

Galaxy population properties in a massive cluster at z~1.4

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High-redshift clusters: the usual reasons…

- The leverage of cluster galaxy observations on galaxy evolution models increases the closer we get to the active galaxy formation epoch
- The comparison of galaxy populations in the highest density environments with respect to average fields across a wide redshift range provides direct insight on the nature and relevance of environmental effects over cosmic times
- Only the high redshift gives us (in principle) the full view of the two independent main channels of galaxy evolution: star formation *and* mass assembly history

XMMU J2235-2557

- X-ray selected, discovered in the XDCP (over a survey area of 11deg^2) (Mullis et al. 2005)
- More than 30 spectroscopic cluster members
- Cluster mass from X-ray (Rosati et al. 2009):

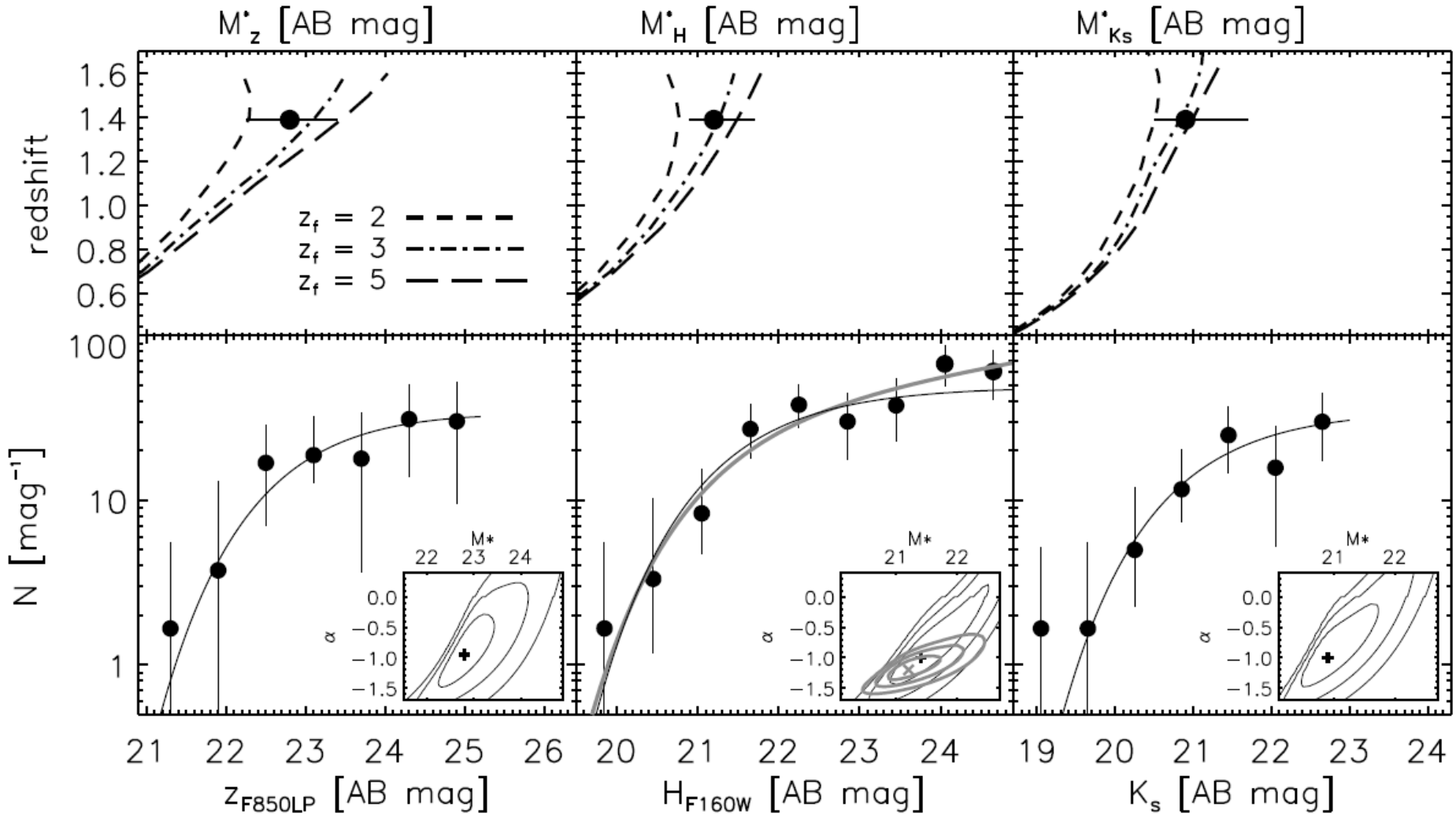
  $M_{<1Mpc} \sim 6x10^{14} M_{sun}$, $M_{proj<1Mpc} \sim 9x10^{14} M_{sun}$

  $M_{500} \sim 4x10^{14} M_{sun}$, $M_{500proj} \sim 7x10^{14} M_{sun}$

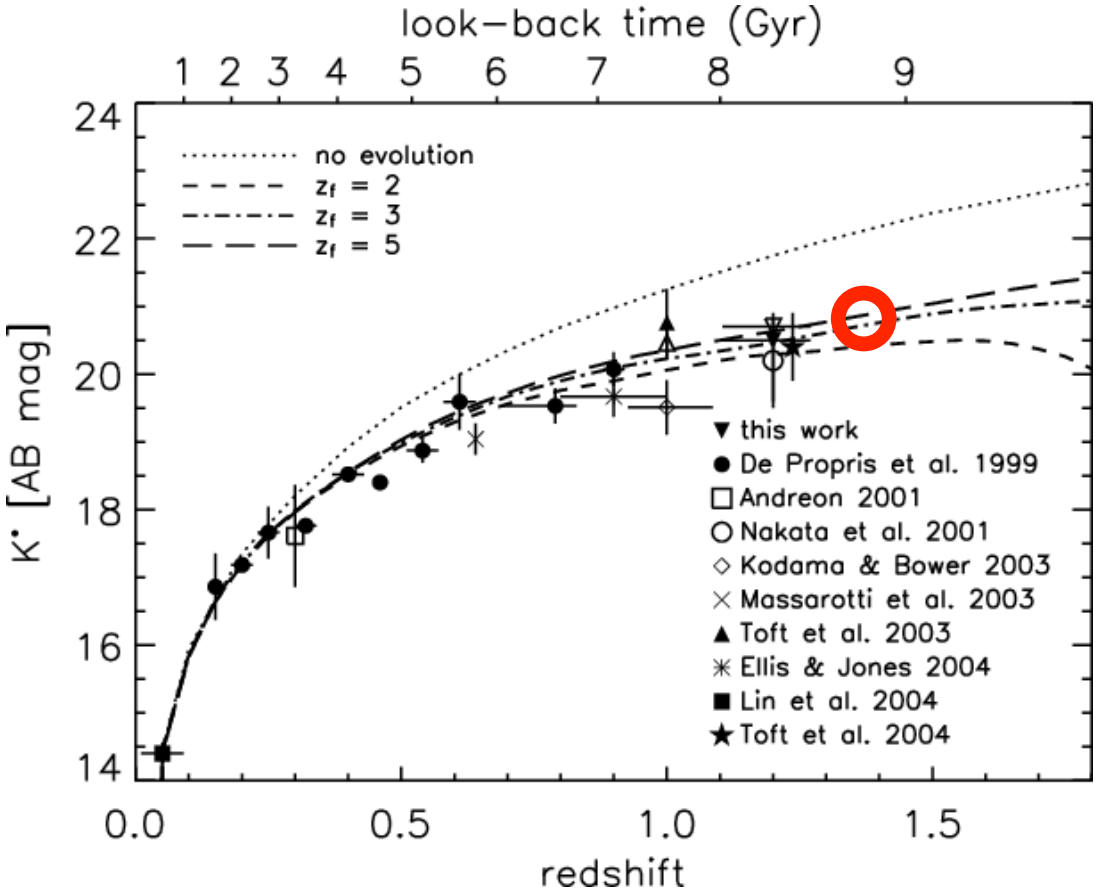
- Cluster mass from weak lensing (Jee et al. 2009):

  $M_{proj<1Mpc} \sim 8.5x10^{14} M_{sun}$

Cluster galaxy luminosity function

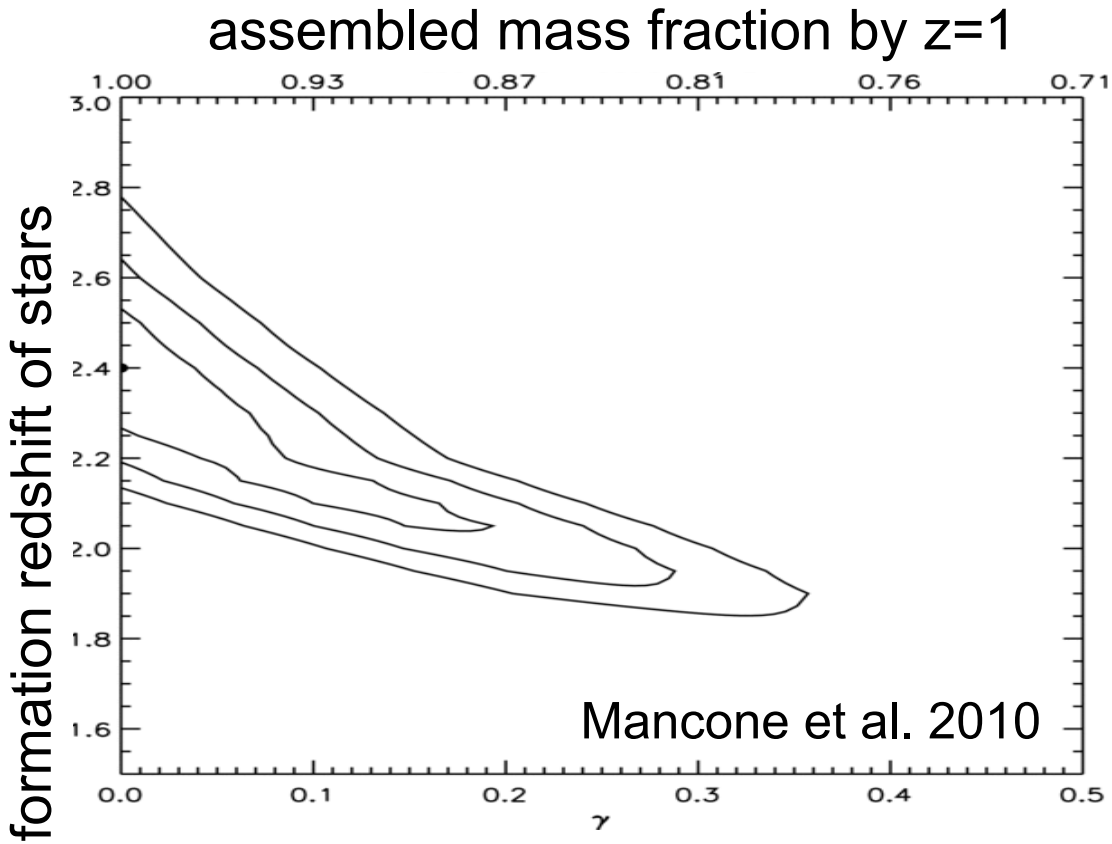


Luminosity function evolution



The shape of the LF and the characteristic magnitude M* are consistent with passive evolution of stellar populations formed at z≥2 (also from restframe K studies, e.g. Andreon 2006, De Propris et al. 2007, Muzzin et al. 2008, Mancone et al. 2010).

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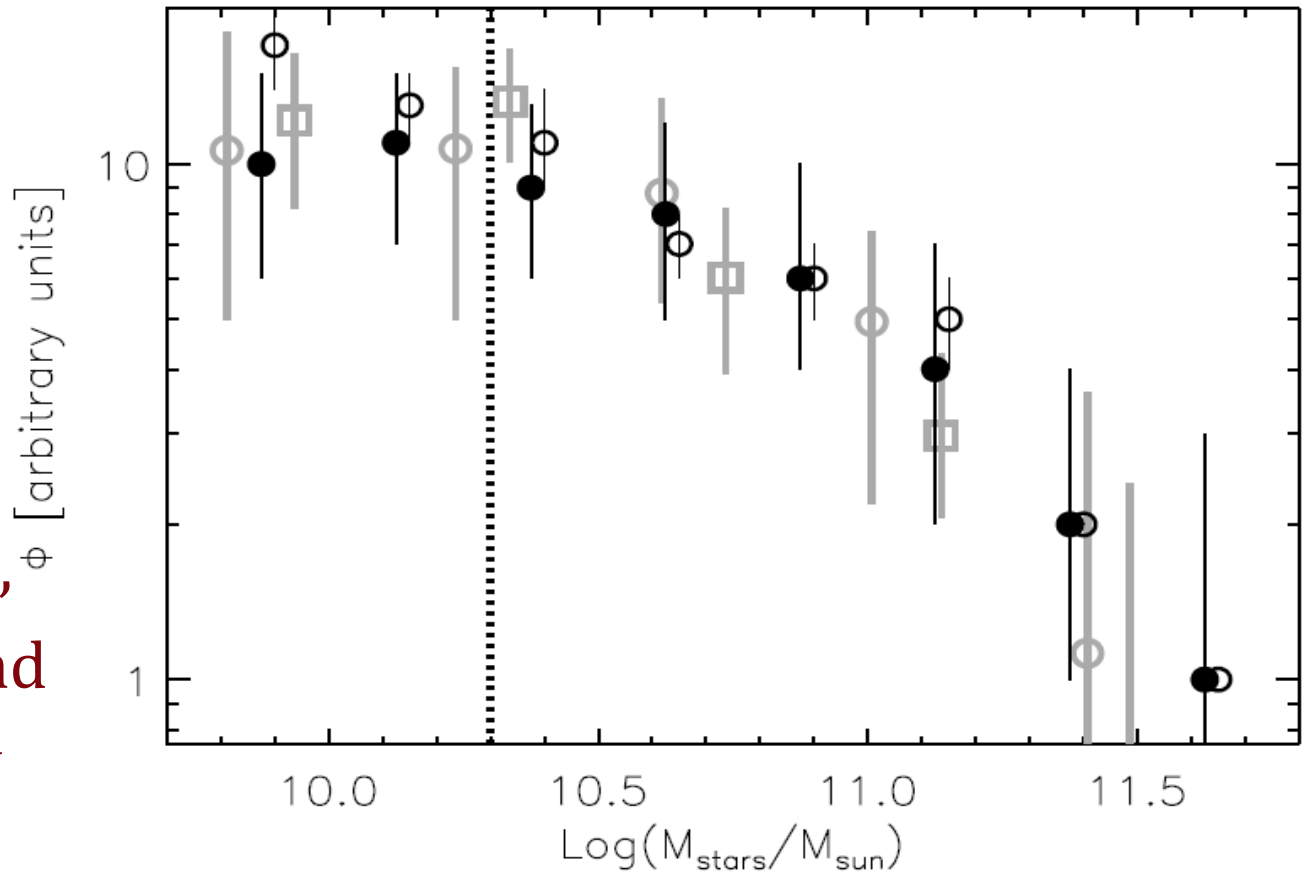
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No significant mass growth is required (at least up to z~1.3, Mancone et al. 2010)

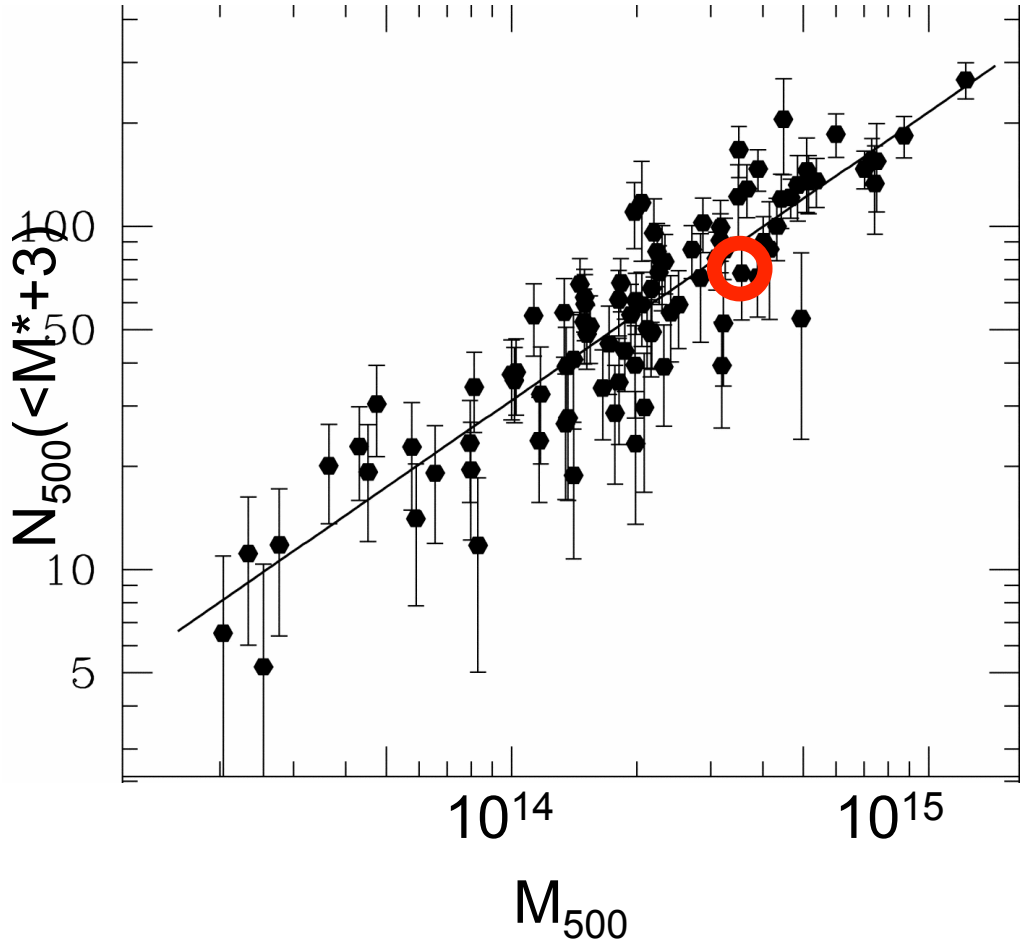
Cluster galaxy stellar mass function

- from K-band LF
- from SED-derived stellar masses of individual cluster members (statistically estimated)

The shape of the stellar mass function is similar to that of z~1 clusters (Kodama & Bower 2003, Strazzullo et al 2006, and to clusters in the nearby Universe)



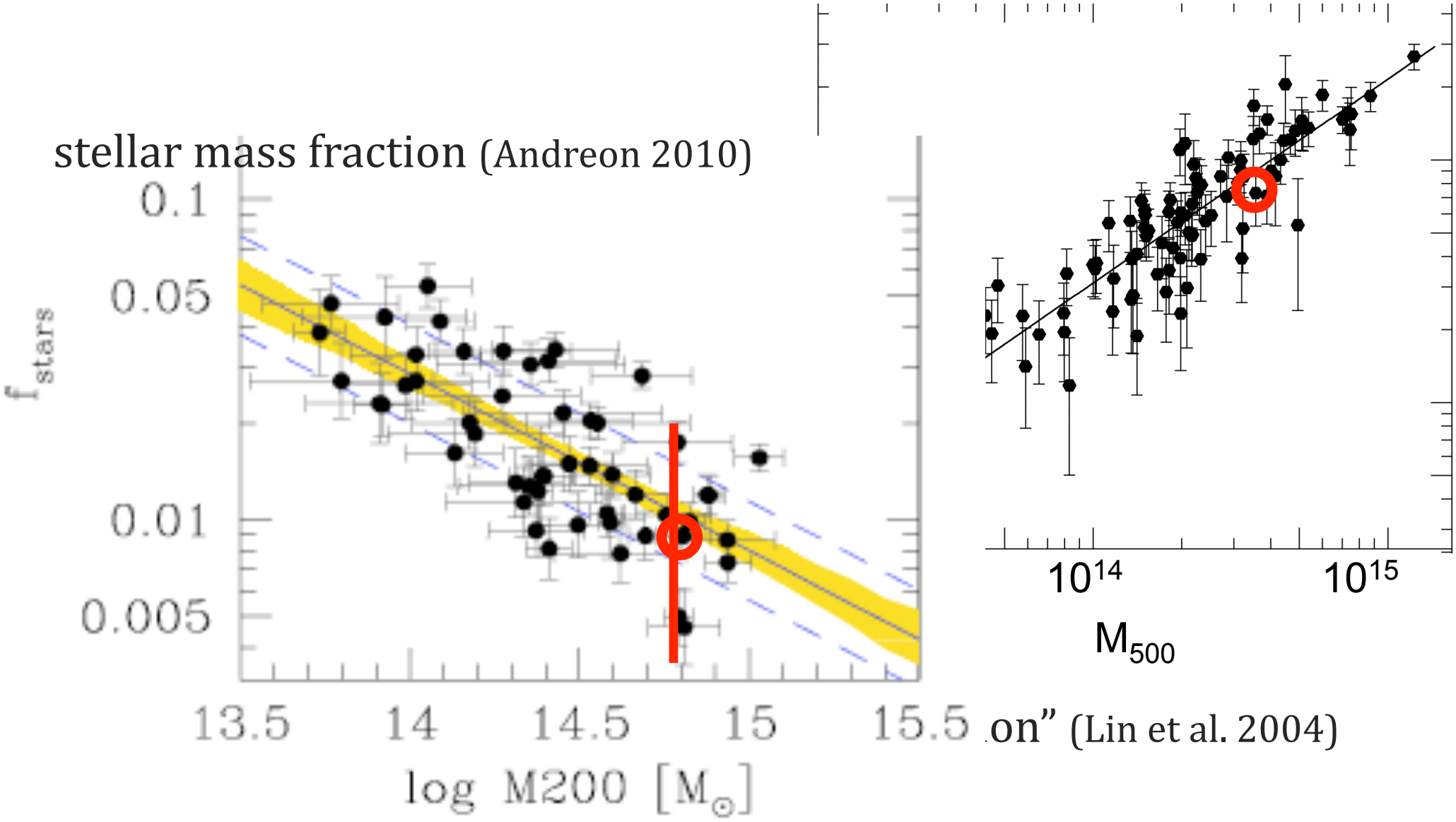
Galaxies (and stars) in the cluster halo



”halo occupation” (Lin et al. 2004)

Galaxies (and stars) in the cluster halo

stellar mass fraction (Andreon 2010)



on" (Lin et al. 2004)

Galaxies (and stars) in the cluster halo

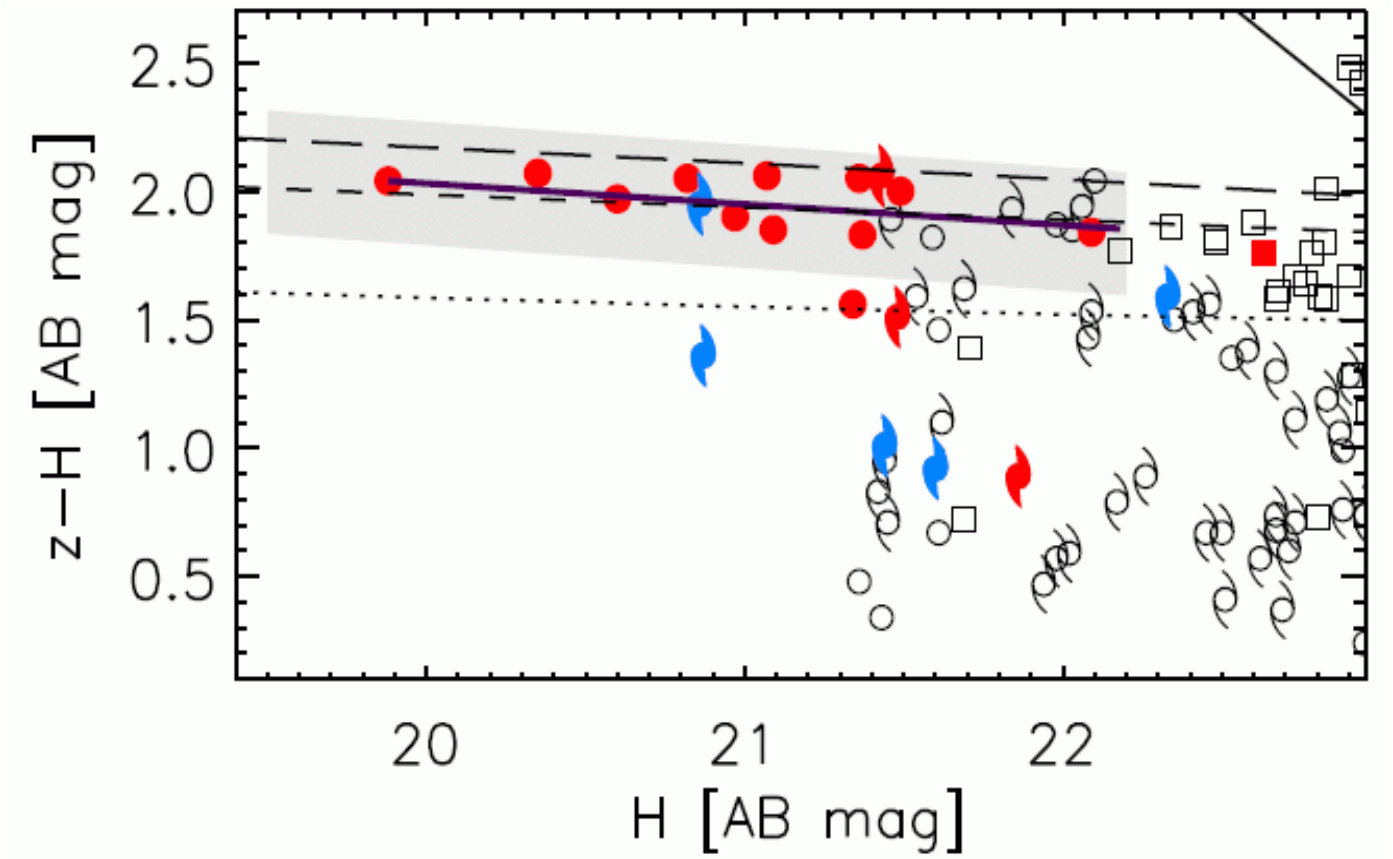
XMMU J2235 looks “similar” to nearby clusters of similar mass.

…BUT:

- at z=0 XMMU J2235 will likely have an $M_{500} \sim 2 \times 10^{15} M_{sun}$
- its (likely) number of M<M*+3 galaxies within r_{500} would then be ~370

- *that is: at z=1.39 we might be observing just ~20% of the final (z=0) cluster galaxy population*
- *and:* N-body simulations (Berrier et al. 2009) claim that 85% of cluster galaxies are accreted between 1 and 9 Gyr ago

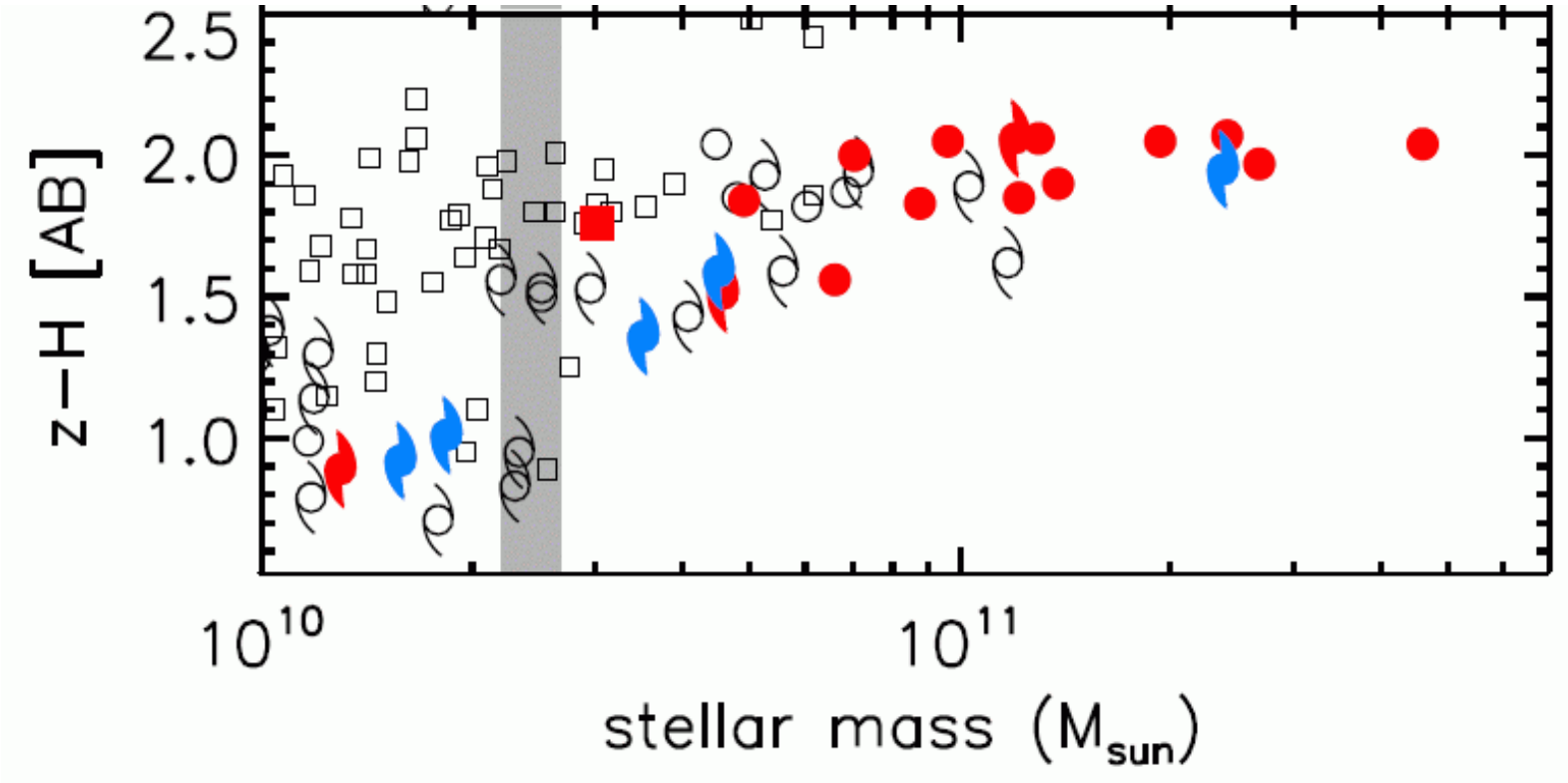
The red sequence at z~1.4



- Spec- and photo-z cleaned
- Models by Kodama & Arimoto (1997)

A tight red sequence is in place with intrinsic scatter ≤0.08. Color and slope of the sequence are in good agreement with passive evolution predictions for a formation redshift >2 (see also Lidman et al. 2008).

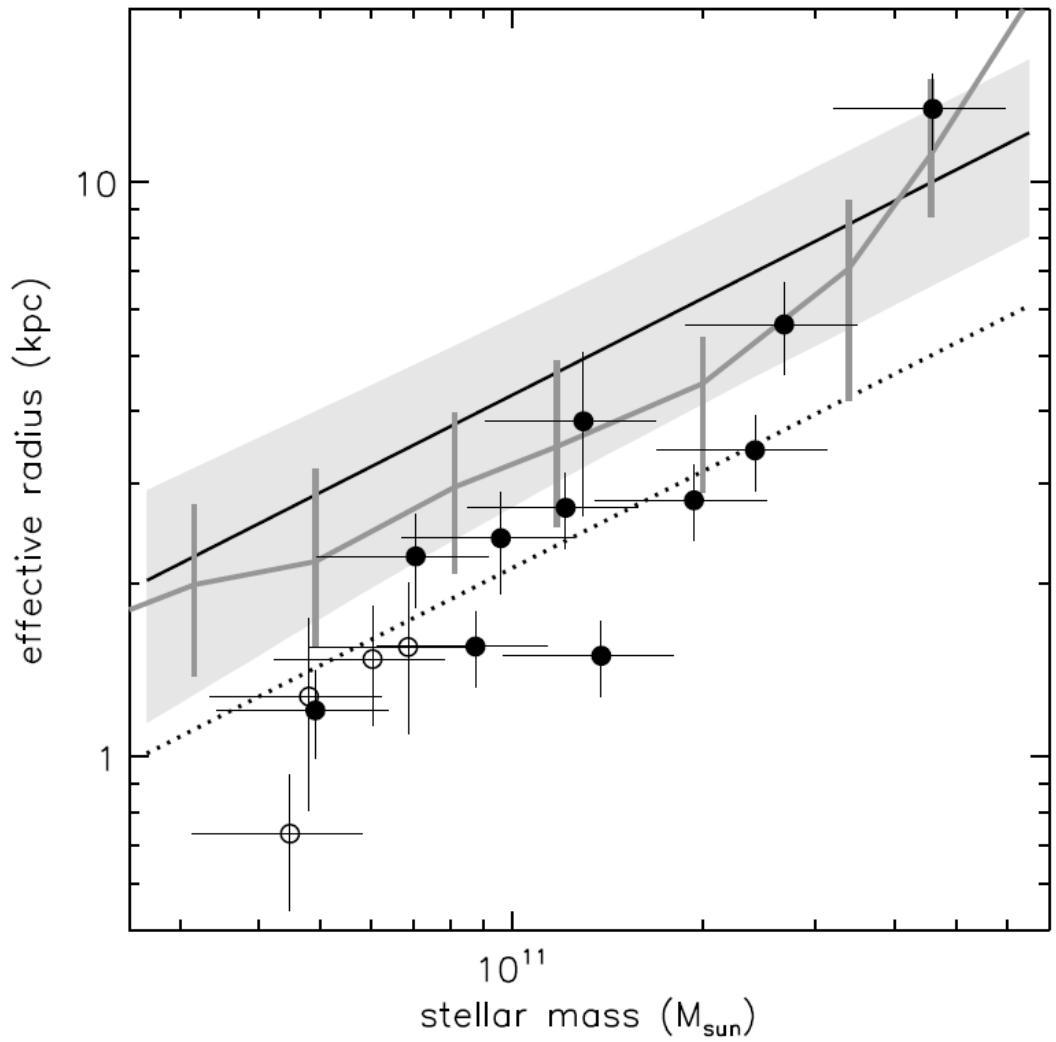
The red sequence at z~1.4



A population of massive (>$10^{11}M_{sun}$) galaxies is already in place.

The high mass population is dominated by red-sequence galaxies, generally of early-type morphology and lacking evidence of star formation. A massive BCG is already assembled (see also Collins et al. 2009, Stott et al. 2010).

Massive red galaxies: stellar masses vs sizes



However, massive red-sequence early-types appear to be smaller than their local counterparts.

Signatures of minor merging/ accretion?

Biases and/or systematics involved?

(Daddi et al. 2005, Trujillo et al. 2006, 2007, Longhetti et al. 2007, Cimatti et al. 2008, van der Wel et al. 2008, Rettura et al. 2010, Mancini et al 2010, Onodera et al. 2010, Valentinuzzi et al. 2010, Saracco et al. 2010)

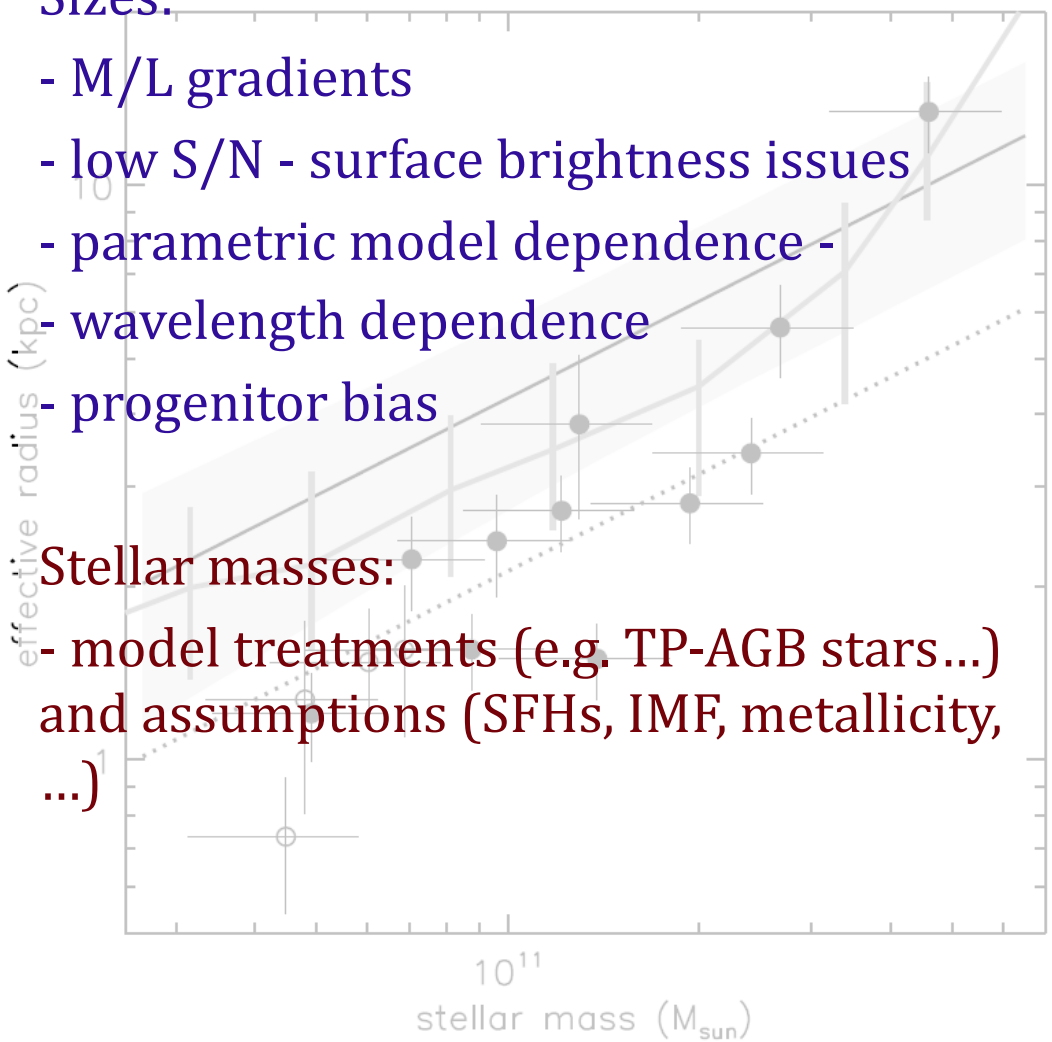
Massive red galaxies: stellar masses vs sizes

Sizes:

- M/L gradients
- low S/N - surface brightness issues
- parametric model dependence -
- wavelength dependence
- progenitor bias

Stellar masses:

- model treatments (e.g. TP-AGB stars…) and assumptions (SFHs, IMF, metallicity, …)

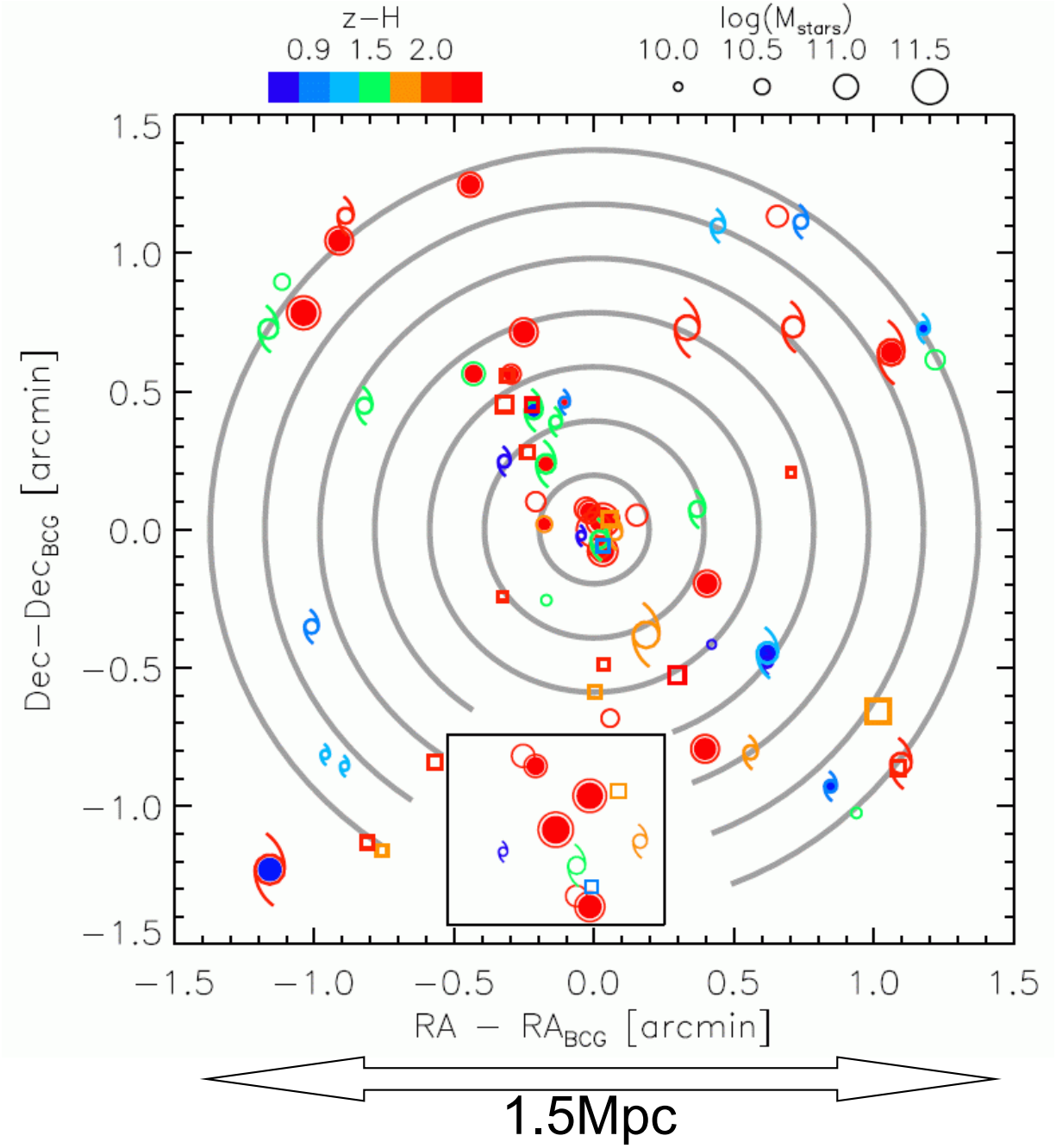


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On-going SF confined out of the cluster central region (~250kpc, see also Rosati et al. 2009, Bauer et al. 2010)

- cluster core dominated by early-type (morphological and spectro-photometric) massive galaxies (SFR < $0.15M_{sun}$/yr)

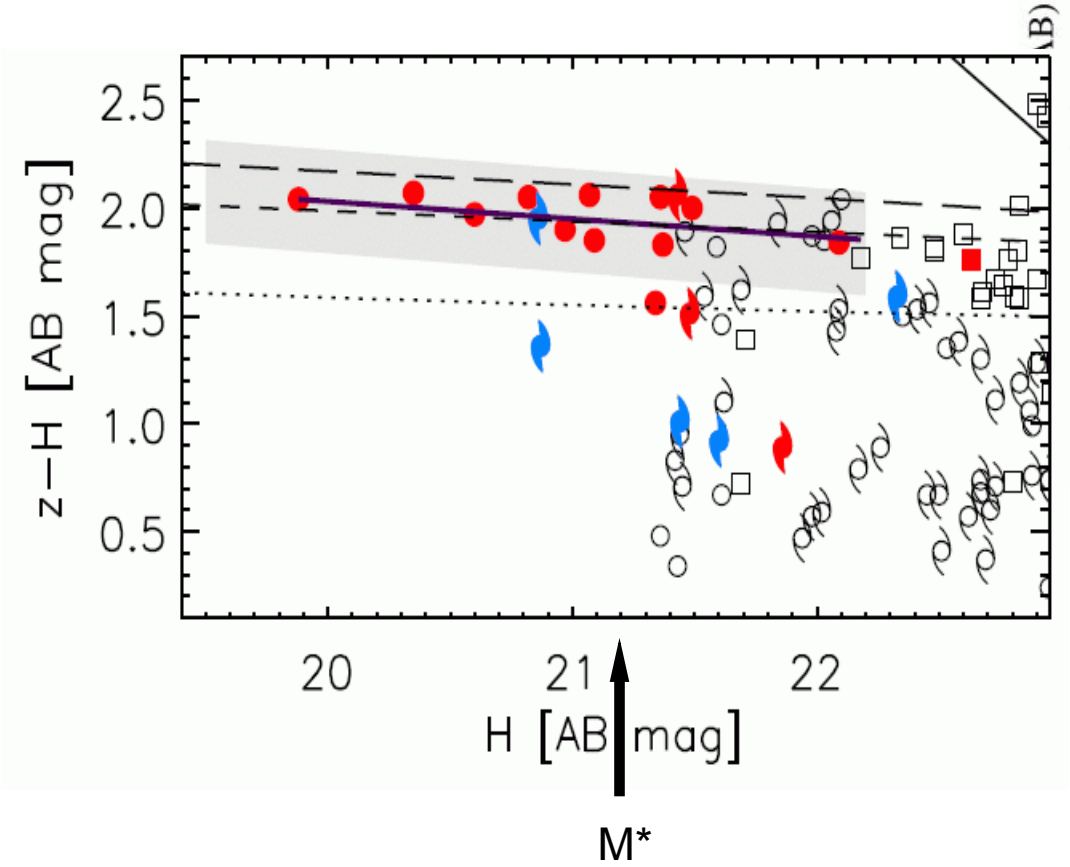
-only one red-sequence galaxy (r~860kpc) has [OII] EW >5Å

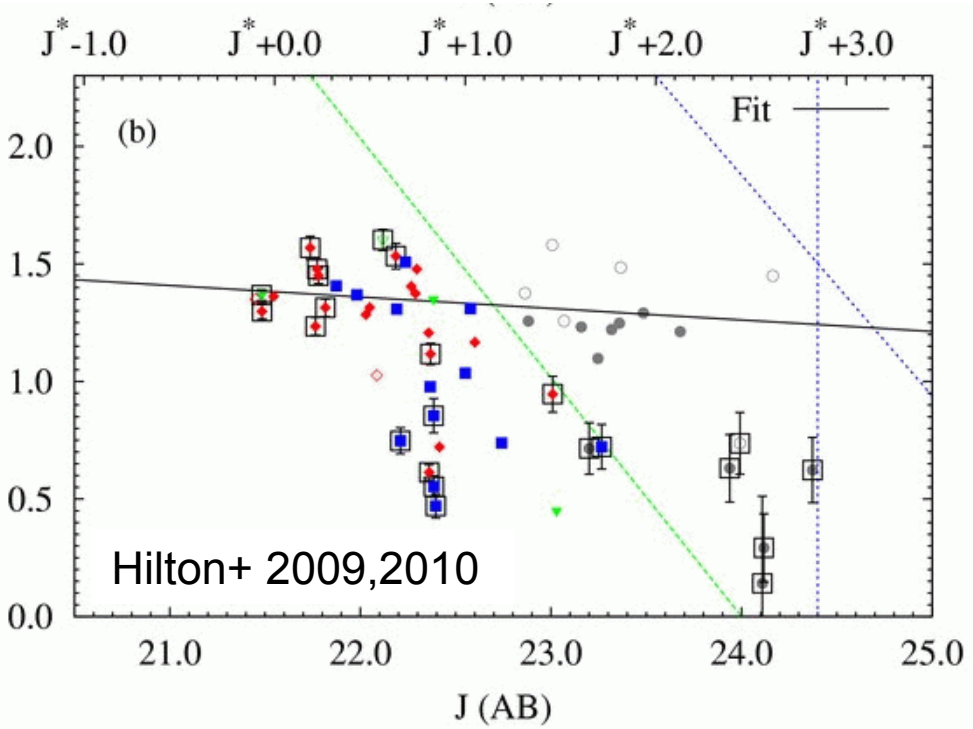
- SFR of SF spec members up to $100M_{sun}$/yr (median ~$25M_{sun}$/yr)

SFH (formation epoch or SF time scale) of *early-types* depends on cluster-centric distance (Rosati et al. 2009)

BUT: the reversal of fortune is <<1Gyr away

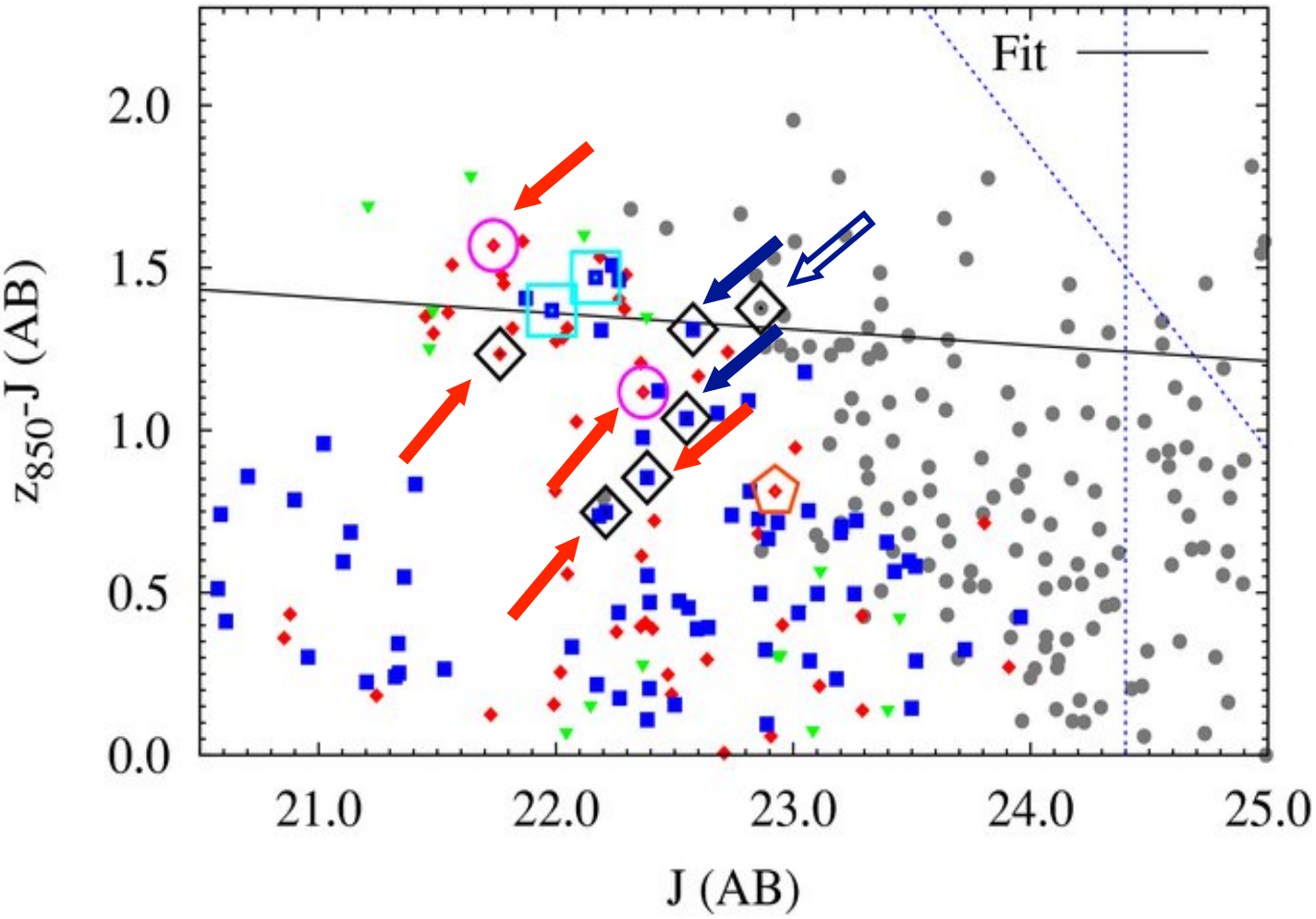
XMMXCS J2215-1738 @ z=1.46
X-ray selected, $L_{X<2Mpc}$~3x10^{44}erg/s
Δt<200Myr





BUT: the reversal of fortune is <<1Gyr away

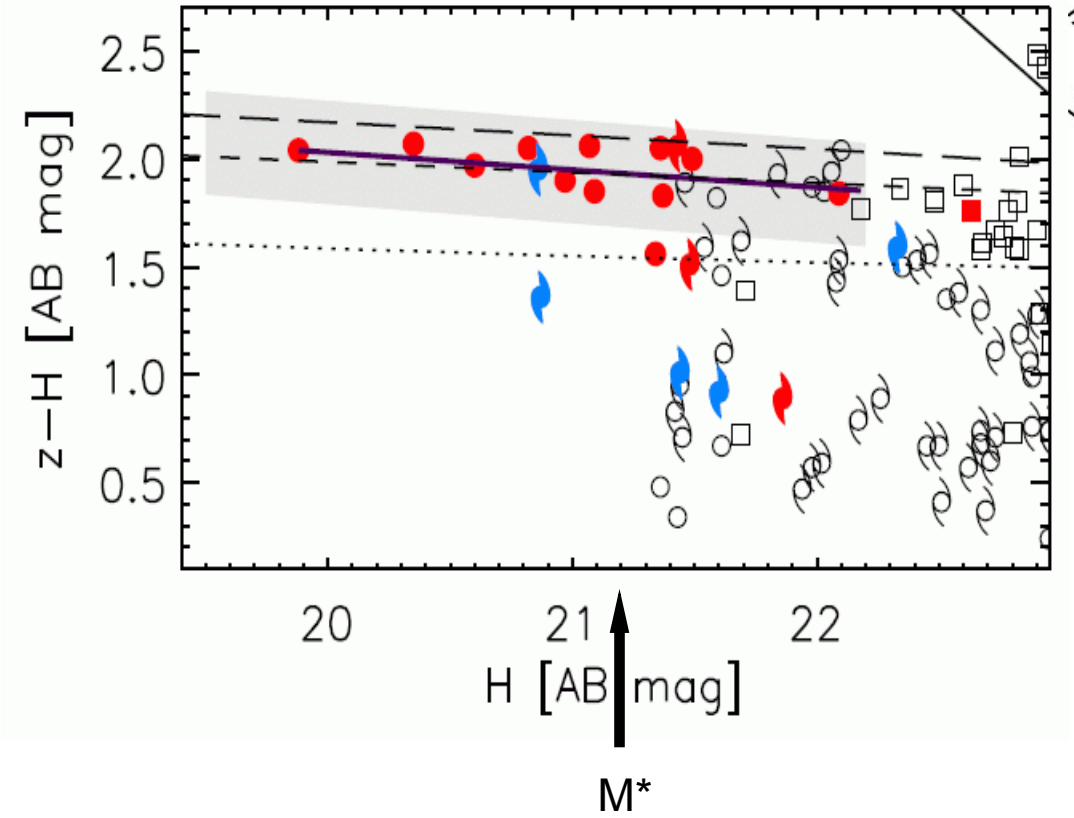
XMMXCS J2215 @z=1.46: AGN and SF activity in cluster center (Hilton+ 2010)

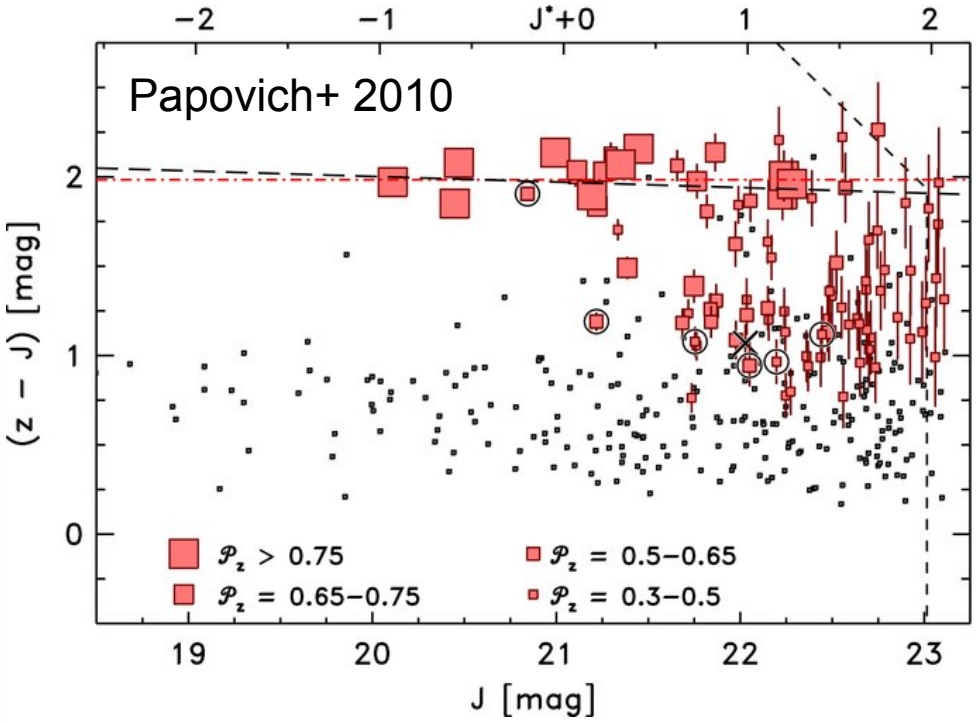


- 5 24μm spec members
  (1 of 5 is an AGN)
  (2-3 at r<250kpc,
  all at r<500kpc)
- 3 24μm phot members
  (1 at r<250kpc)
- SFRs ~ 100 M_{sun}/yr

BUT: the reversal of fortune is <<1Gyr away

CIG J0218-0510 @ z=1.62
IR selected, $M_{(r<1Mpc)}$~1-4x$10^{14}M_{sun}$
Δt<600Myr





BUT: the reversal of fortune is <<1Gyr away

CIG J0218 @z=1.62: star formation (and/or AGN) activity in the cluster center (Tran+ 2010)

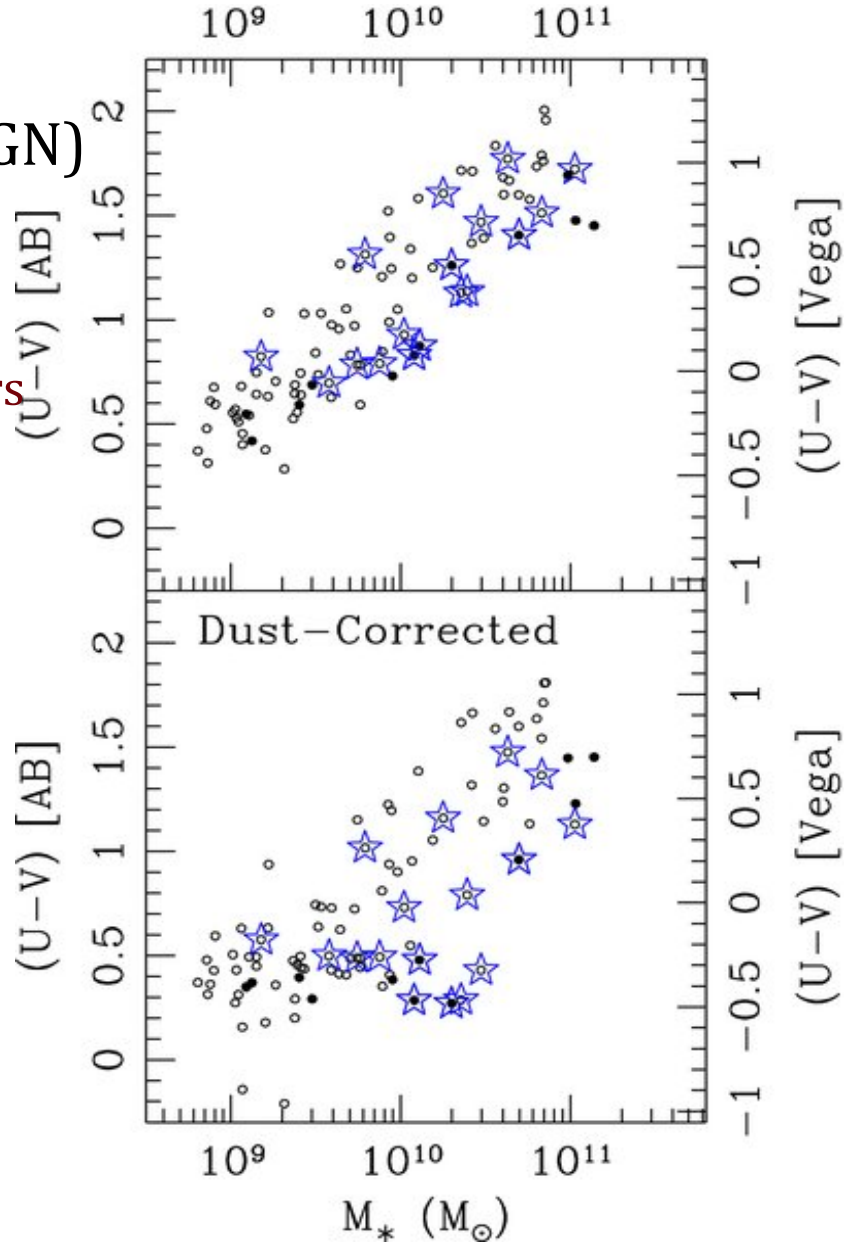
- 4 (out of 12) 24μm (>40μJy ~ 3 x 10^{11} L_{sun}) spec mbrs
- 13 (out of 80) 24μm photometric members
- 3 (1 spec, 2 phot) are ULIRGs, the rest are LIRGs

(only 1 in 2000+ at z<1 is a ULIRG, but …)

(the spec ULIRG (and one more 24μm source) has AGN mid-IR colors)

- In the cluster center (r<500kpc) the SFR density based on 24μm sources alone is ~1700 $M_{sun}yr^{-1}Mpc^{-2}$

(while star formation quenched at r<500kpc at z<1…)



And thus… outlook

- Cluster outskirts: exploration still ongoing
- Reddened SF galaxies contaminating the red sequence? (no MIPS24 available, but Herschel observations are planned)
- Blue galaxies: observing biases still hamper definite conclusions on SF (and whole) galaxy population
- (Cold) gas reservoirs: probing gas associated with cluster galaxies will be crucial for a better understanding of ongoing/potential star formation vs definitive quenching, spectral and morphological evolution, size evolution, environmental effects.