On the Halo metallicity gradient using RR Lyrae stars

G. BONO, Univ. Of Rome Tor Vergata + many others [G.F., E.V.]

OUTLINE OF THE TALK

→ Setting the scene

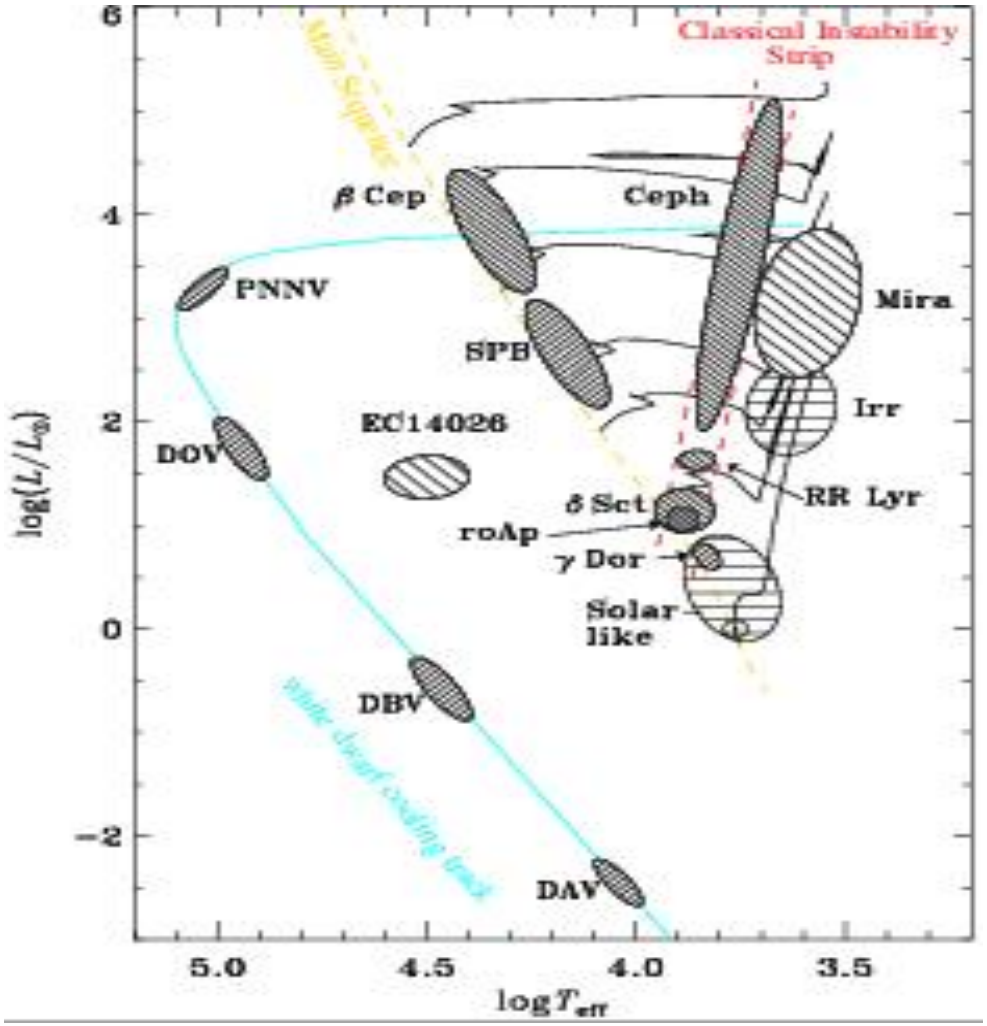
→ Photometry & Spectroscopy

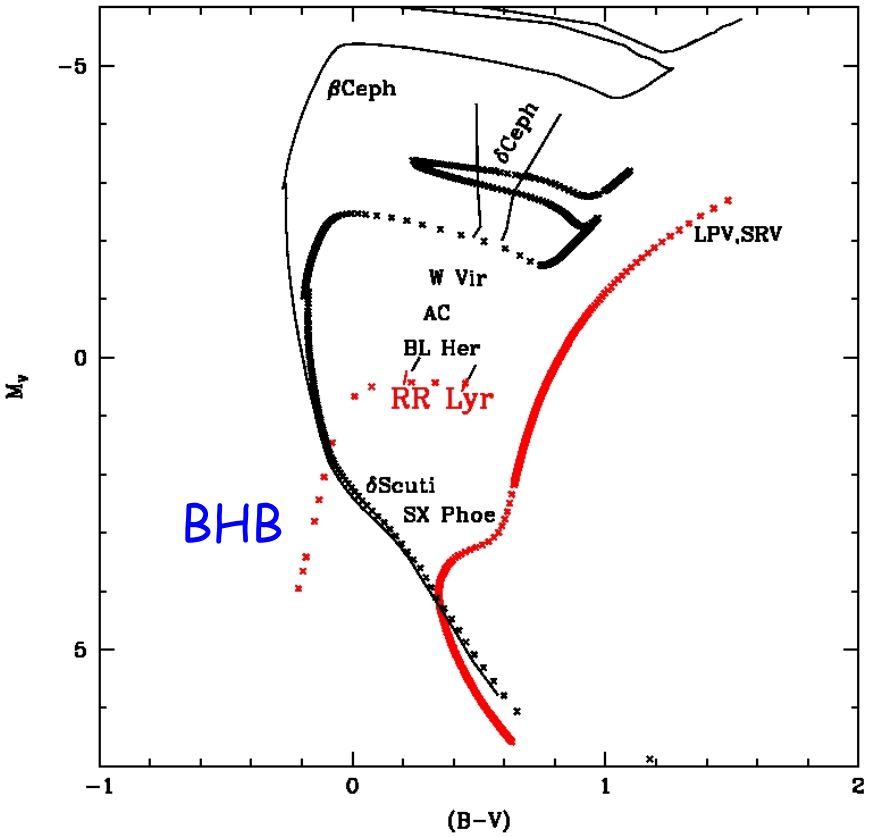
→ Metallicity Distribution function

→Metallicity gradients

→ Conclusions

RR Lyrae Pulsation & Evolutionary Properties

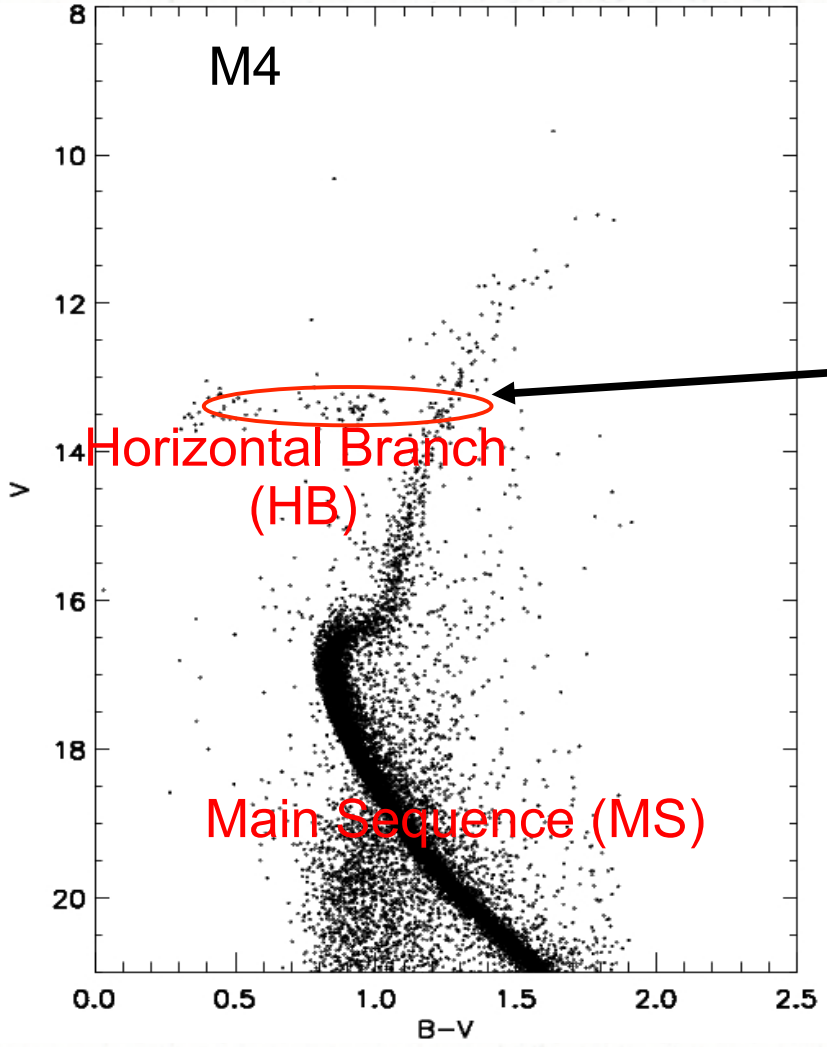




RR Lyrae Instability Strip

Easy selection either color-color plane (BHB) or variability (RRL)

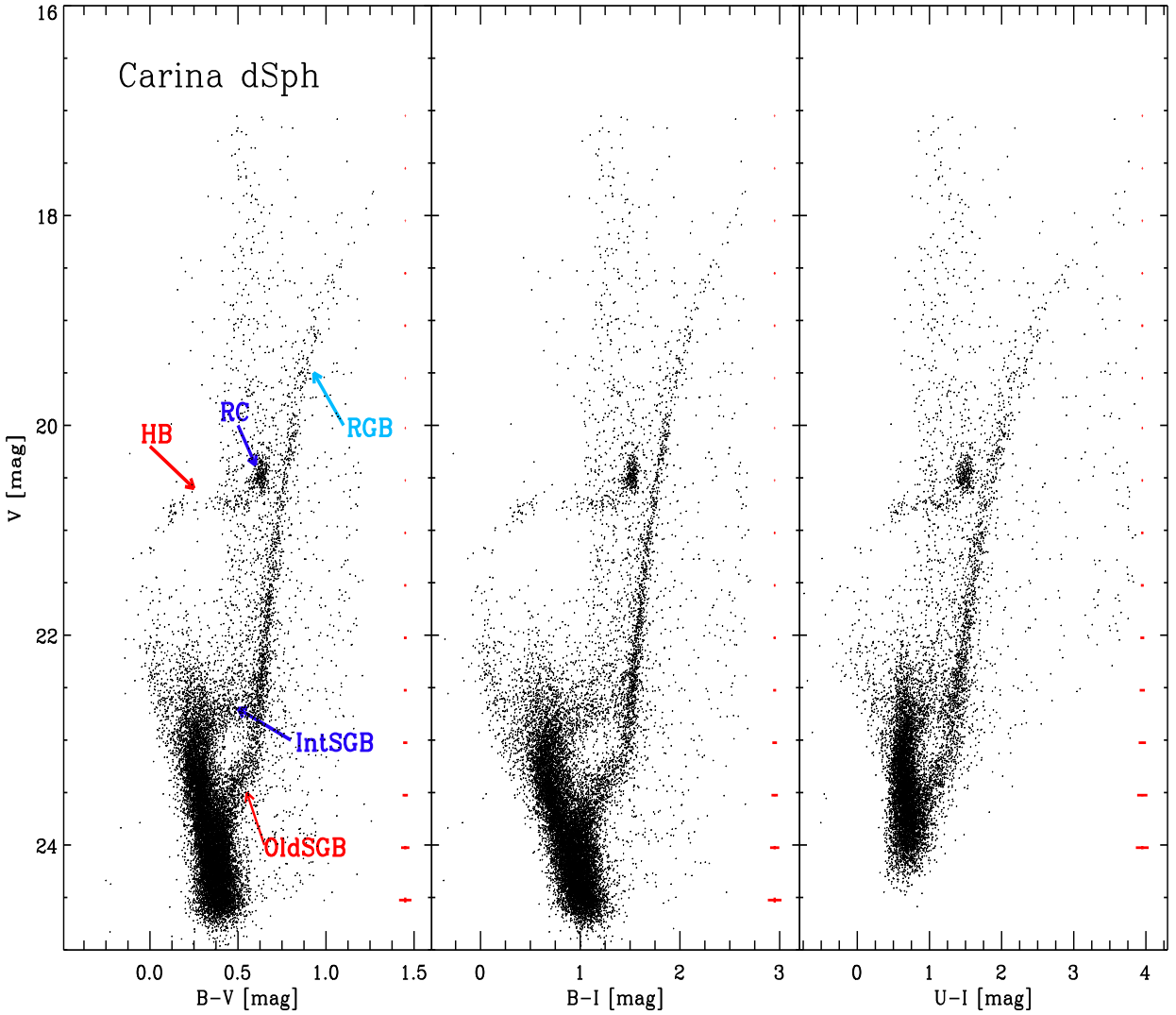
RR Lyrae variables

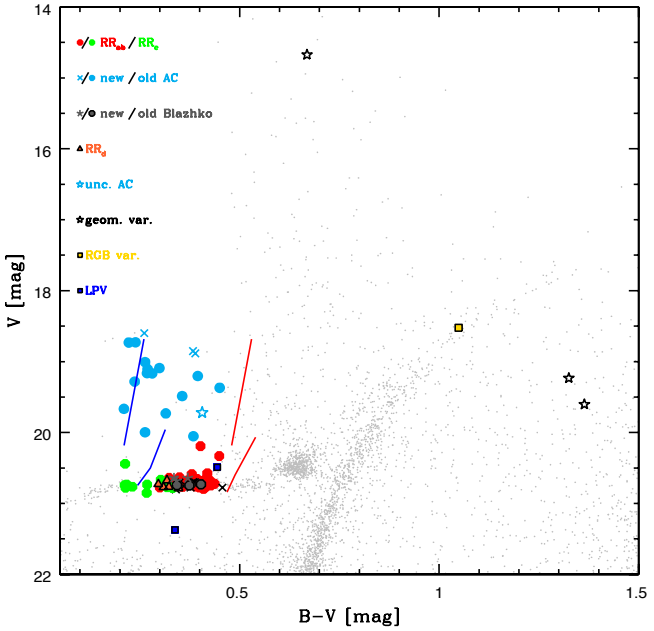


Stetson + (2014)

- Initial mass (MS): ~0.8-0.9 M_{sun}
- Mass (HB): ~0.6-0.8 M_{sun}
- Core He + Shell H burning
- [Fe/H] ~ -2.5 – 0.5 (*Smith 2005)*
- Old: >10 Gyr (GCs, halo, bulge)

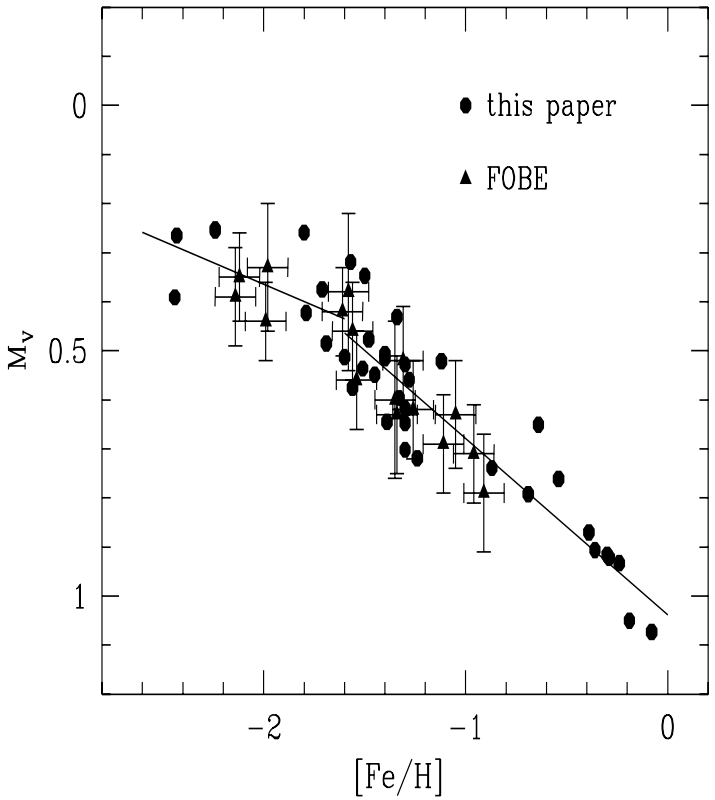
Carina RR Lyrae

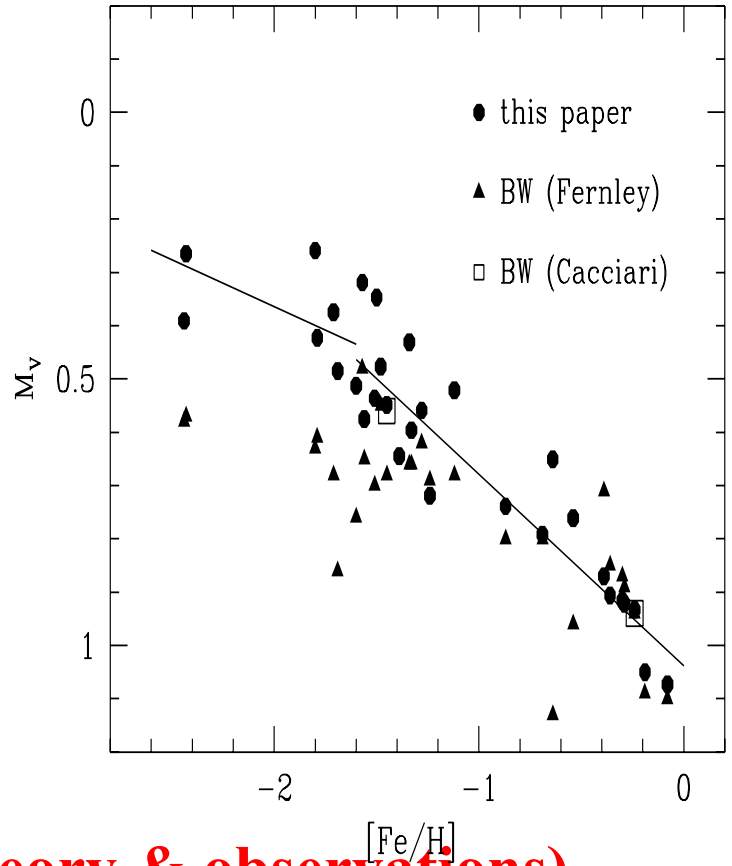




Carina dSph
Coppola et al. (2014)

$M_V = \alpha + \beta$ [Fe/H]

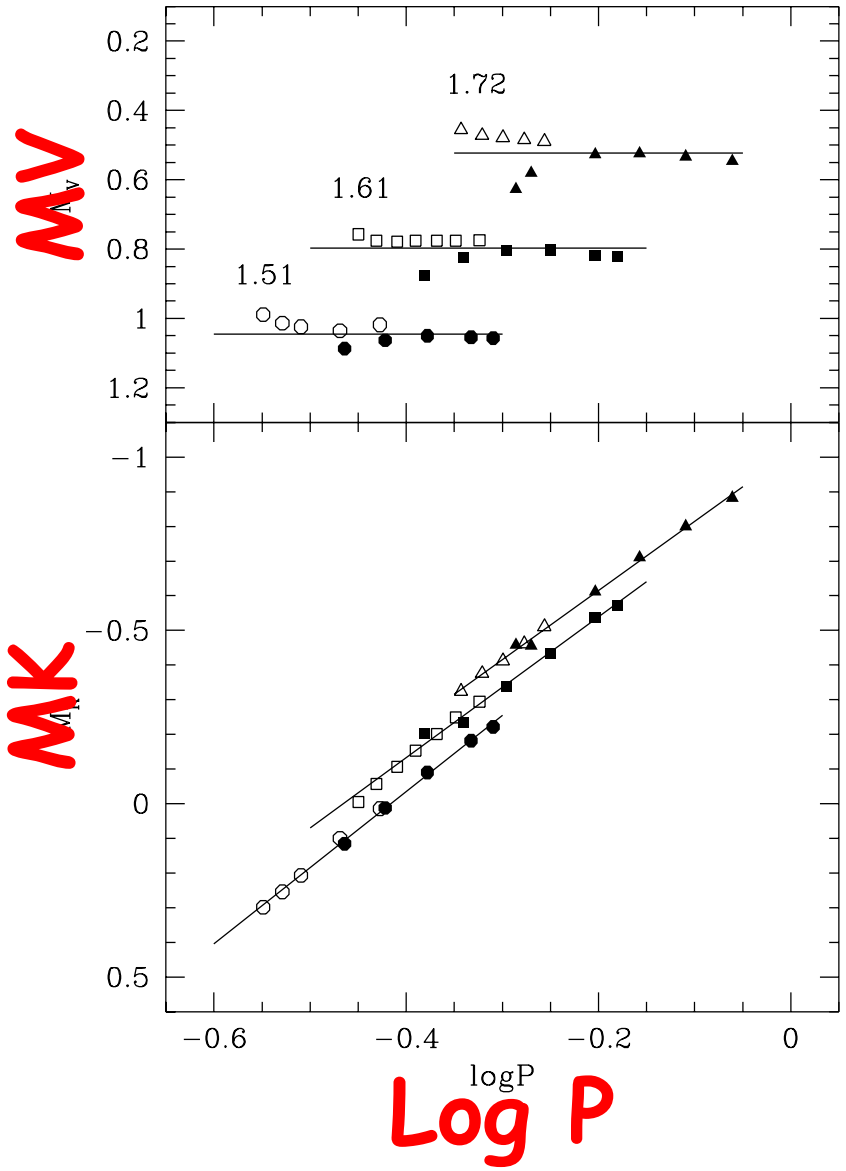




Uncertainties on both α and β (theory & observations)
Evolutionary effects
Heavy dependence on individual reddening uncertainties
Individual metal abundances

Bono et al. (2003), Cassisi et al. (2004), Catelan et al. (2005).

Why NIR is better than optical?

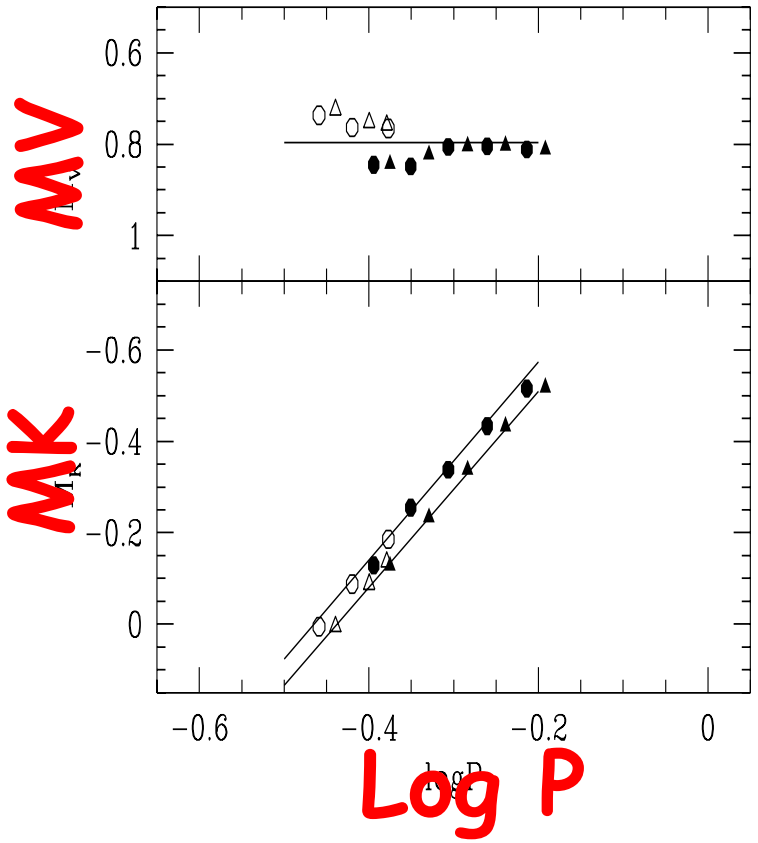


Longmore et al. (1989)

$$Mv(RR) = \alpha + \beta\,[Fe/H]$$

Affected by evolutionary effects!

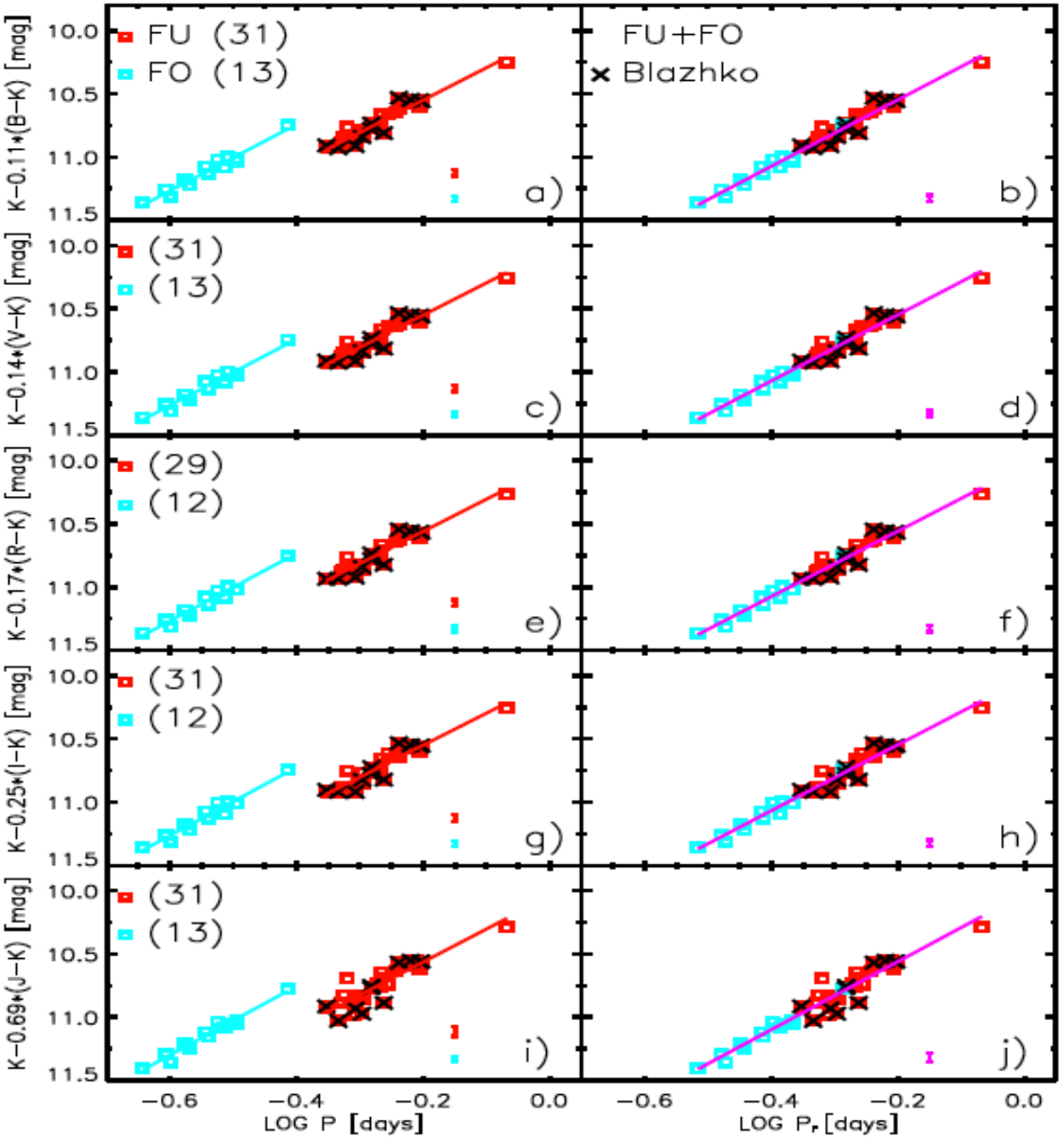
Bono et al. (2001)



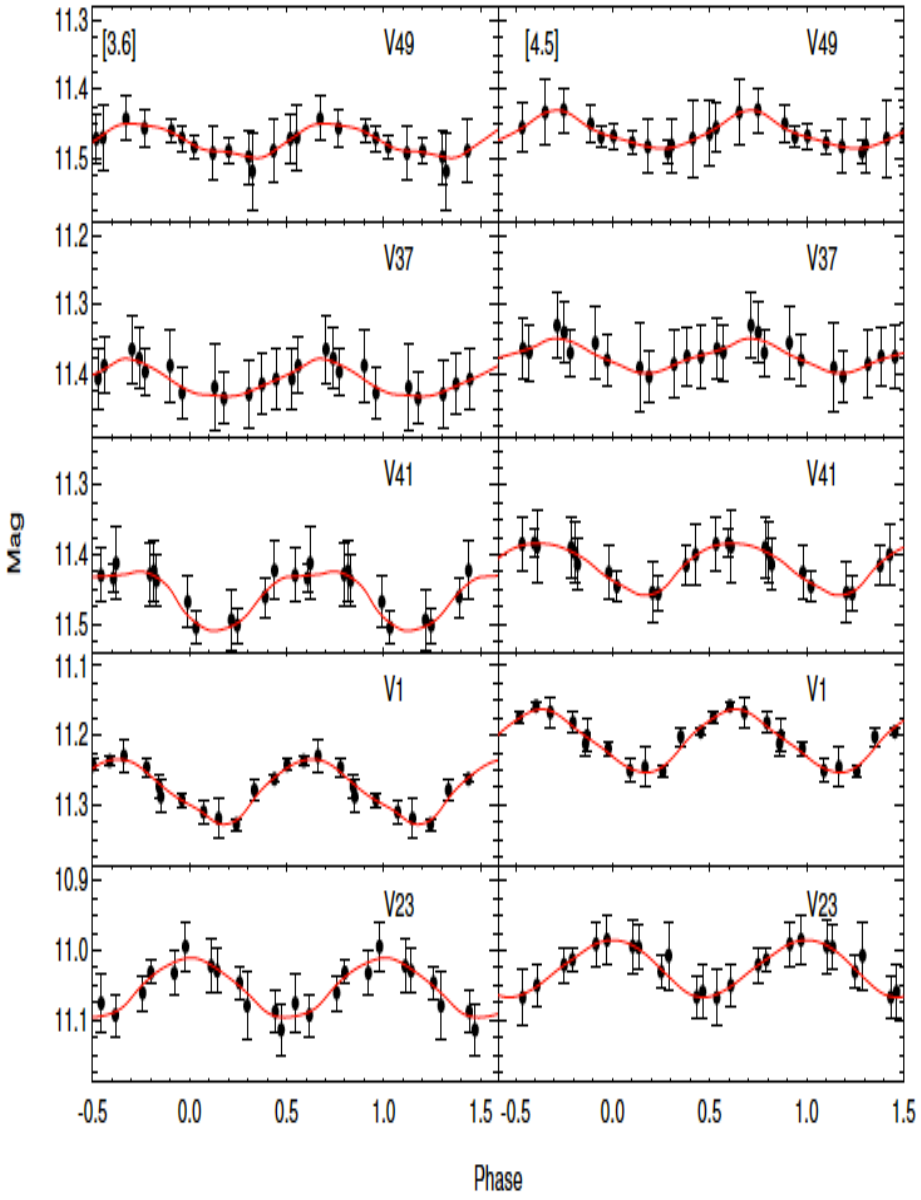
M4 a new spin to GC distance scale

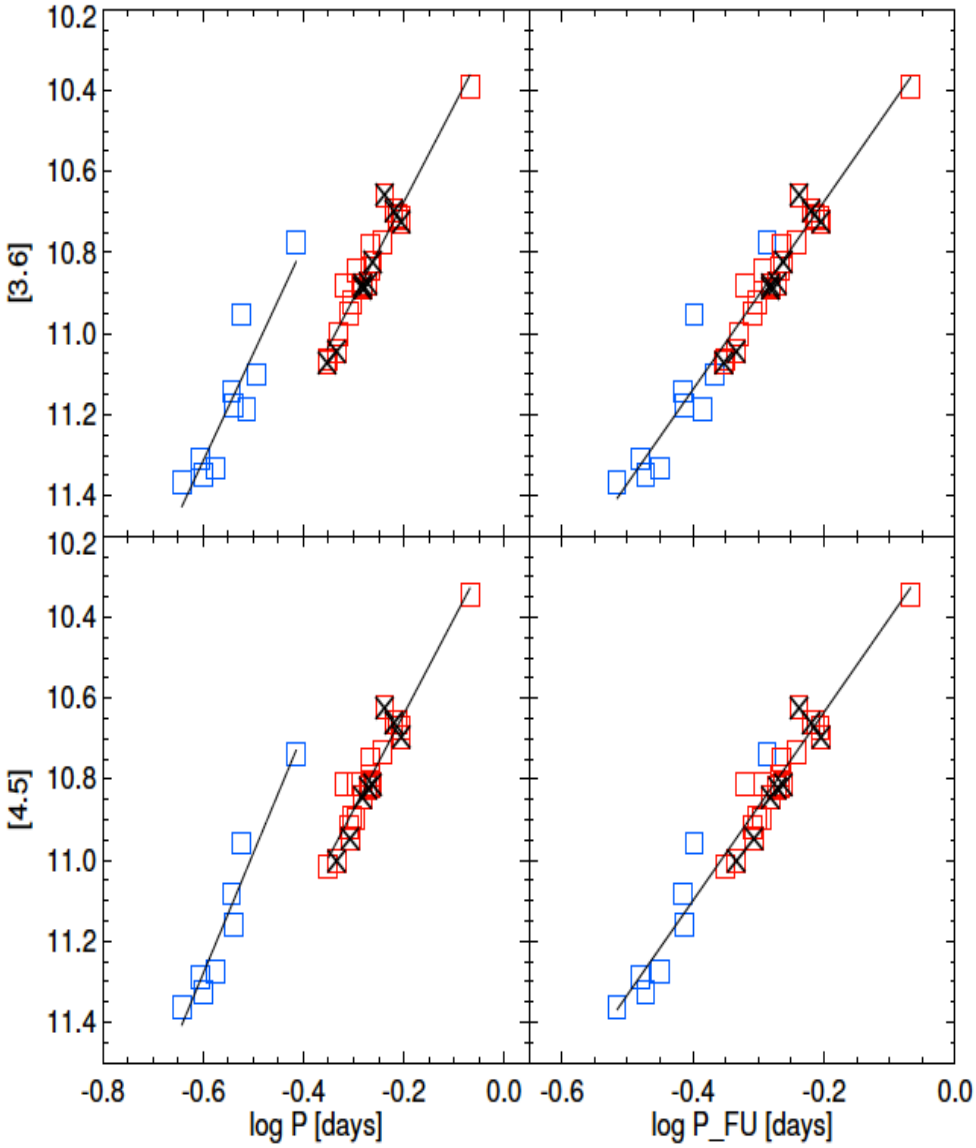
Optical/NIR

PW relations

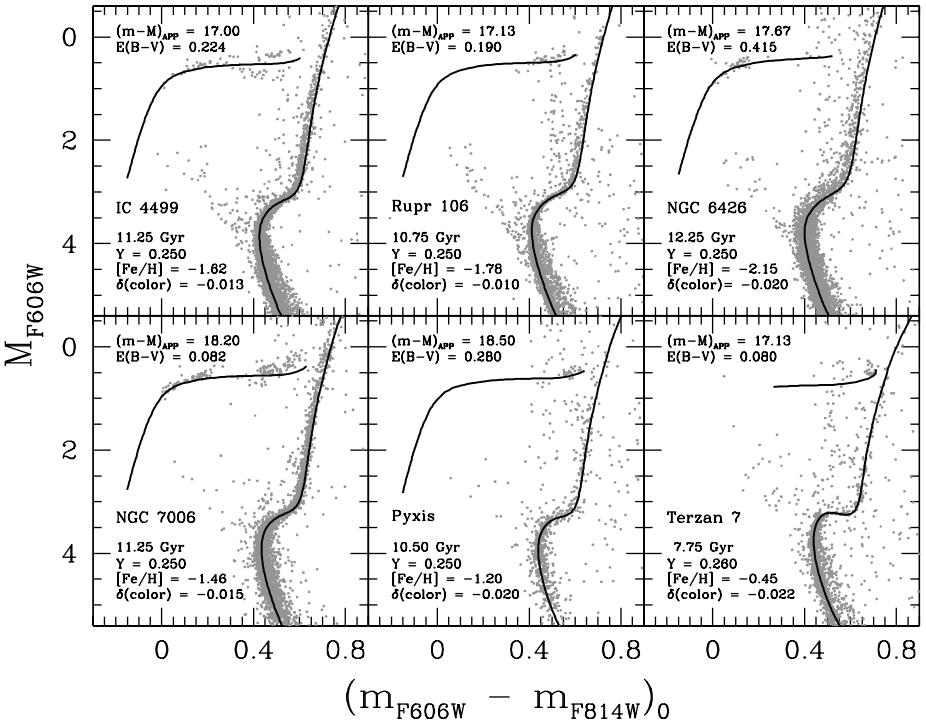


New accurate M4 distances
Spitzer + Wise data (Neeley + tbs)





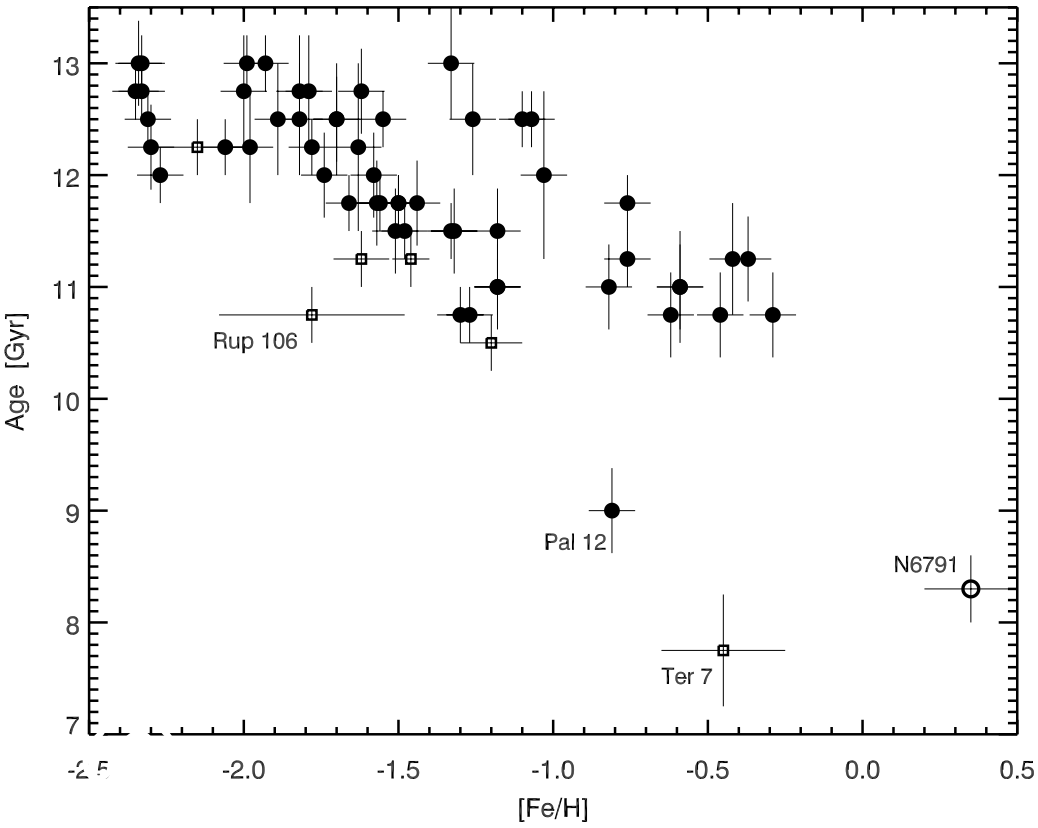
GCs as tracers of the Halo



Leaman + (2013): 61 GGCs

Absolute & relative ages

Two AMRs for [Fe/H]≥-1.8

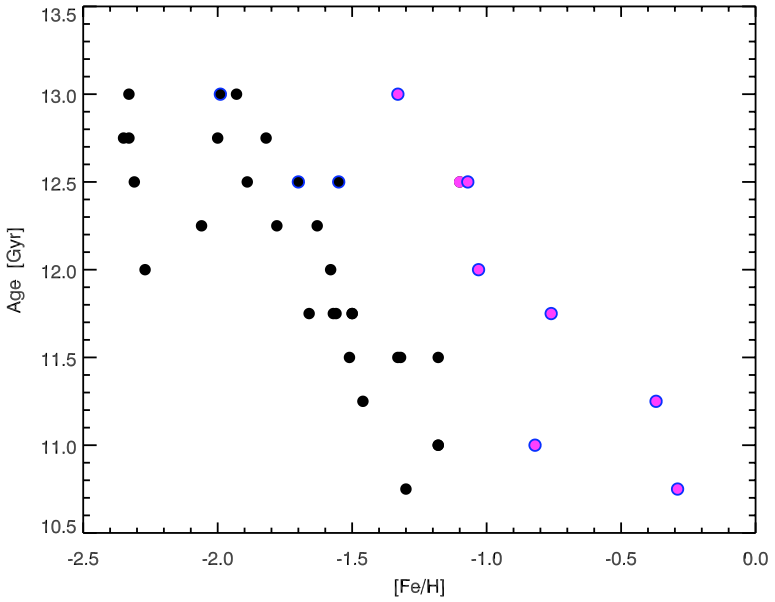


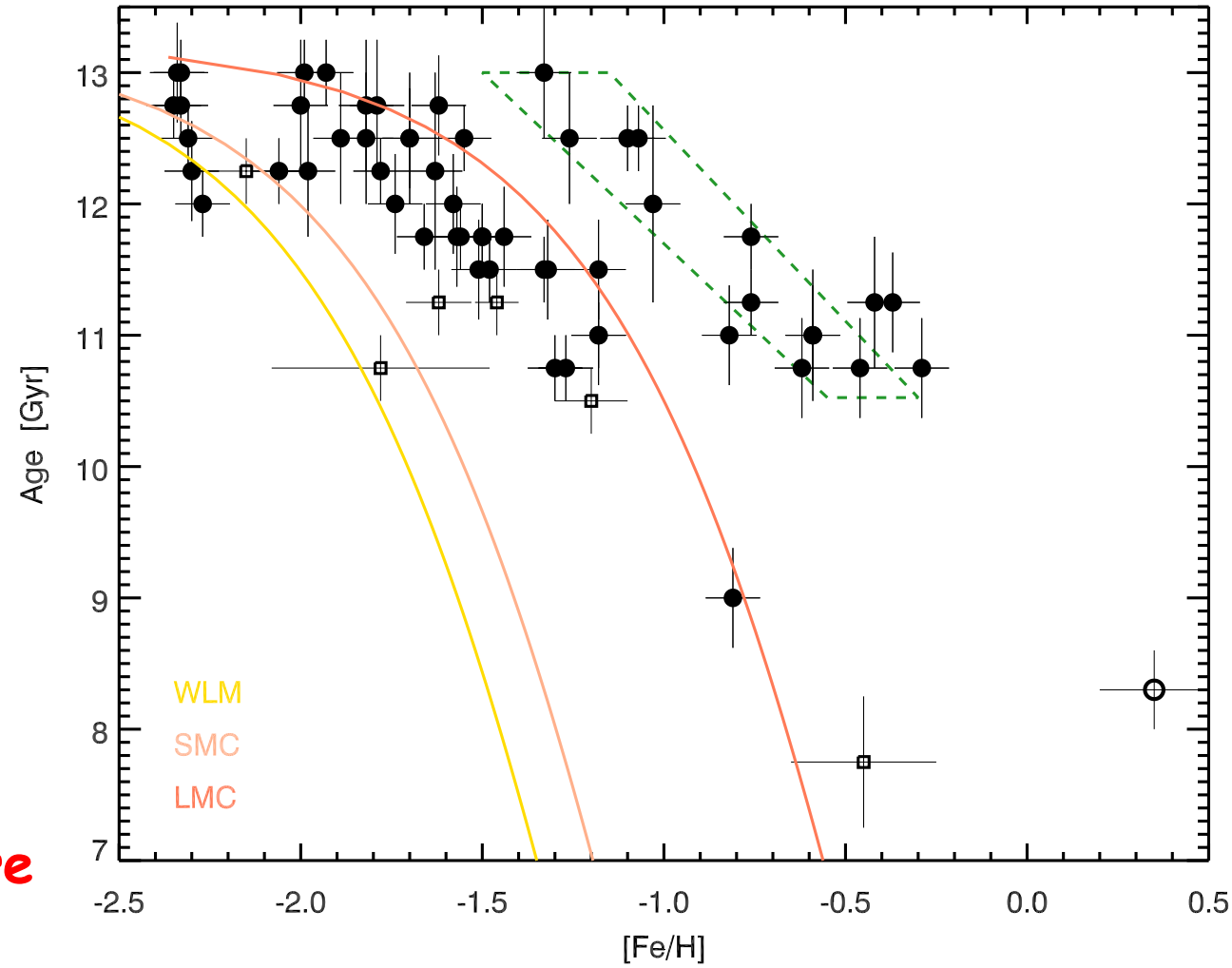
1/3 of the sample is, at fixed age, 0.6 dex more metal-rich

Eggen, Lynden-Bell Sandage (1962)

Searle & Zinn (1978)

Leaman + (2013)



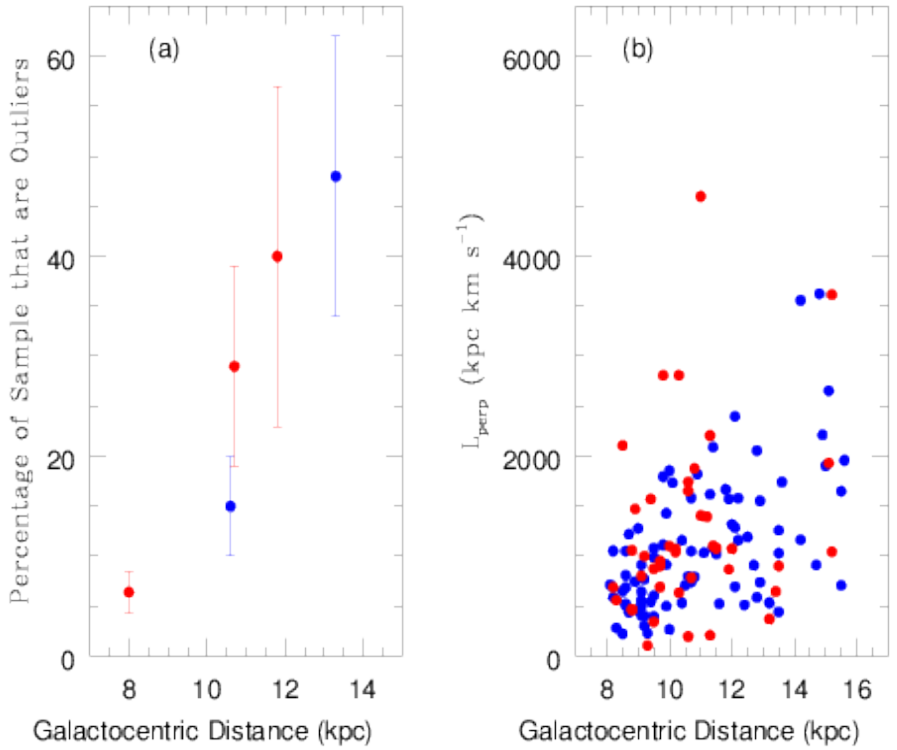


Their orbital properties are typical of disk/bulge GCs.

The bulk of the M.-R. sequence formed in the Galactic disk

A significant fraction of the M.-P. ones formed in dwarf galaxies that have been accreted by the MW.

New findings



Kinman et al. (2007, 2012)
Anticenter: 51BHB + 58 RR
NGP a few hundred

Galactic V motion is retrograde for RR+BHB with R_G > 10 Kpc
[Carollo+ 2010; Beers+ 2012]
The Outer halo is retrograde when compared with the solar neighborhood/inner halo

According to Angular momentum Distributions stars in the halo can be split in two groups:
Main concentration (relaxed, Hattori & Yoshii 2011) +
outliers

The ratio between out. & main con. increases as a function of R_G
The halo becomes more spherical with increasing R_G
Simulations (McCarthy + 2012)
Predict inner halo more flattened than outer halo

TRACERS OF THE GALACTIC HALO

Layden (1994) Suntzeff + (1994) Kinman + (200X)

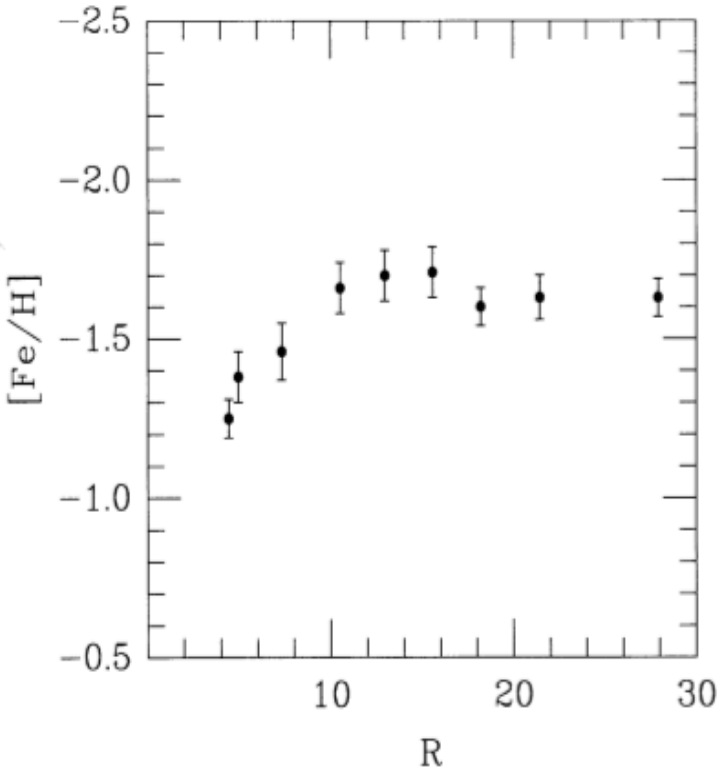


FIG. 4*a*

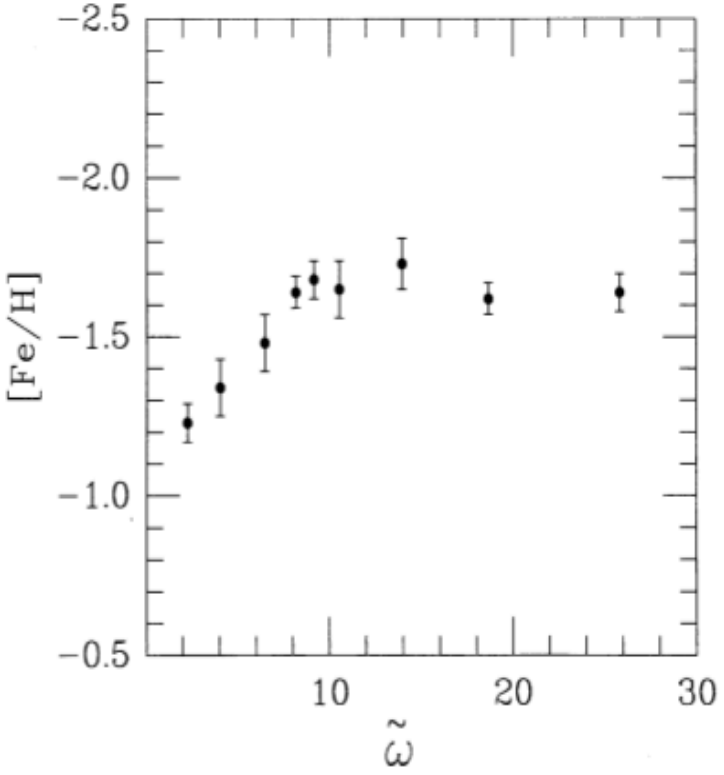


FIG. 4*b*

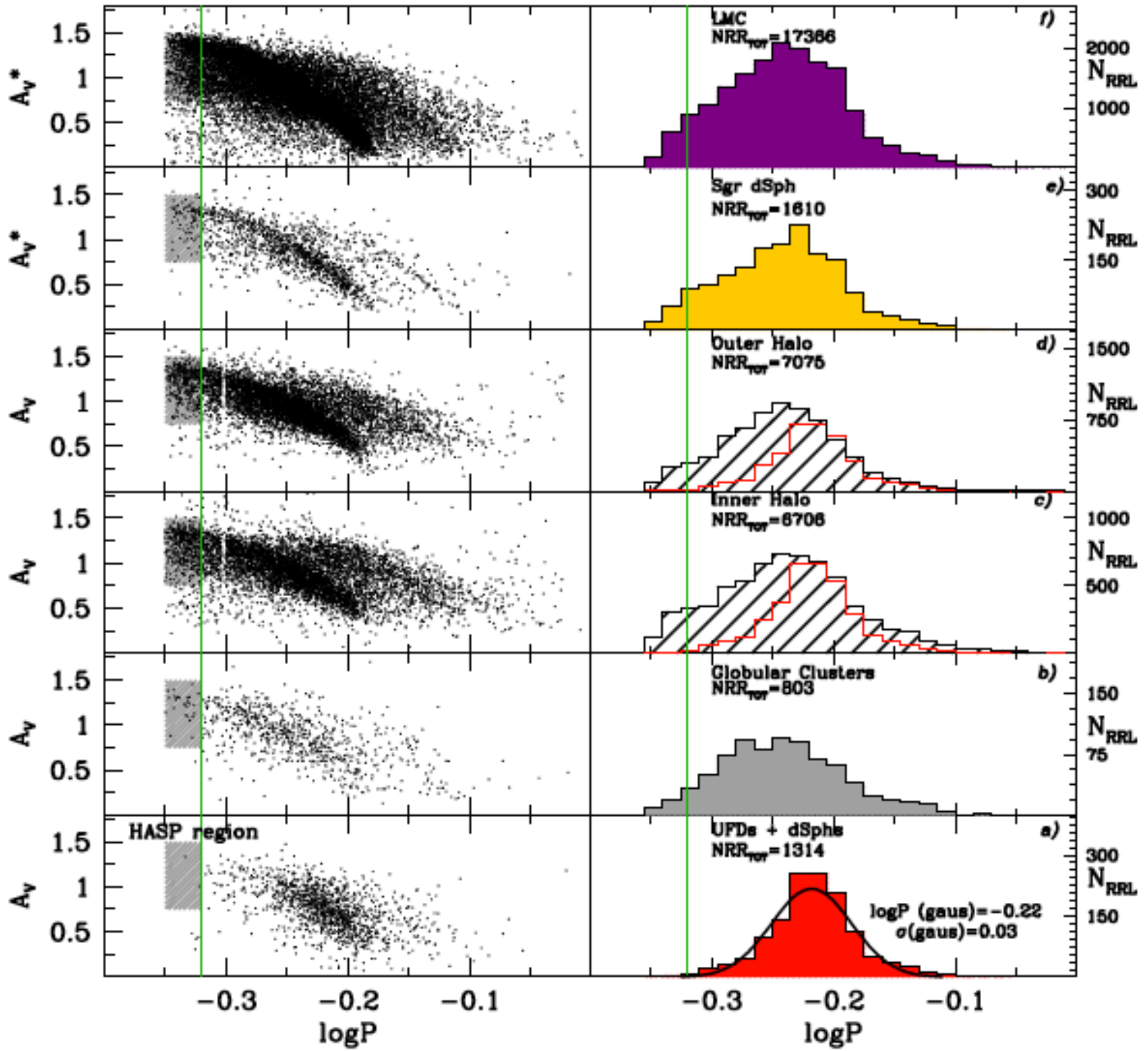
FIG. 4.—Averaged abundance for the 171 stars as a function of distance from the Galactic center. Data are plotted (*a*) as a function of galactocentric distance and (*b*) as a function of galactocentric distance projected onto the Galactic plane. The data have been averaged into bins of 20 stars each (except the last bin, which has 11). The error bars represent the errors in the mean. In both panels, the nonzero gradient inside the solar circle is clear. Outside the solar circle, the 113 Lyraes have an average $\langle [Fe/H] \rangle = -1.65$ with a dispersion of 0.27 dex.

Drake + (2013), Torrealba + (2015) MDFs of Halo RR Lyrae using Fourier parameters of optical (V,I) light curves

Photometric surveys of the halo

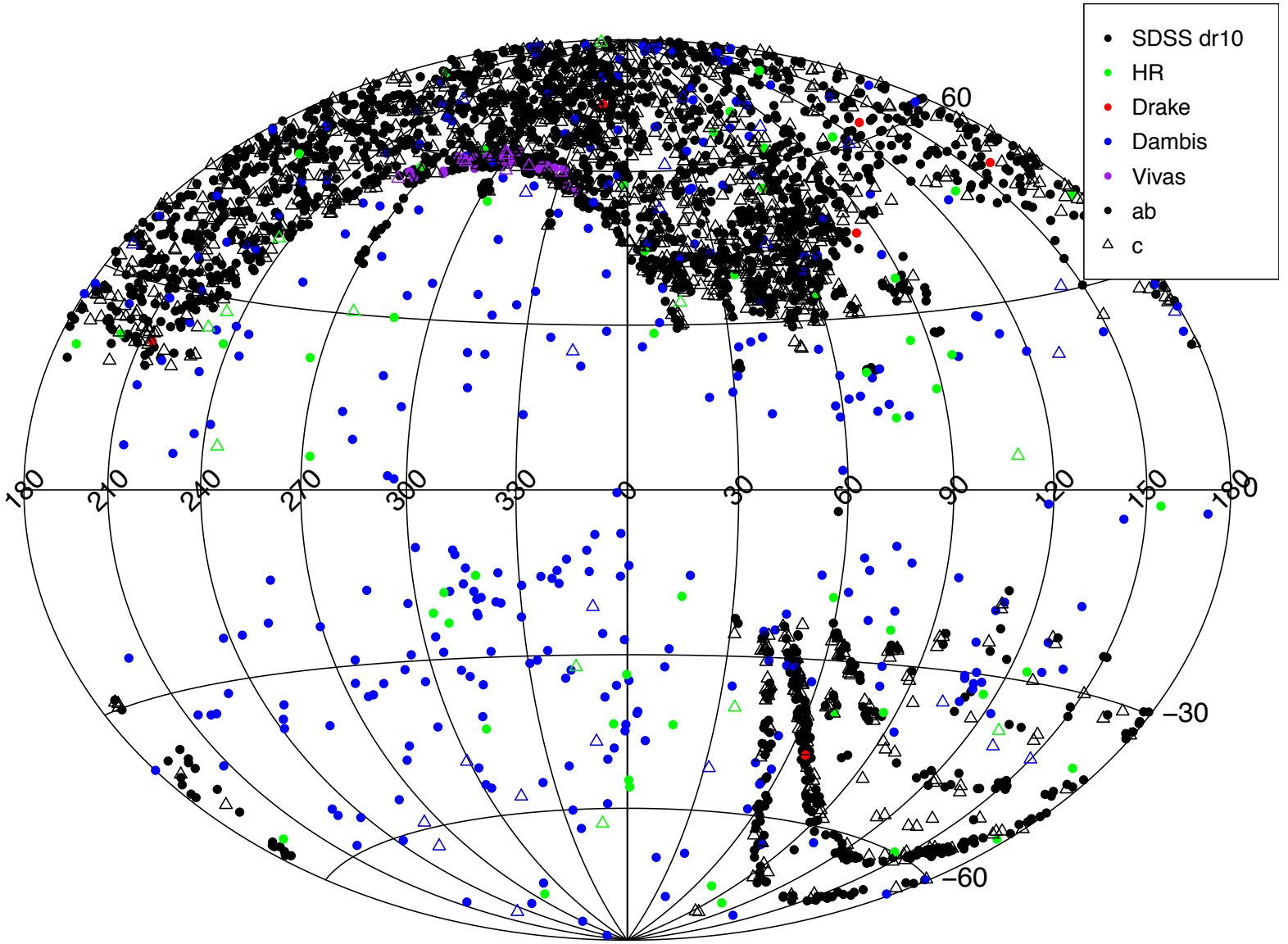
QUEST → Zinn + (2013)
CATALINA → Drake + (2013)
LONEOS → Miceli + (2008)
ASAS → Pojmanski + (2005)
LINEAR → Sesar + (2013)

A New Spin!



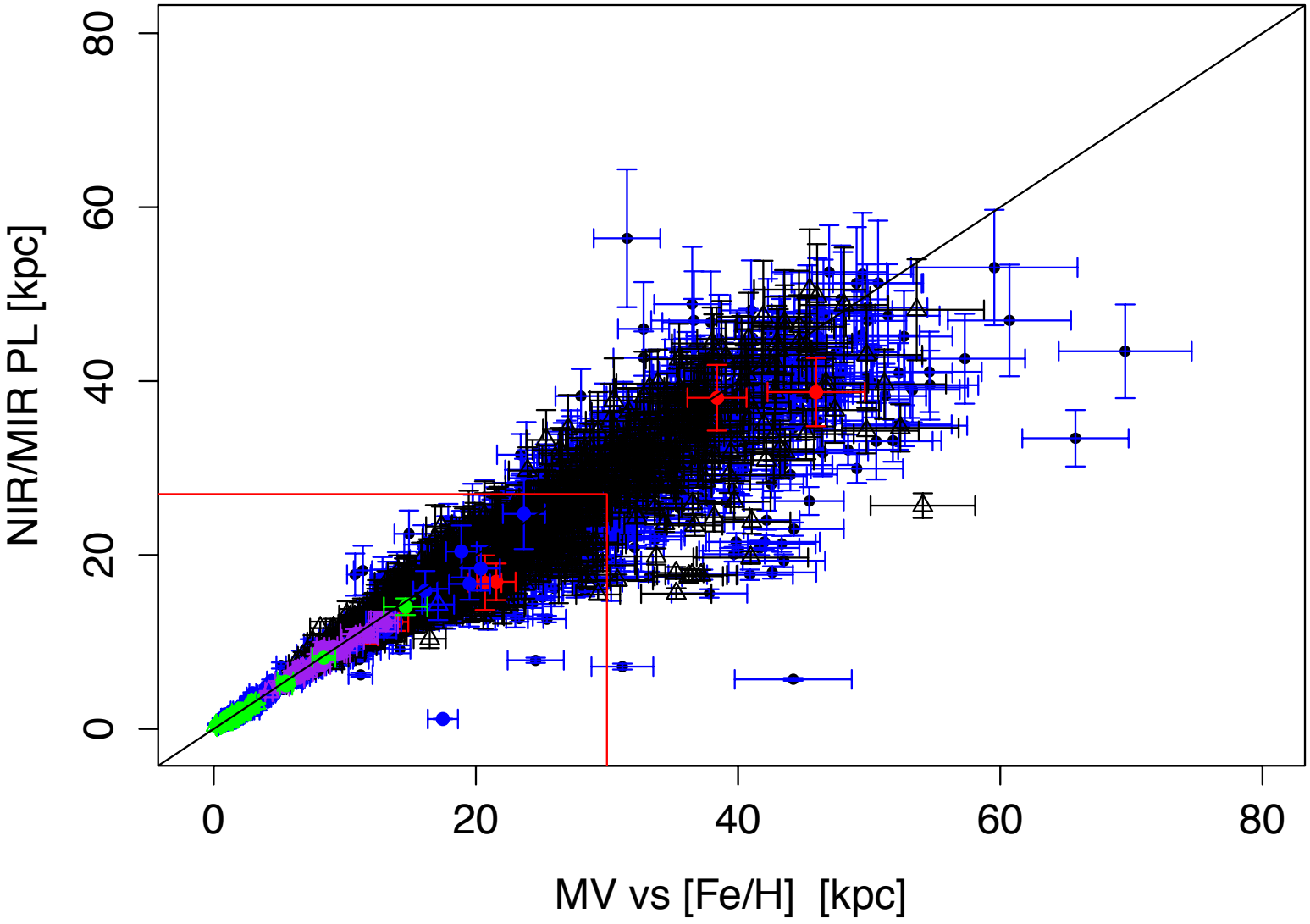
Fiorentino et al. (2015)

RR Lyrae (~3600) metallicities

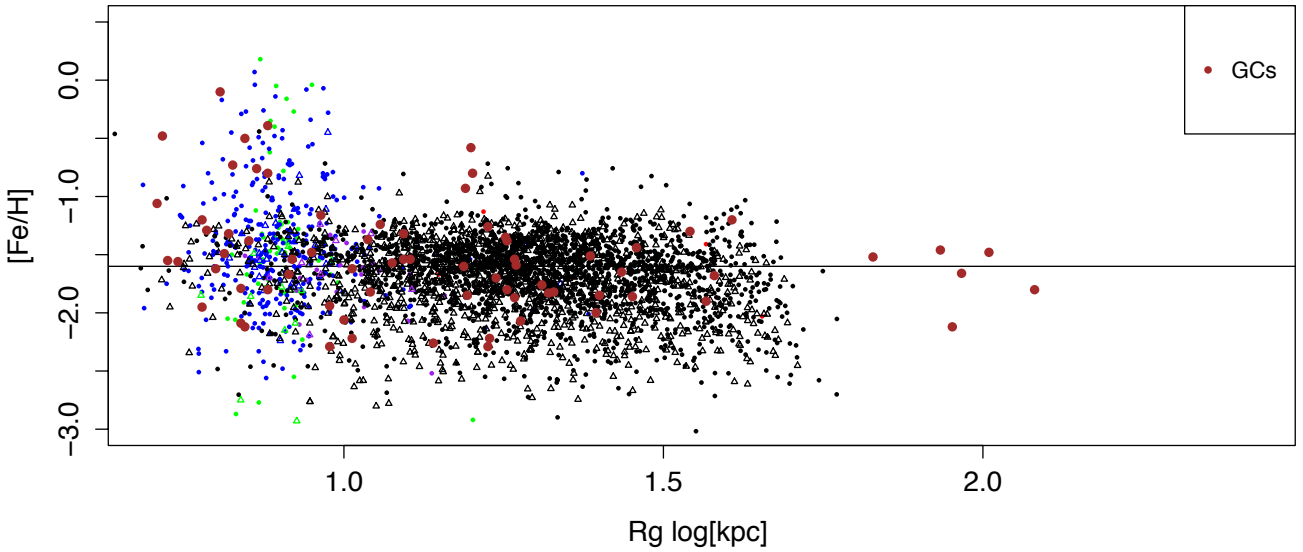


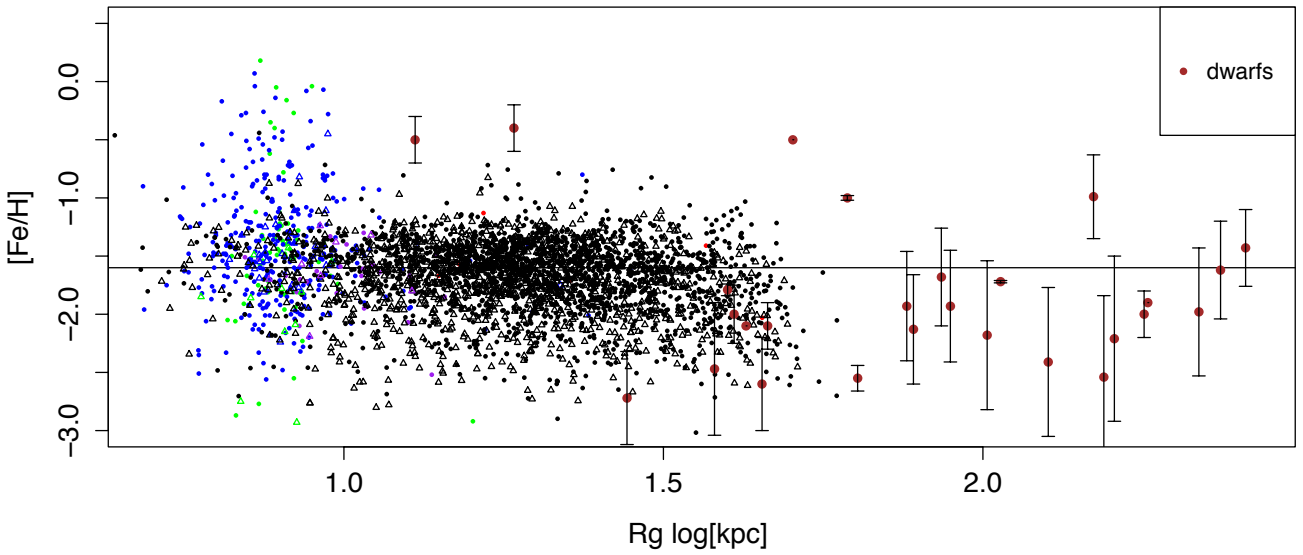
Bono + (2015)

Homogeneous RRL distances



RR Lyrae metallicities





RRL metallicity gradient

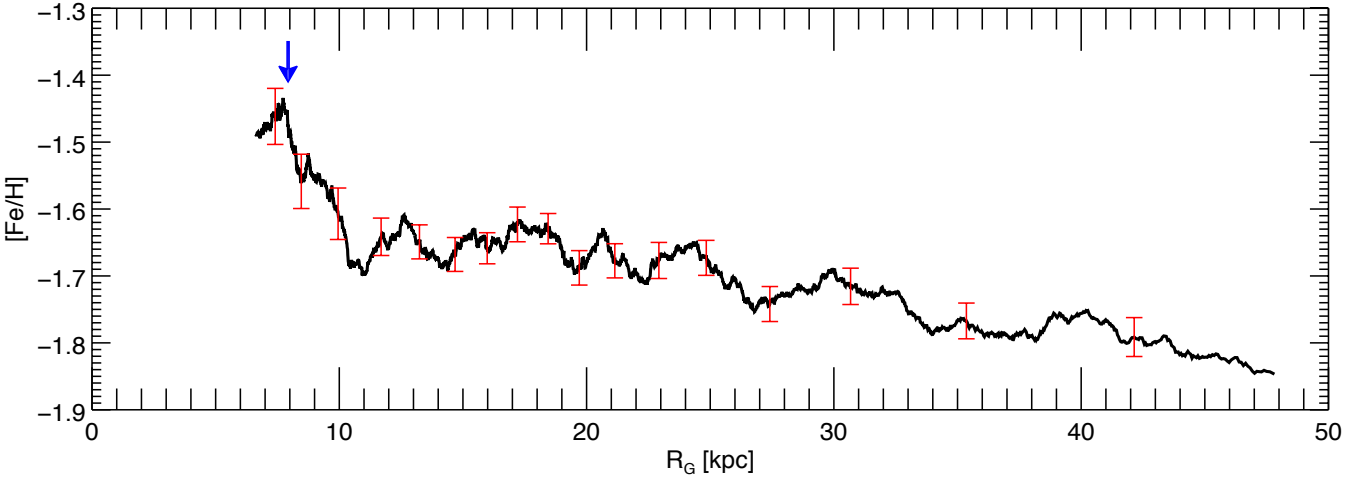
Smooth transition
Over a substantial
fraction of the Halo

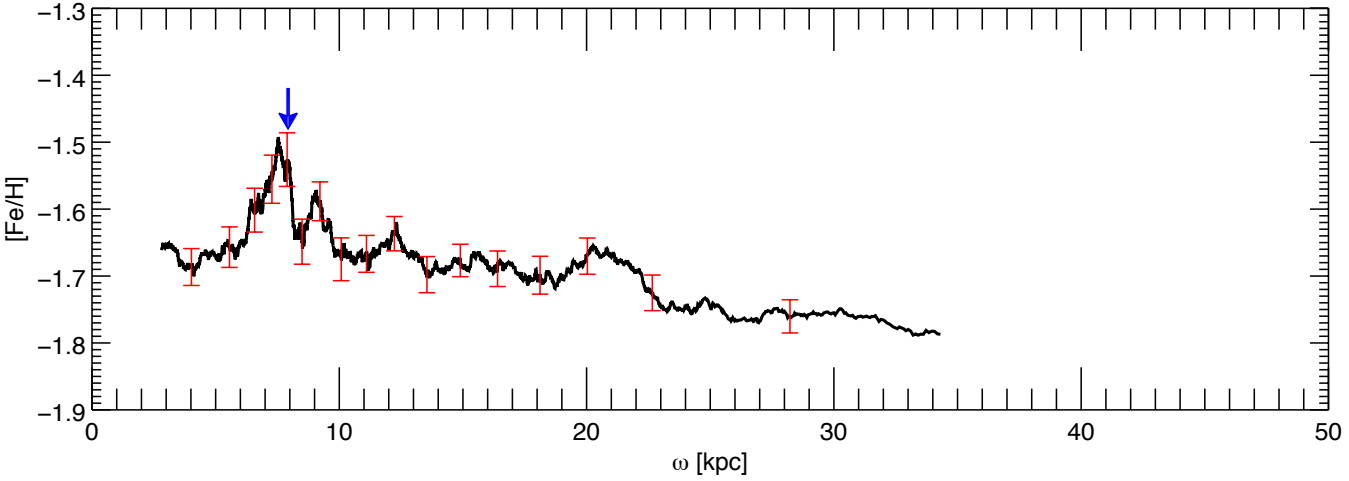
→ talk W. Evans

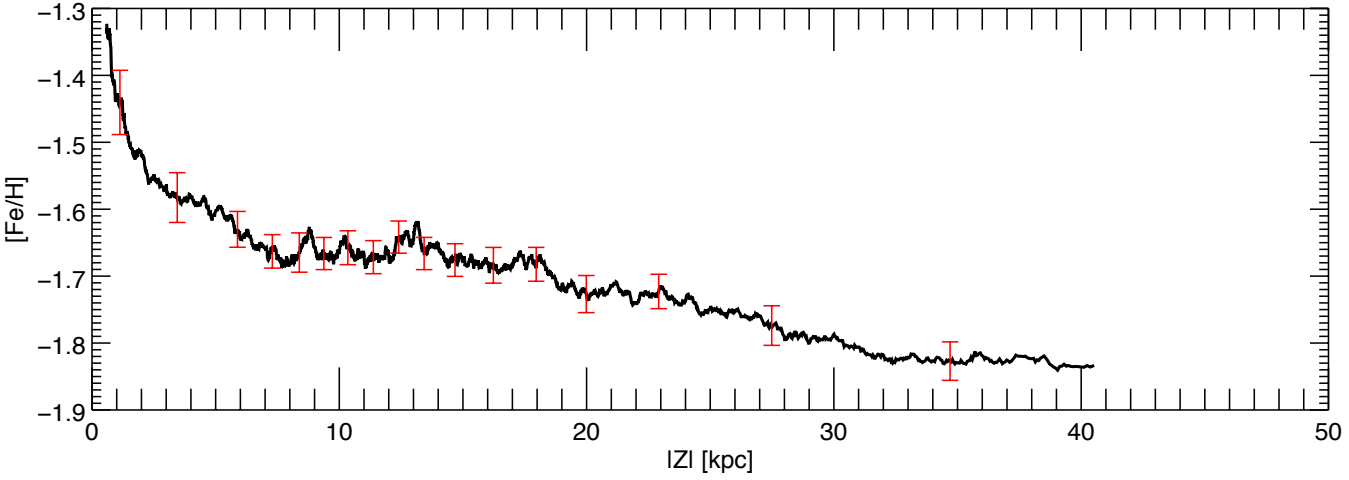
Steady increase for
RG < 10-15 Kpc

→ poster by G.F.

Evidence of secondary features







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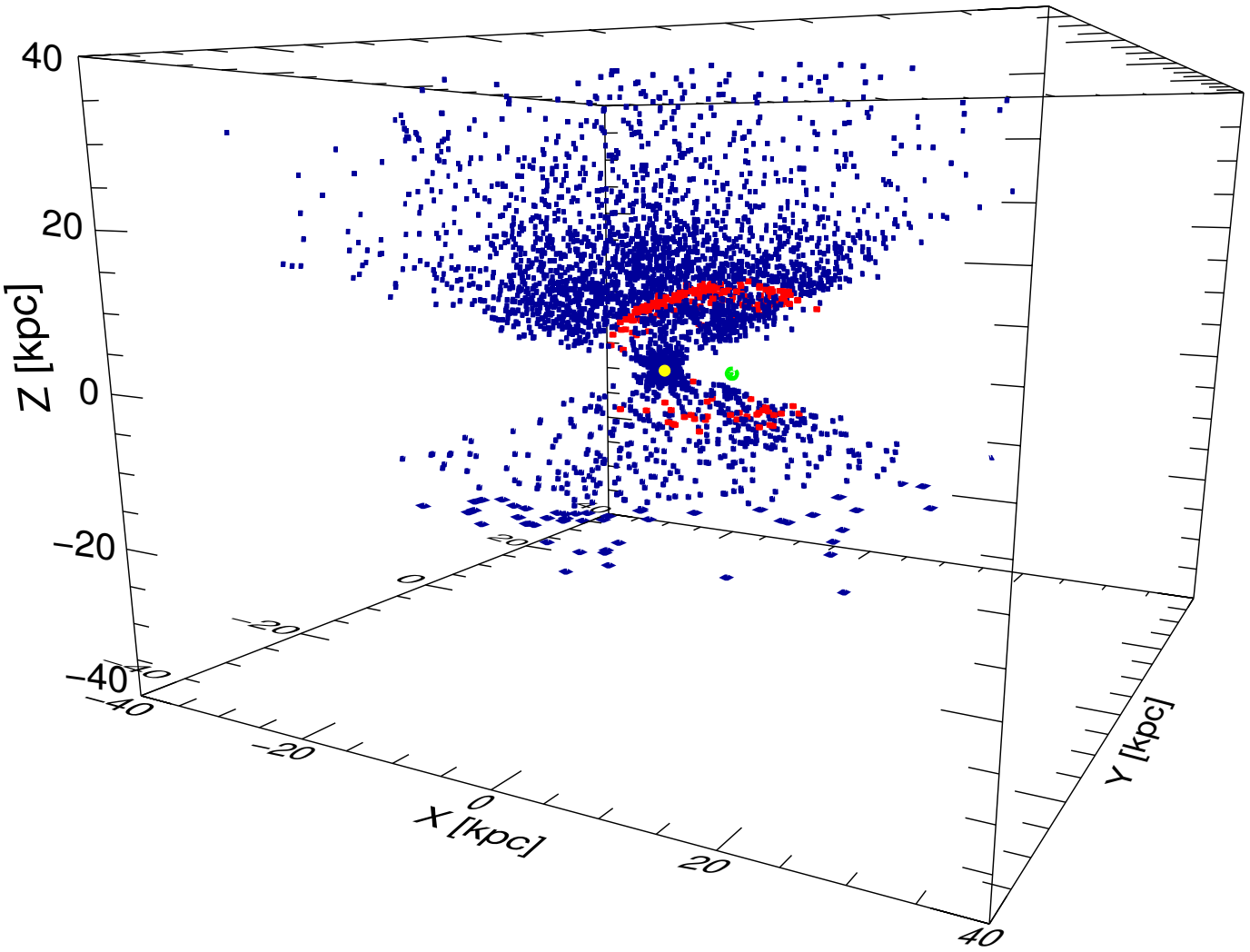
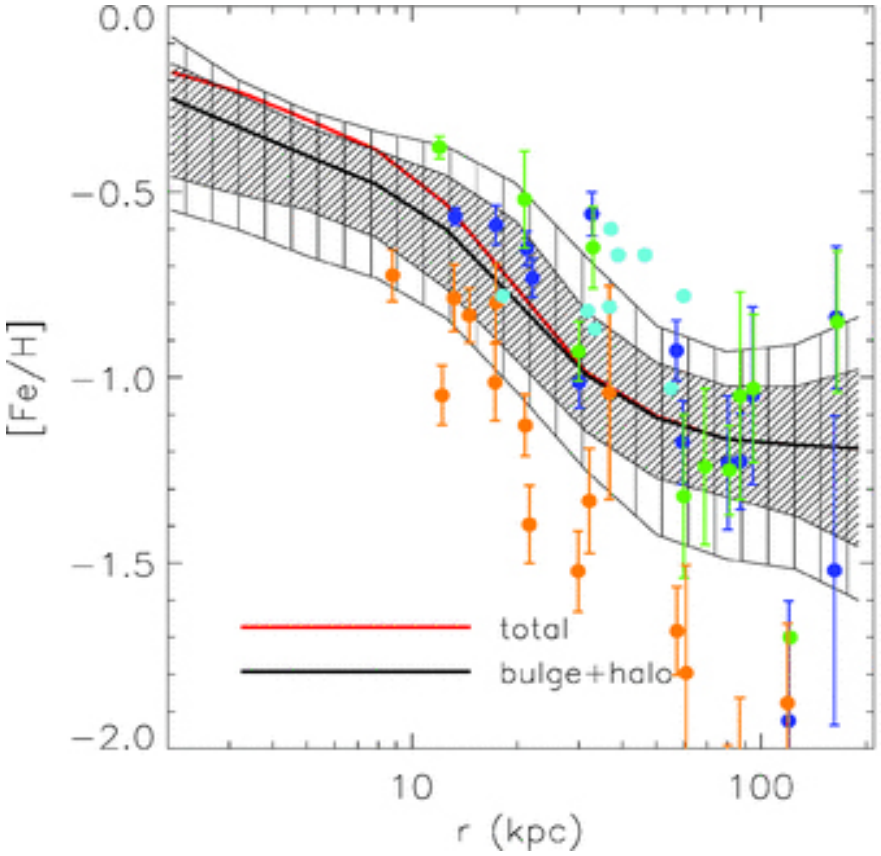
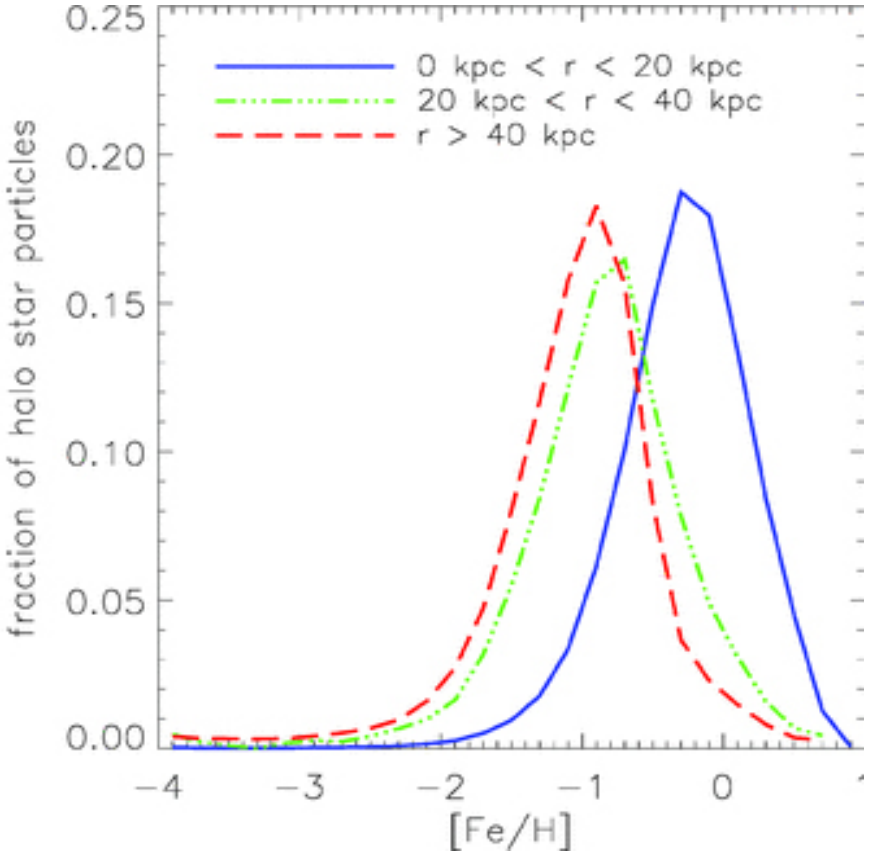


Comparison with numerical simulations



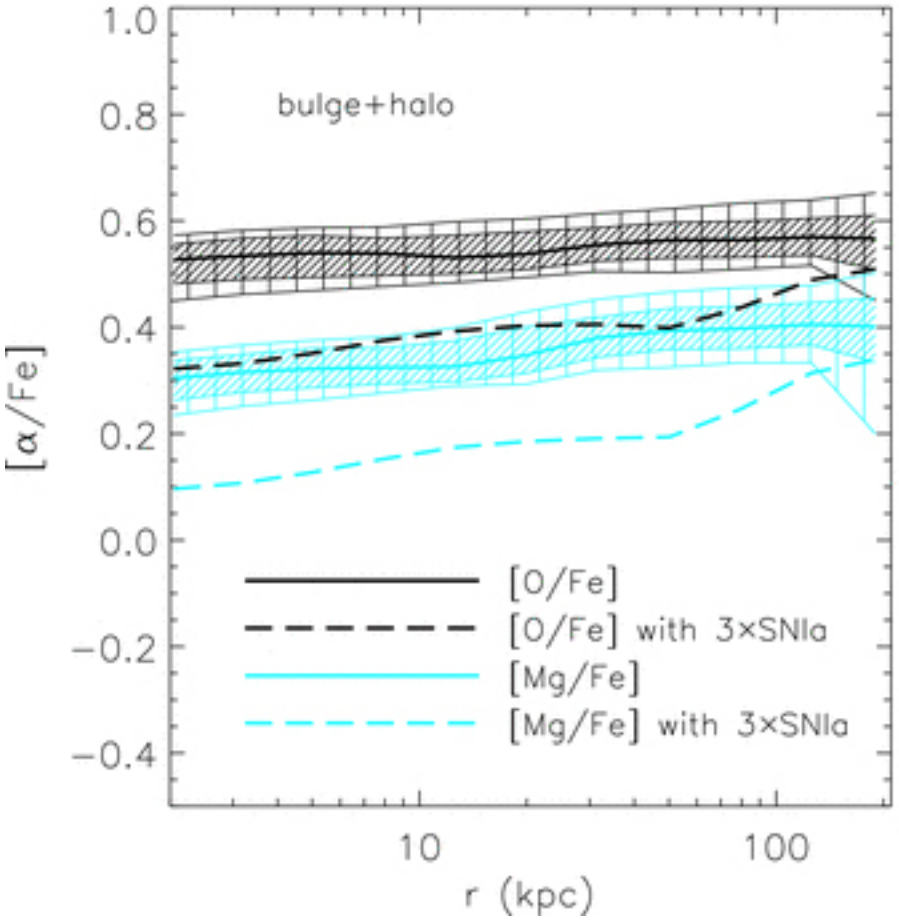


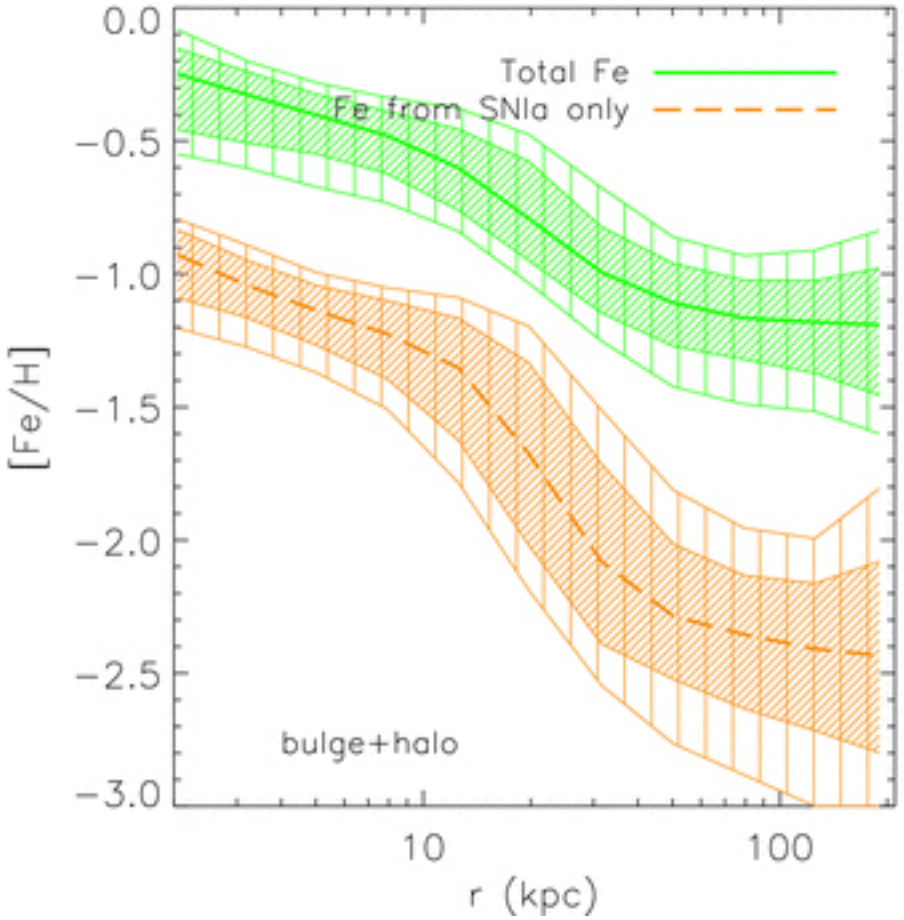
Theory is predicting a large Fe enhancement in the inner halo

& a sharp increase for RG~20-30 kpc

Font + (2011), Bulge+Halo → talk by L. Greggio

Probably no tension





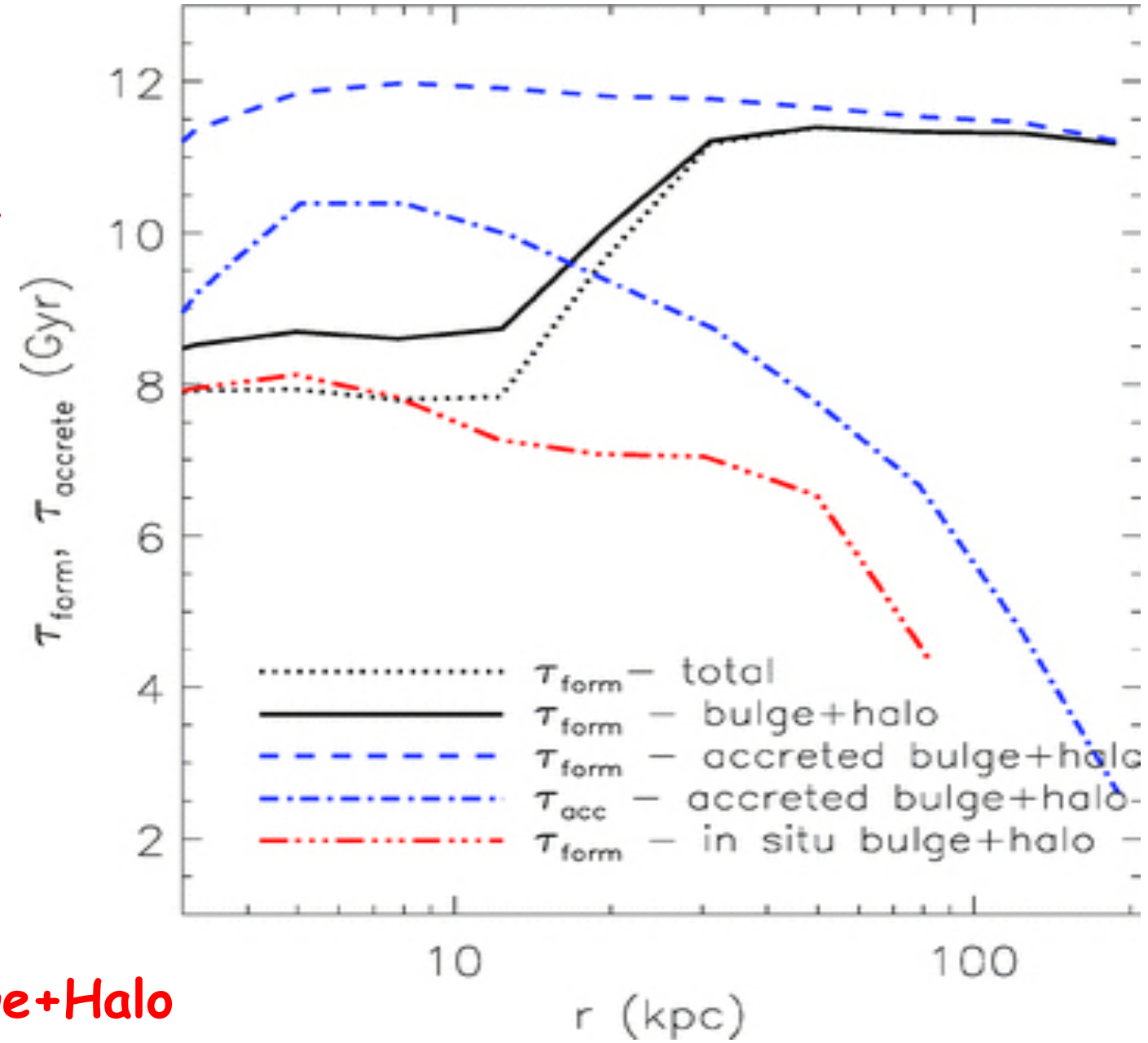
Font + (2011), Bulge+Halo

Halo age distribution function

The in situ component
Seems to be younger
than the accreted one

but

no RR Lyrae for ages
younger than 10 Gyr



Font + (2011), Bulge+Halo

Conclusions

The structure of the Galactic Halo is becoming popular thanks to wide field imagers and MOS
Photometric surveys are playing a crucial role

The RR Lyrae are fundamental beacons for the Structure of the Galactic Halo

Solid evidence of a linear Fe gradient

New data are coming with UVES@VLT + EFOSC2@NTT

We desperately need wide field spectroscopy
one RR Lyrae per square degree!