The stellar halos of six nearby disk galaxies: A direct test of models of galaxy formation

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MPA

Galaxy
Halos
Outer Disks
Substructure
Thick Disks
Star Clusters

Main collaborators:

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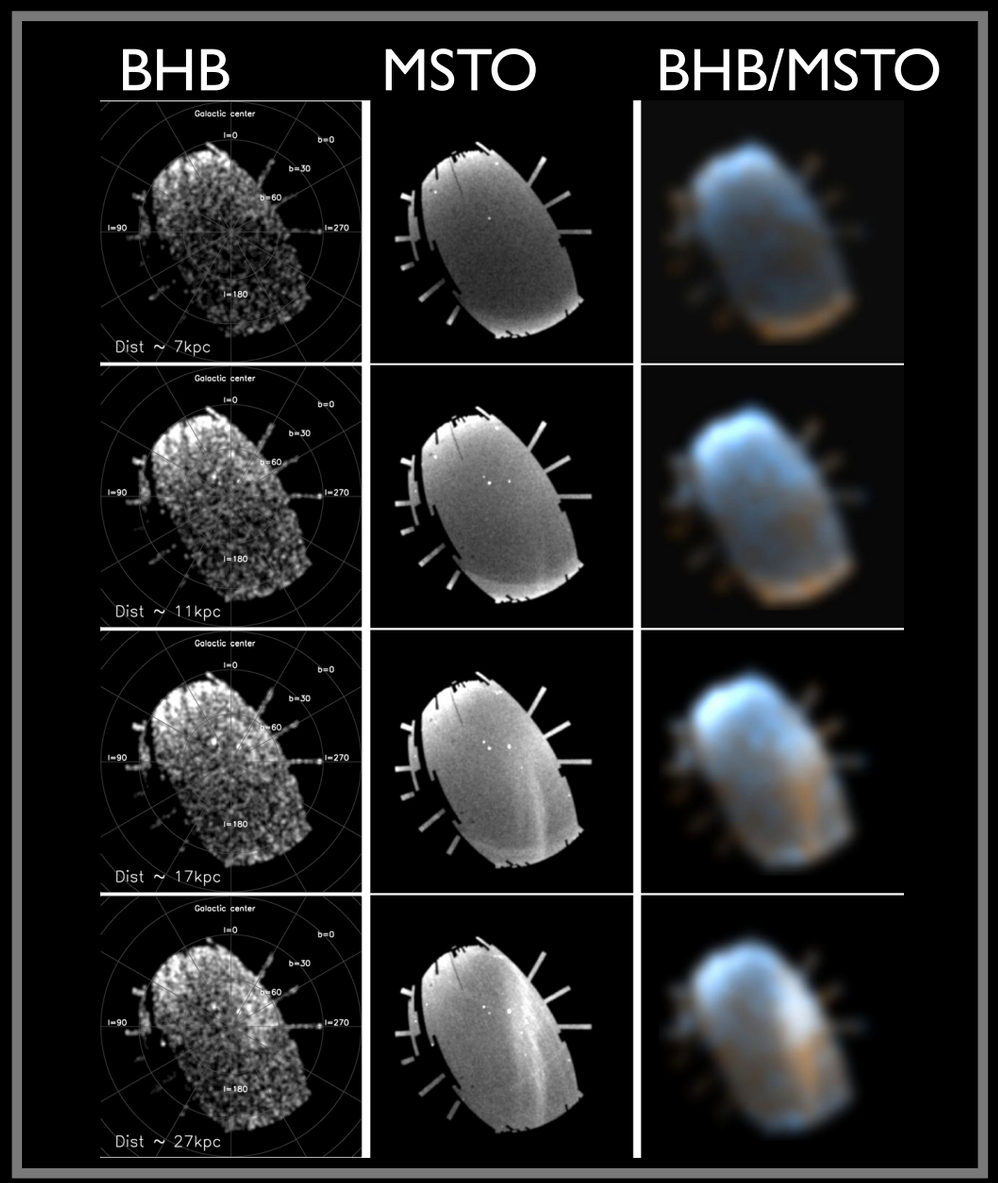
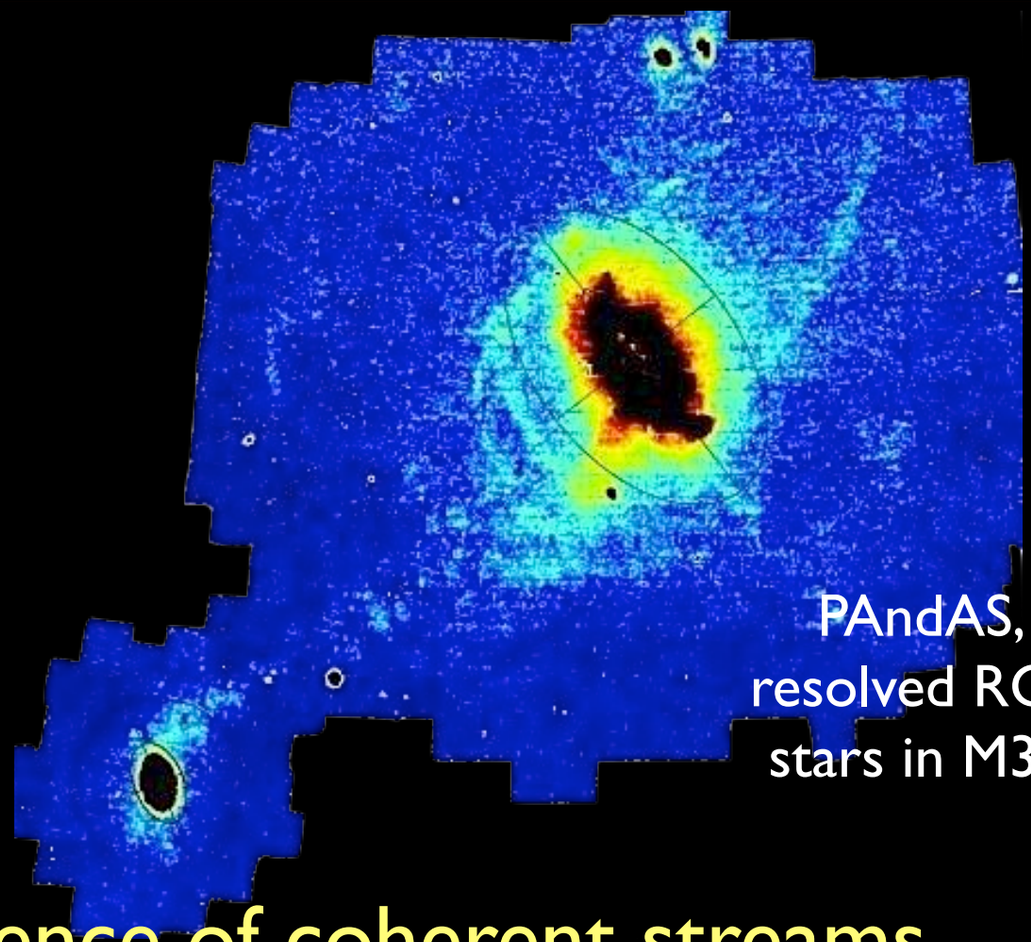
Baryons at low density workshop, ESO 25.02.15

Stellar halos of disk galaxies: Information on the growth history of galaxies

Resolving stars in halos is one of the best approaches to study them and test model predictions



Bell et al .(2010)



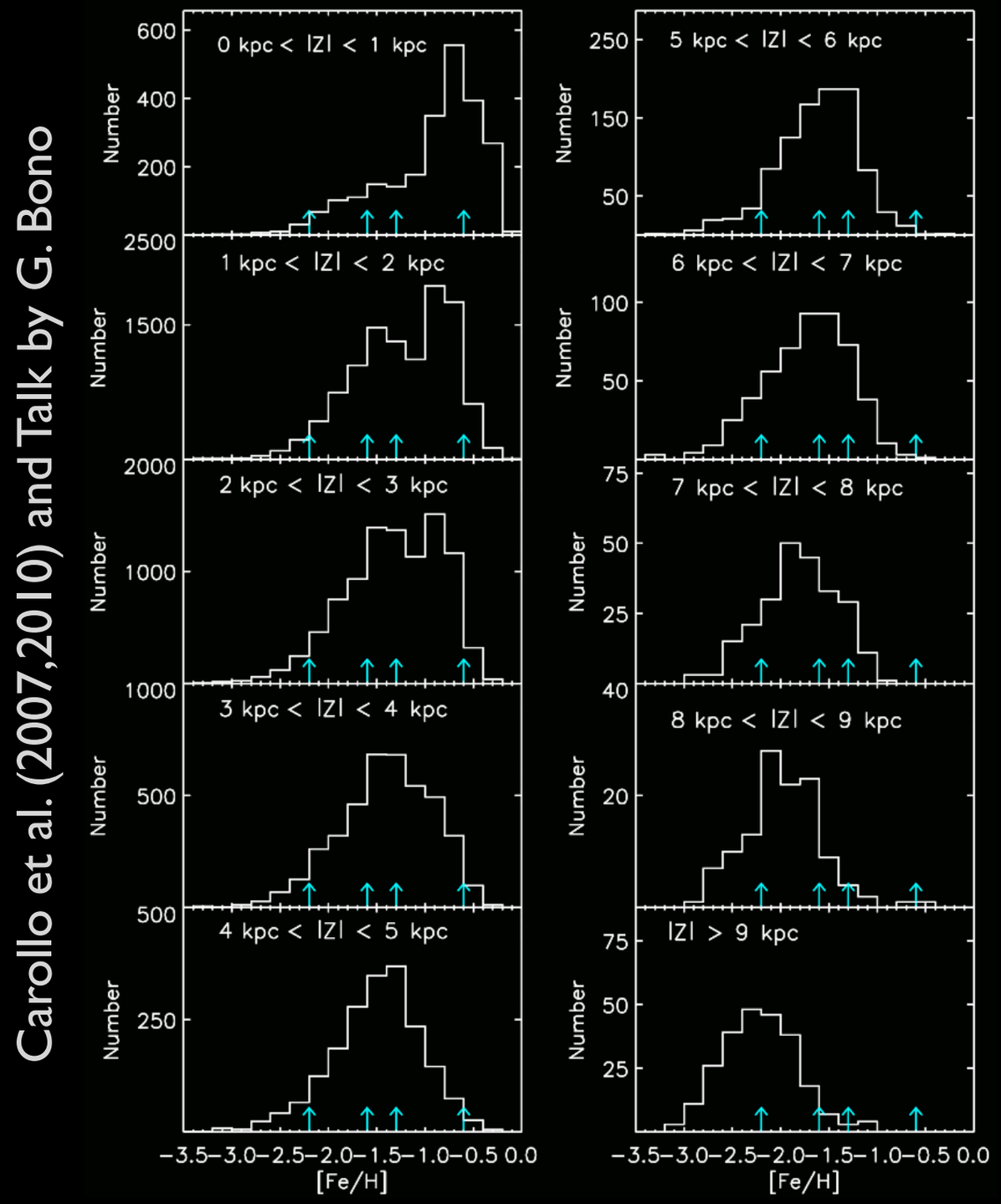
PAndAS, resolved RGB stars in M31

✓Presence of coherent streams, shells, satellite galaxies, etc.

✓Stellar population variations within a stellar halo

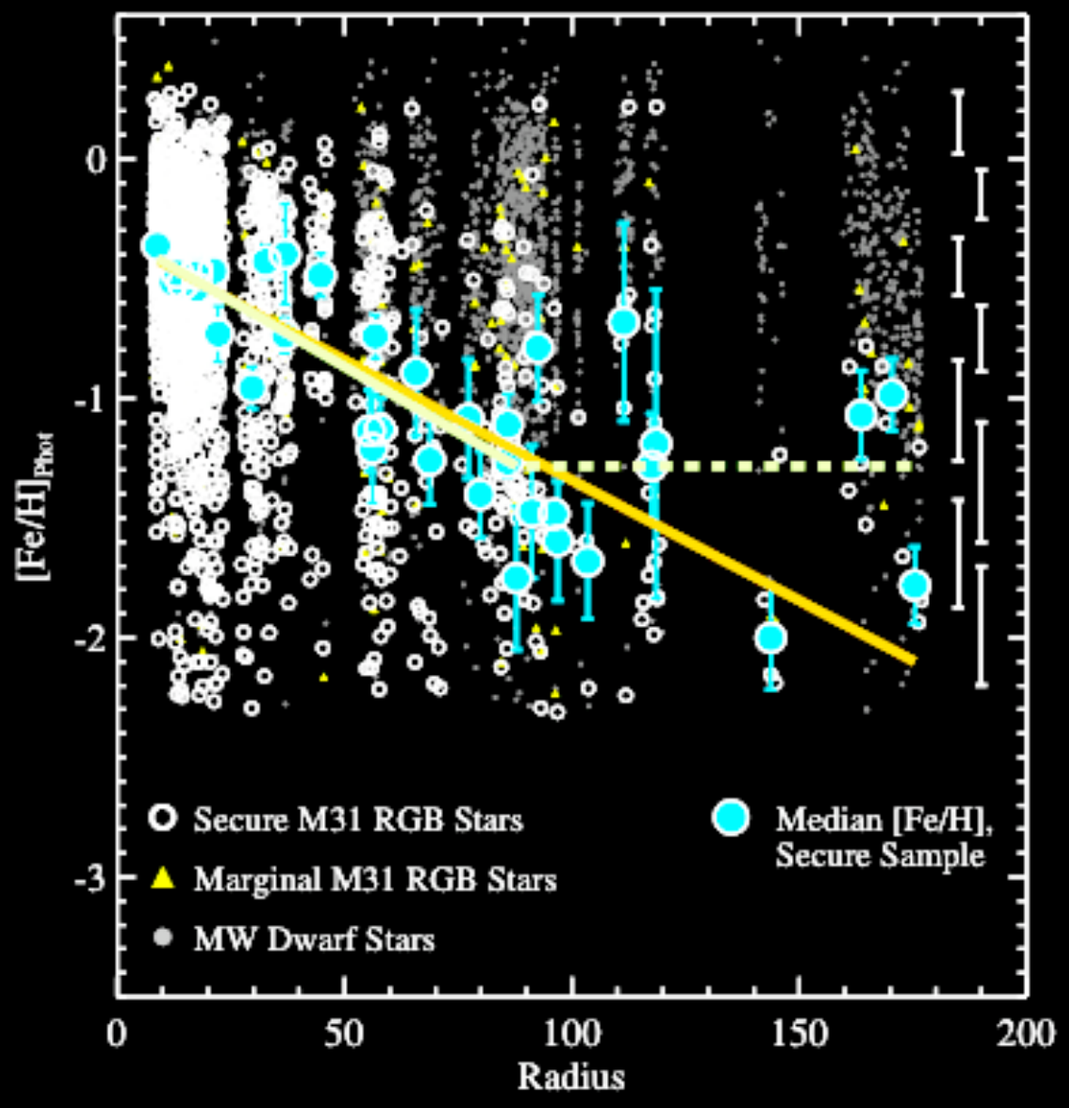
✓ The existence of a halo metallicity gradient or the lack of it reflect the assembly of the galaxy

Metallicity gradient in the MW's halo



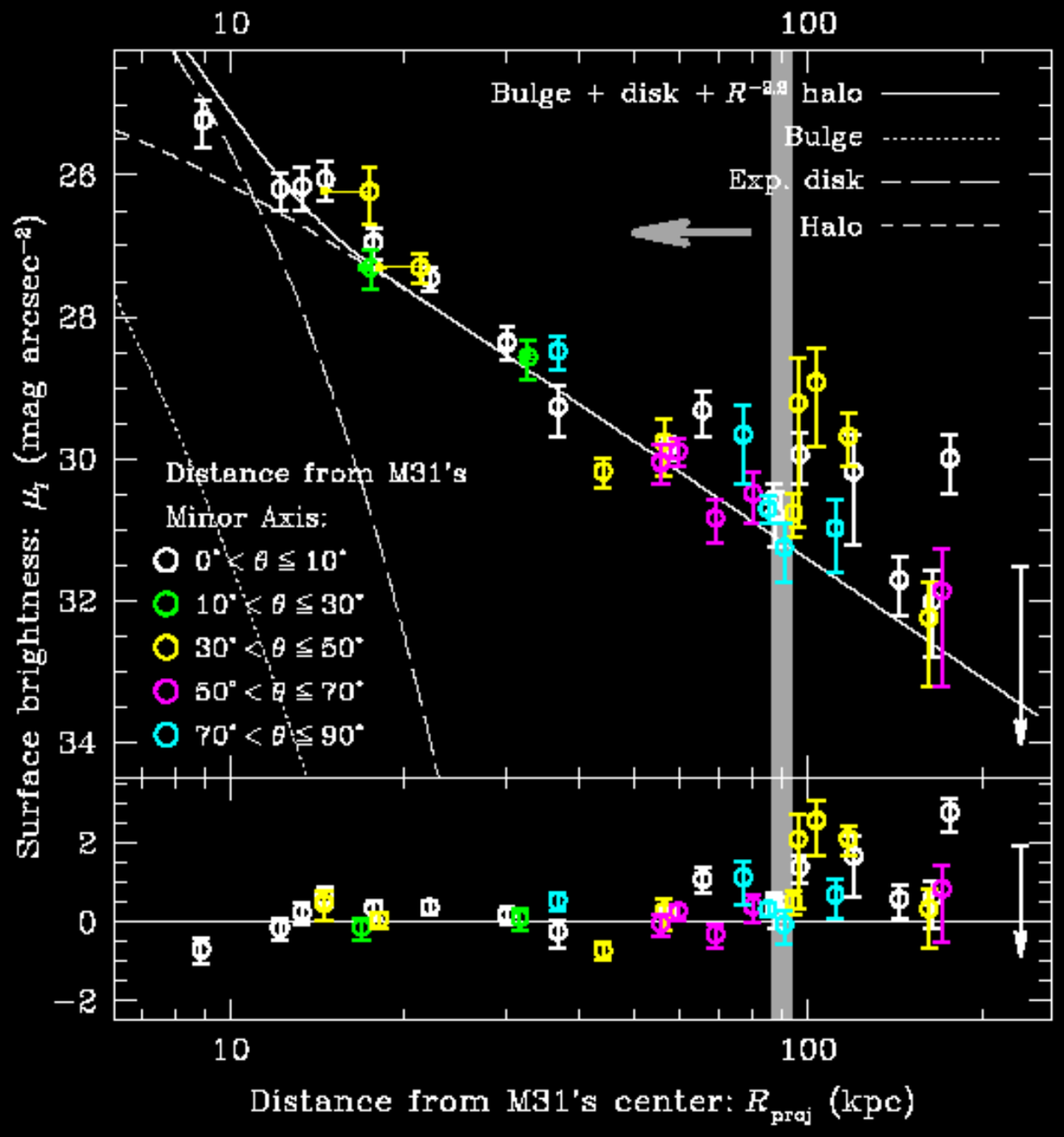
Carollo et al. (2007,2010) and Talk by G. Bono

Clear metallicity gradient in M31's halo



Gilbert et al. (2014, also Ibata et al. 2014)

✓ Stellar halos are predicted to have steep density profiles



M31's halo

Single power law of α = -2.2+/- 0.2 from 10 to 200 kpc (Gilbert et al. 2012). Ibata et al. (2014) find α ~ -3 from 30 to 200 kpc from PAndAS.

MW's halo

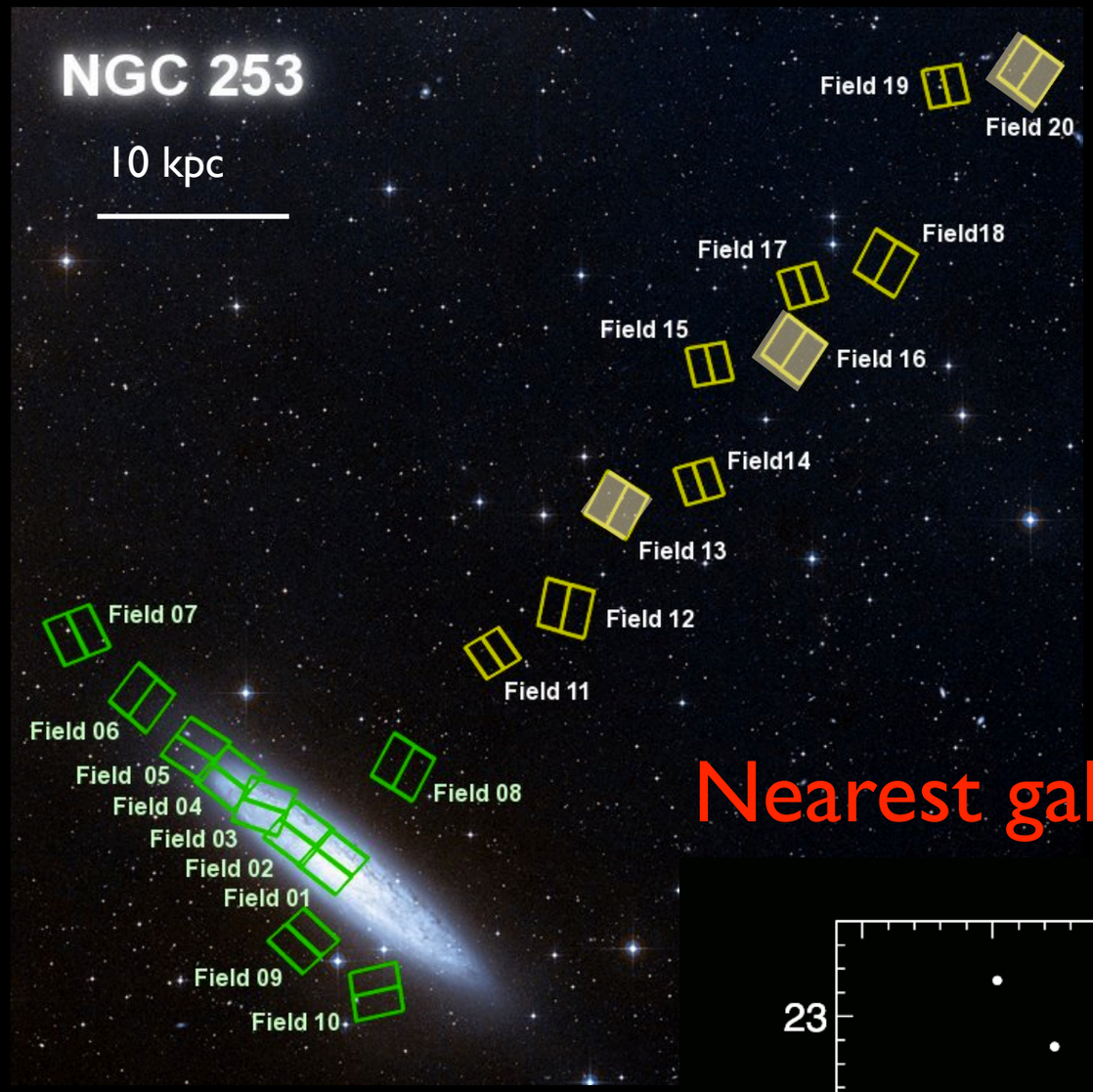
Broken power law -2 > α > -4 at R < 25 kpc and -4 > α > -5 for R > 30 kpc (Watkins et al. 2009, Deason et al. 2011)

✓ Models predict substantial galaxy-to-galaxy scatter in stellar halo properties, motivating studies of other stellar halos

- V_max > 170 km/s
- Edge-on or highly inclined
- D ~ 3.5 to 14 Mpc
- HST ACS and WFC3 observations

GHOSTS survey: Largest study of the resolved stellar populations in the outer disks and halos of nearby disk galaxies

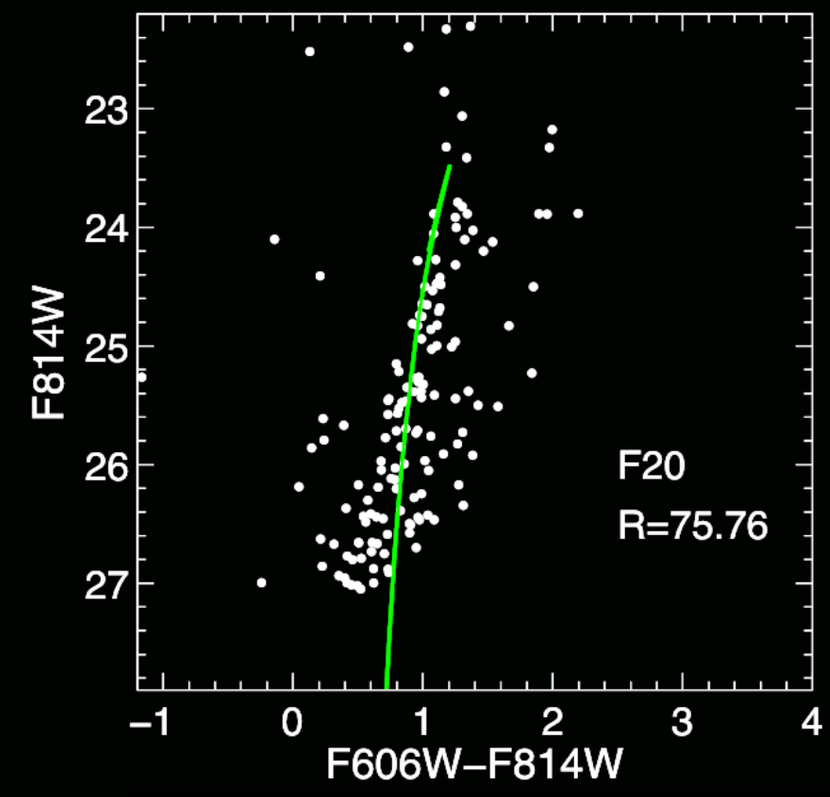
HST resolves red giant branch stars down to ~ 2 mag below TRGB

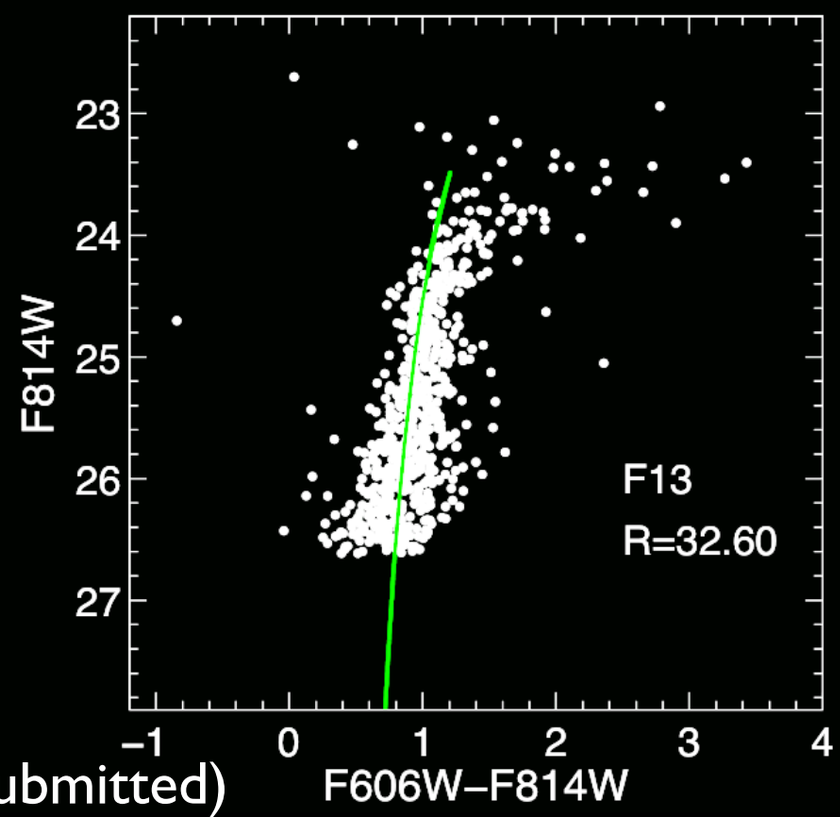


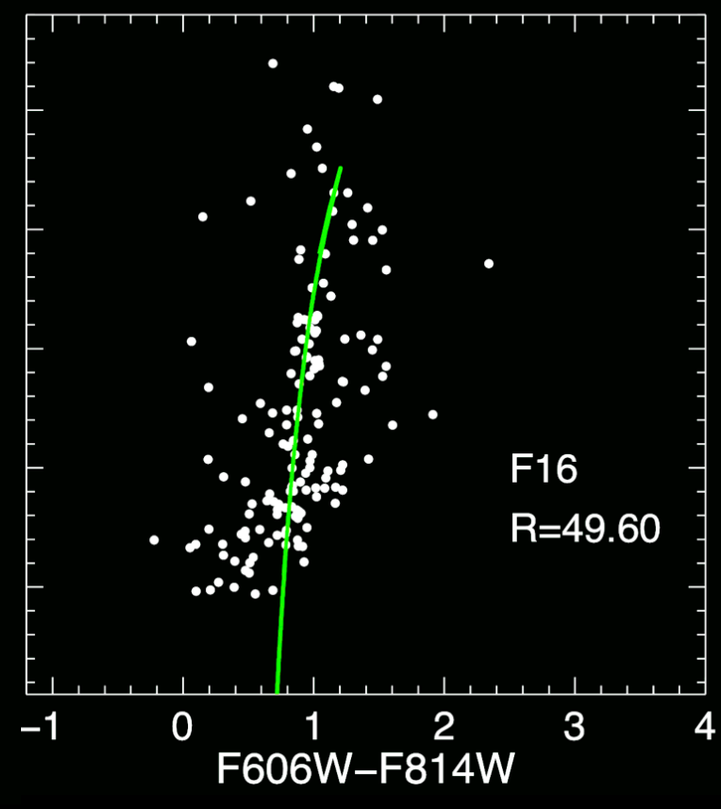
Nearest galaxy studied

D ~ 3.5 Mpc

Vrot ~ 194 km/s

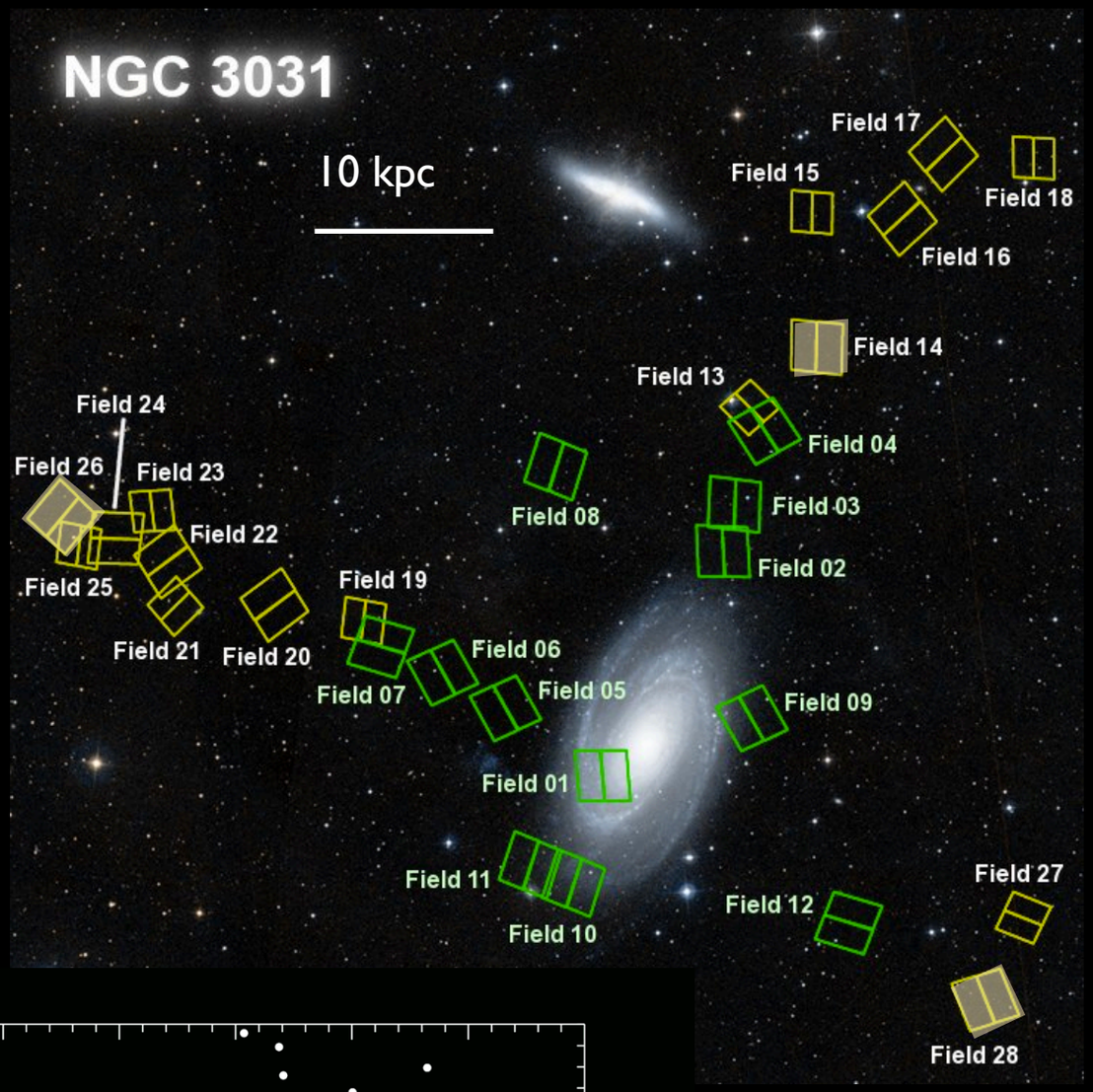


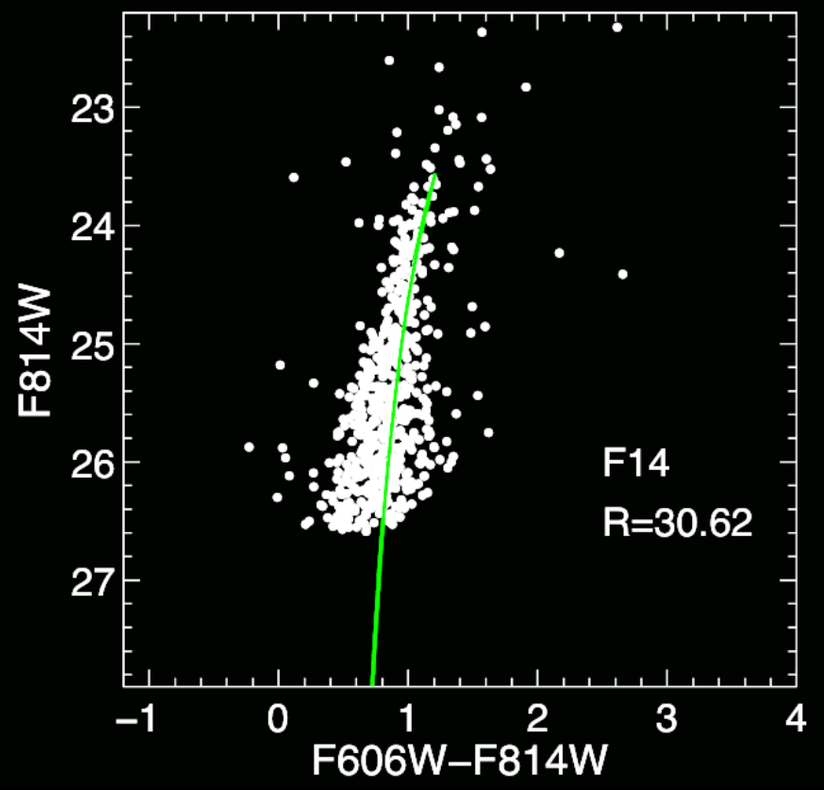


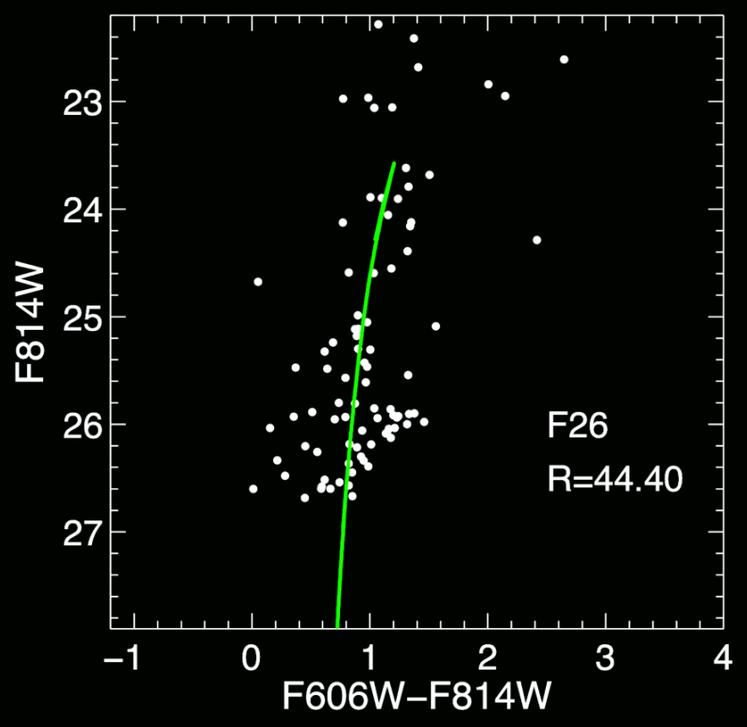


Monachesi et al. 2015 (to be submitted)

HST resolves red giant branch stars down to ~ 2 mag below TRGB

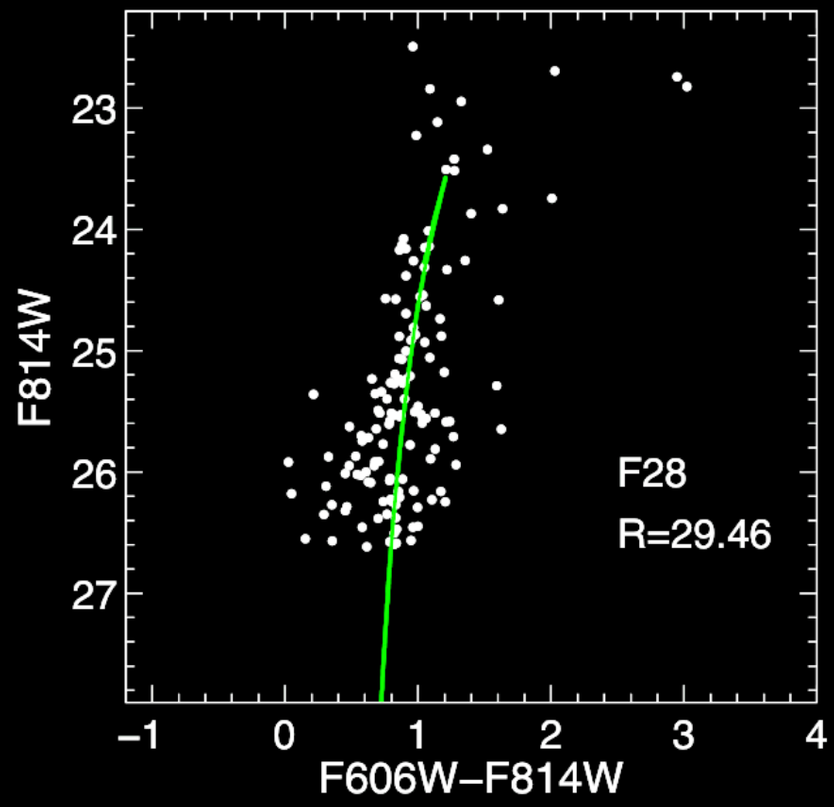






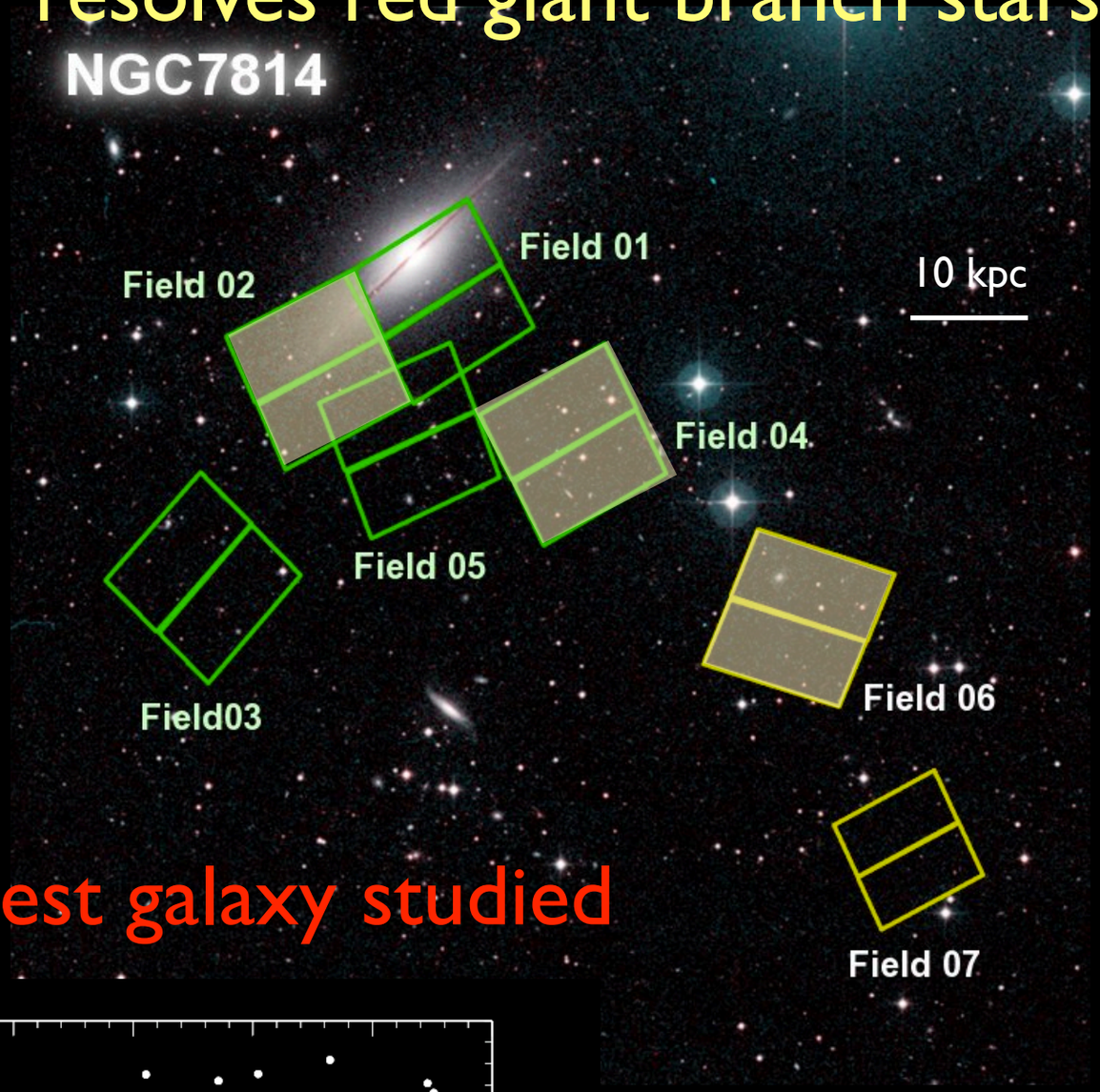
D ~ 3.7 Mpc

Vrot ~ 224 km/s



Monachesi et al. 2013, 2015 (to be submitted)

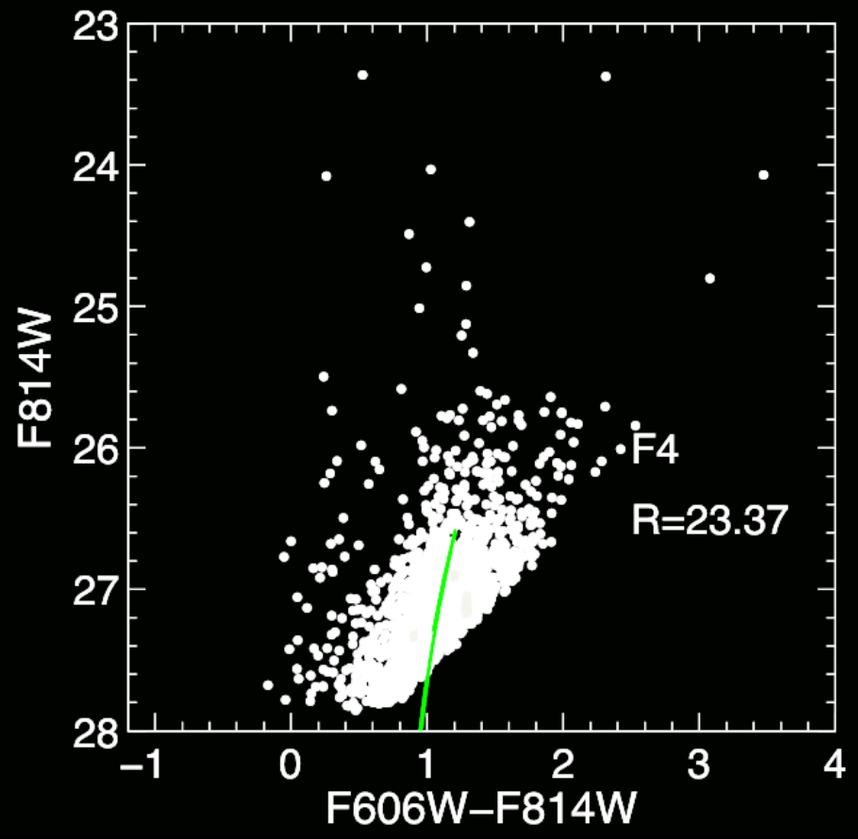
HST resolves red giant branch stars down to ~ 2 mag below TRGB

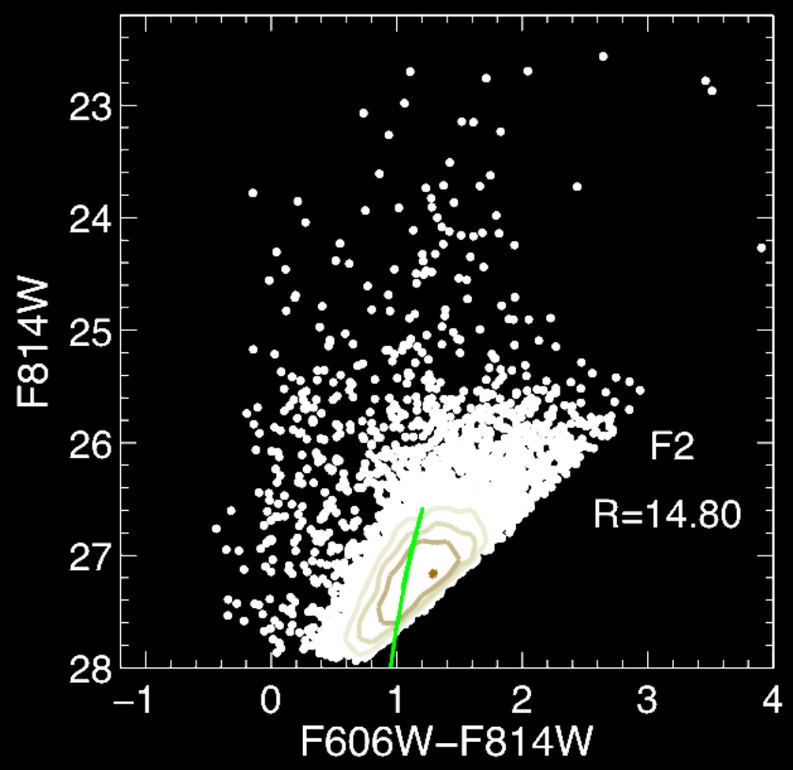


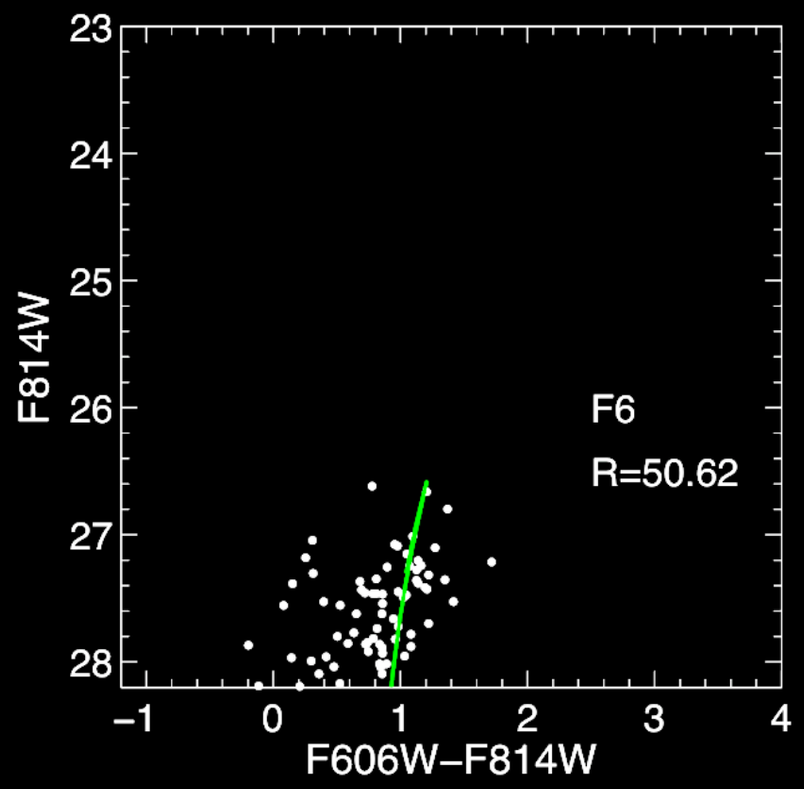
Farthest galaxy studied

D ~ 14.4 Mpc

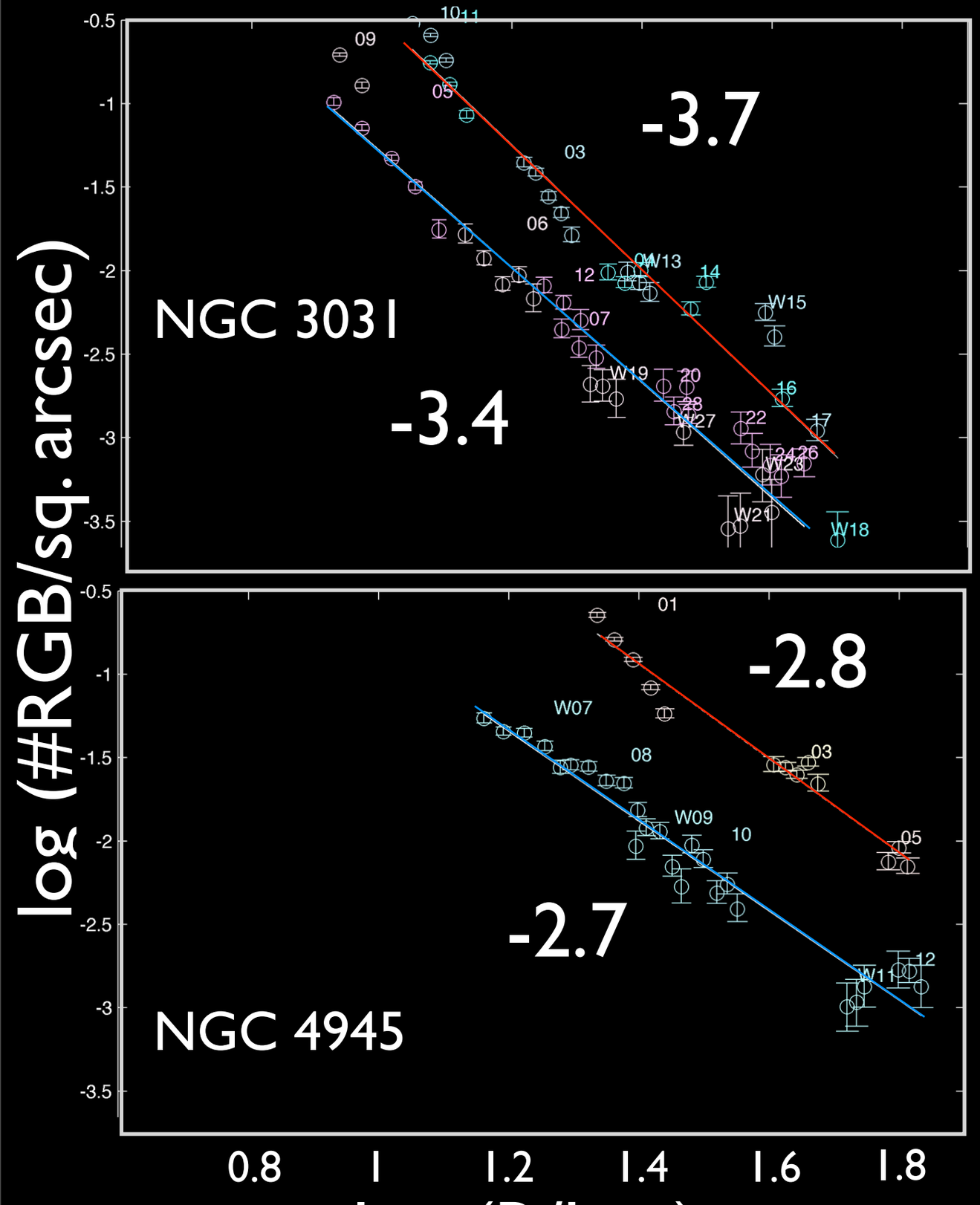
Vrot ~ 231 km/s







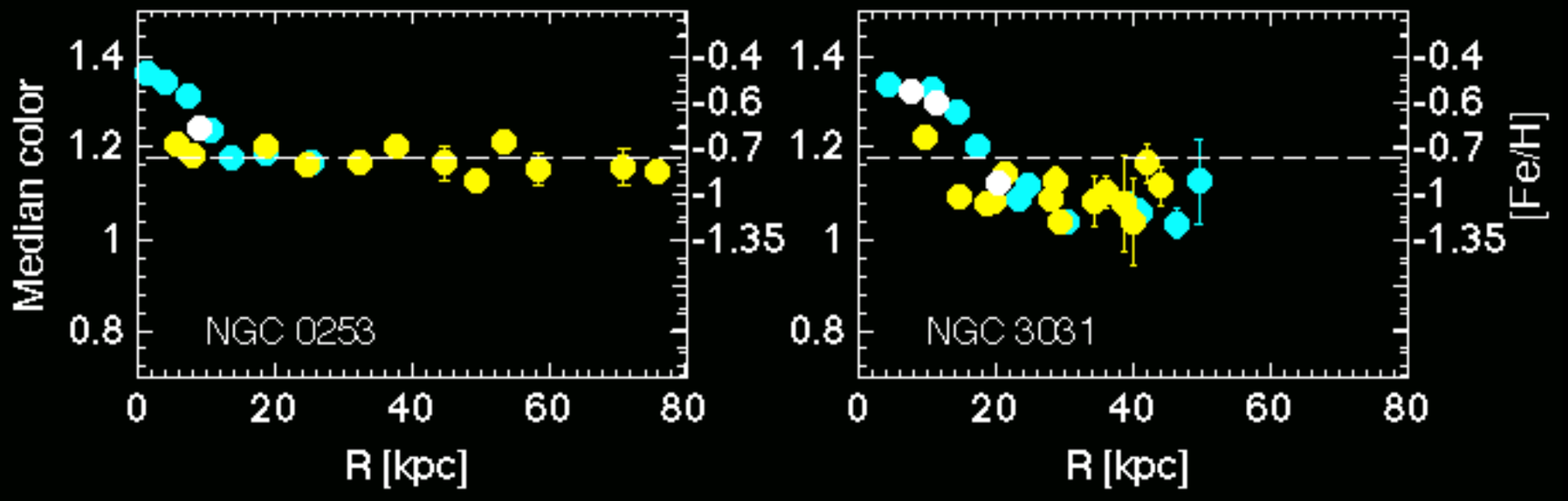
Projected stellar density profiles of halos

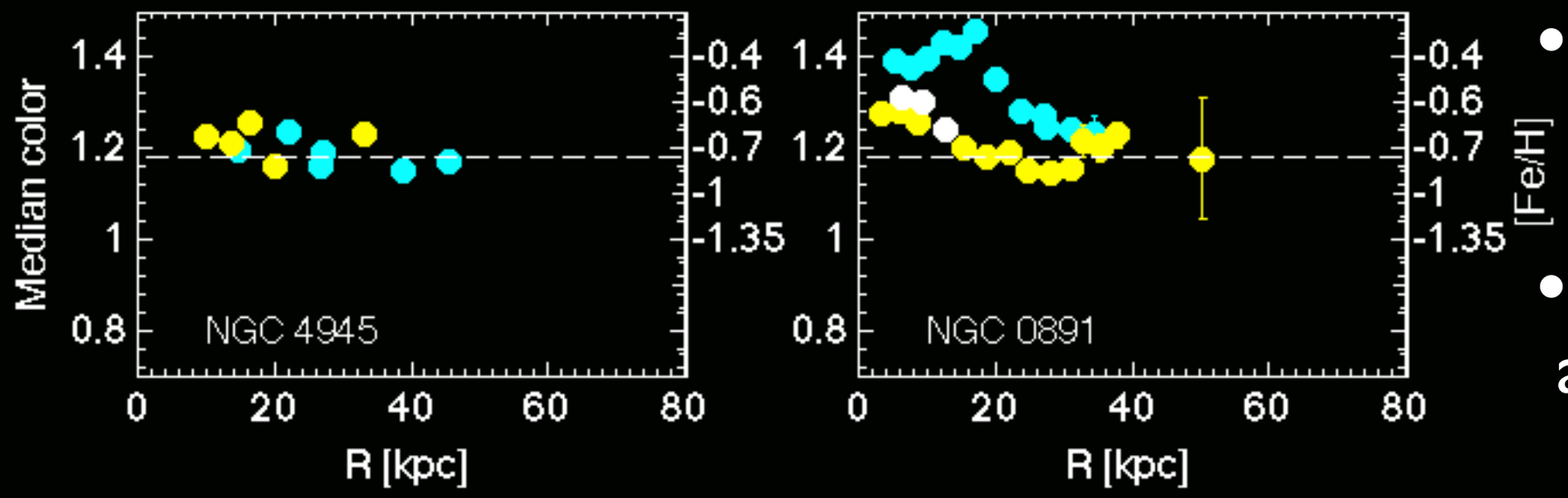


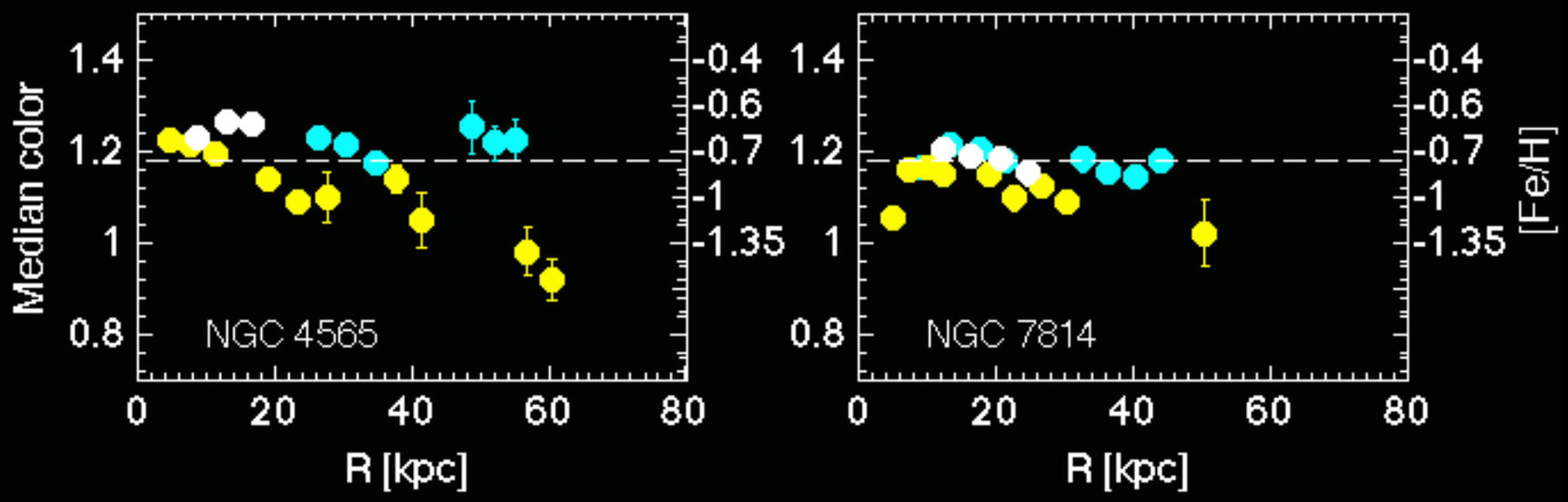
- Power law profiles -2>α> -4.5 over 10 to 70 kpc
- Scatter around these power law profiles RMS ~ 0.18 dex
- Halos appear flattened with 0.4 < b/a < 0.7 at ~ 30 kpc

Harmsen et. al (in prep.)

MW mass-like GHOSTS galaxies: Color profiles





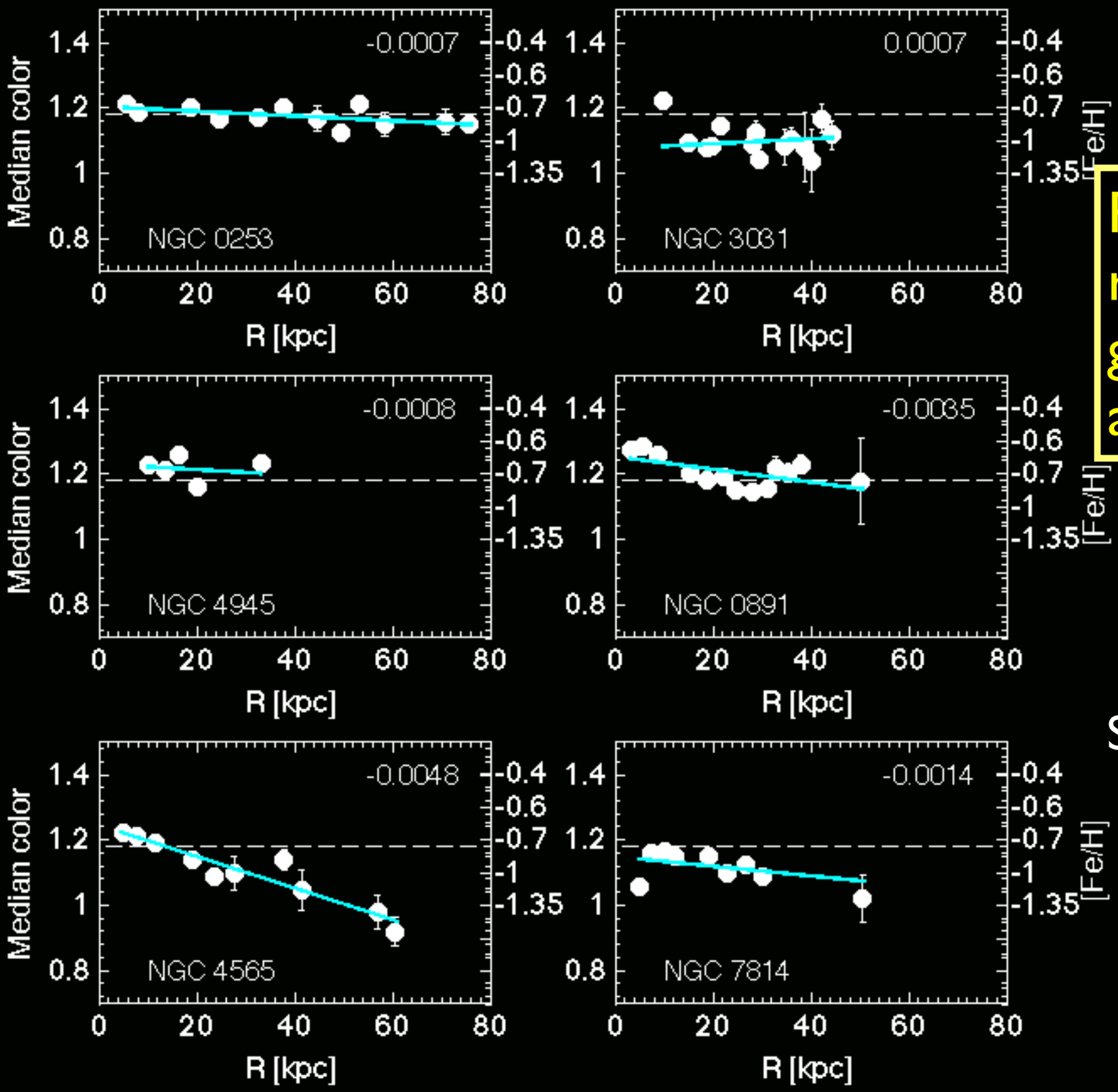


Minor
Major
Intermediate

- Color variations from field to field
- Fields along the major axis are typically redder than those along the minor axis at similar radial distances

Monachesi et al. 2013, 2015 (to be submitted)

Only minor axis fields: cleaner sample of stellar halo stars



RGB color profiles reveal likely metallicity gradients in 2 systems, absent in 4

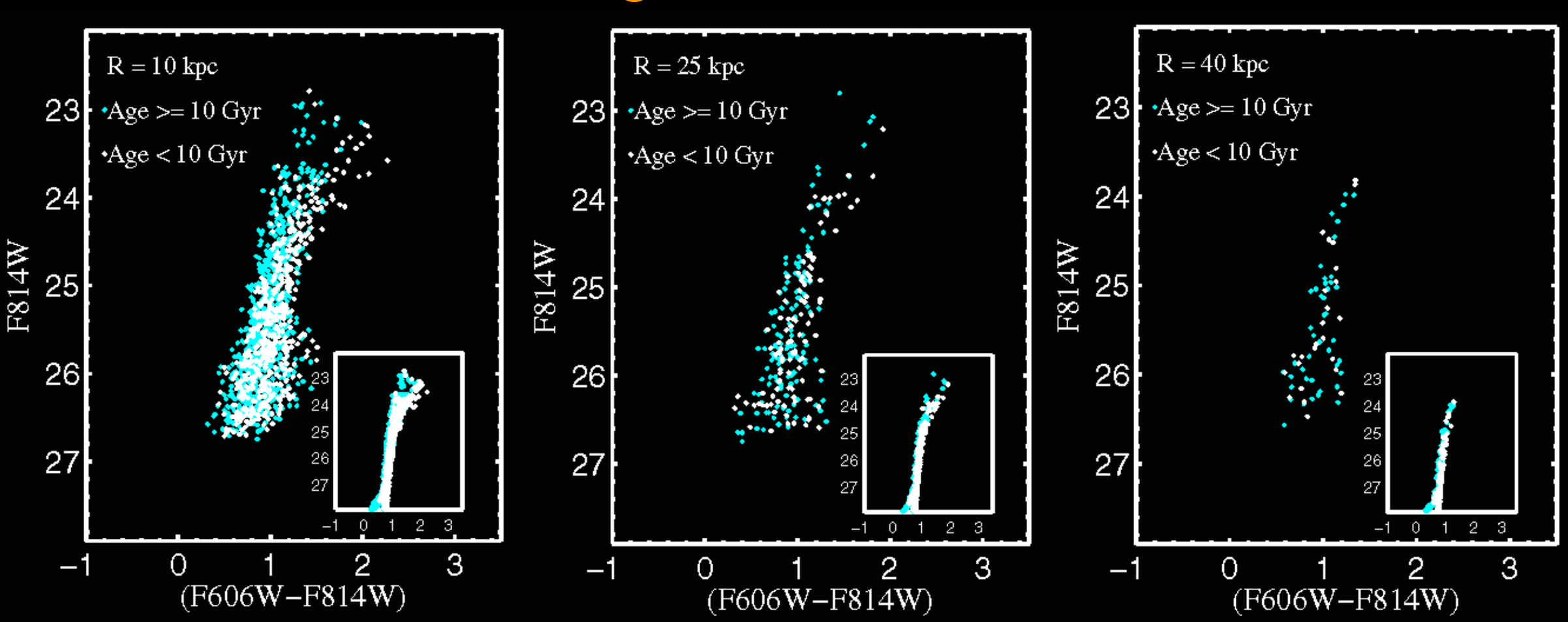
Metallicity estimates from Streich et al. (2014) relation

Monachesi et al. 2013, 2015 (to be submitted)

Direct comparison with models: From star particles to CMD

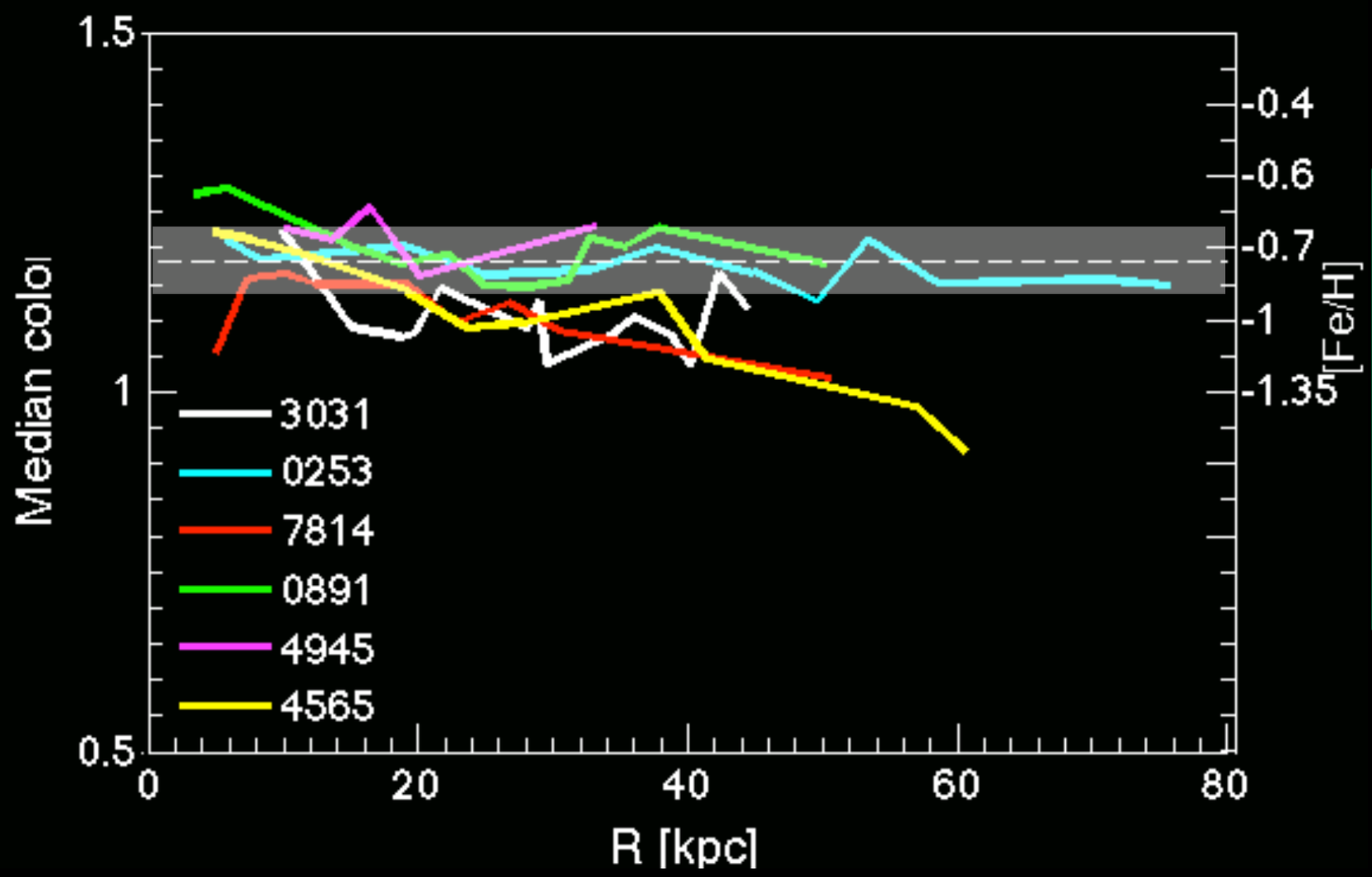
- ✓Bullock & Johnston (2005) models: Stellar halo built entirely from accreted satellite
- ✓Padova luminosity functions + IAC-STAR synthetic CMD
- ✓HST-like fields stars from B&J model
- ✓Simulate the observational effects on the stars from the models
- ✓Perform the same exact analysis as done with the observational data

Model CMDs at different galactocentric distances for ACS-like fields



Monachesi et al., 2013

Stellar halo color profiles of minor axis fields



- B&J models predict flat color profiles in the stellar halo out to ~70 kpc

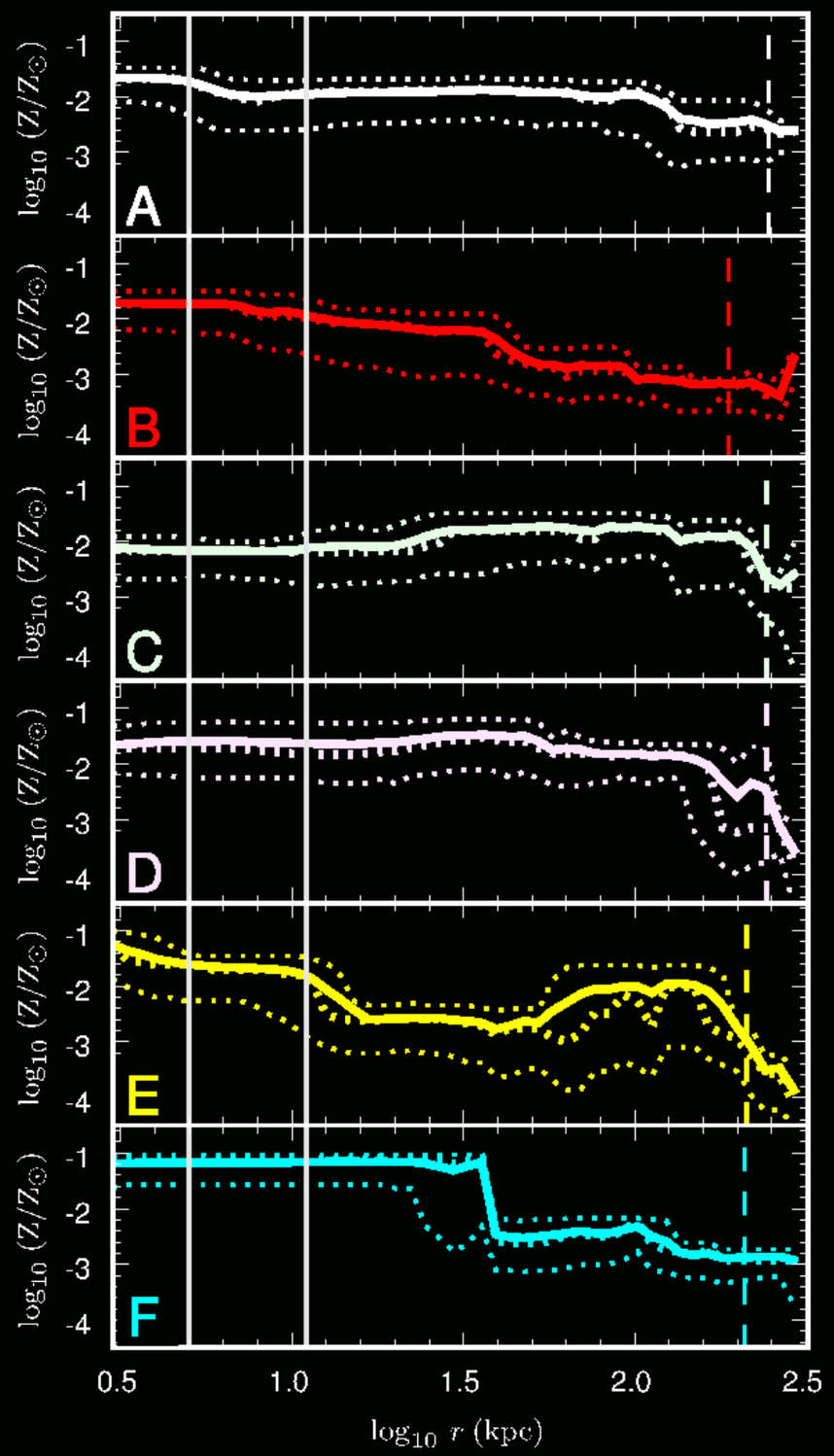
[Fe/H] > -1.3 dex for all galaxies out to ~ 70 kpc

More metal rich than MW's stellar halo, which has a [Fe/H] ~ -2 at radii > 20 kpc. But, are we comparing same things?

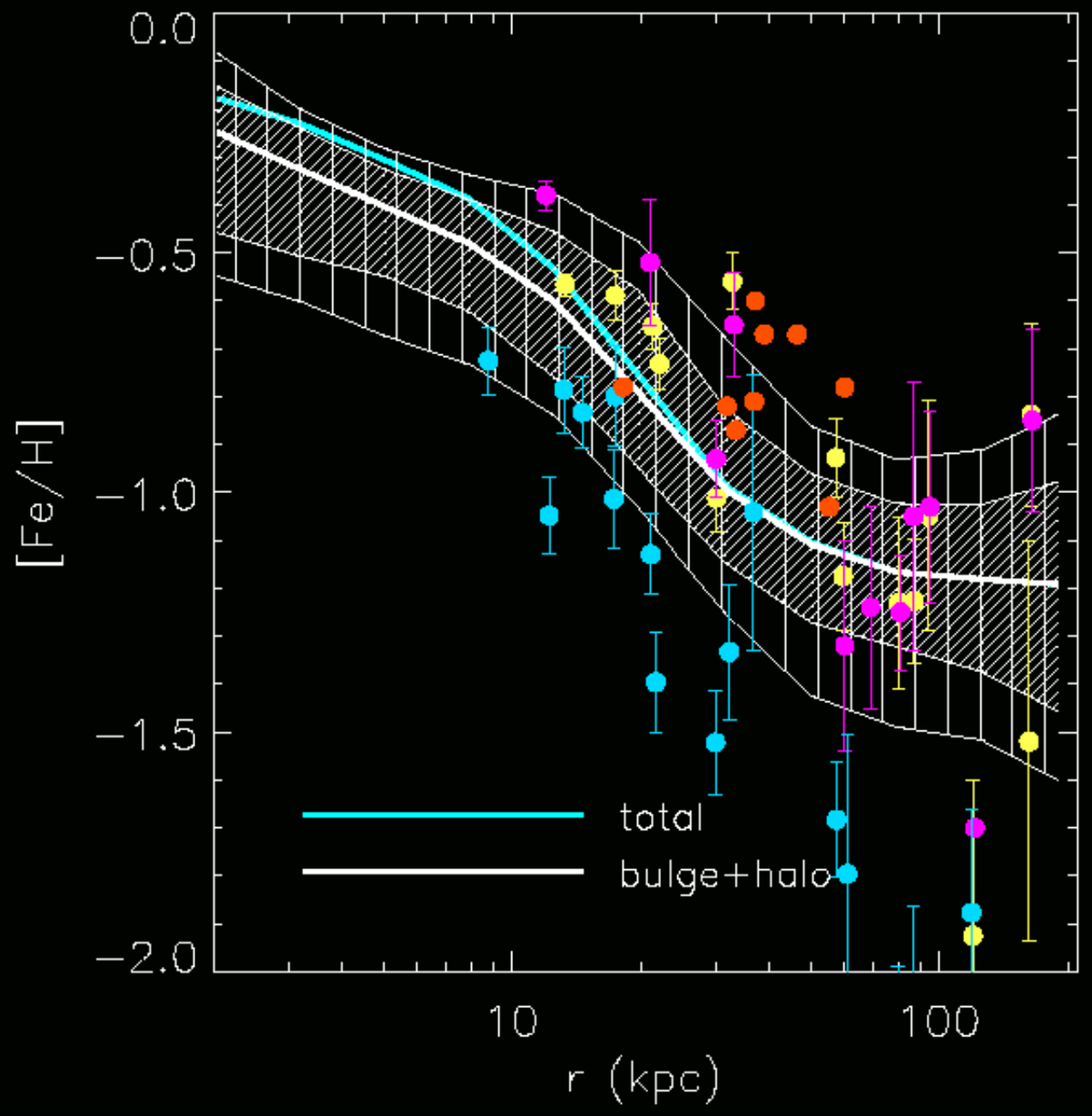
Monachesi et al. 2013, 2015 (to be submitted)

Model predictions

Only accreted stars: Diversity of metallicity profiles although mostly flat (e.g. Cooper et al. 2010)



In-situ and accreted stars: Strong metallicity gradients (e.g. Font et al. 2011)



Conclusions

- ✓ ALL GHOSTS MW-like galaxies have extended stellar halos
- ✓ Their stellar halos show stellar population variations and display a diversity of metallicity profiles. They are more metal rich than -1.4
- ✓ They show substructure at ~40% RMS level from projected stellar density profiles fit with power law functions
- ✓ Stellar halos built entirely from accretion predict, on average, flat metallicity profiles (B&J 2005, Cooper et al. 2010) which agree with 4/6 GHOSTS observed stellar halos

Next

- ✓ Careful determination of shape and mass of the stellar halos
- ✓ Detailed comparison of GHOSTS stellar halos with EAGLE simulations (high res. hydrodynamic sims + large statistics) to interpret the data