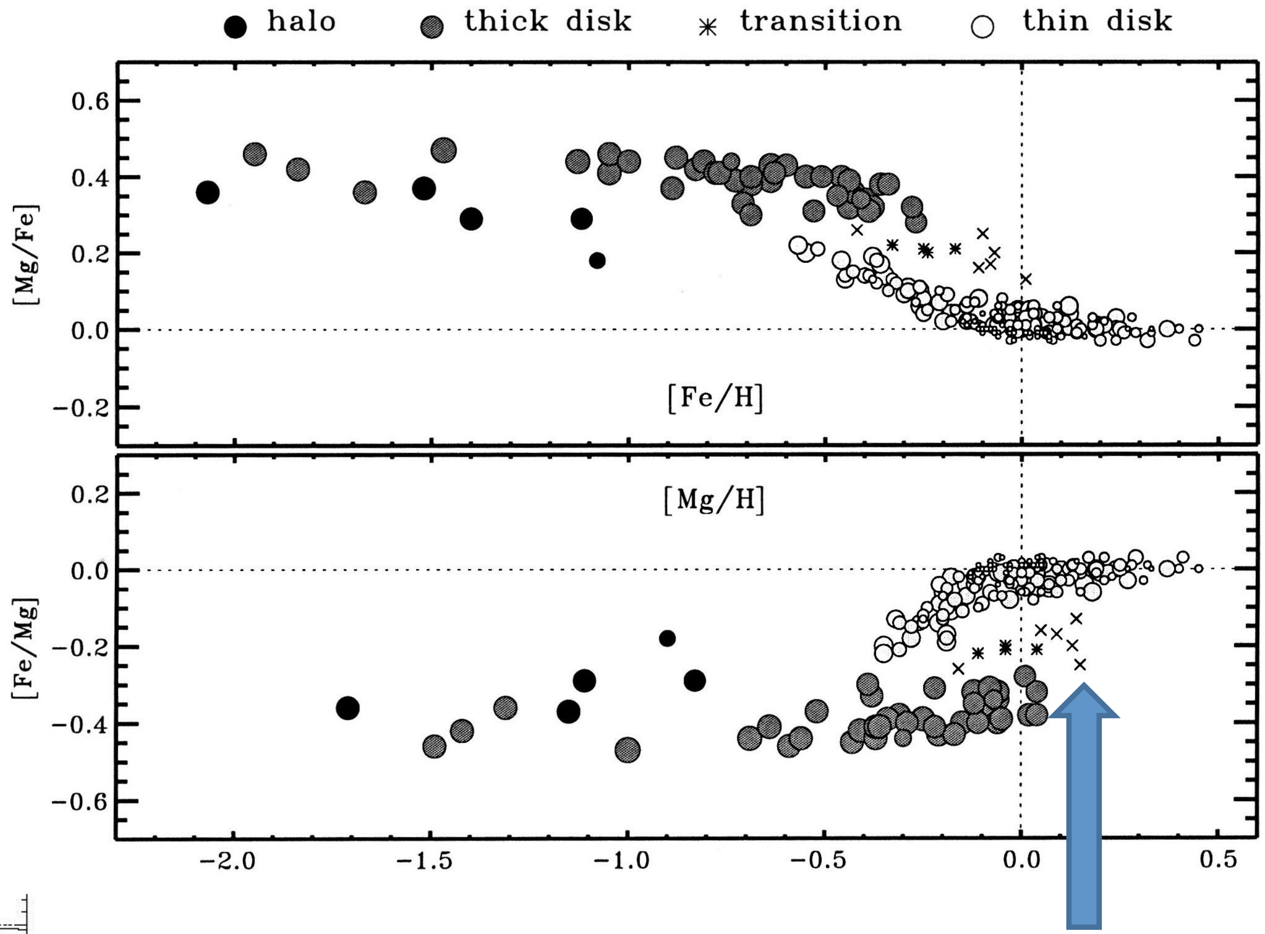


Topical chemical evolution models: lots more detail, but the same essential physics as simple model.

Chemical evolution models allow very large element ratio scatter – not seen

This model from Wyse + gg





Element ratio data from Fuhrmann

The metallicity DF of the thin disk is very narrow

Can a significant merger hide in that tight correlation?

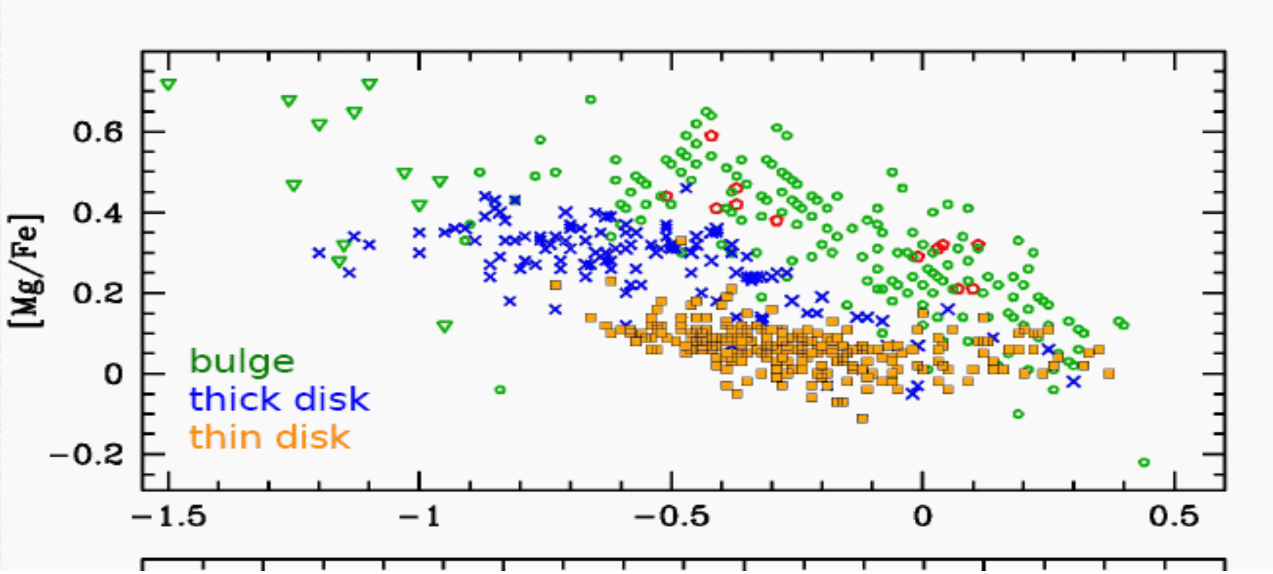
Element ratios are one effective way to identify "populations"
This distinction is the basis of future surveys eg hermes

We hope to doubt discover the reality is interestingly complex

Magnesium from the GIRAFFE sample

200 stars in the
b=–6° field

Standard IMF (#1)
Well-mixed (#2)
Fast recycling (#3)



We have seen several studies of high precision element ratios
All show clear bimodality between thick and thin disk
All are clearly inconsistent with the Bovy etal study.

L11 (2011)

Fascinating sample!

Things to note:

Bimodal DF at -0.5dex
➔not Bovy-like

➔What are the hamr stars?
Metal-rich thick disk?
Element ratio scatter?

➔What are the low alpha metal-poor stars?

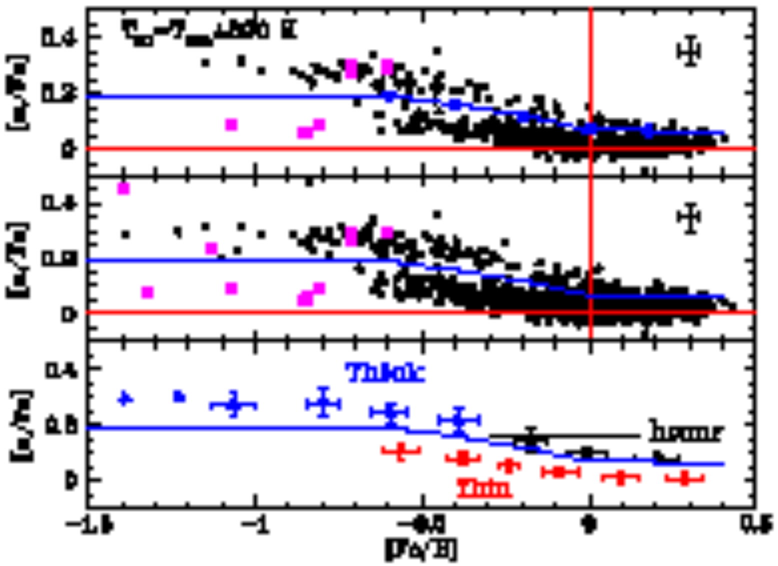
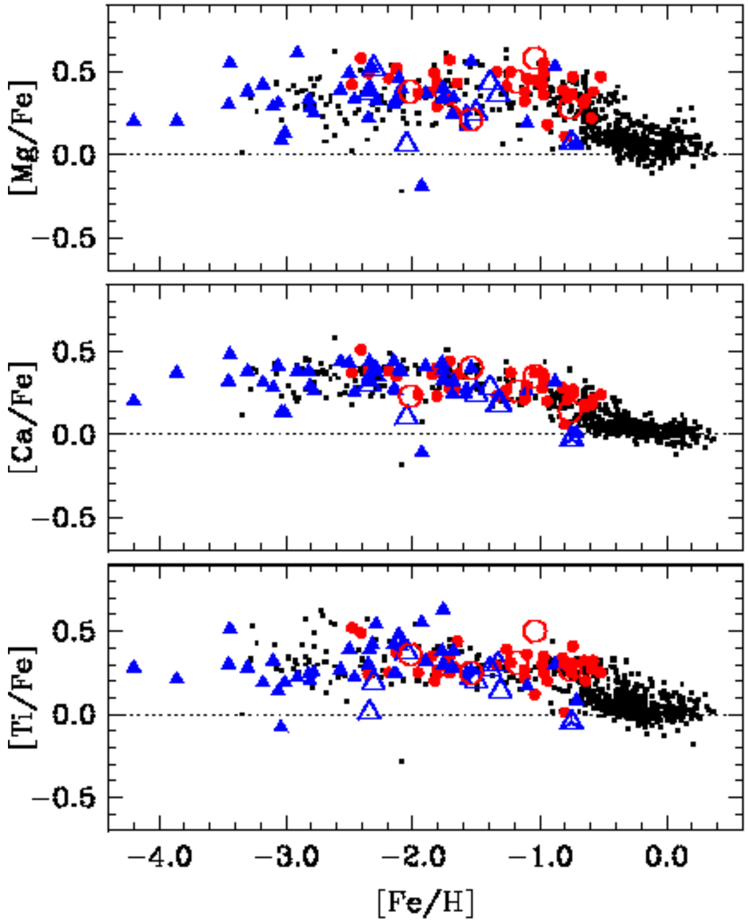


Fig. 1. [α/Fe] versus [Fe/H] for the whole sample (*middle*) and for stars with $T_{\rm eff} = T_\odot \pm 300$ K (*top*). Magenta squares refer to halo stars. Blue filled circles are the separation points between low- and high-α stars, which are minimas of the [α/Fe] histograms for five metallicity bins (from [Fe/H] = −0.7 to 0.25) and the blue dashed curve is the corresponding separation curve passing on that points. *The bottom panel* is the [α/Fe] versus [Fe/H] plot for the whole sample in several bins of metallicity. The blue triangles refer to the thick disk stars, black filled circles to the metal-rich high-α stars (hamr), and the red crosses to the thin disk stars. Error bars in *the lower panel* correspond to the standard deviations, and the error bar in *the upper and middle panels* are the average errors in the [α/Fe] and [Fe/H].

Adibekyan etal 2011

Scatter-free distribution functions?

Narrow range in [el/Fe] ➔ good mixing
Plateau ➔ universal IMF, efficient mixing
Sharp break ➔ narrow time
Metal-poor thick disk like halo, or?????



The very small scatter in [el/Fe] at every [Fe/H] is remarkable.
This implies efficient ISM mixing on long spatial scales in times short relative to the enrichment time [>kpc, <1Gyr?]

Why should the outer thick disk have high alpha

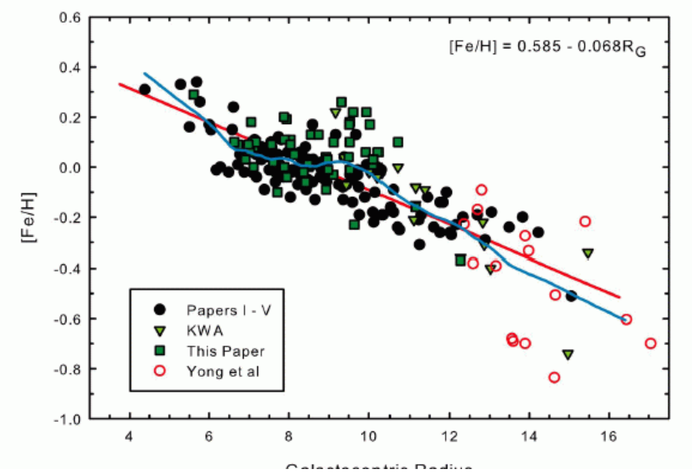
How do the expected major mergers work?

Gas accretion time must drive SFR (dG prob)

SNe –driven fountains must mix old+new gas highly efficiently on kpc scales
➔ Consistent with smooth shallow gradients

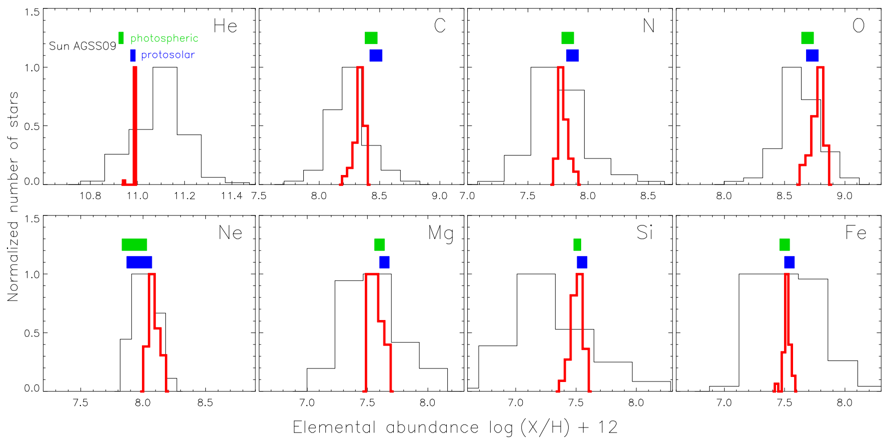
We have seen several abundance gradient studies, which raise two puzzles

1) Is the gradient really smooth with radius? ➔ fountain dominance?
2) There is a serious inconsistency – the ISM is locally close to solar, many young open clusters are supersolar – there is a calibration challenge here.



NB: Metallicity can DECREASE with time, with inflow
SMR does not imply migration
But young star abundances MUST match ISM

Does the warp change everything??
What sets the abundance floor at large radius?



conclusion

- Our sympathies to the earthquake victims
- Many thanks to the organisers – big success in challenging circumstances
- Impressive balanced programme by subject, gender, and age

- Precision; large samples; calibration; are the future – and lots more careful thought of how all this detail makes up a big picture