The YMC-GC link

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Testing GC formation scenarios: The Fornax dSph

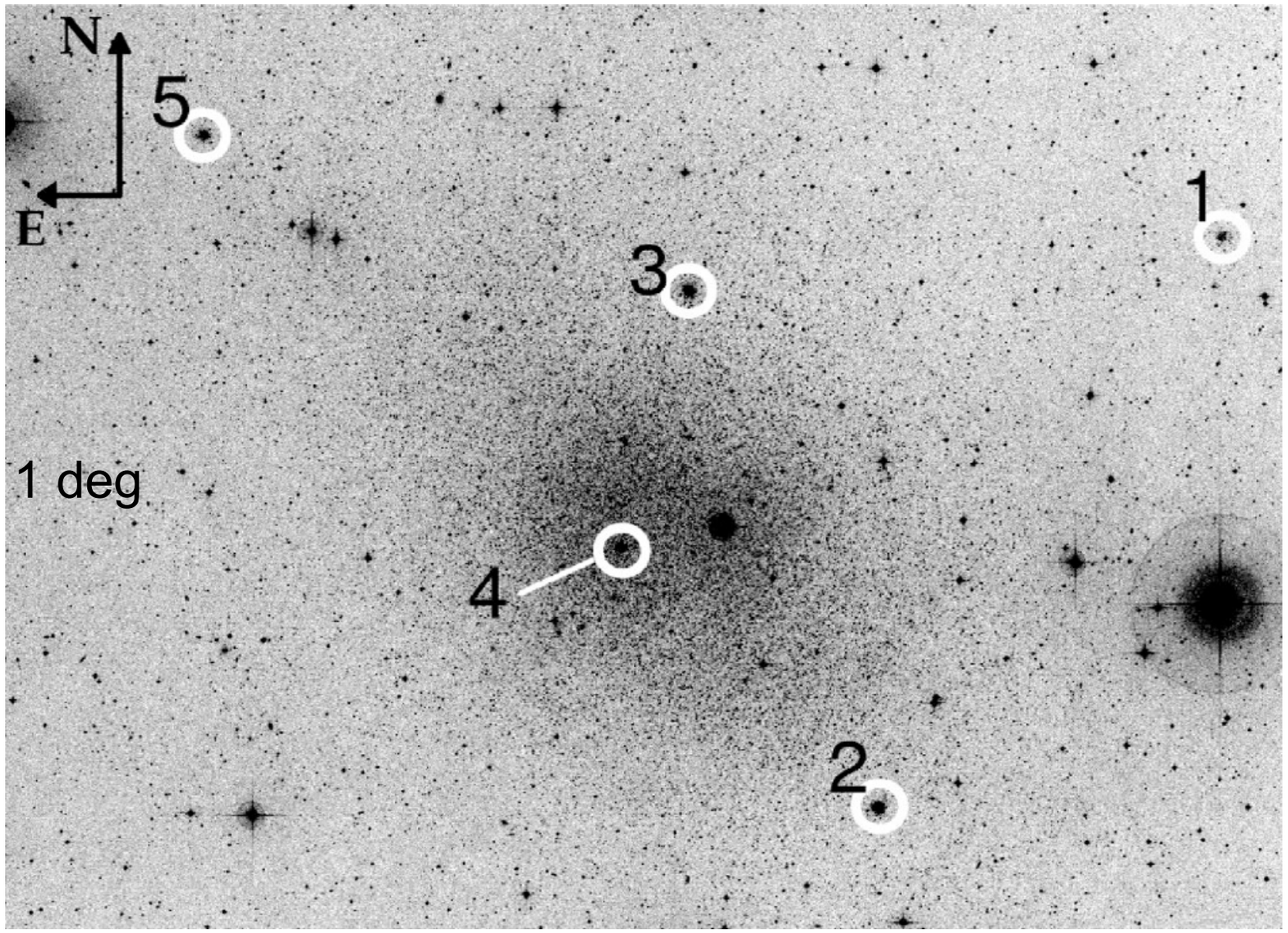


Image from Letarte et al. (2006)

M_V ~ -13.1 (Mateo 1998)

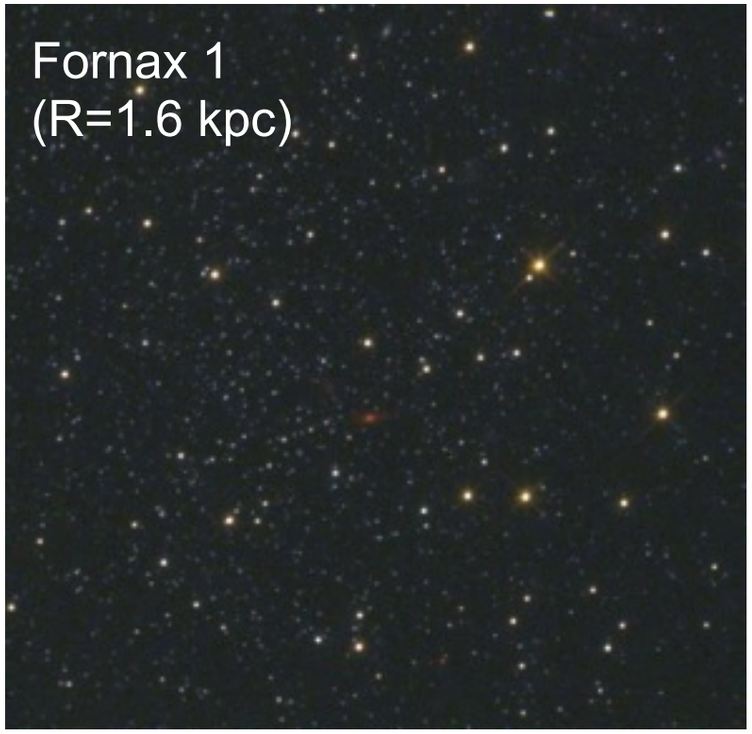
5 globular clusters (Hodge 1961)

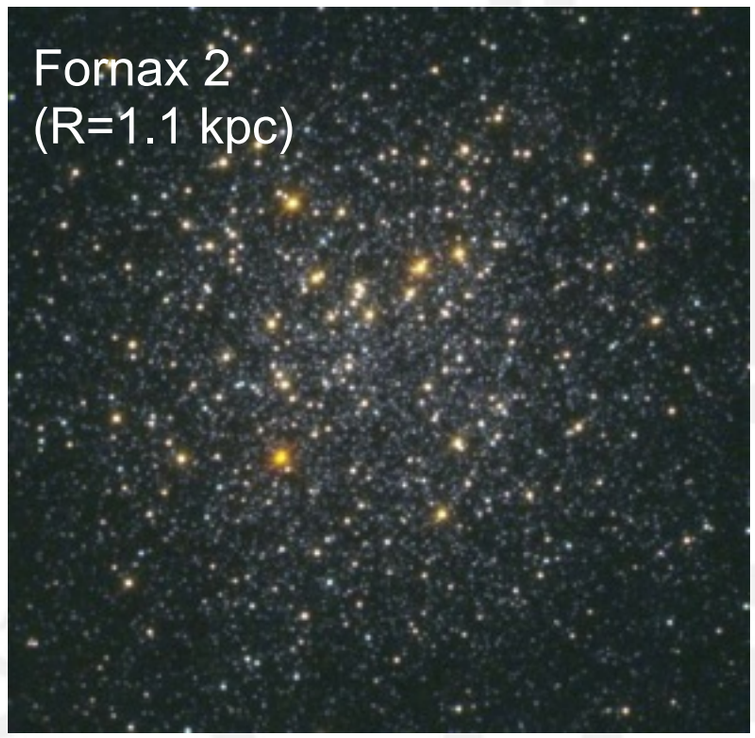
Extremely high GC specific frequency, S_N ~ 26 (Milky Way: S_N~1)

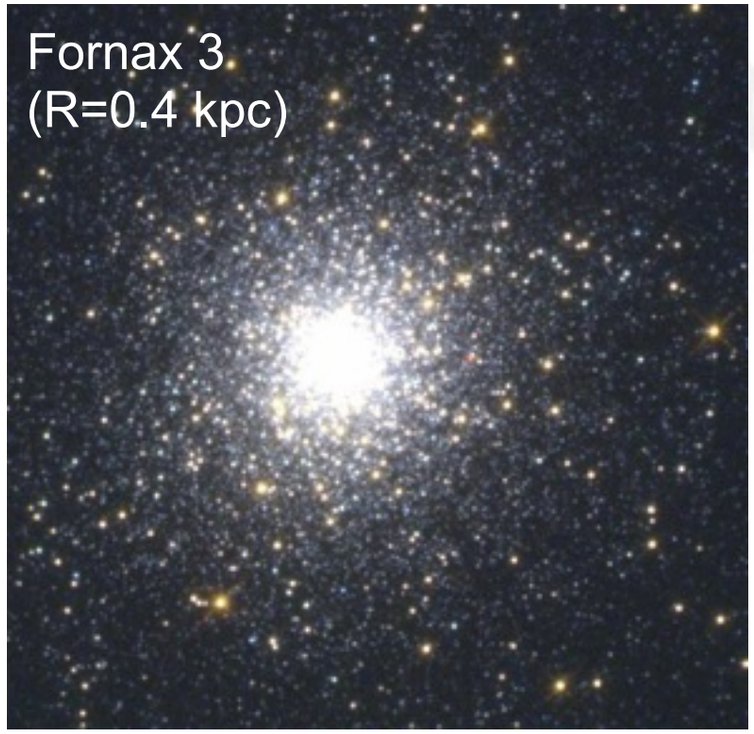
Fornax 1, 2, 3, 5

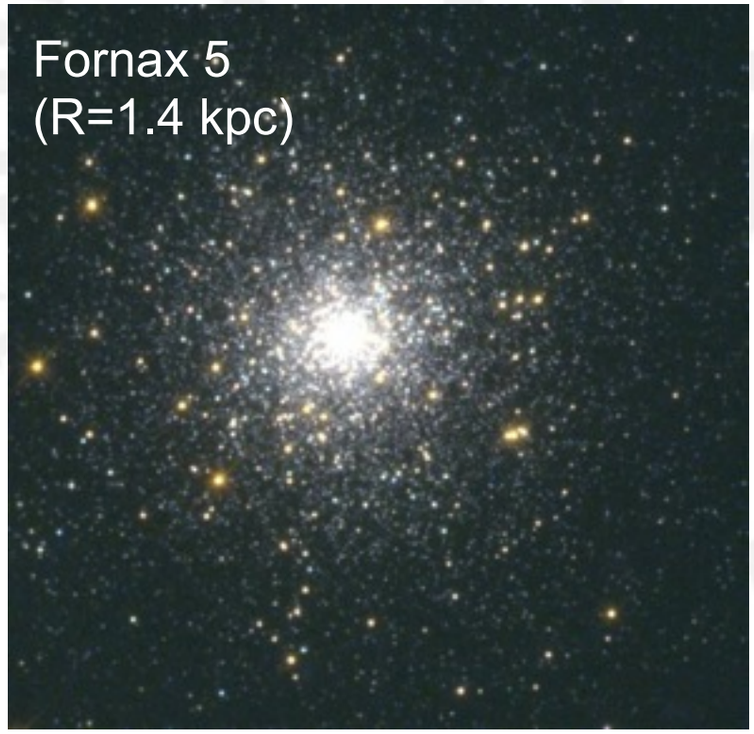
HST WFPC2+WFC3
F343N/F555W/F814W

~24 pc

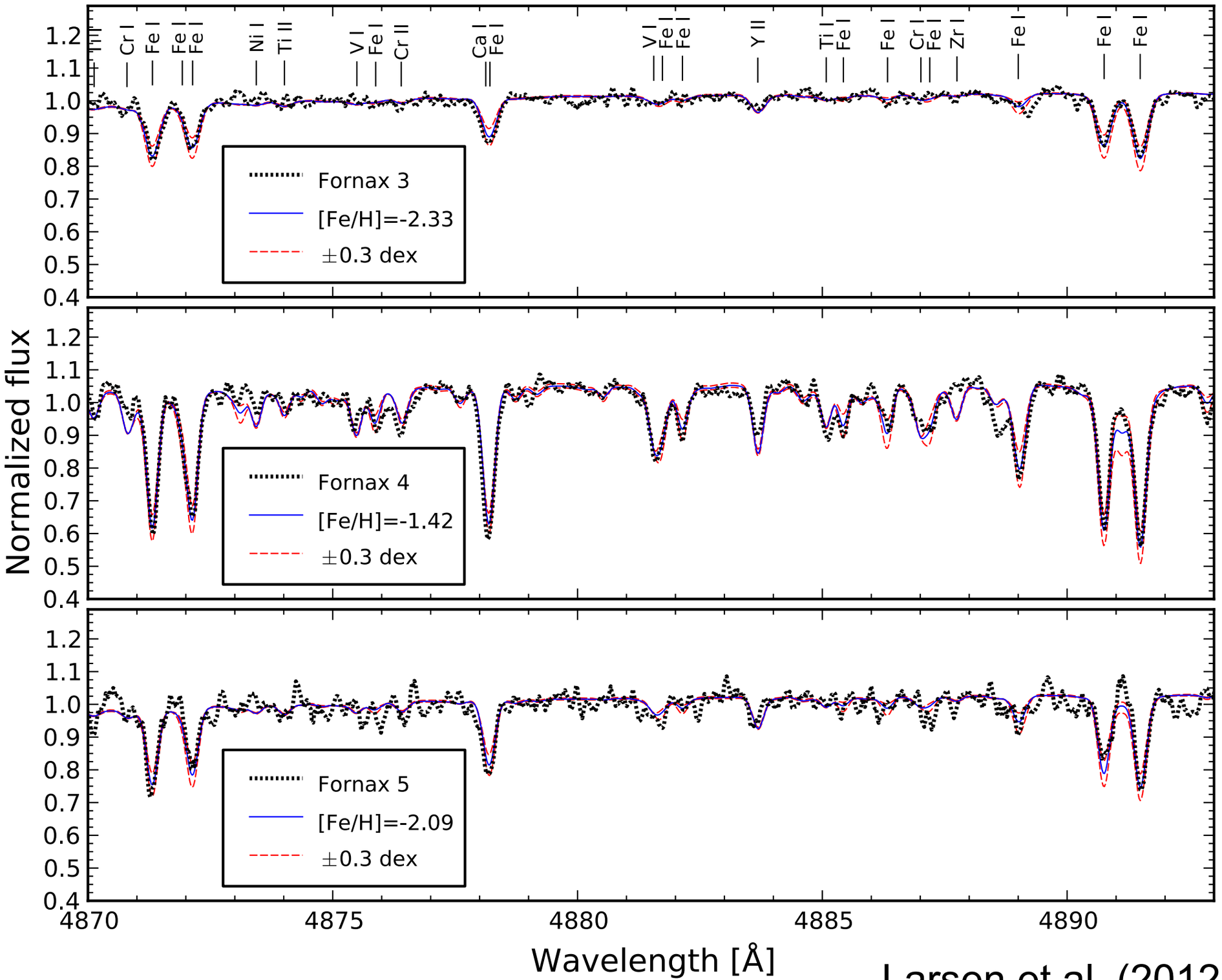








Spectroscopy of Fornax GCs



Larsen et al. (2012)

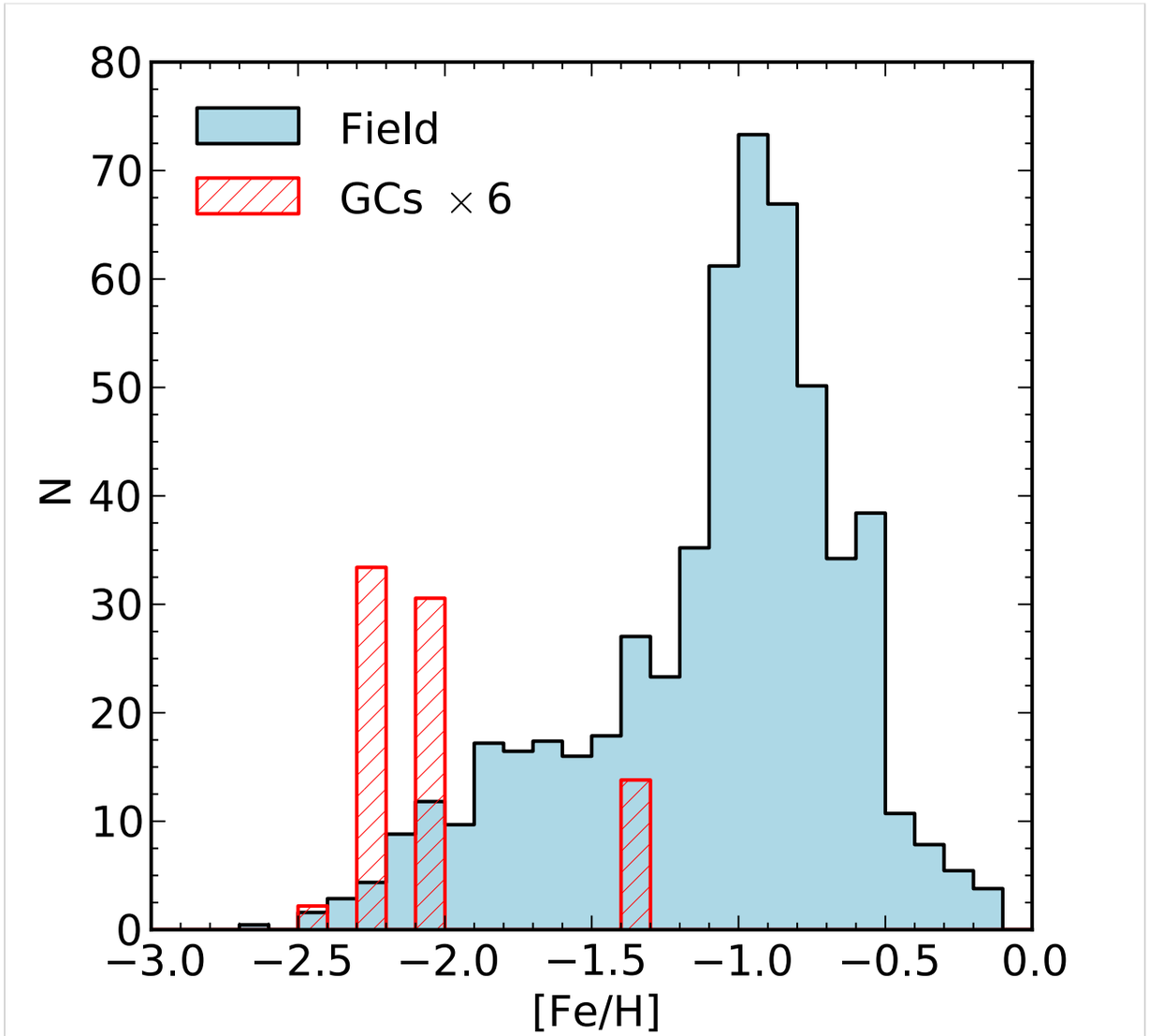
Fornax dSph GC metallicities from high-dispersion spectroscopy

	[Fe/H]	[Ca/Fe]	v_r (km s^{-1})	Source	
Fornax 1	-2.5 ± 0.1	$+0.15 \pm 0.04$	59 ± 1	Letarte et al. 2006	Indiv. stars
Fornax 2	-2.1 ± 0.1	$+0.20 \pm 0.03$	64 ± 1	Letarte et al. 2006	Indiv. stars
Fornax 3	-2.3 ± 0.1	$+0.25 \pm 0.08$	60.4 ± 0.2	This work	Integr. light
Fornax 4	-1.4 ± 0.1	$+0.13 \pm 0.07$	47.2 ± 0.1	This work	Integr. light
Fornax 5	-2.1 ± 0.1	$+0.27 \pm 0.09$	60.6 ± 0.2	This work	Integr. light

- Fornax 1, 2, 3, 5 all have [Fe/H] < -2
- Fornax 4 significantly more metal-rich, [Fe/H] ~ -1.4
- [Ca/Fe] moderately super-solar for all five GCs

Larsen et al. (2012)

Field stars and GCs in Fornax: Metallicity distributions



Larsen et al. (2012, A&A 544, L14)

Field stars: Battaglia et al. (2006), corrected for spatial coverage

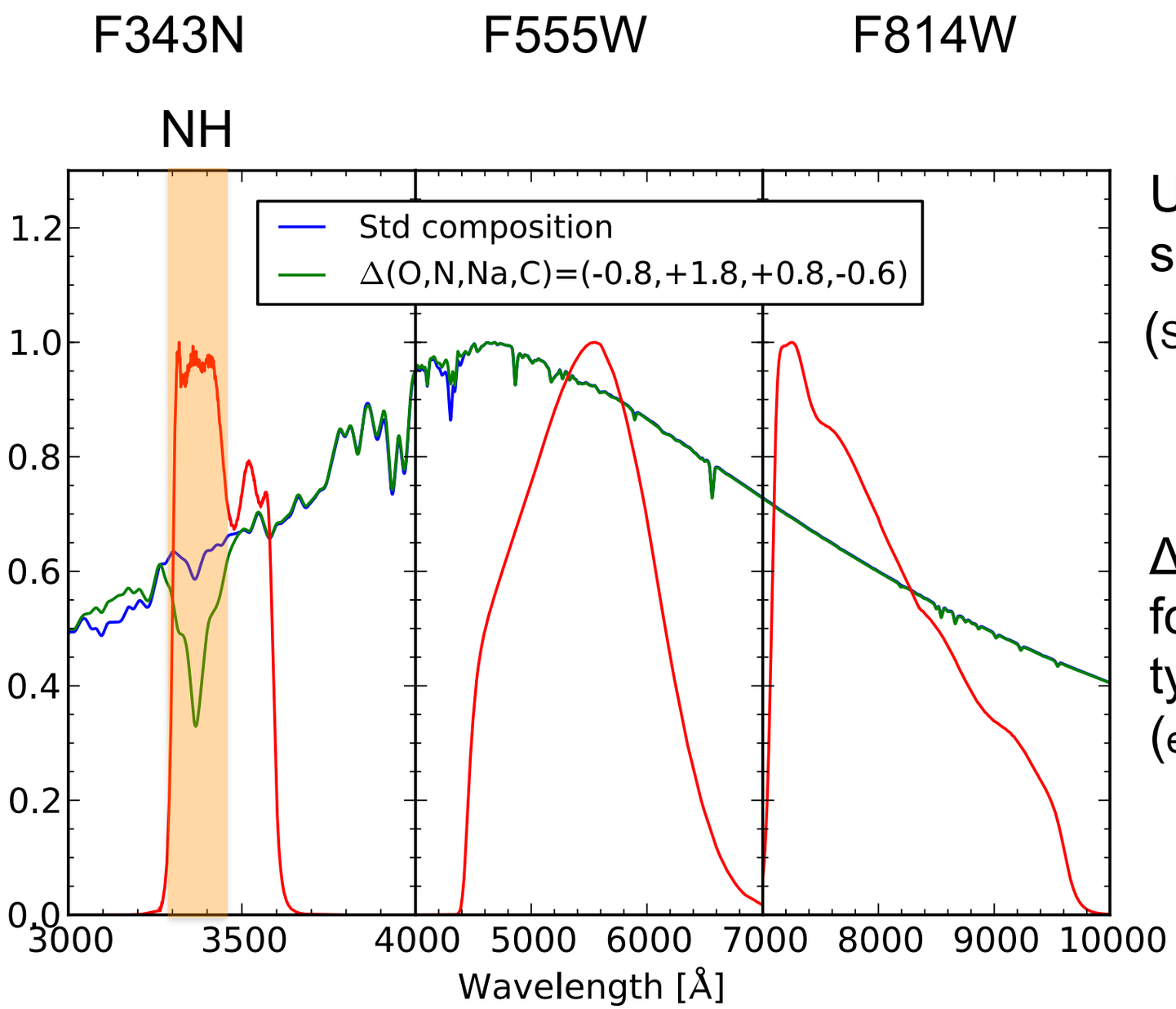
For [Fe/H] < -2:
Mass in field stars ~ 3×10^6 $M_\odot$
Mass in GCs ~ 1×10^6 $M_\odot$

About 1/5-1/4 of all metal-poor stars in Fornax dSph belong to F1/F2/F3/F5.

Clusters could at most have been ~4-5 times more massive initially!

And this assumes no other clusters or field stars formed with similar metallicity, no “infant mortality”!

Constraining abundances with photometry



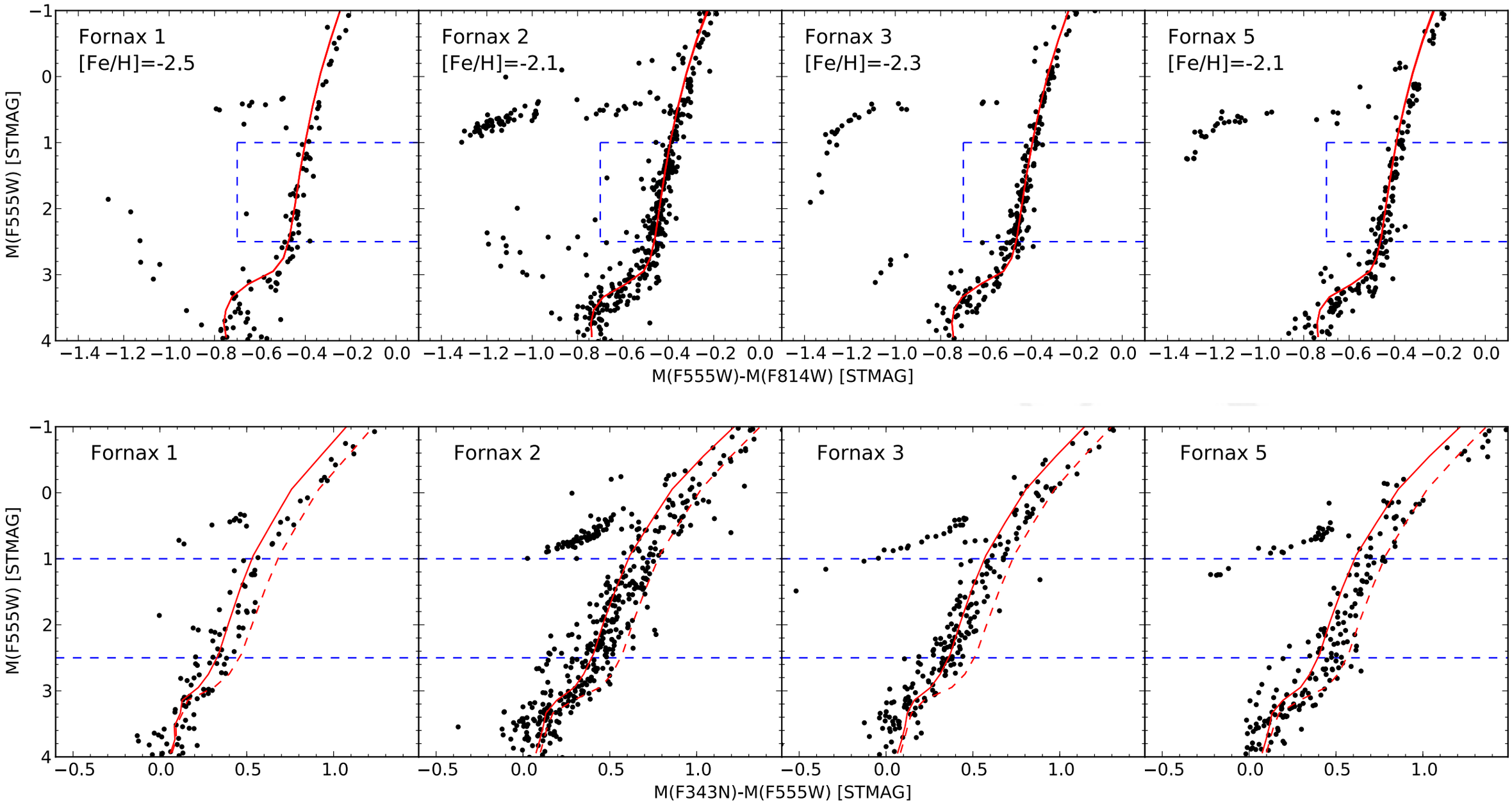
U-band photometry sensitive to N abundance

(Sbordone et al. 2011; Monelli et al. 2013)

$\Delta(m_{F343N}-m_{F555W})$ ~0.2 mag for Δ[N/Fe]~2; typical range seen in GCs (e.g. Yong et al. 2008)

CMDs of Fornax GCs

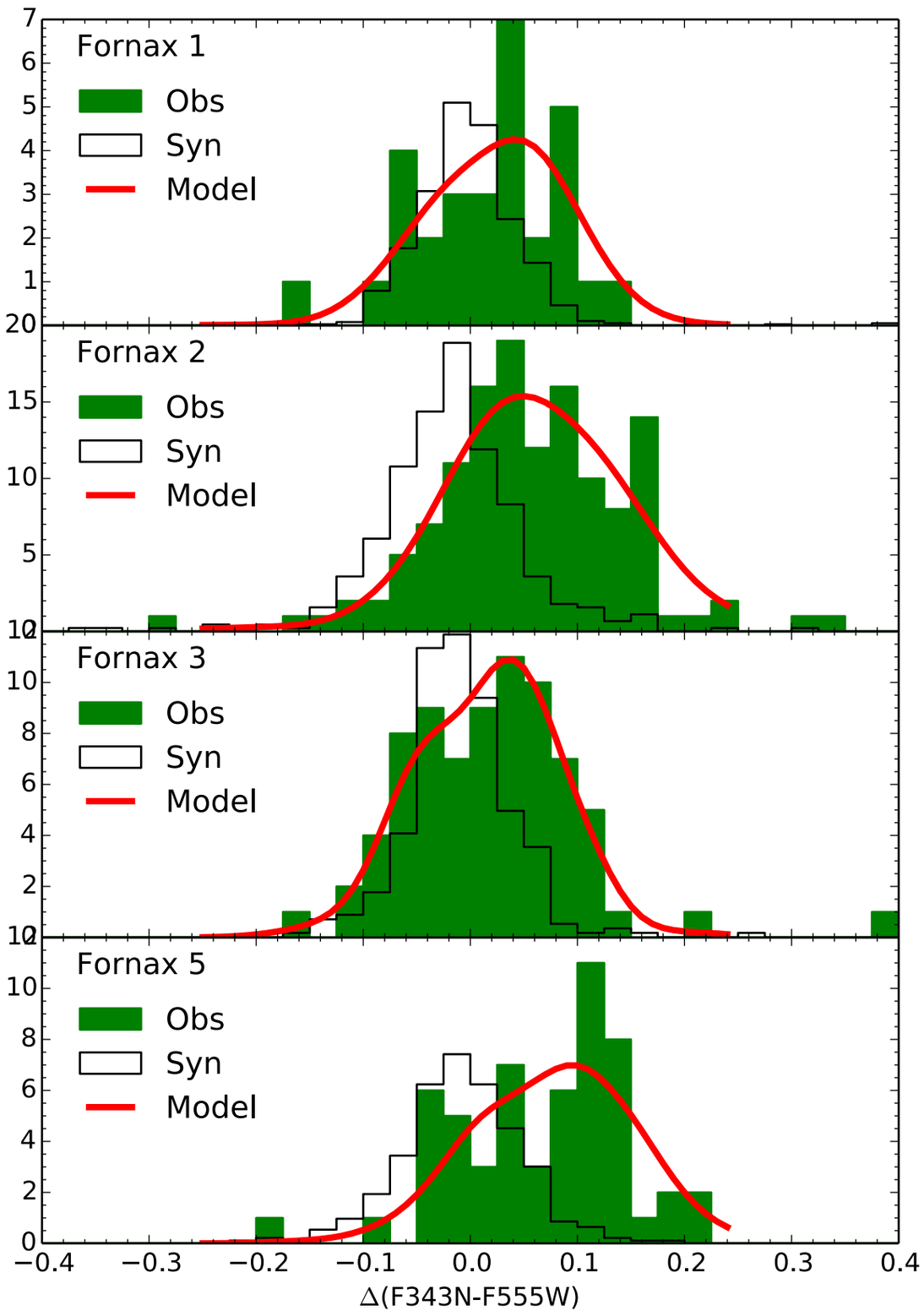
V-I: Spread consistent with errors
F343N-V: Spread larger than errors



Isochrones from Dotter et al. 2007
Synthetic colours based on ATLAS12/SYNTHE model spectra

Larsen et al., in prep

F343N-F555W colour spreads in the Fornax GCs



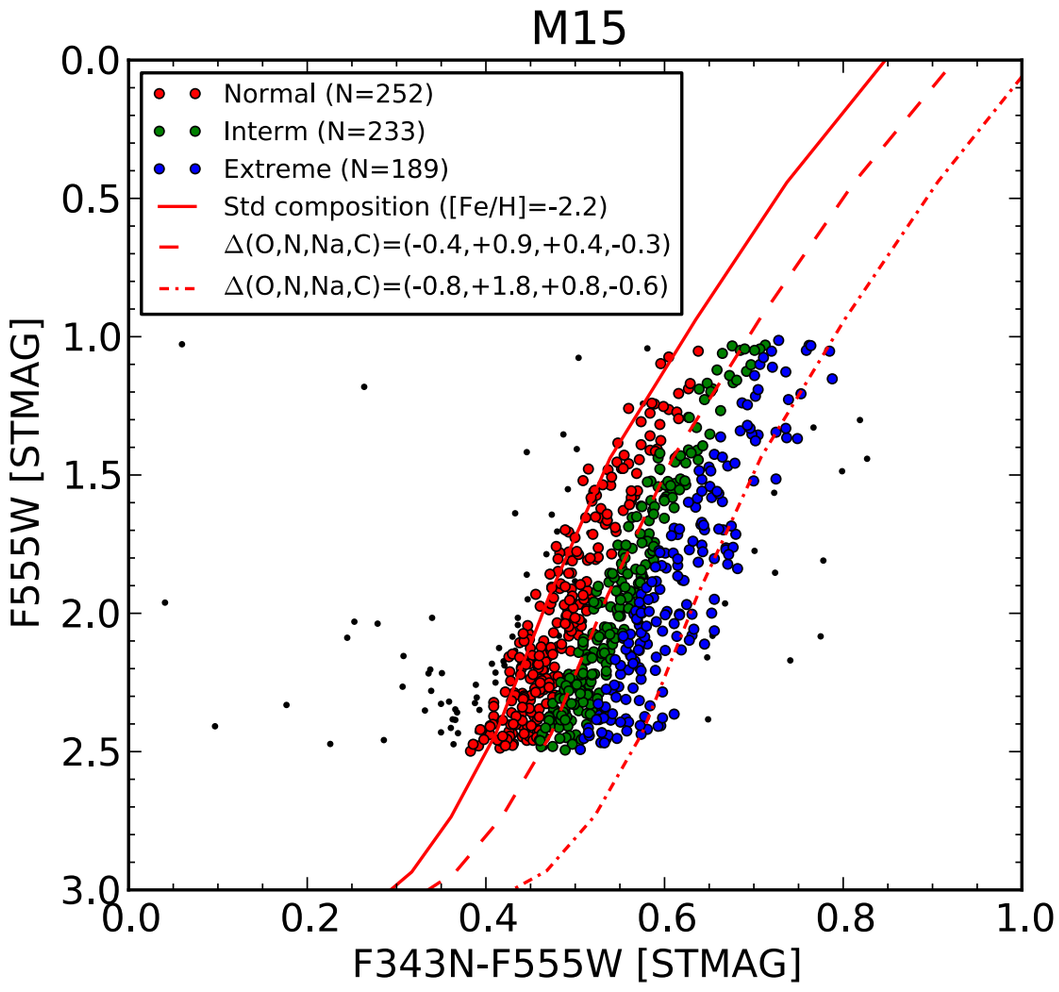
Observed colour spreads significantly larger than errors.

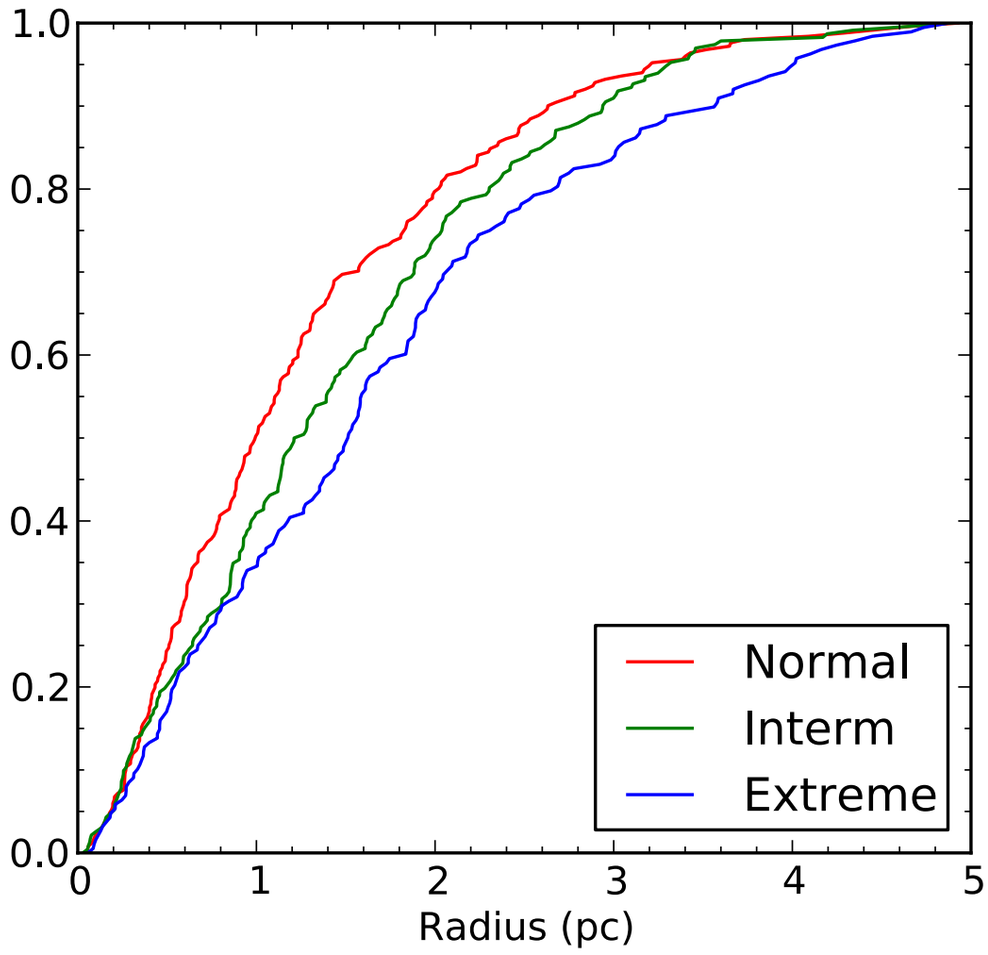
Intrinsic spreads ~0.15 mag (if uniform distr.) →

Δ[N/Fe] ~ 2 dex
Similar to Galactic GCs.

Red curves:
Double Gaussian fits convolved with error distributions → roughly 50% N-enhanced stars (F1/F3/F5: ~60%, F2: ~40%)

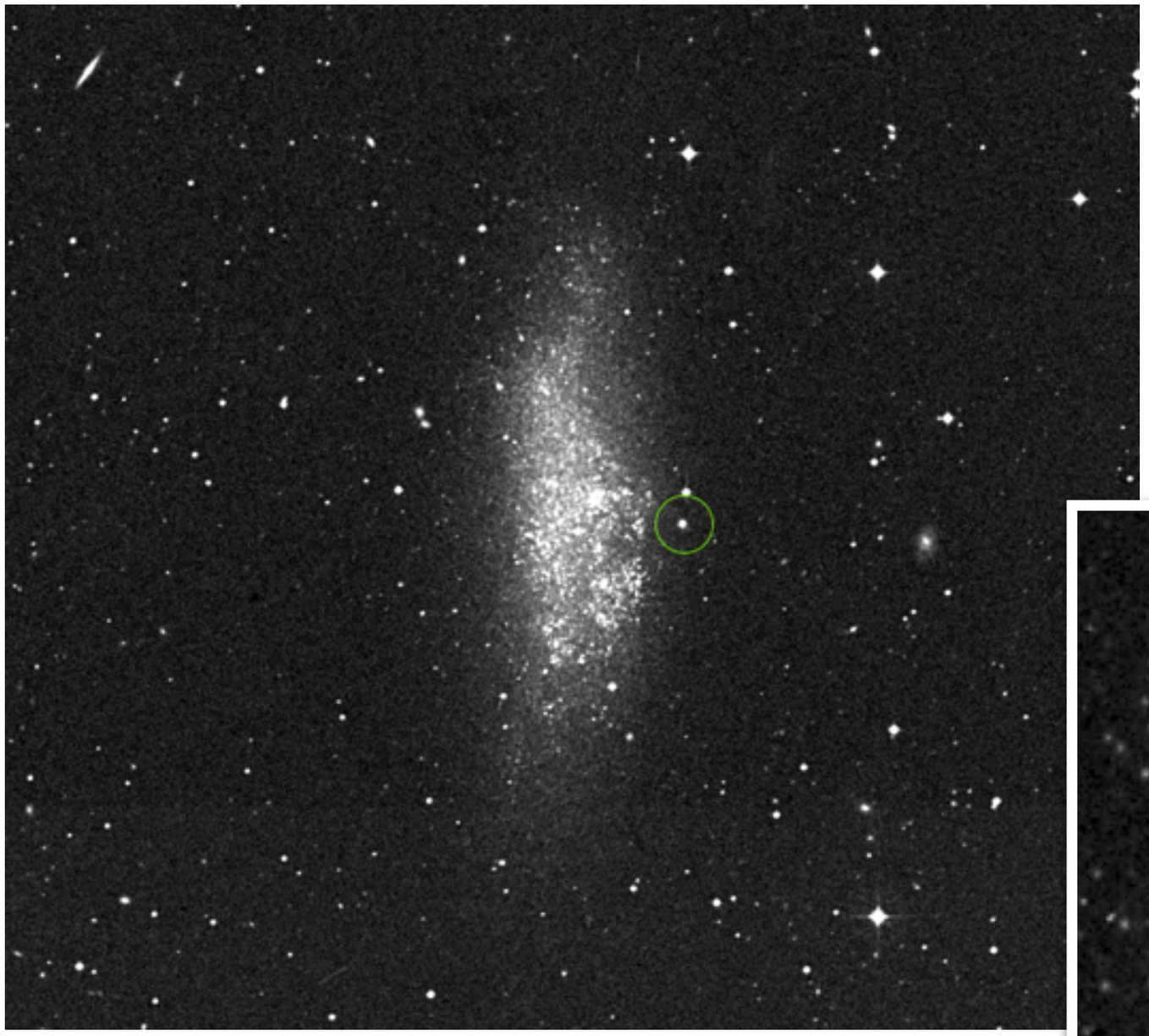
M15: 2nd generation less concentrated? (!)





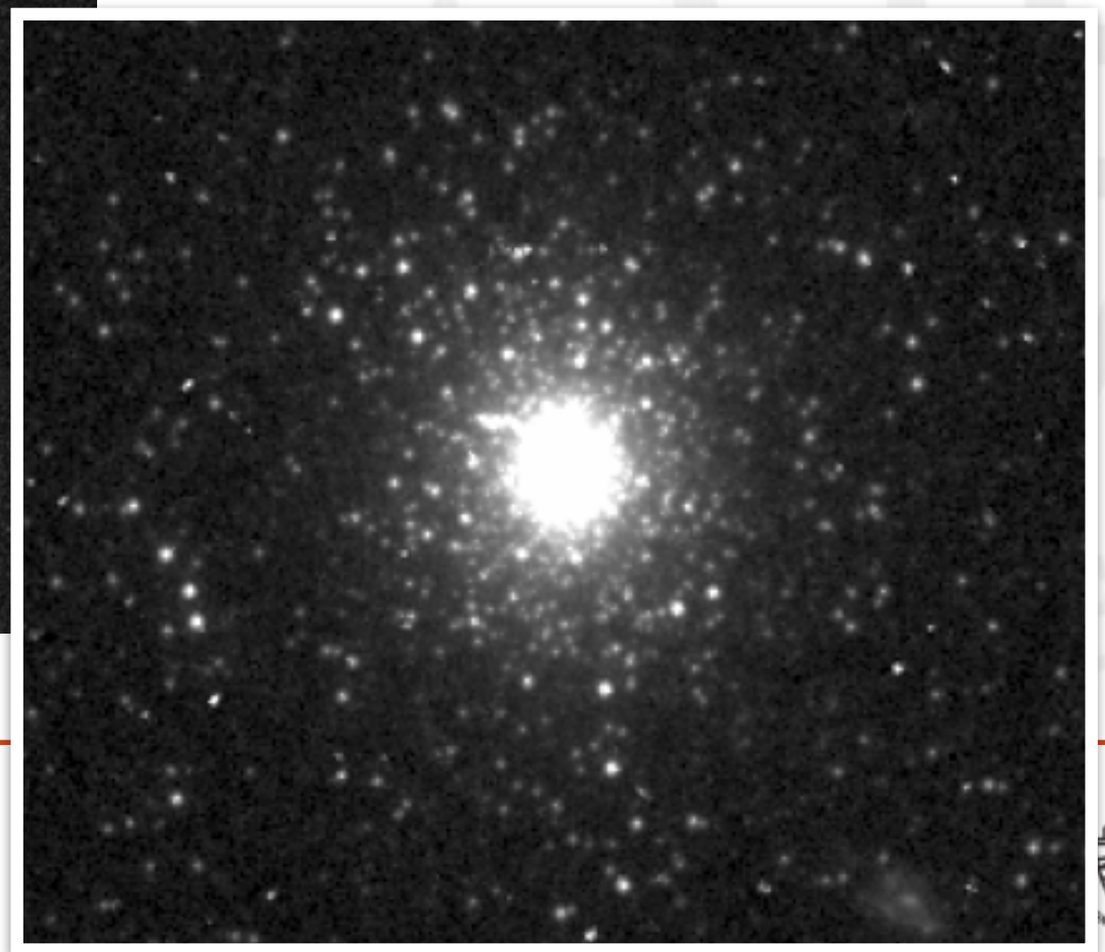
Opposite to trend found by Lardo et al. (2010) for R > 1 R_h (3 pc)

Is Fornax unique? The WLM dIrr



Integrated-light spectroscopy:
[Fe/H] ~ -2
Na enhanced, Mg depleted

(Larsen et al. 2014)



WLM field stars vs GC

GC

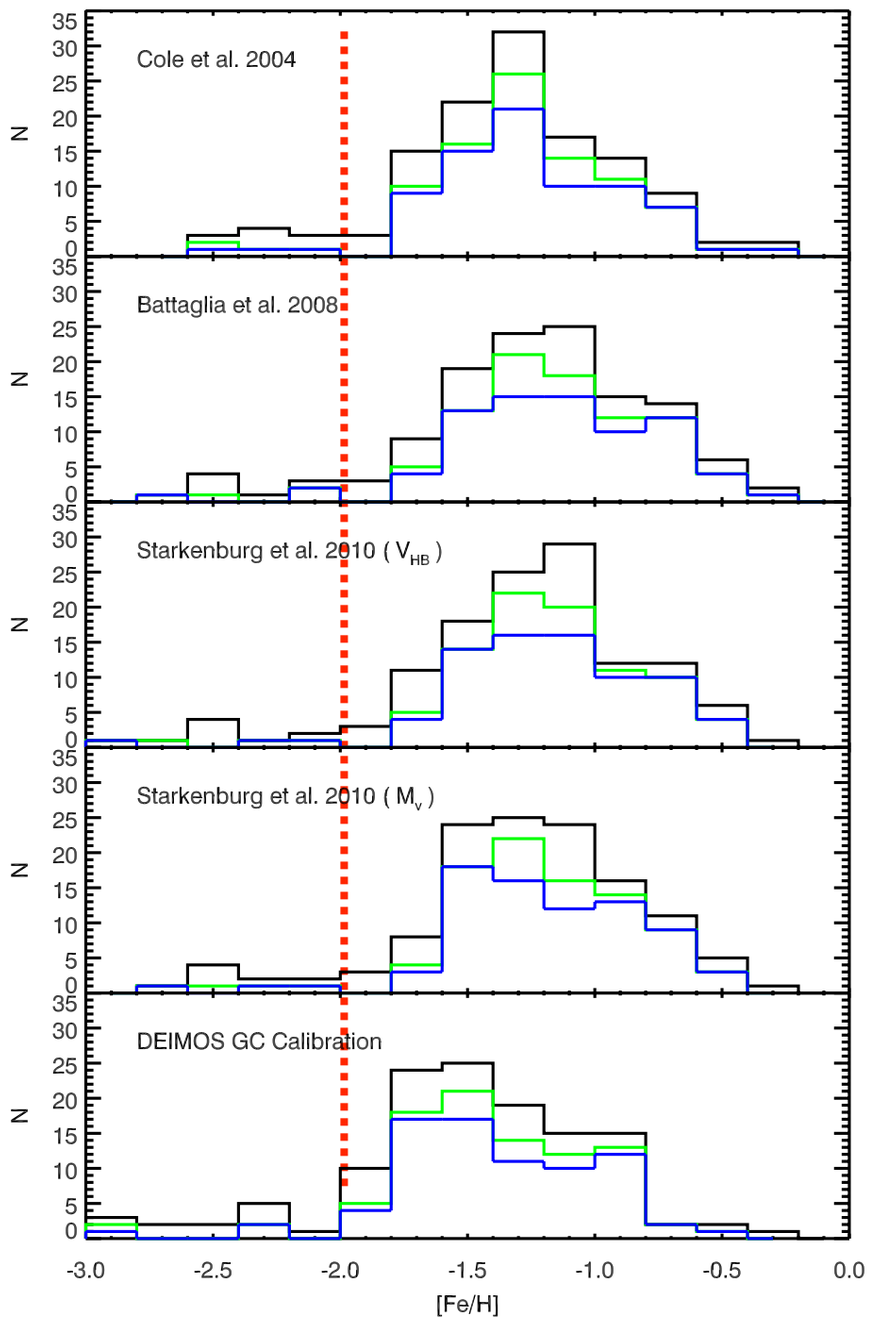


Figure 2. Full metallicity distribution functions for 126 stars out of 180 stars in our WLM data set in which the spectra had S/N $\gtrsim 10\,\text{Å}^{-1}$. Each panel shows the distribution derived from a different empirical calcium triplet calibration. The full distribution is shown in black, the original 78 stars from the FORS2 data set of Paper I are shown in blue, and DEIMOS spectra of the highest S/N quality are shown in green. Within a given calibration, samples show good agreement, providing confidence in even the lowest S/N DEIMOS stars.

Field stars:

<[Fe/H]> = -1.28

10% of stars have [Fe/H]<-1.74

(Leaman et al. 2013, from Ca II IR triplet spectroscopy of RGB stars)

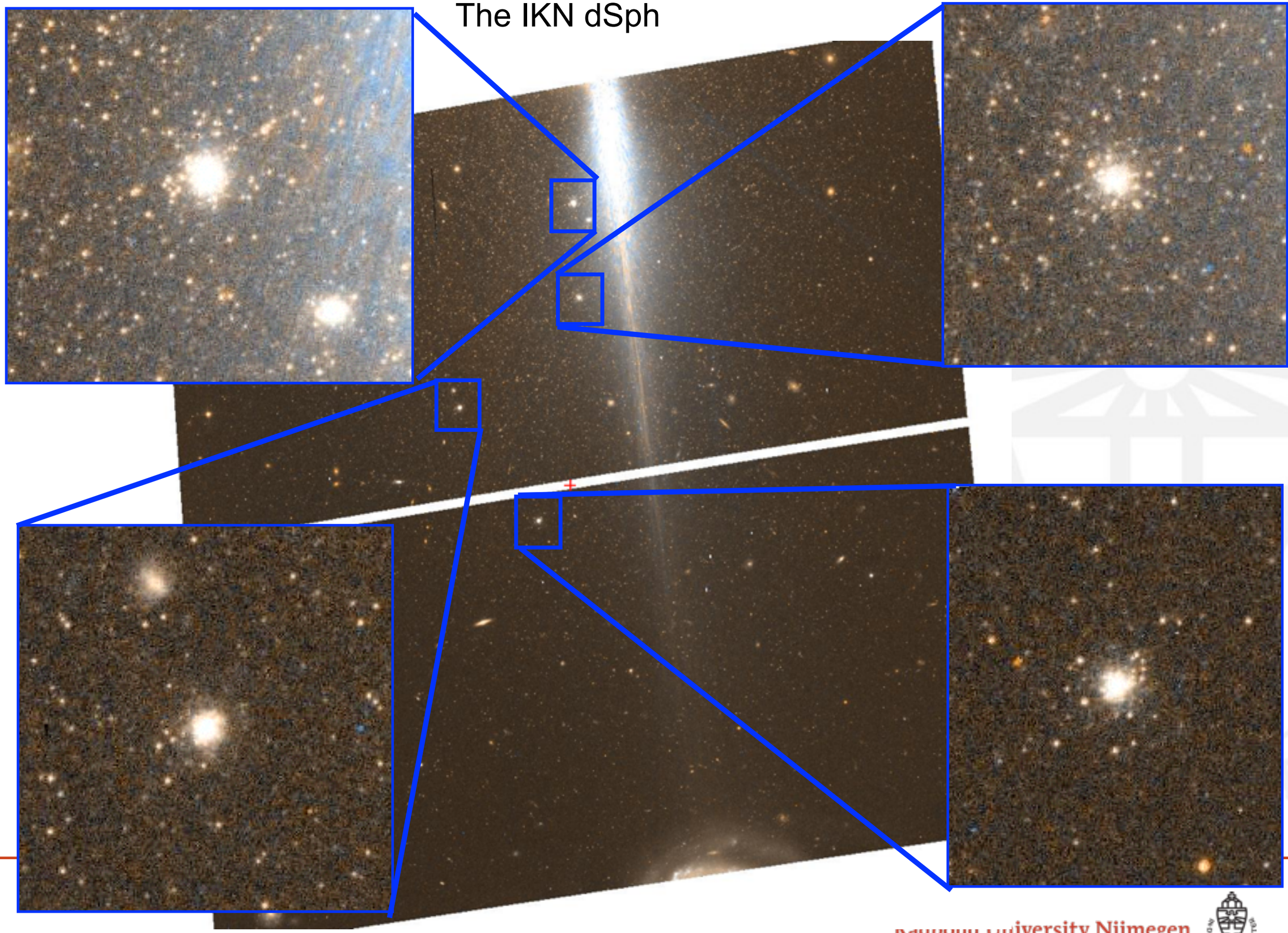
Globular cluster:

Metal-poor ([Fe/H]~-2.0)

Accounts for 17%-31% of metal-poor stars

(Larsen et al. 2014)

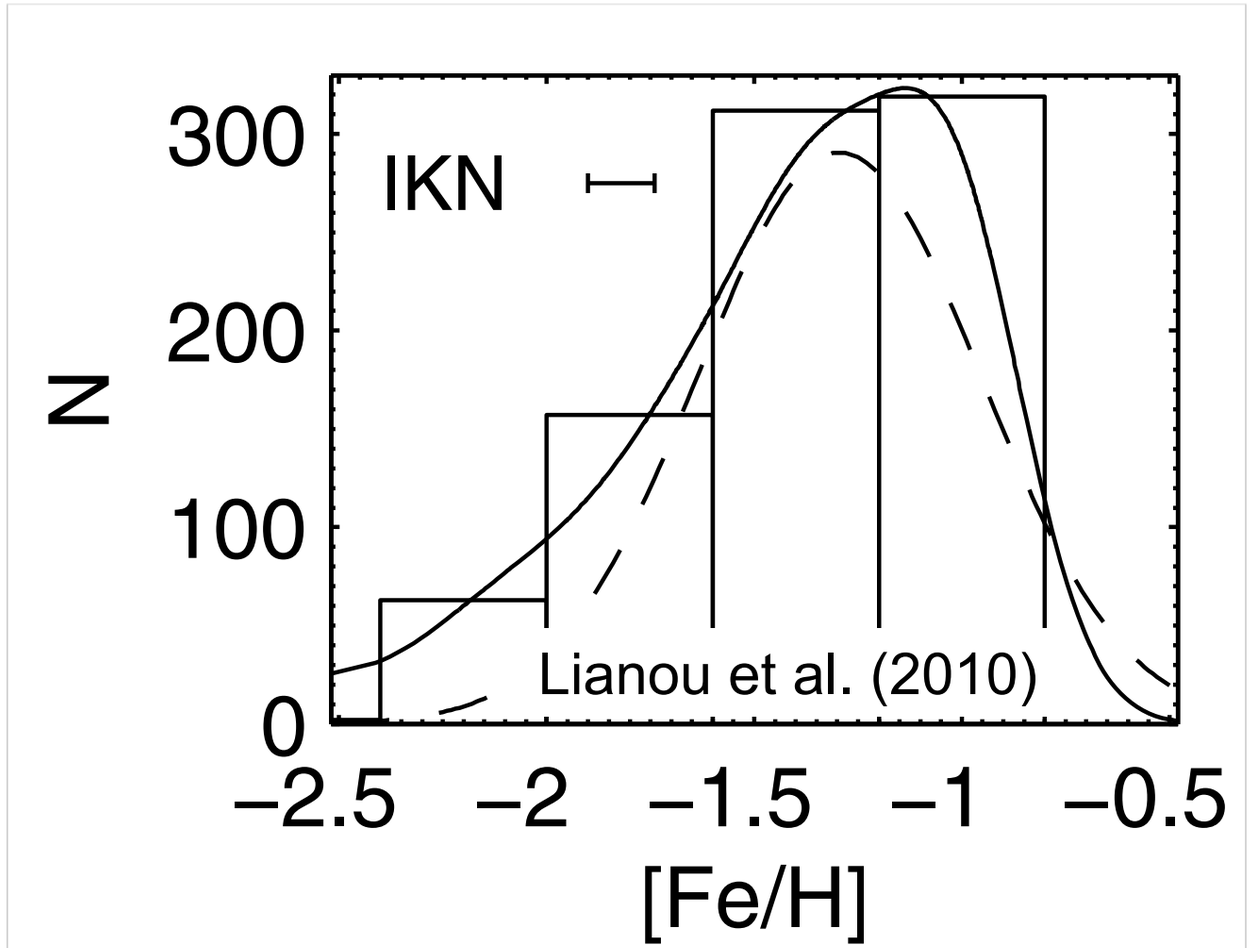
The IKN dSph



Field star metallicities (from photometry of RGB)

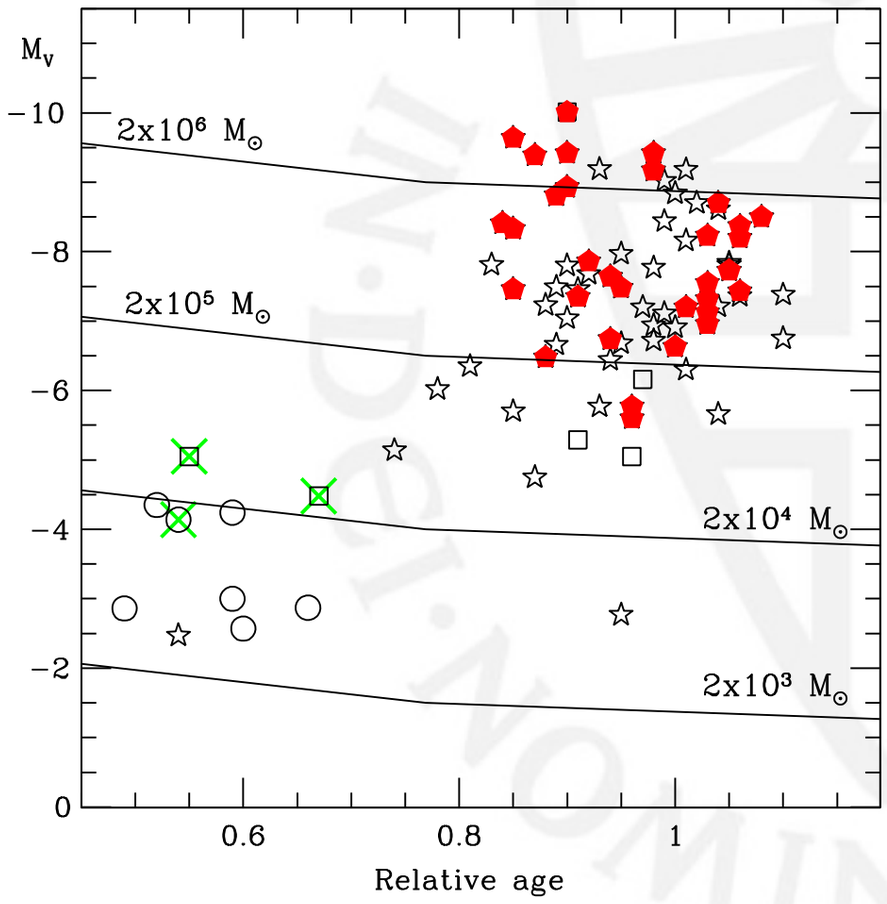
IKN

$L_{\rm GC}/L_{\rm tot} \approx 13\%$



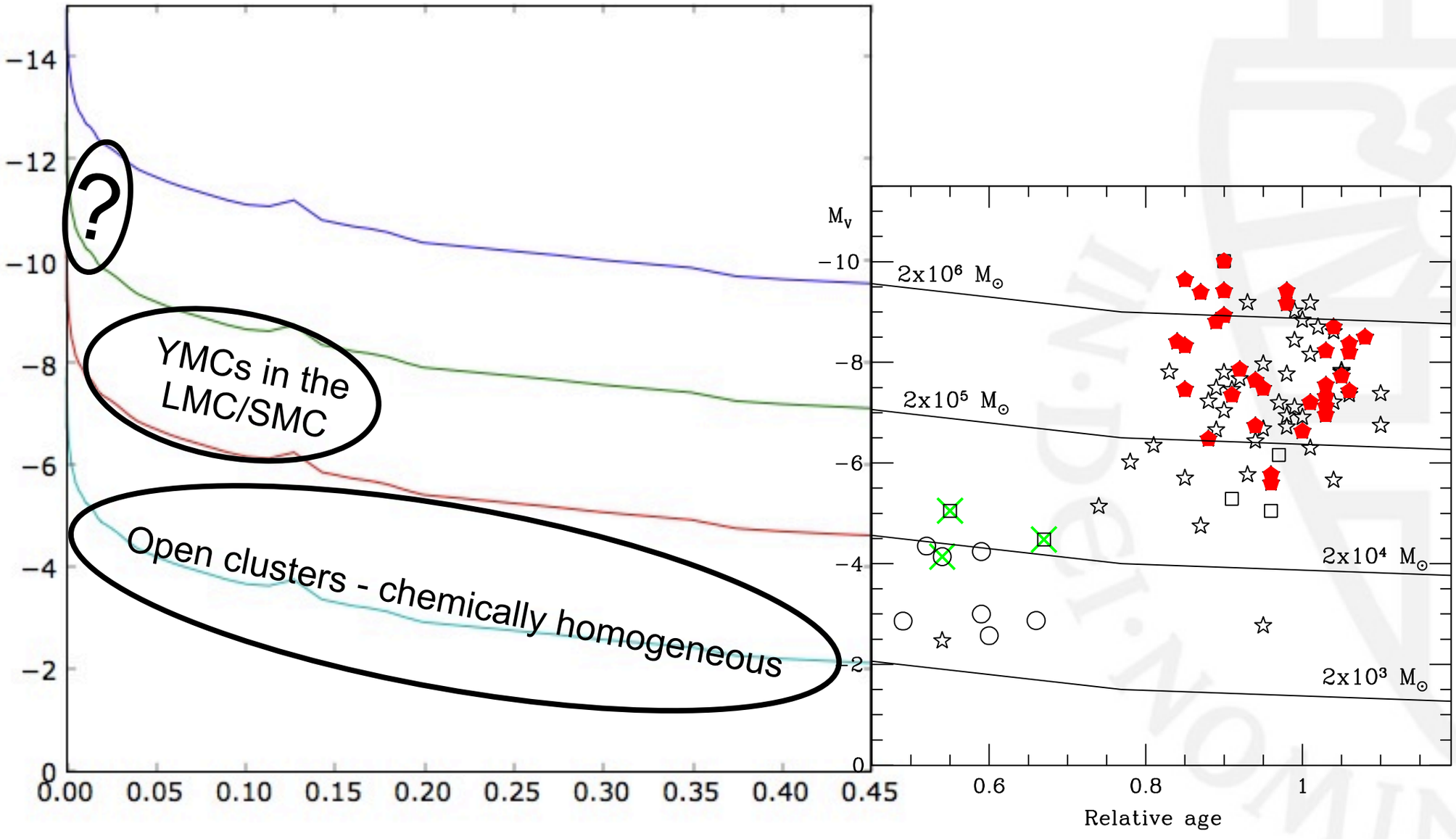
- 1 GC has spectroscopic metallicity [Fe/H]~-2.0 (Keck/ESI, Larsen et al., 2014.)
  Field:GC ratio about 1:1 at [Fe/H]=-2
- High GC/field ratio in Fornax is *not* unique.

Na-O anticorrelation in old GCs



Gratton et al. (2012)

What about young clusters?



Gratton et al. (2012)

Resolved photometry of YMCs

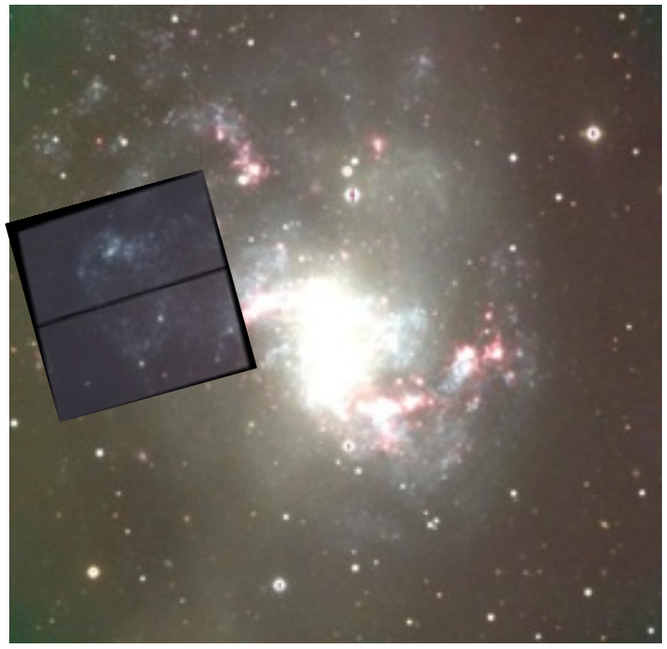
NGC1313-A:

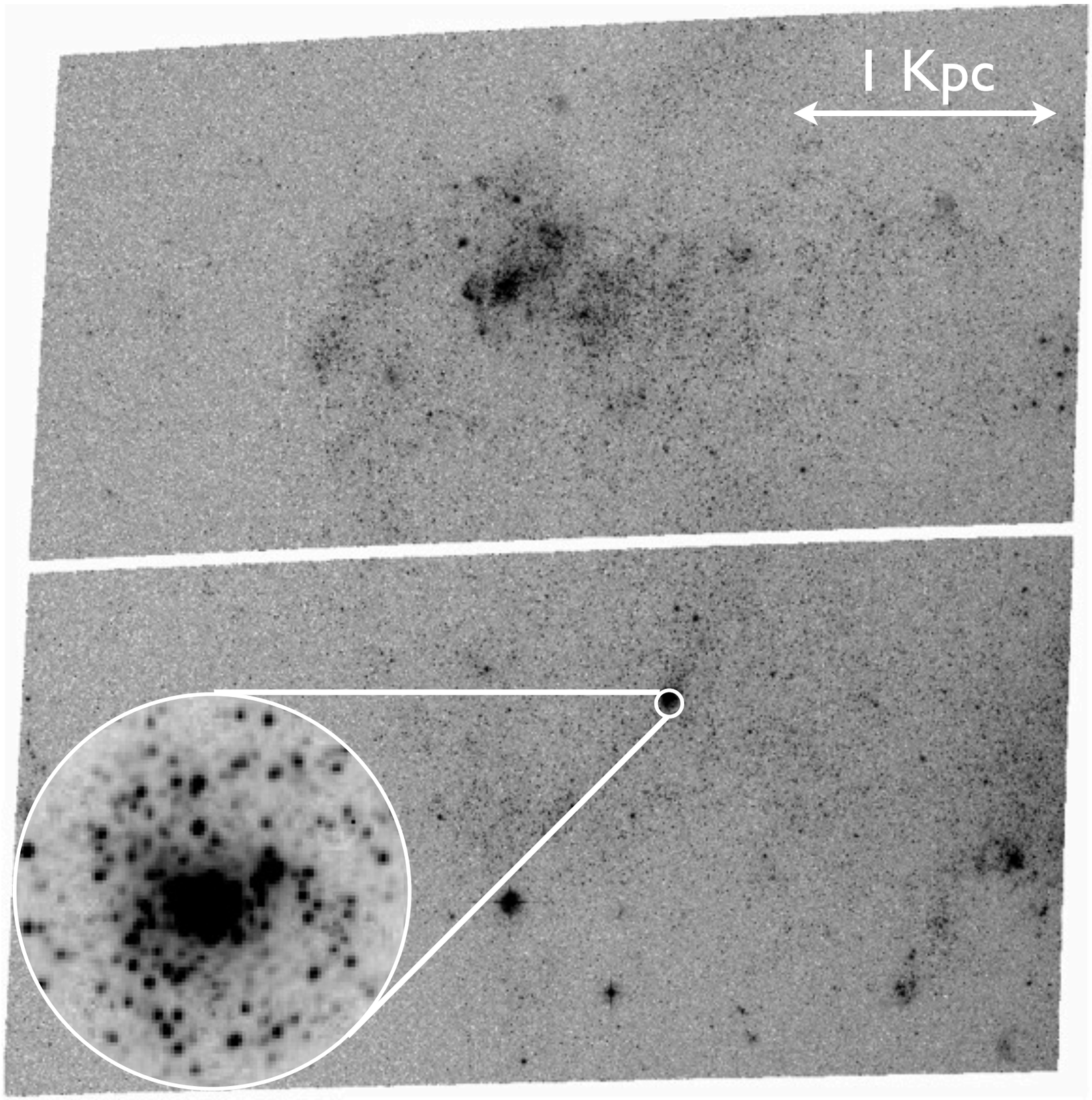
Age ~ 50 Myr

Mass ~ 3×10^5 $M_\odot$

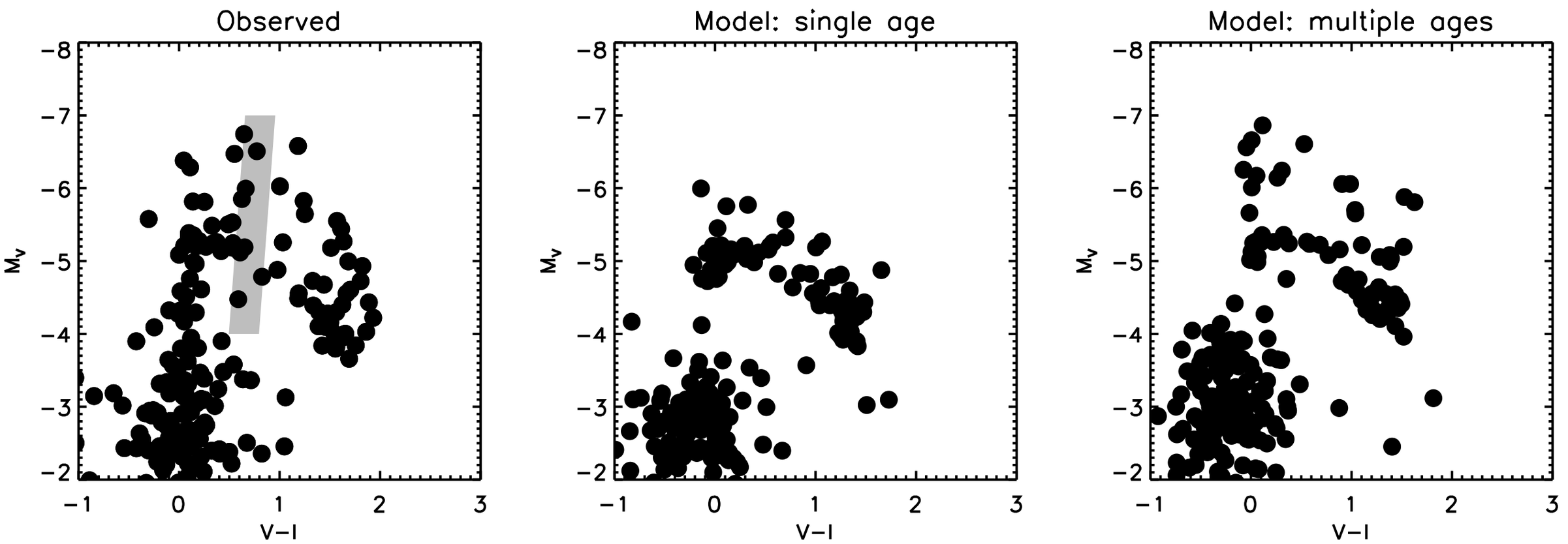
(Larsen et al. 2011)

"Young globular cluster?"





Resolved photometry: Multiple ages..?



Age = 5.6×10^7 yr

Ages =

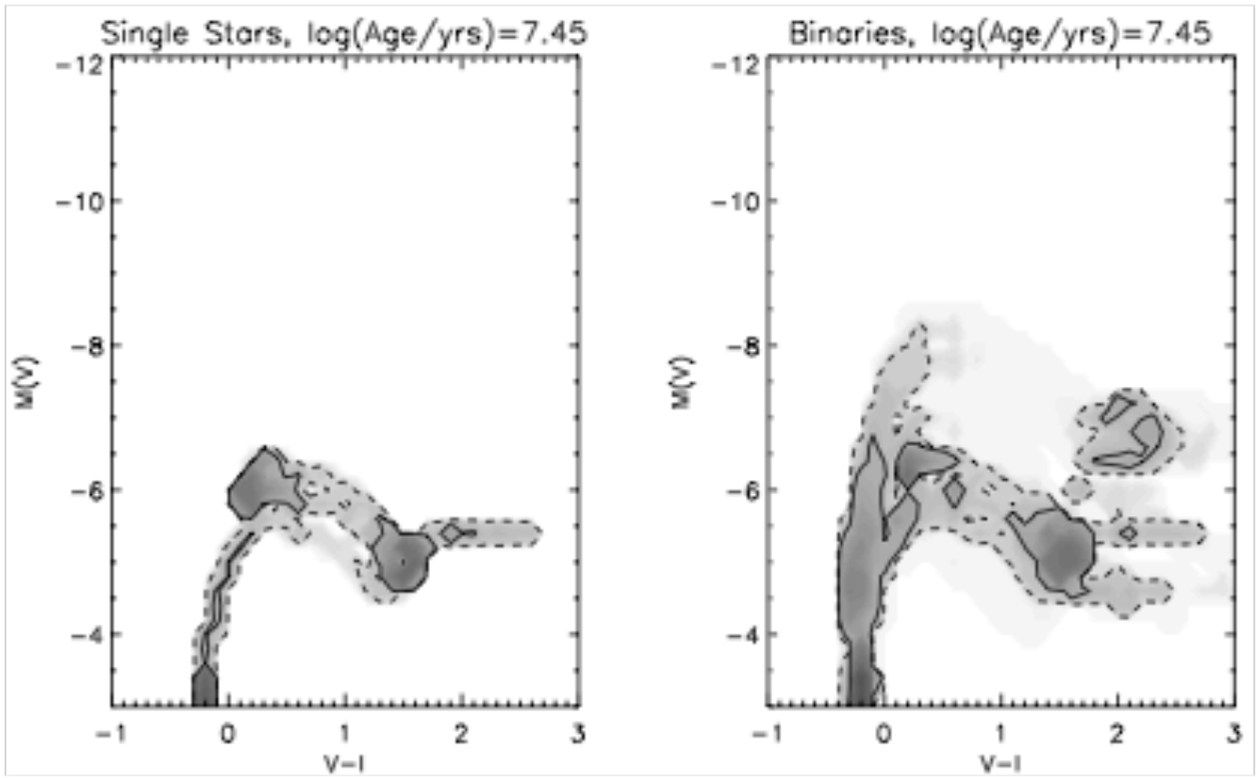
5.0×10^7 yr (65%)

3.2×10^7 yr (20%)

2.0×10^7 yr (15%)

Larsen et al. (2011)

.. or interacting binaries?

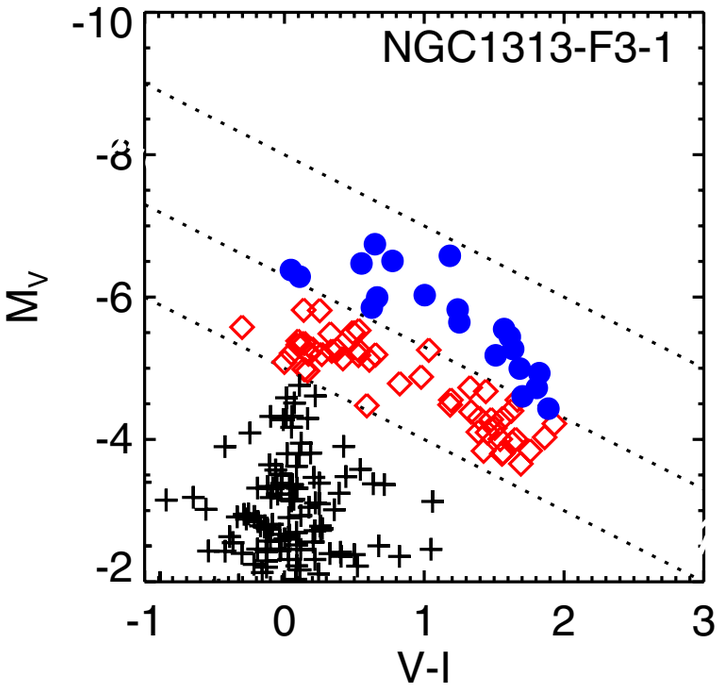


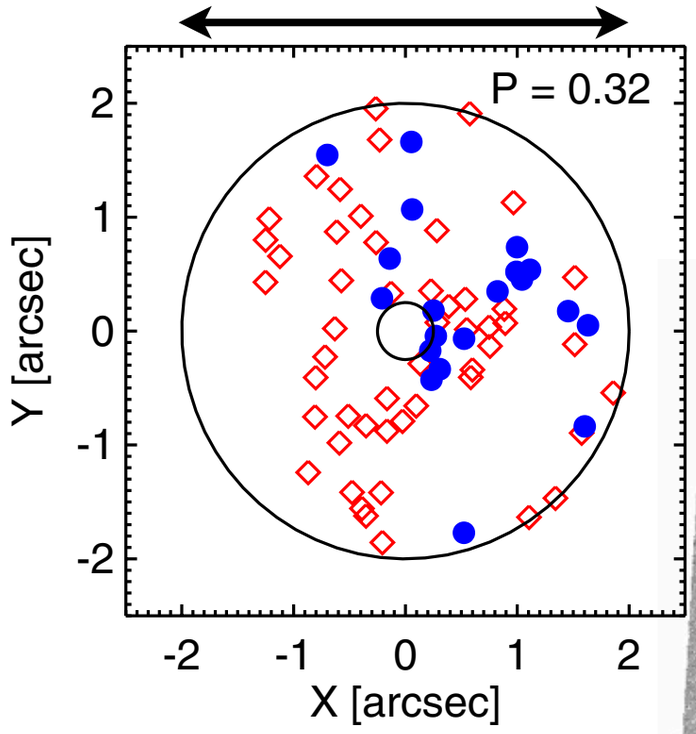
About 4 of 10 O stars have companions that may interact (Sana & Evans 2010)

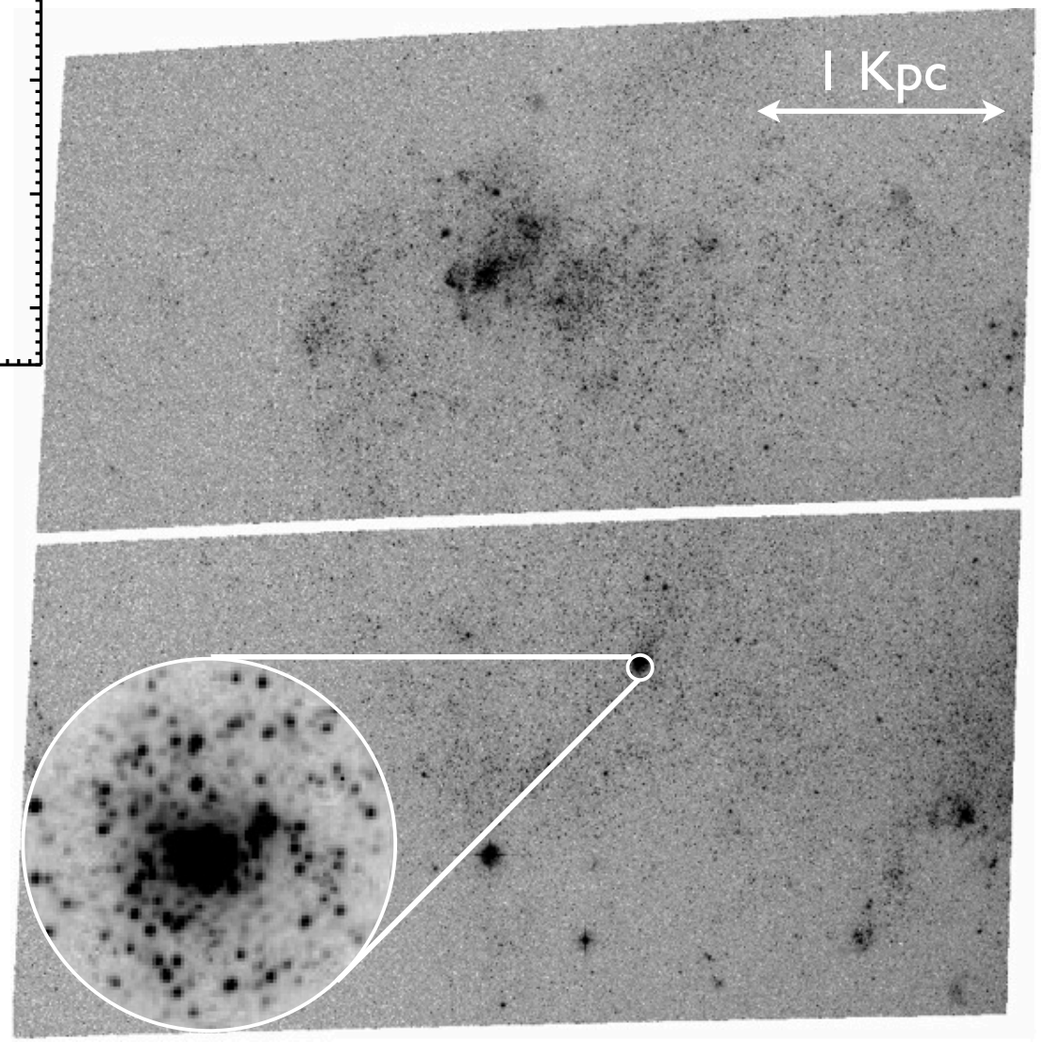
Accretion/merging → “blue stragglers” and more massive giant stars. May produce effect similar to age spread.

Larsen et al. (2011), using models based on BPASS code (Eldridge & Stanway 2009)

“Young” and “old” stars: different spatial distributions?







Conclusions

- Multiple stellar populations not only in Milky Way GCs but also in Fornax dSph
- Important constraints on GC formation scenarios from dwarf galaxies:

  Large fraction of metal-poor stars in GCs, little mass loss / infant mortality
- Relation to YMCs: *Unclear*