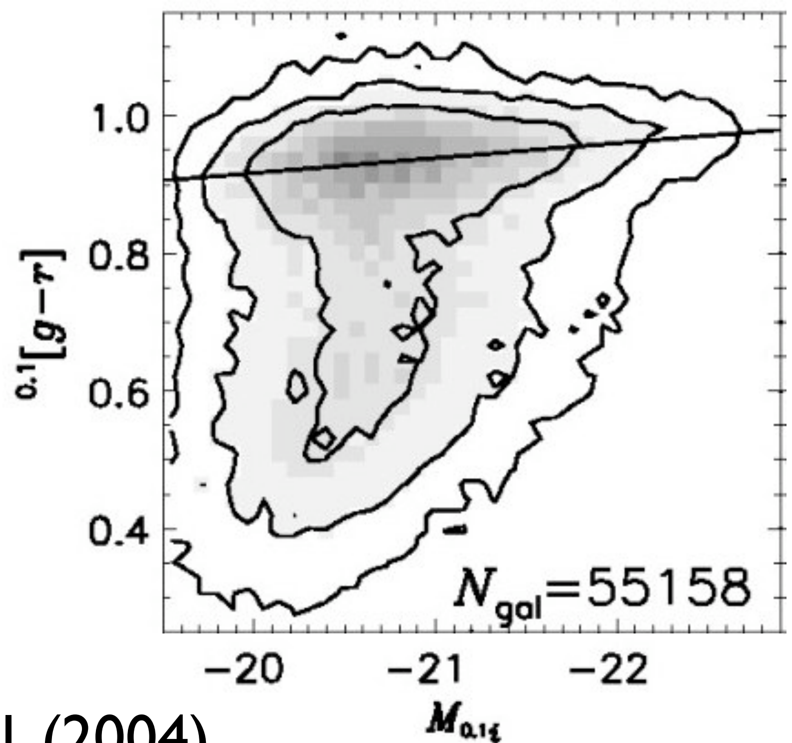
Malaysia 09 - Galaxy evolution & environment
Kuala Lumpur, 30 March - 3 April 2009

Tracing dusty star formation through redshift and environment with Spitzer/MIPS

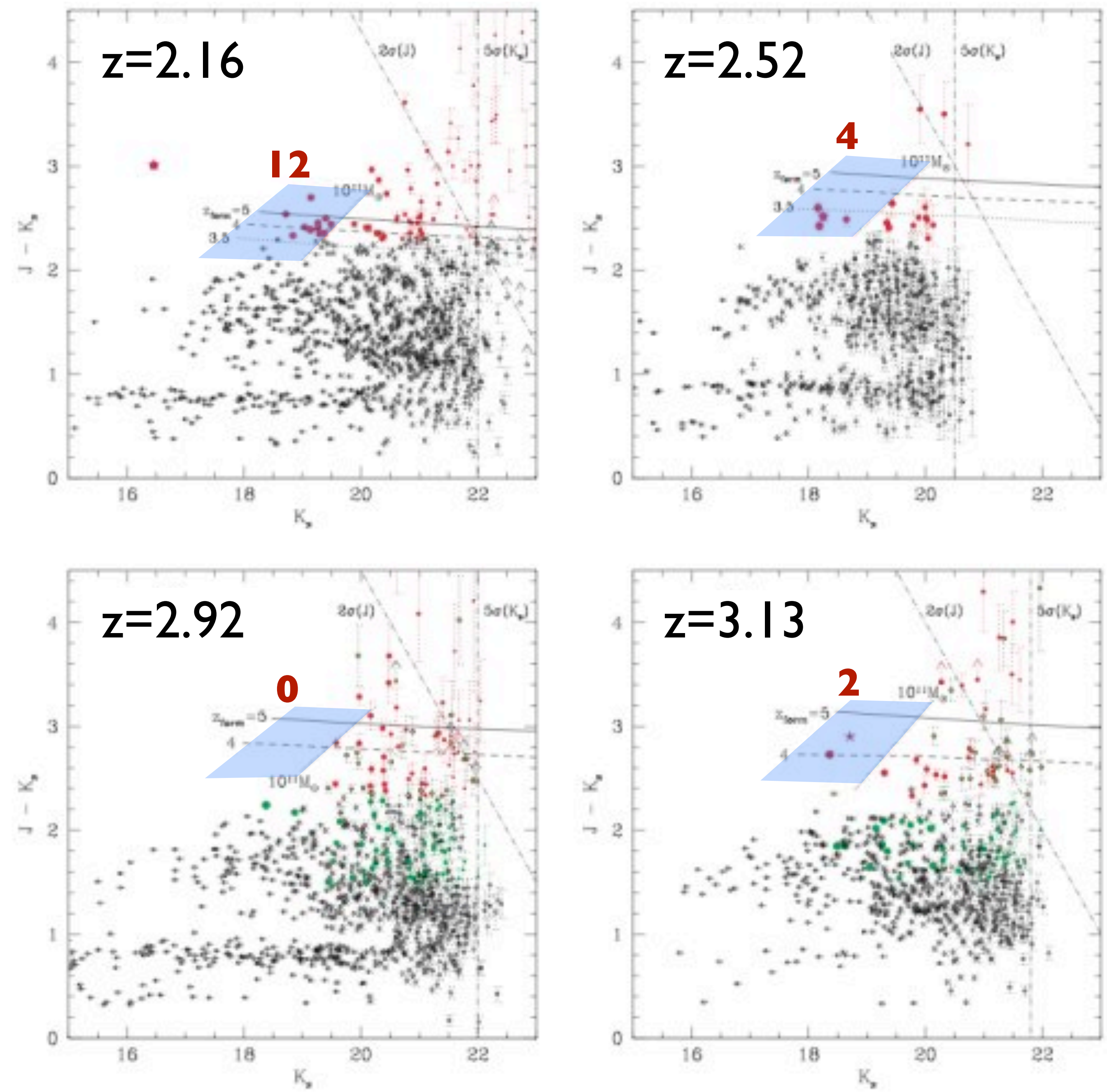
Amélie Saintonge
University of Zürich

in collaboration with Kim-Vy Tran

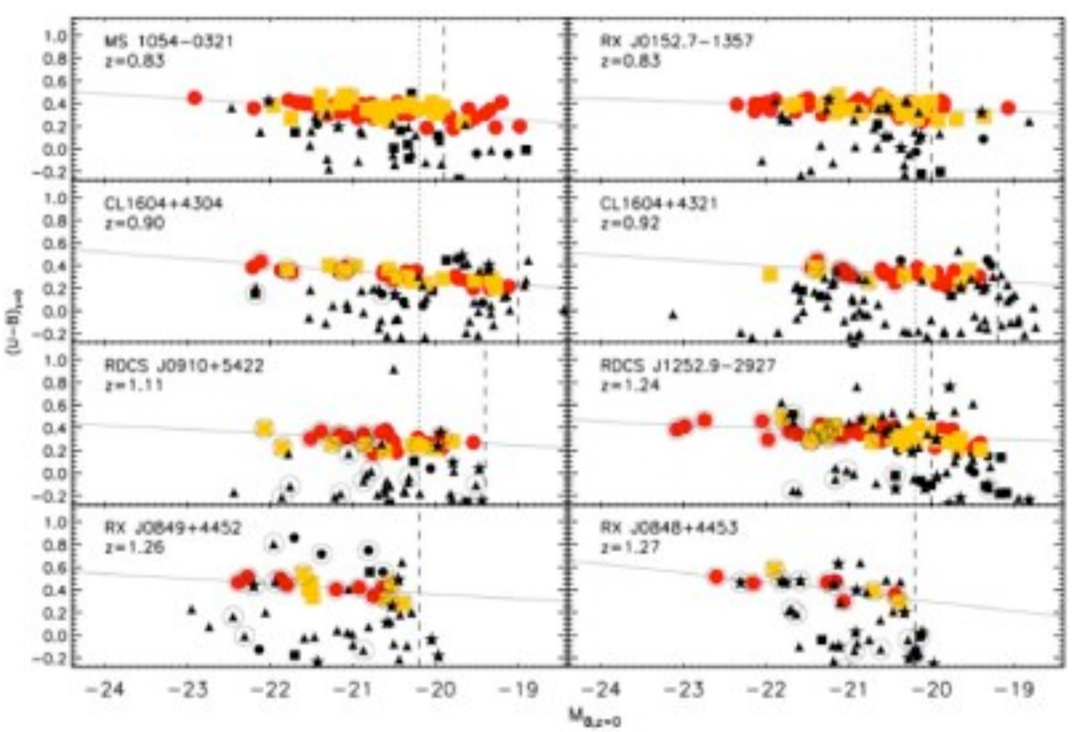
Forming the red sequence:
when does it happen?



Hogg et al. (2004)



Kodama et al. (2007)

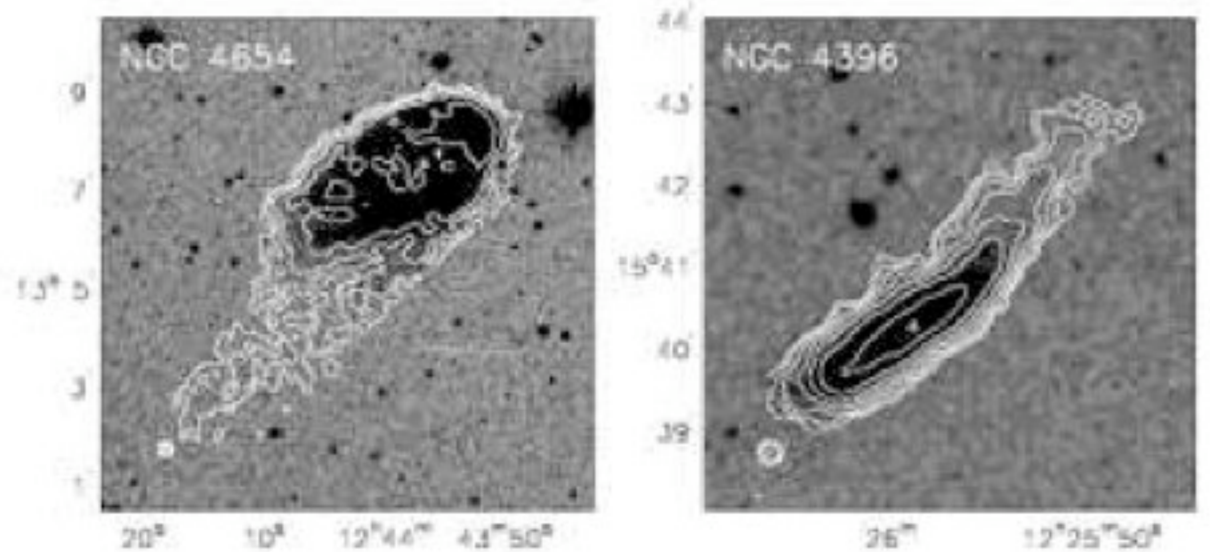


Mei et al. (2008)

Forming the red sequence:
where (and how) does it happen?

“cluster” processes:

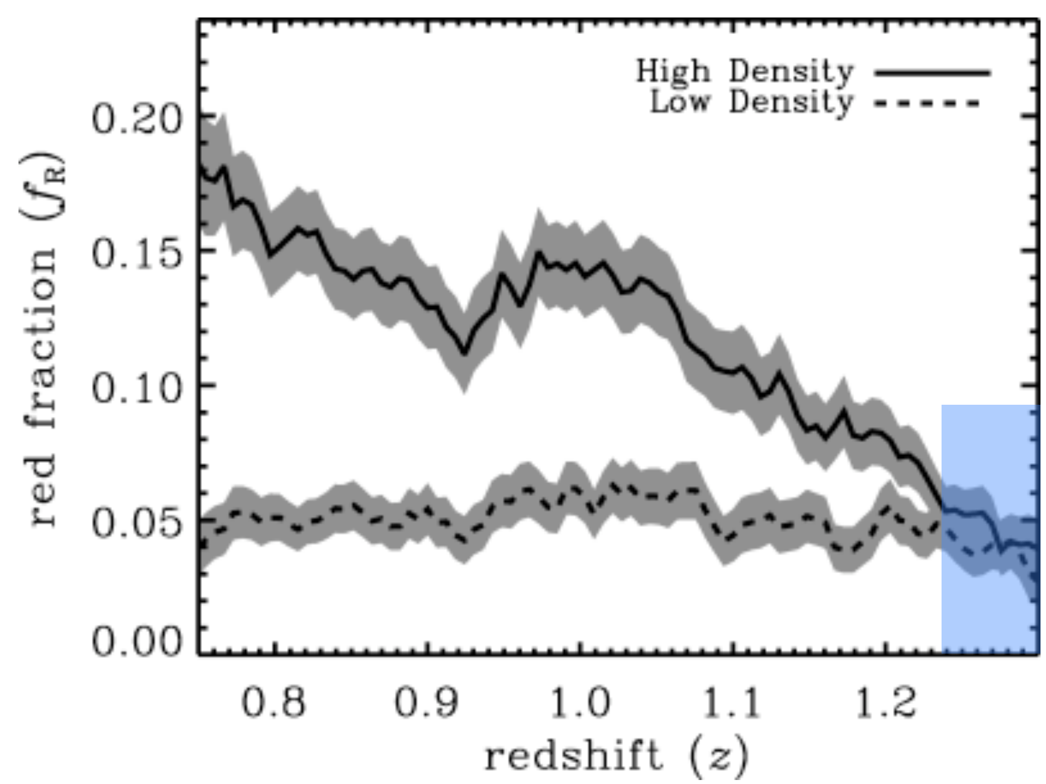
- ram-pressure stripping
- galaxy harassment
- tidal interactions



Chung et al. (2007)

“group” processes:

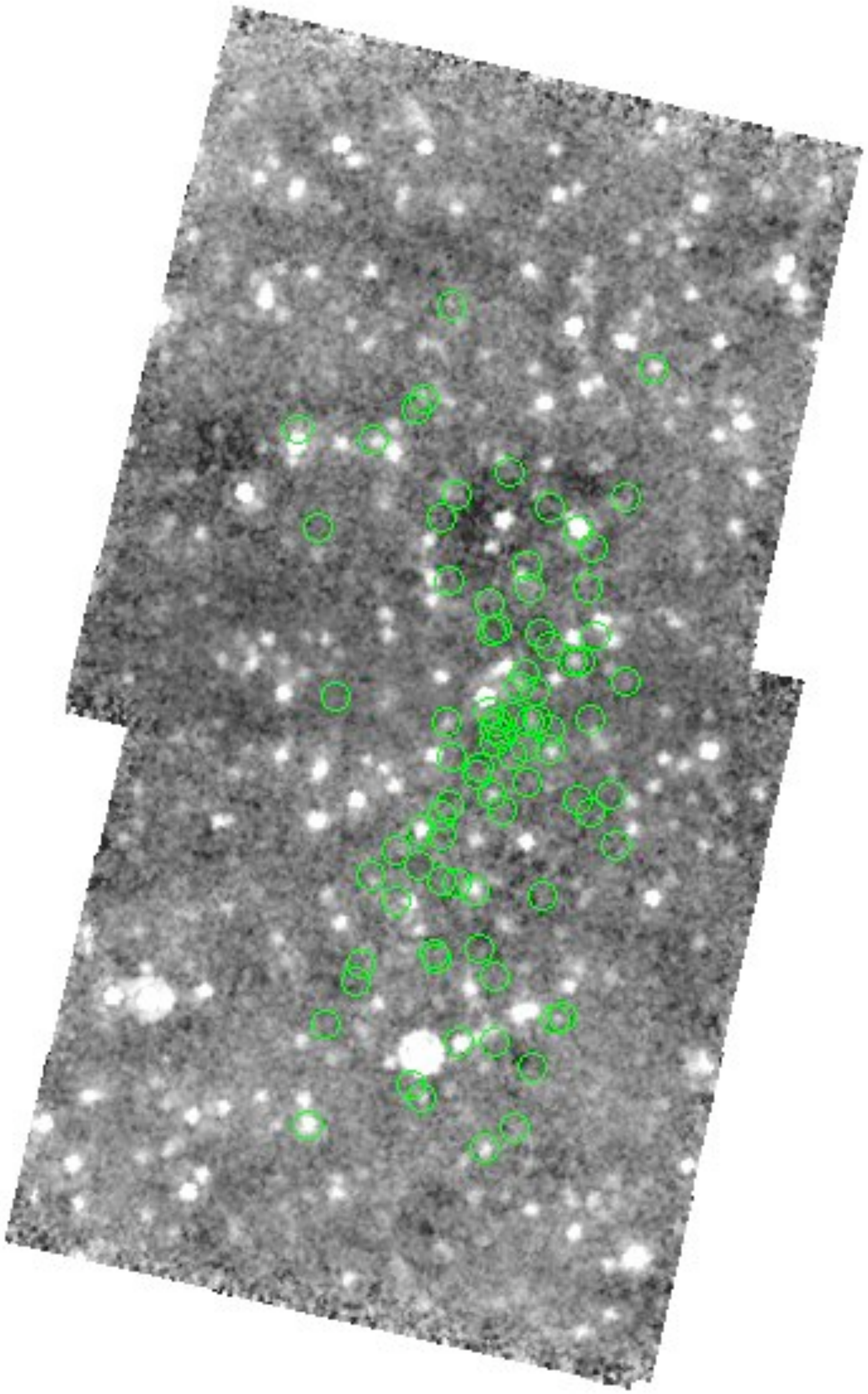
- merging
- AGN feedback
- galaxy-galaxy interactions



Cooper et al. (2007)

SMIRCS : *Spitzer Mid-IR Cluster Survey*

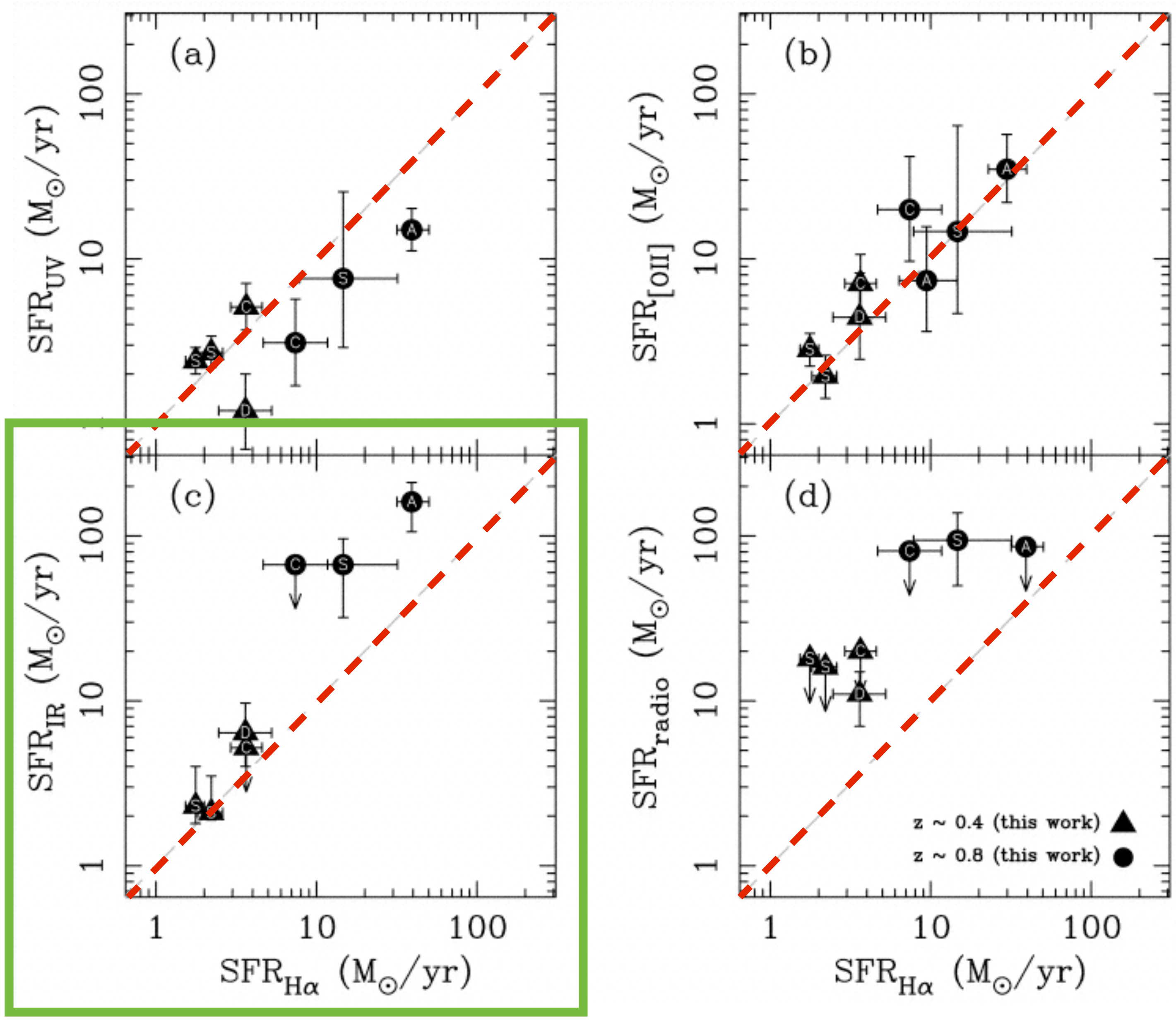
Cluster	z
Coma	0.023
Abell1689	0.18
MS1358	0.33
CL0024	0.40
MS0451	0.54
MS2053	0.59
MS1054	0.83
RXJ0152	0.83



MS2053 (z=0.58)

The need for mid-IR studies

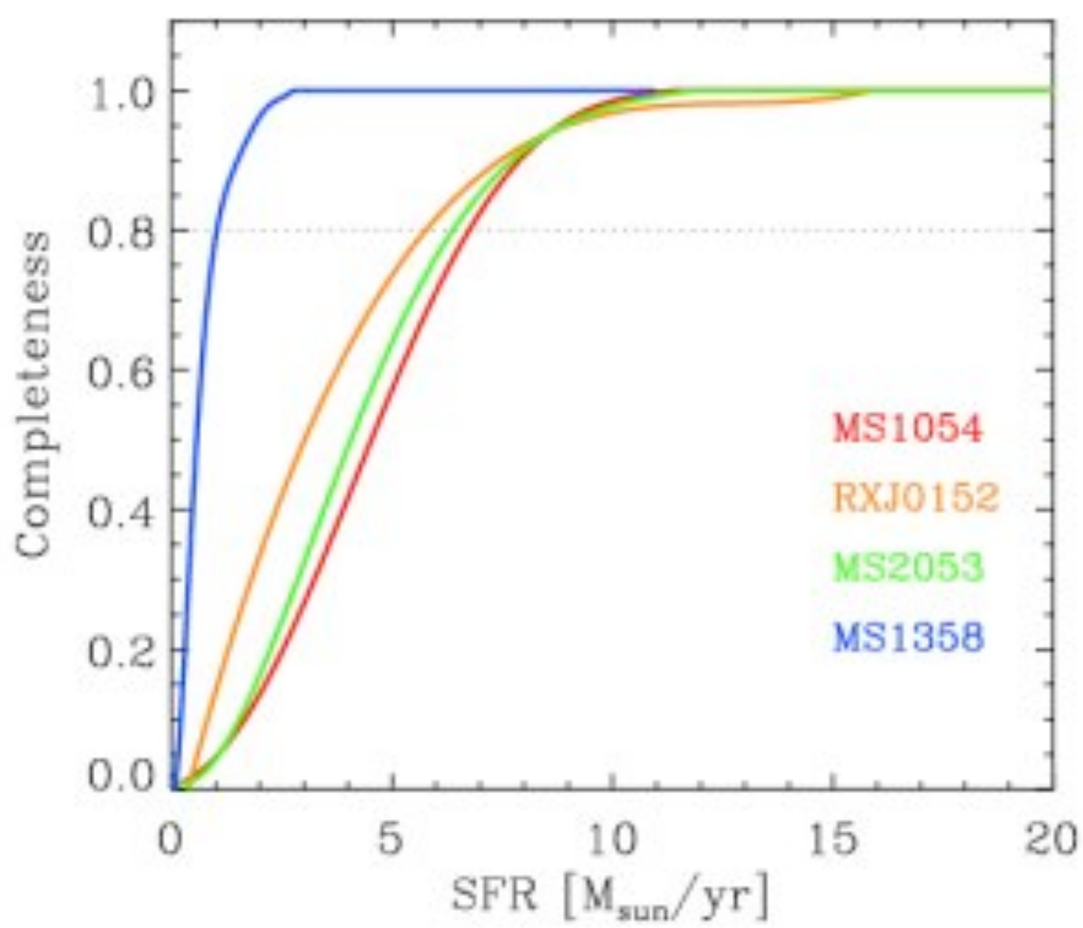
Dust introduces large uncertainties in the conversion between UV/ optical colors and total star formation rates
(Bell 2002)

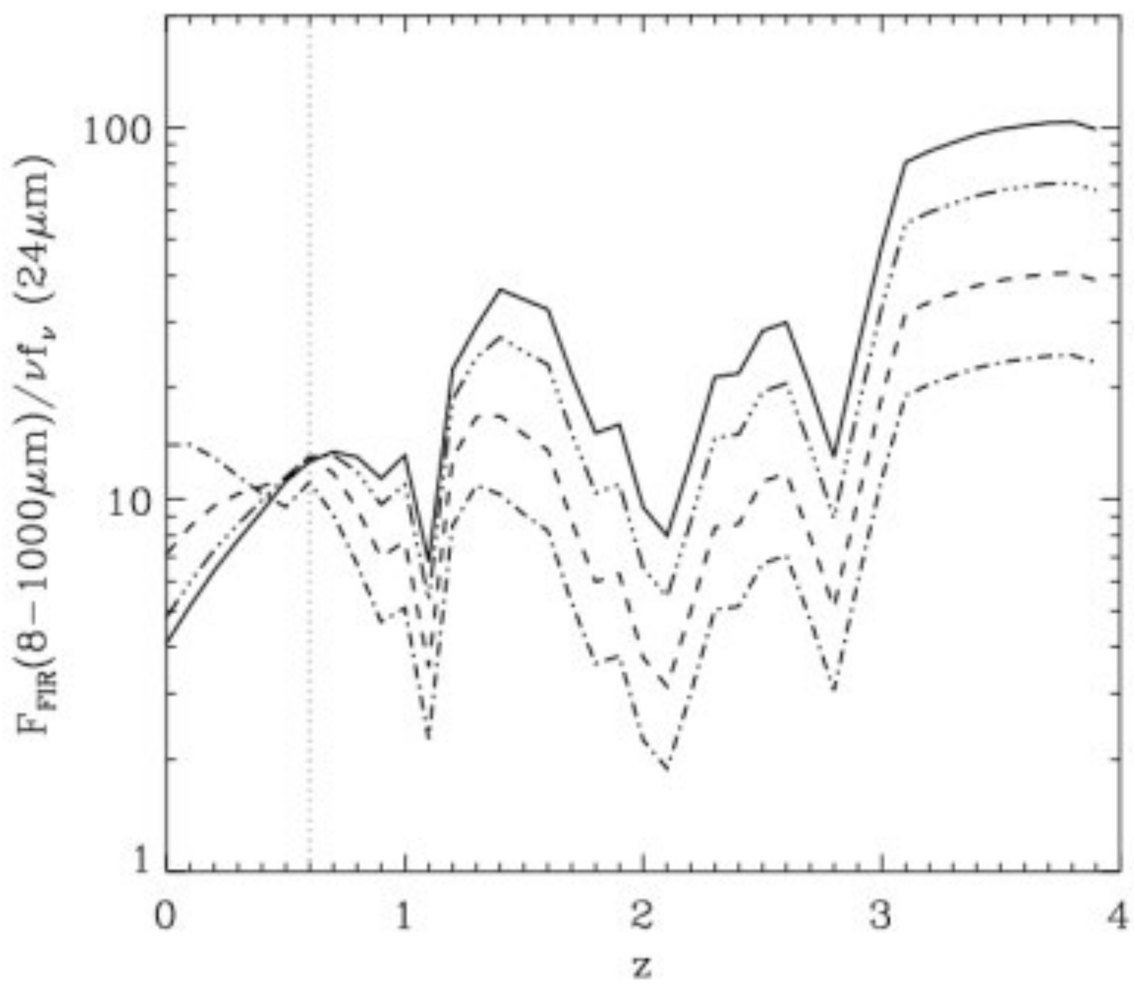


Cardiel et al. (2003)

Star formation rates

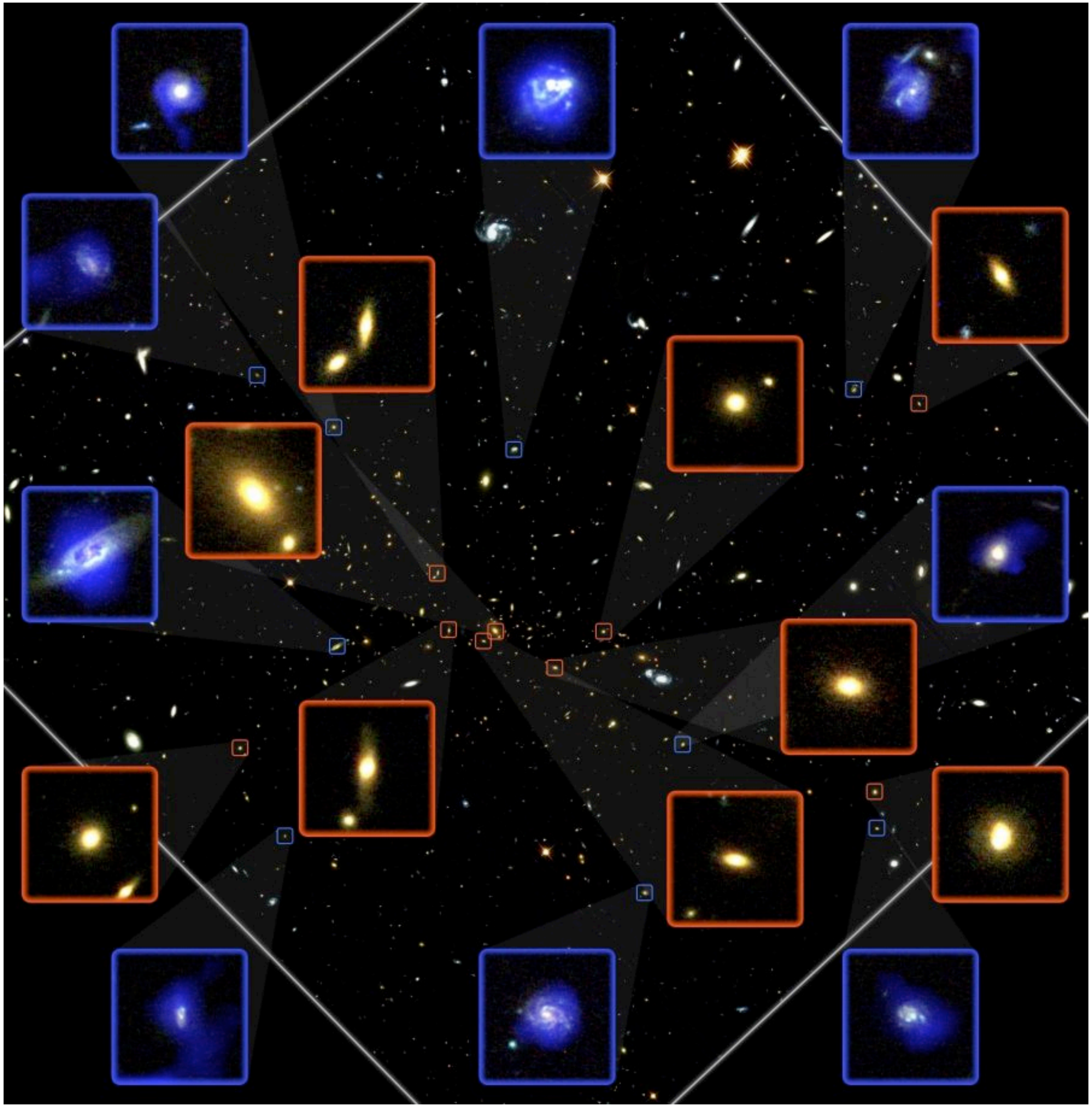
Total IR luminosity inferred from the 24μm measurements with the Dale et al. SEDs





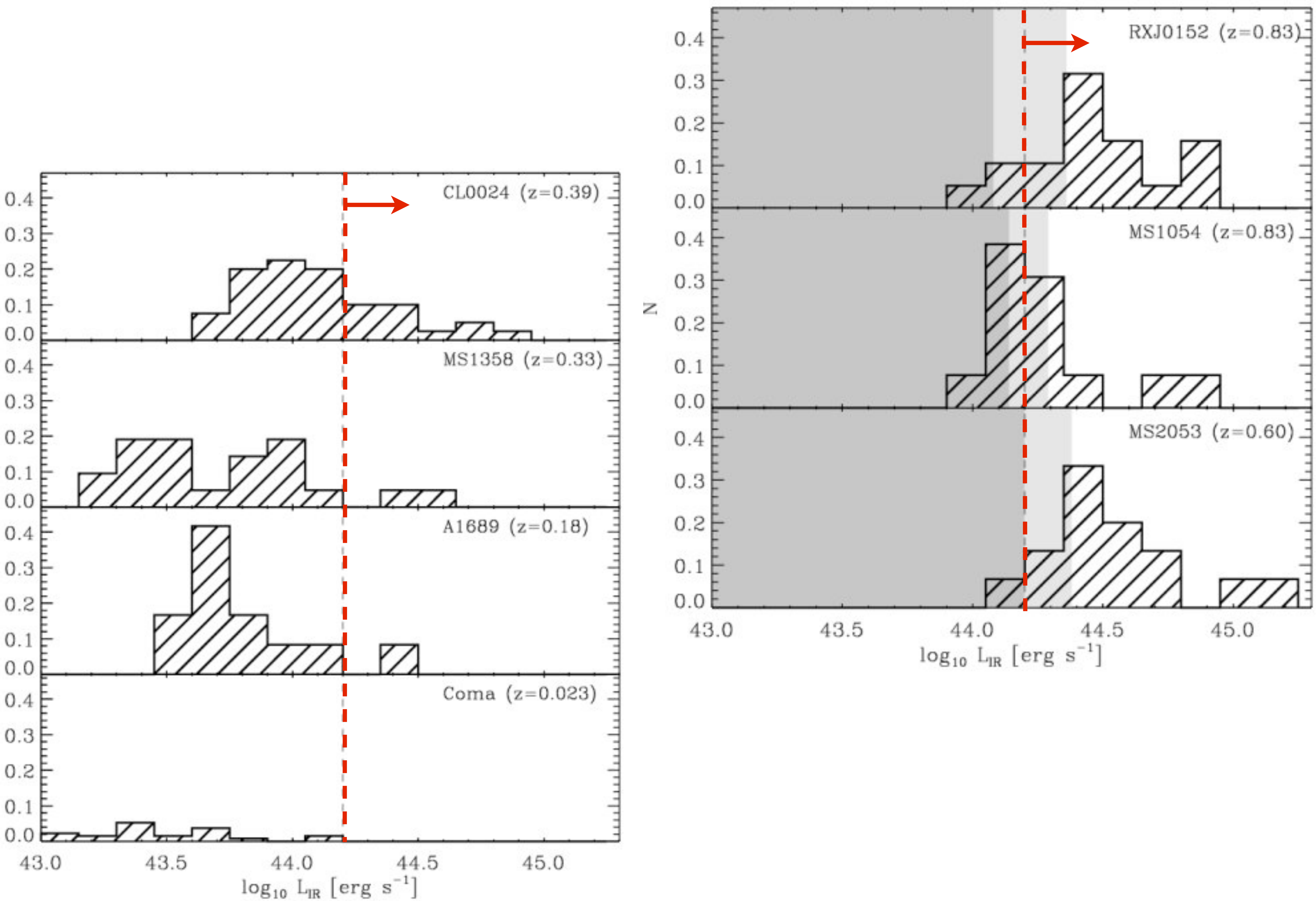
... under the assumption that the 24μm emission comes from SF and not AGN

MIPS-detected galaxies



MS1054
z=0.83

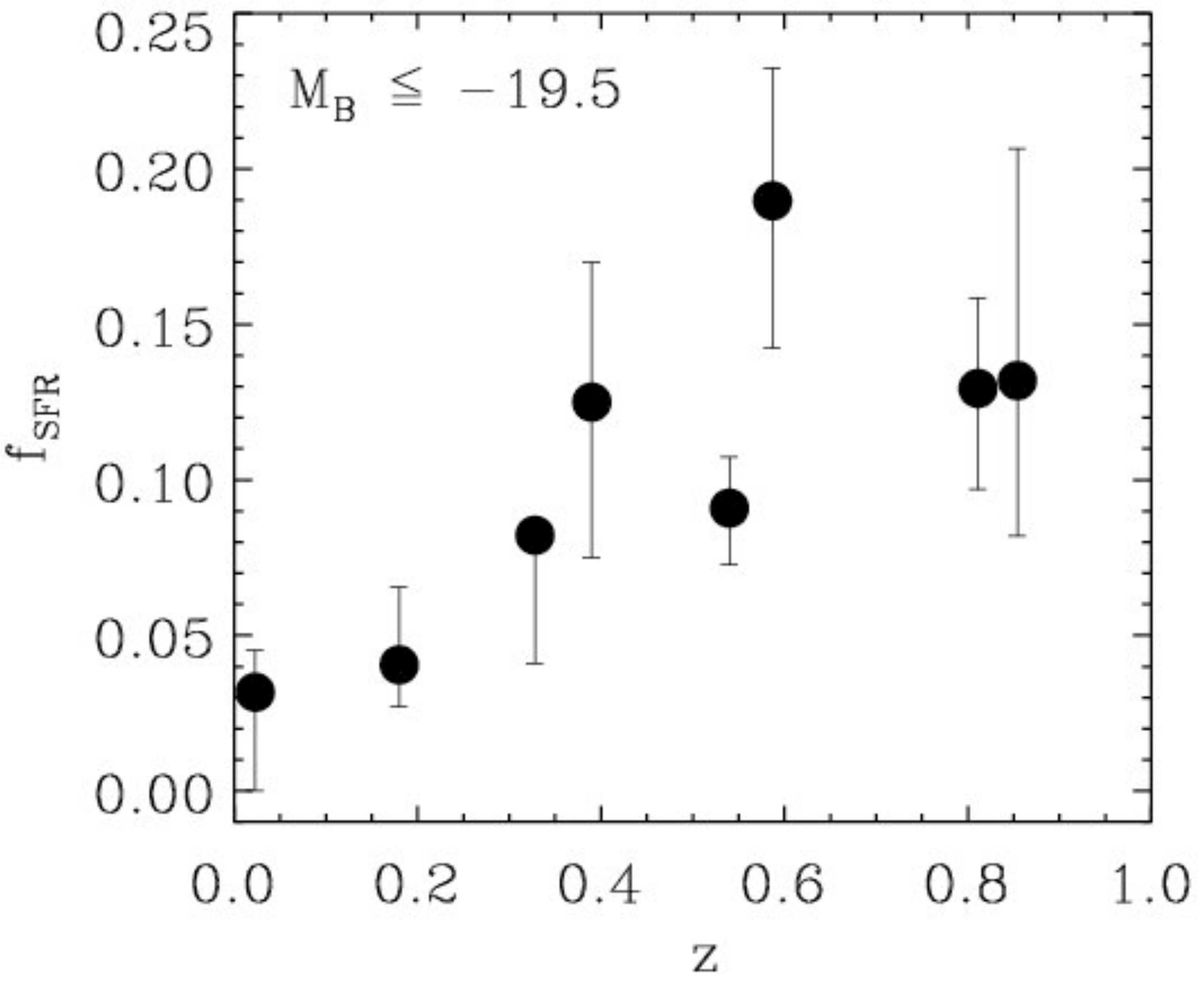
IR-luminosities of cluster members



Evolution of dusty star formation

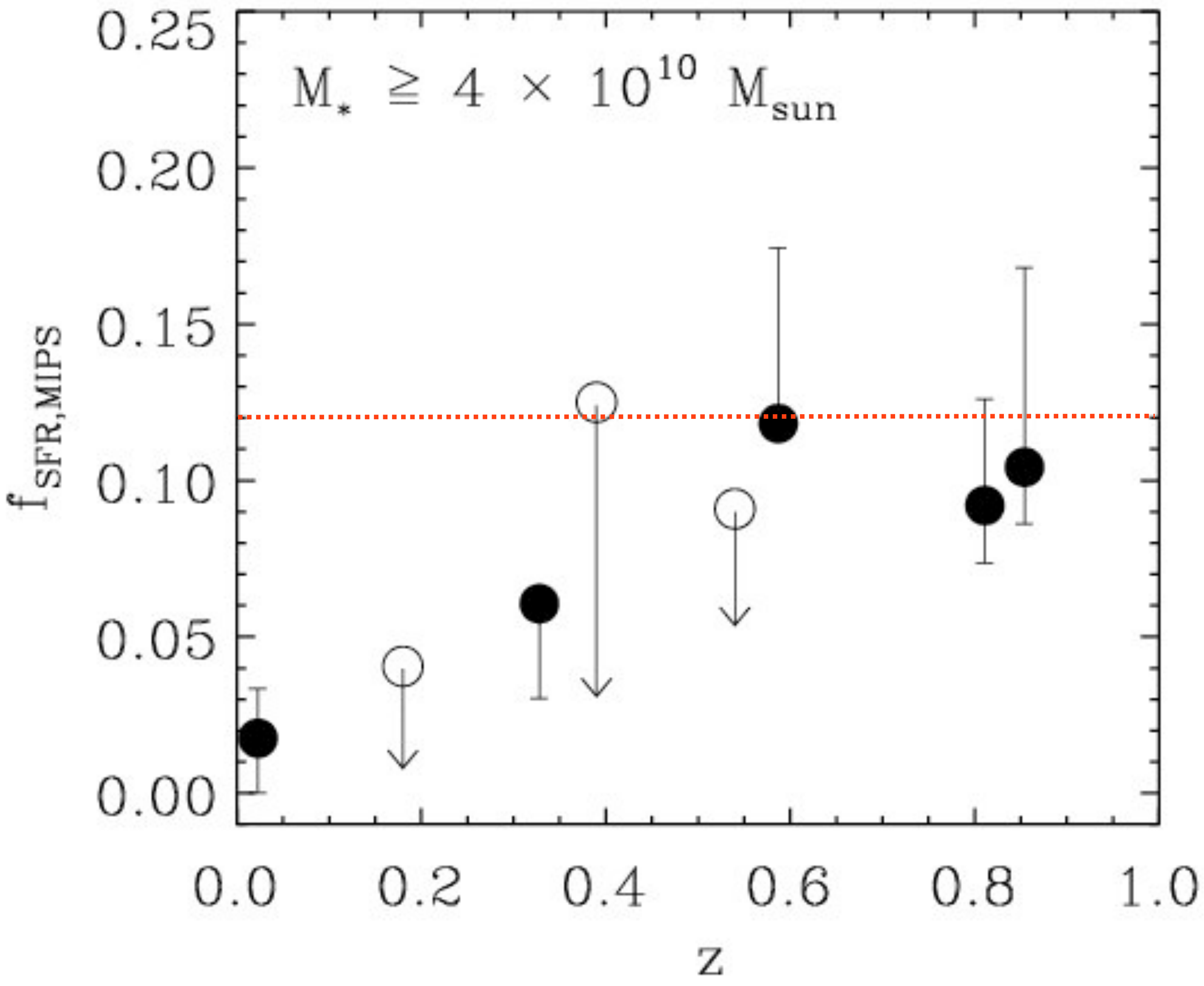
- $M_B < -19.5$
- within 1Mpc of the cluster center
- SFR > 5 $M_\odot$/yr

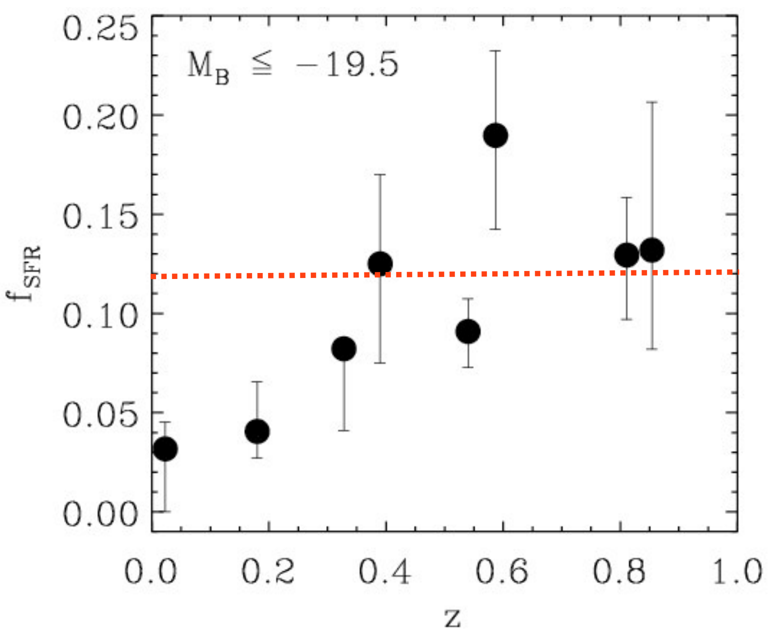
+ completeness correction if needed



Saintonge, Tran & Holden (2008)

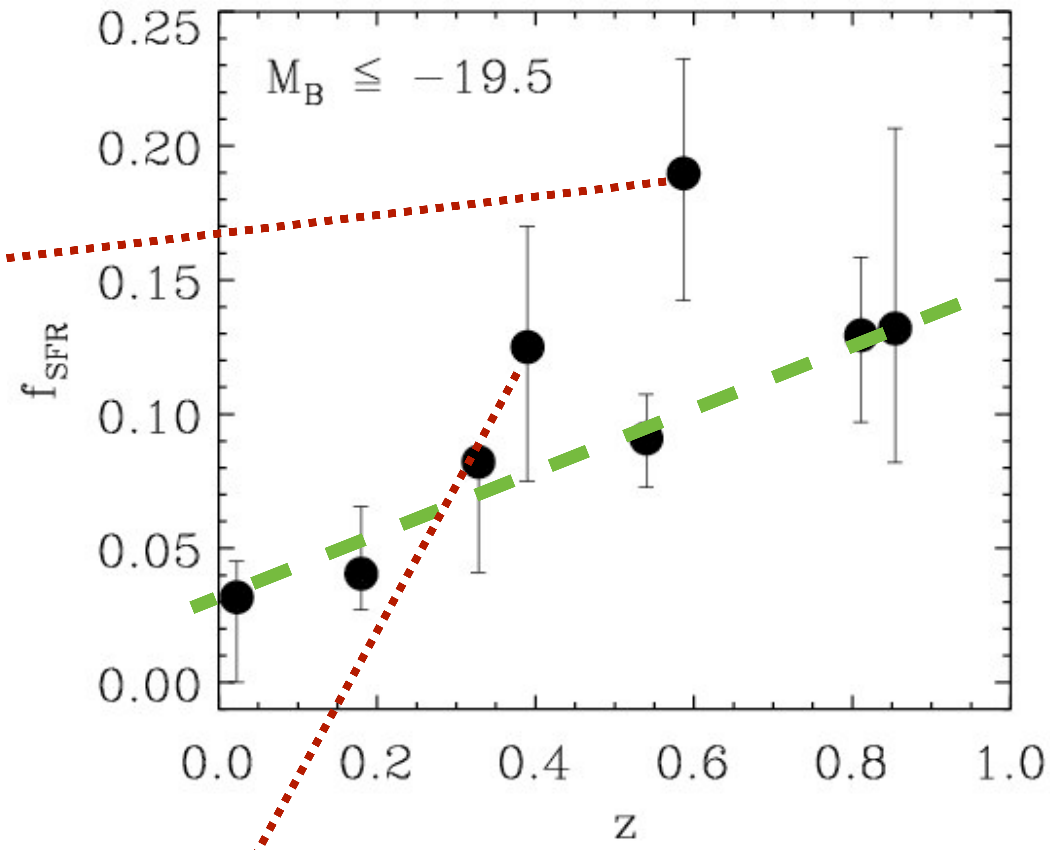
Evolution in a mass-selected sample

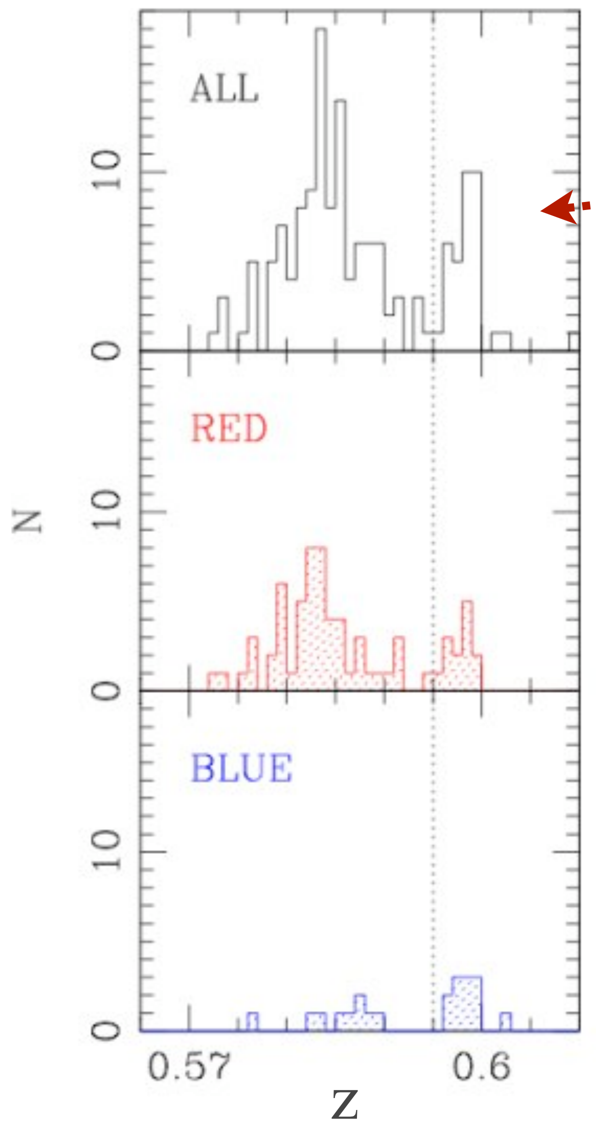




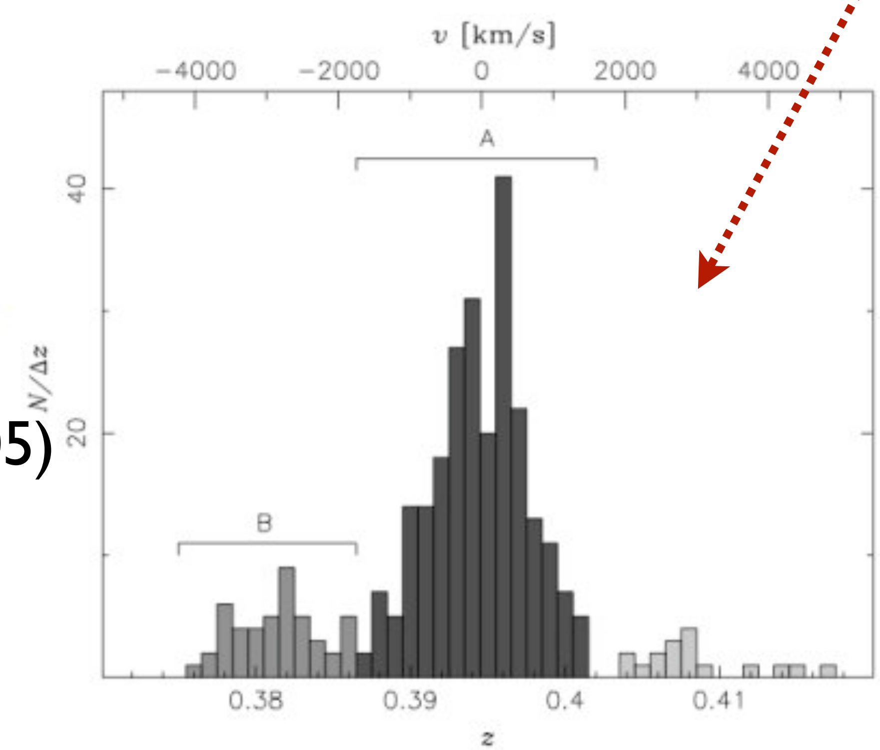
Saintonge, Tran & Holden (2008)

The origins of the effect?



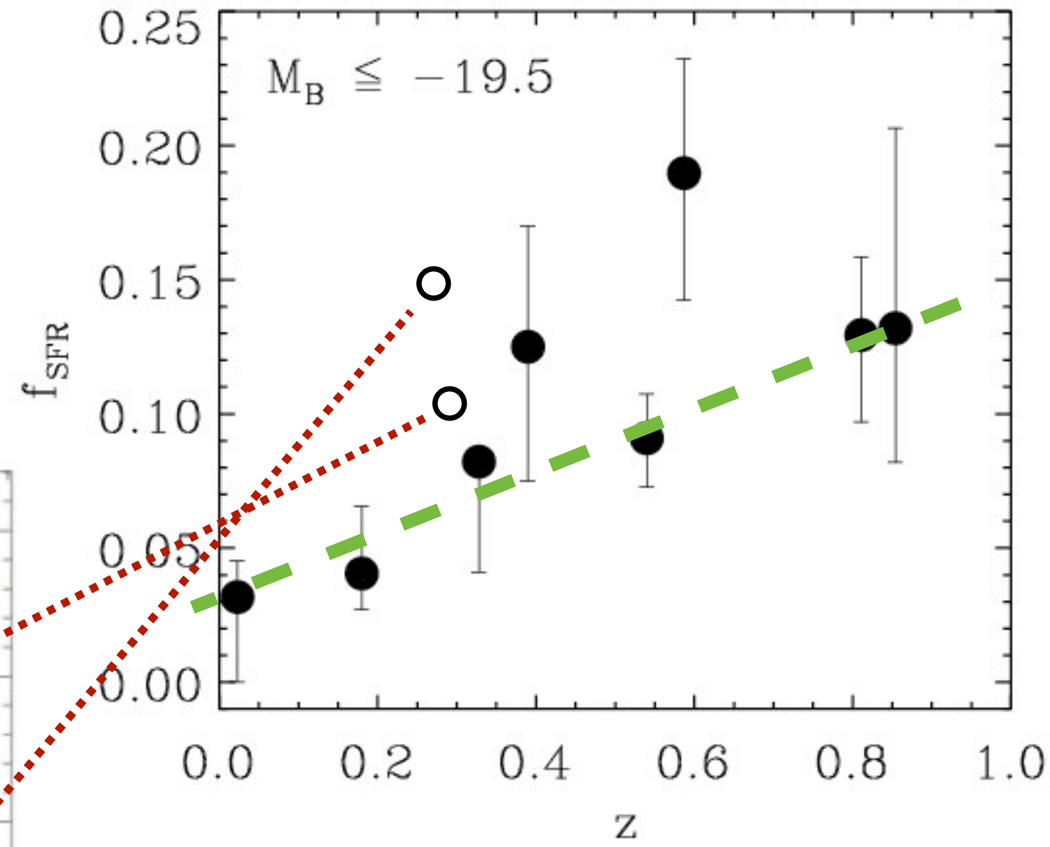


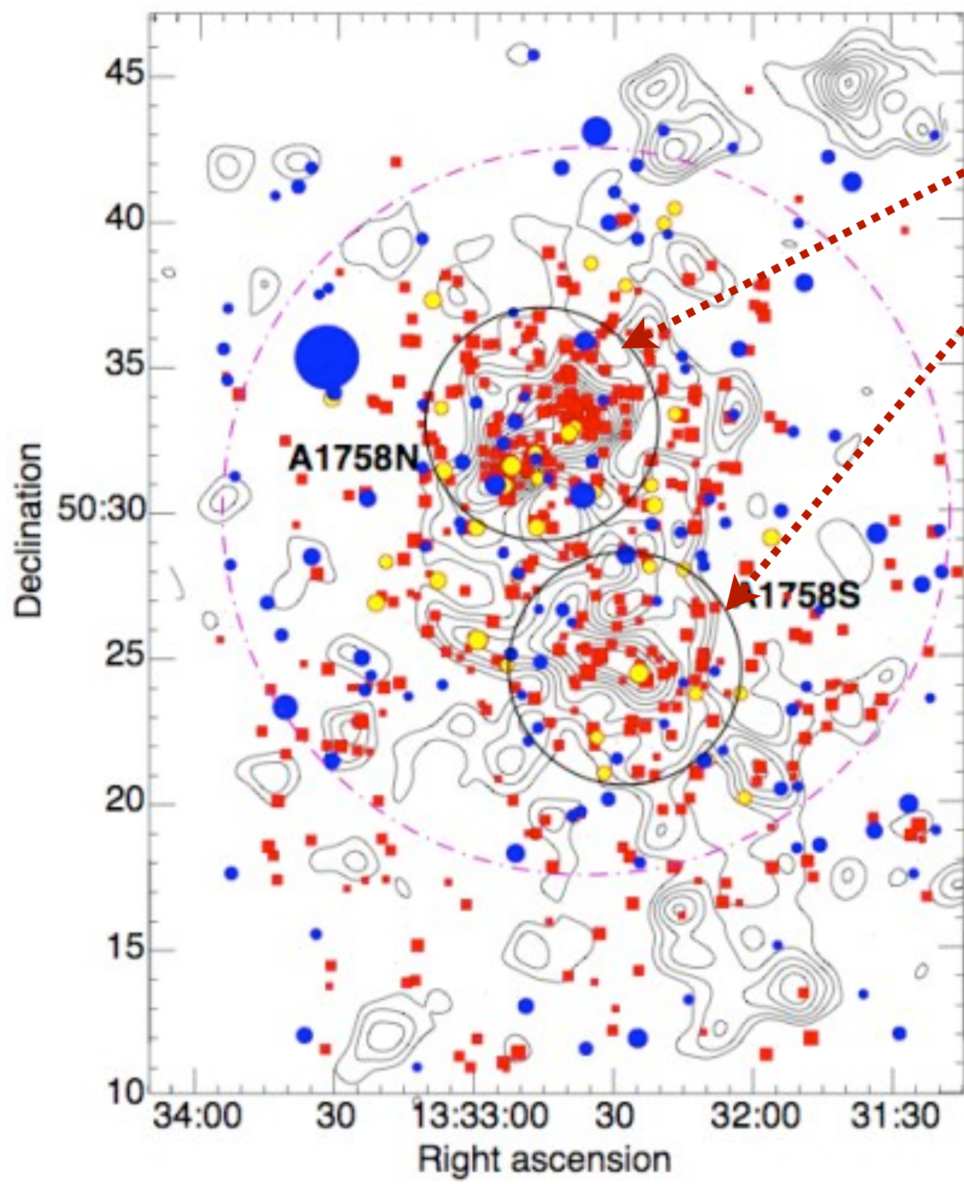
MS2053: Tran et al. (2005)



CL0024: Czoske et al. (2002)

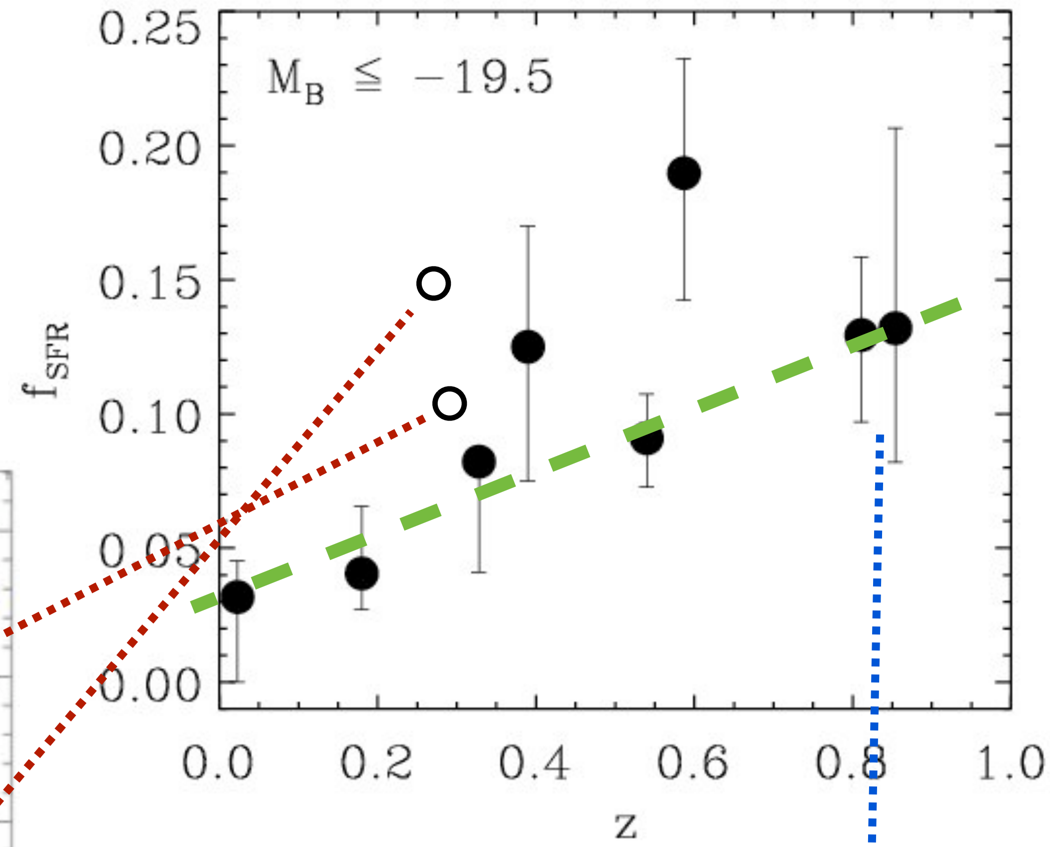
The origins of the effect?

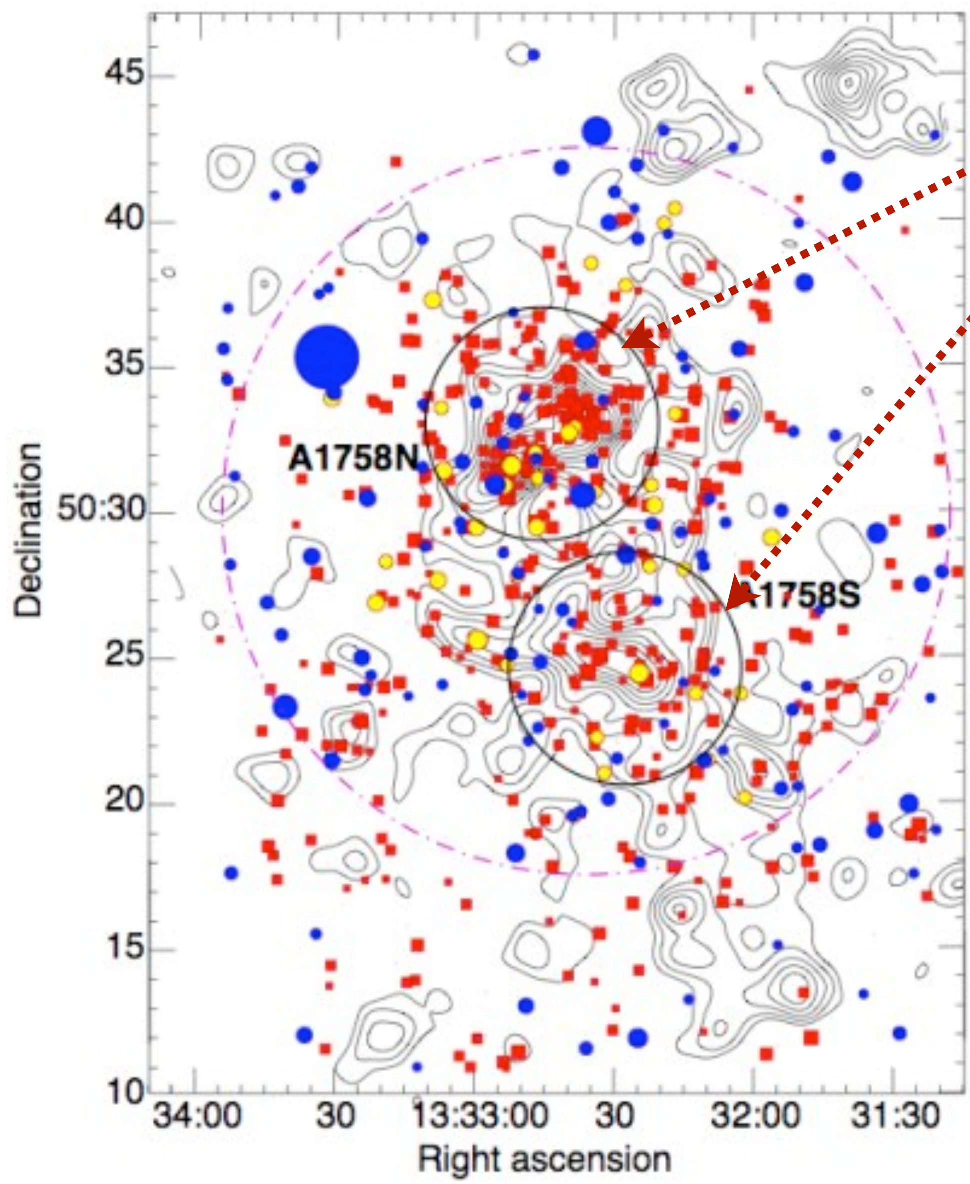




Haines et al. (2009)

The origins of the effect?





Haines et al. (2009)

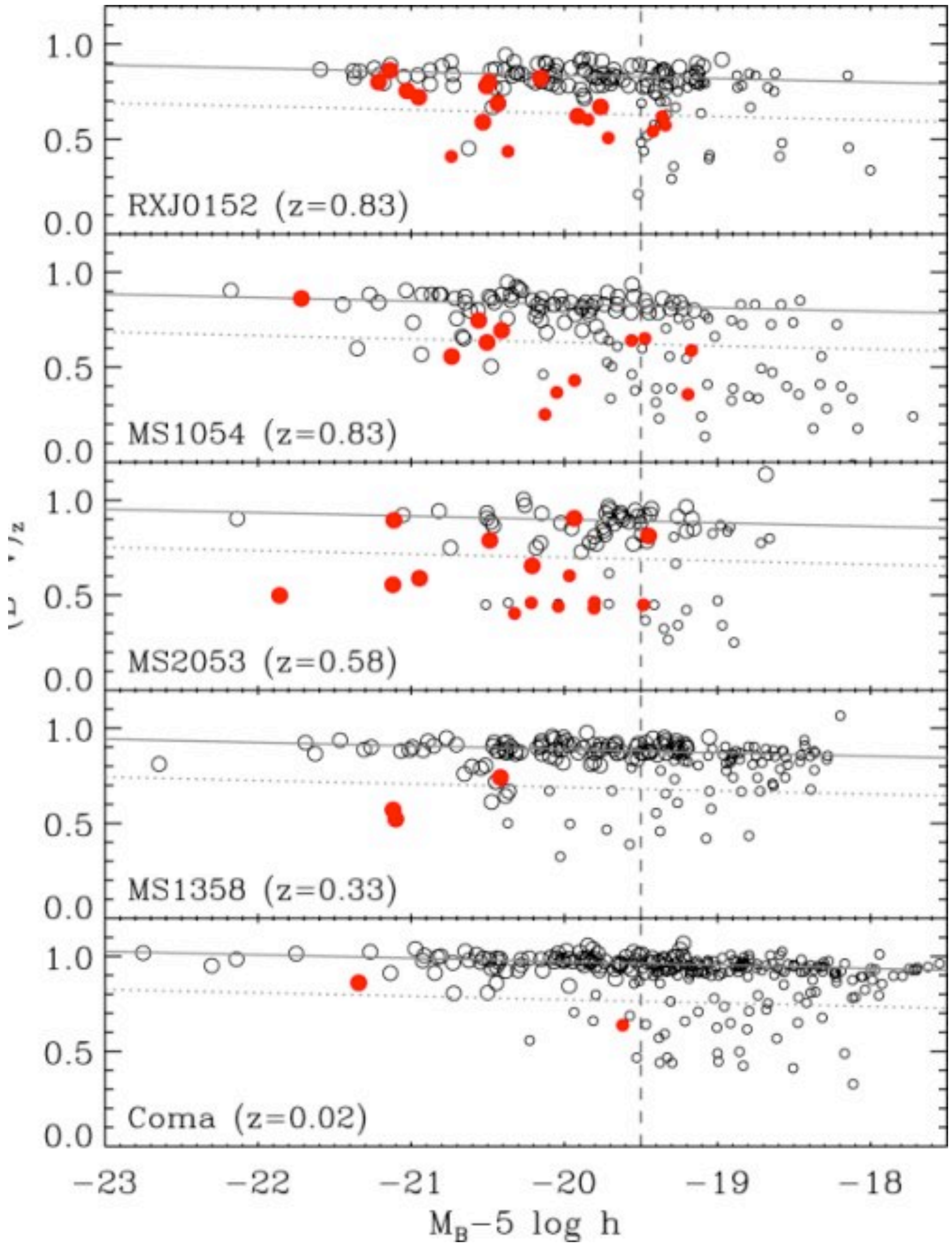
Excess of MIR sources on the outskirts, especially at higer z

see also: Marcillac et al. (2007), Koyama et al. (2008), Gallazzi et al. (2009), poster by Temporin et al.

What are these galaxies?

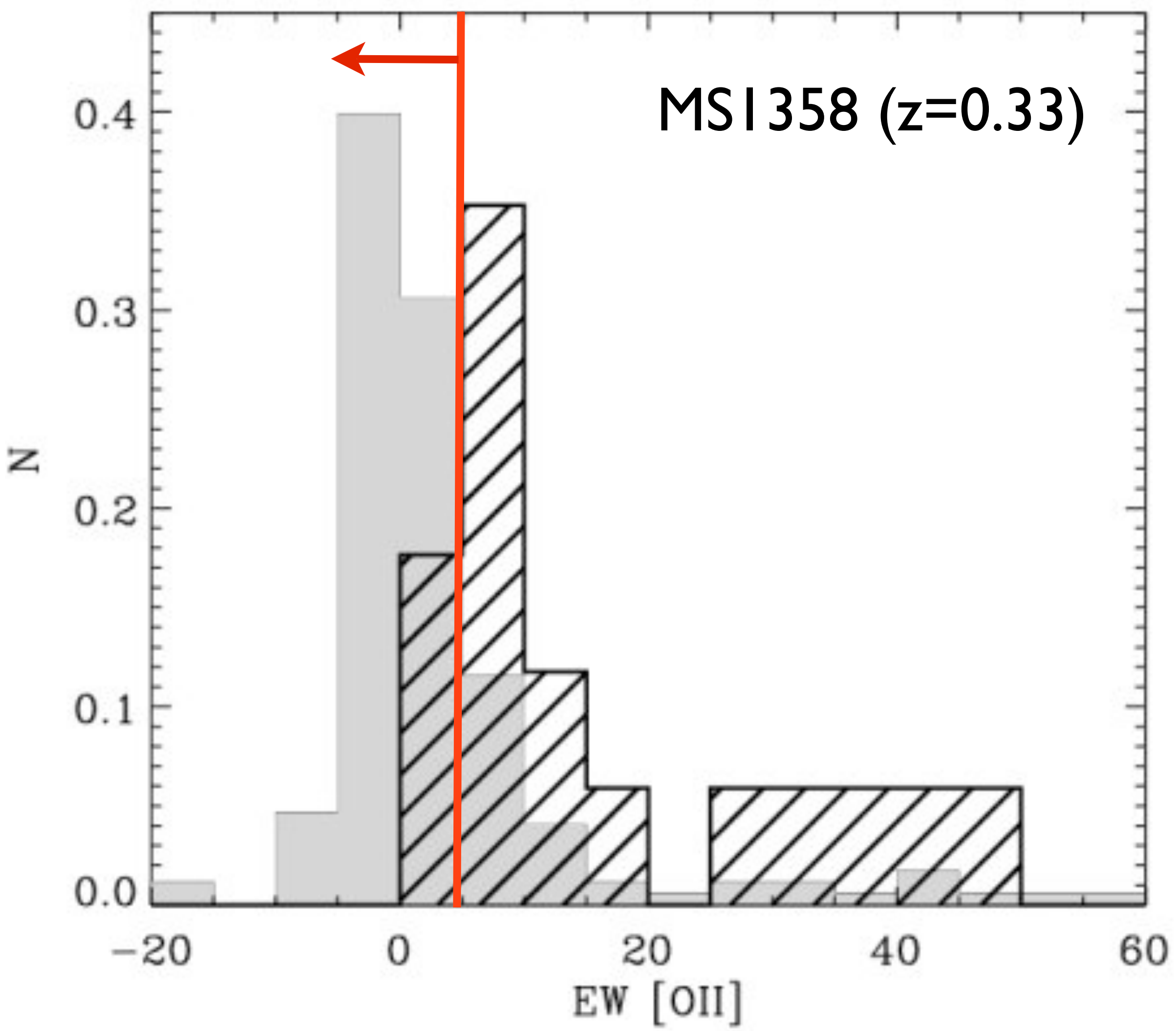
only confirmed members are plotted

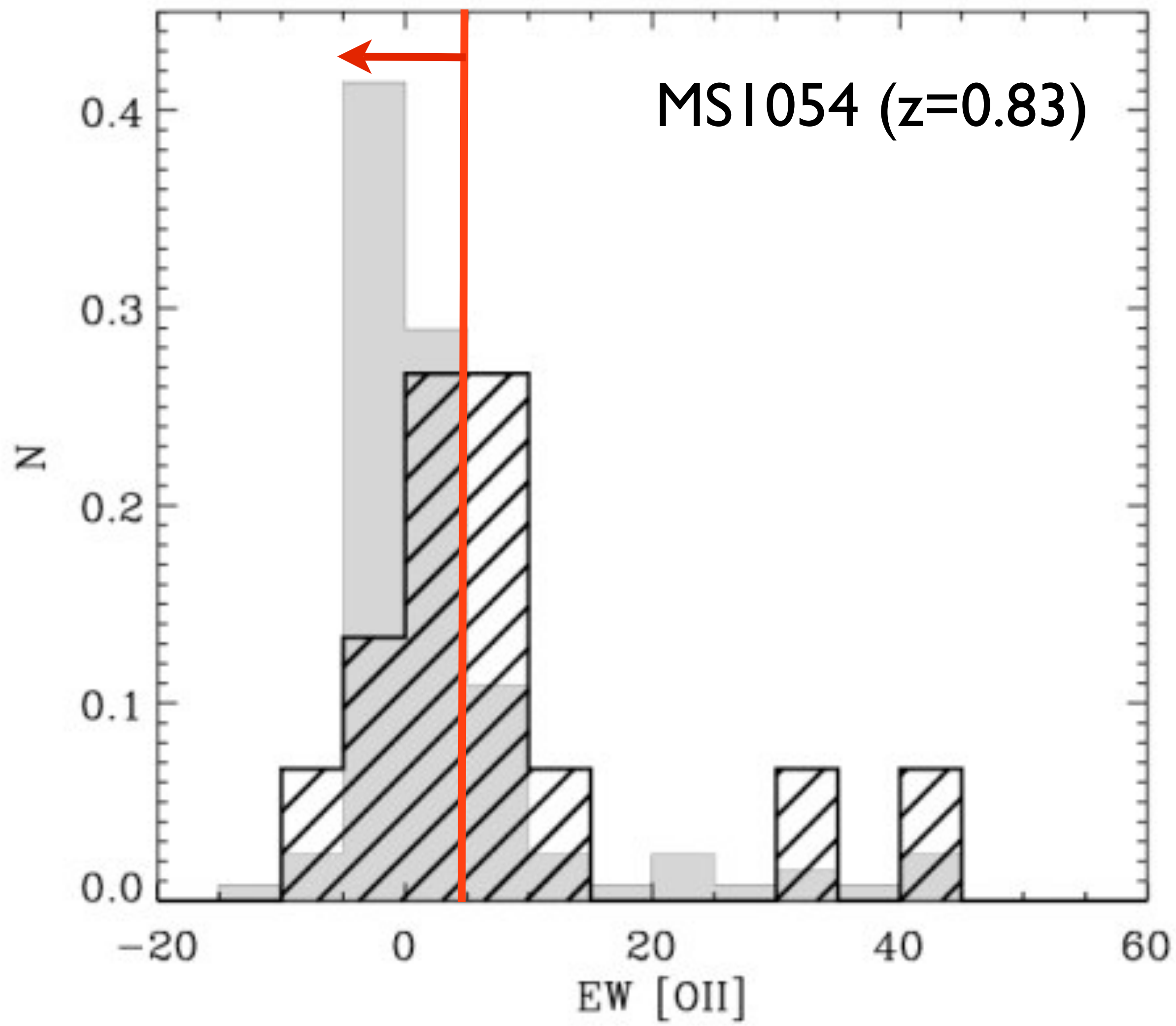
color symbols are detected at 24μm with SFR > 5 M☉/yr



Saintonge, Tran & Holden (2008)

Optical properties of the MIPS detections





MIR Butcher-Oemler effect :

1 The MIR data show an increasing fraction of dusty star-forming members with redshift and provide evidence for the infall interpretation.

2 Taking into account galaxies with obscured star formation, the effect is even stronger than when Butcher-Oemler galaxies are selected only based on color.

Environment questions :

1 How do the MIR properties of cluster galaxies compare with the field?

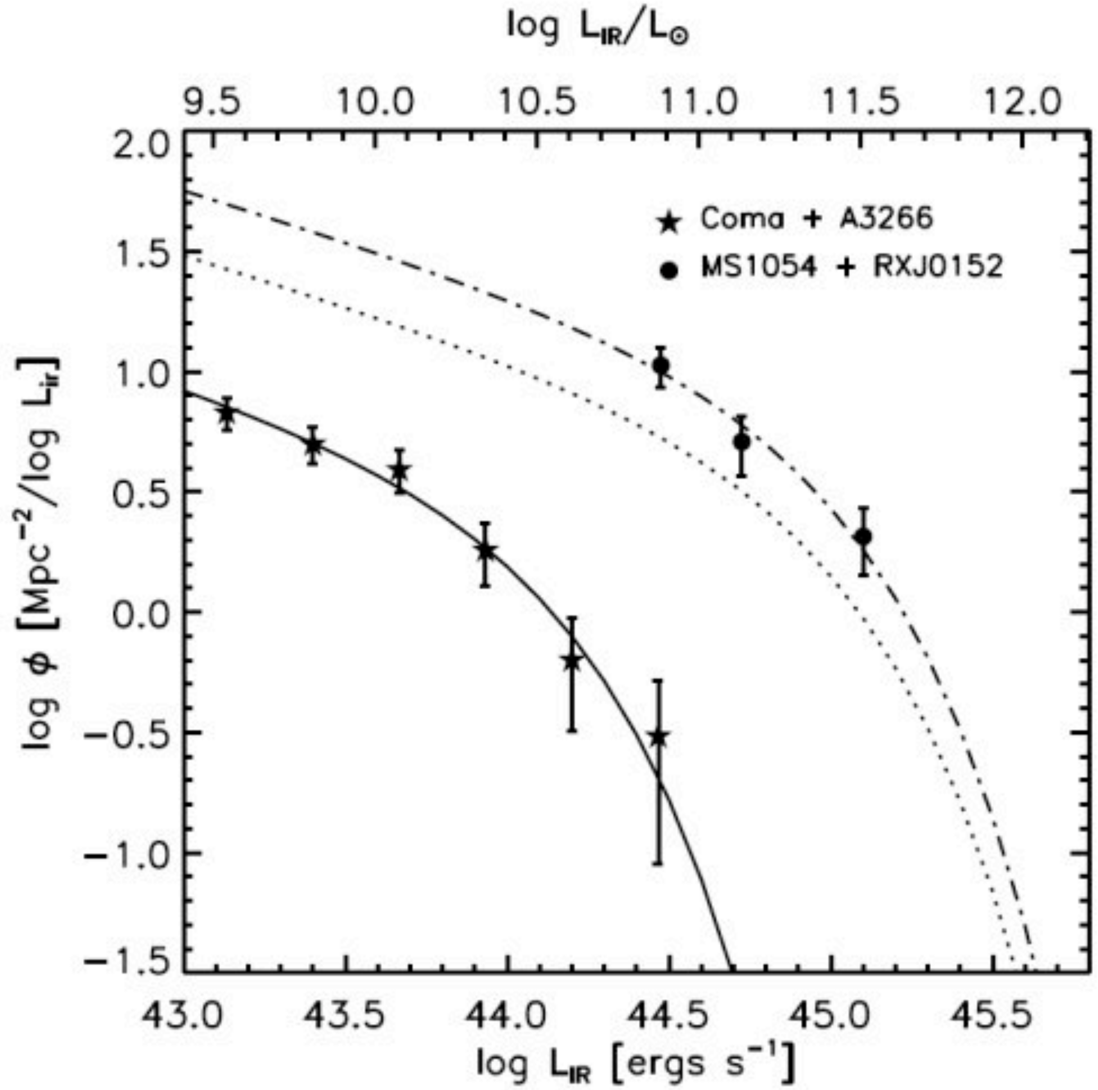
2 Does the MIPS SF fraction change across environment at a given z?

3 What environments are most critical in transforming late-types into early-types?

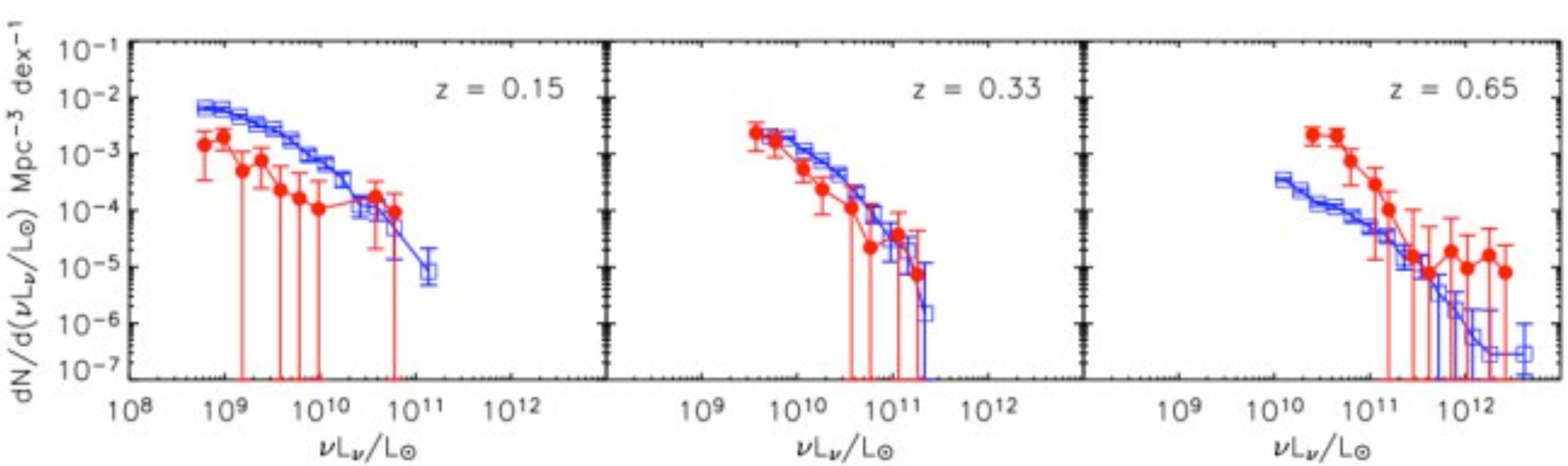
The infrared luminosity function

evolution of the 24μm LF to *z*=0.8 mostly consistent between cluster and field

differential evolution of the 8μm cluster and field LFs



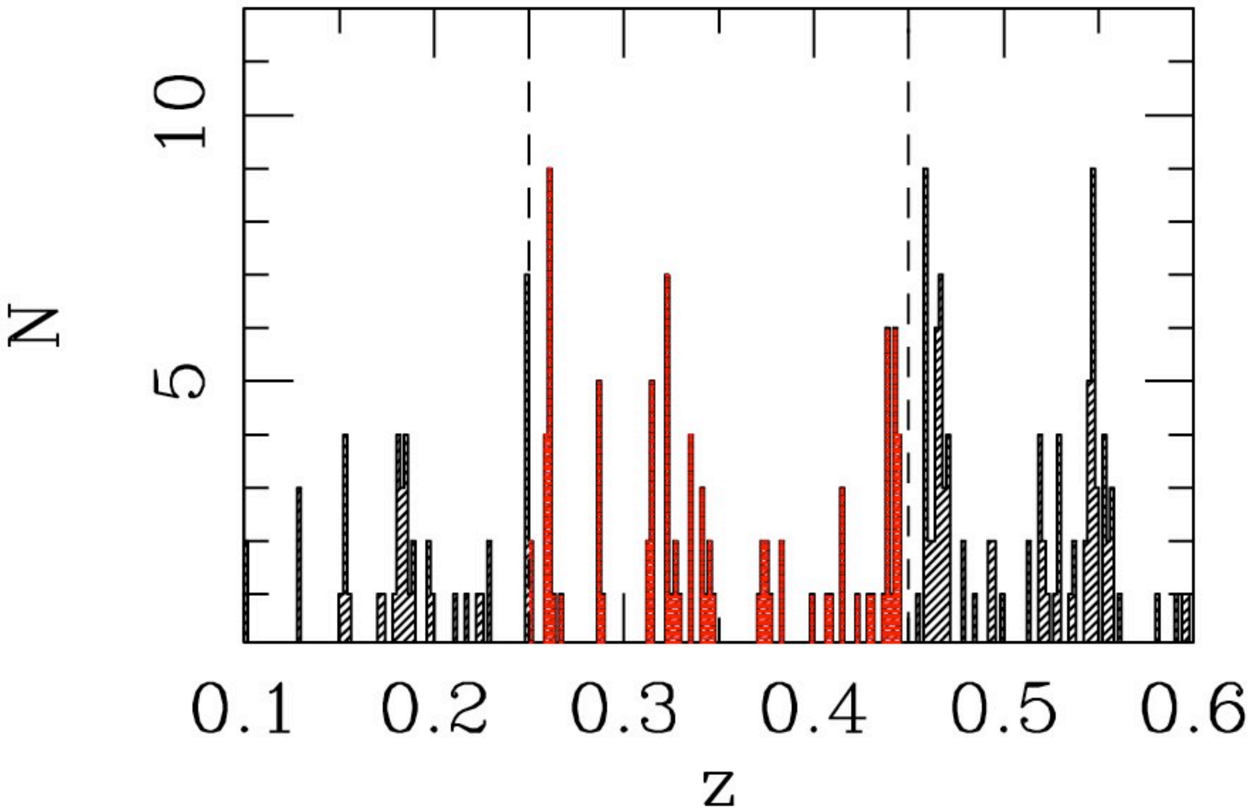
Bai et al. (2009)



Muzzin et al. (2008)

A field sample

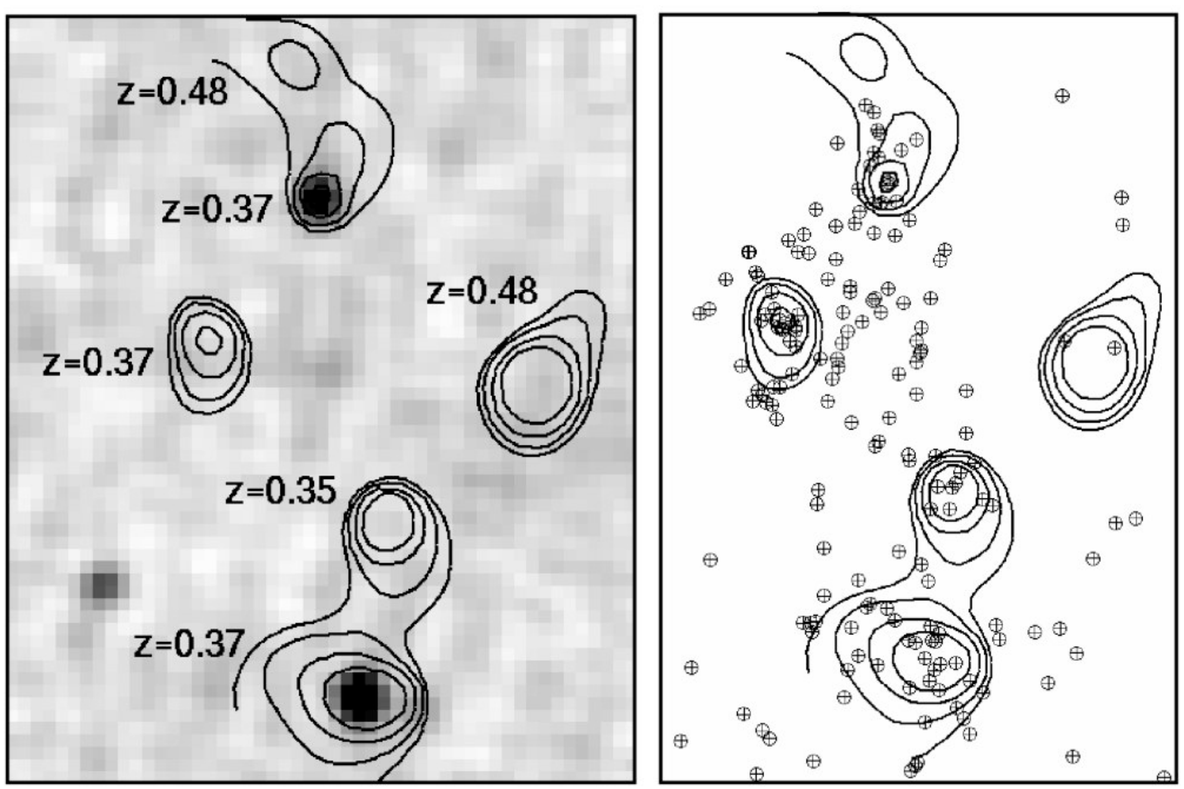
- for comparison with lowest density environments
- sample selected from the same magnitude-limited redshift catalogs and MIPS mosaics



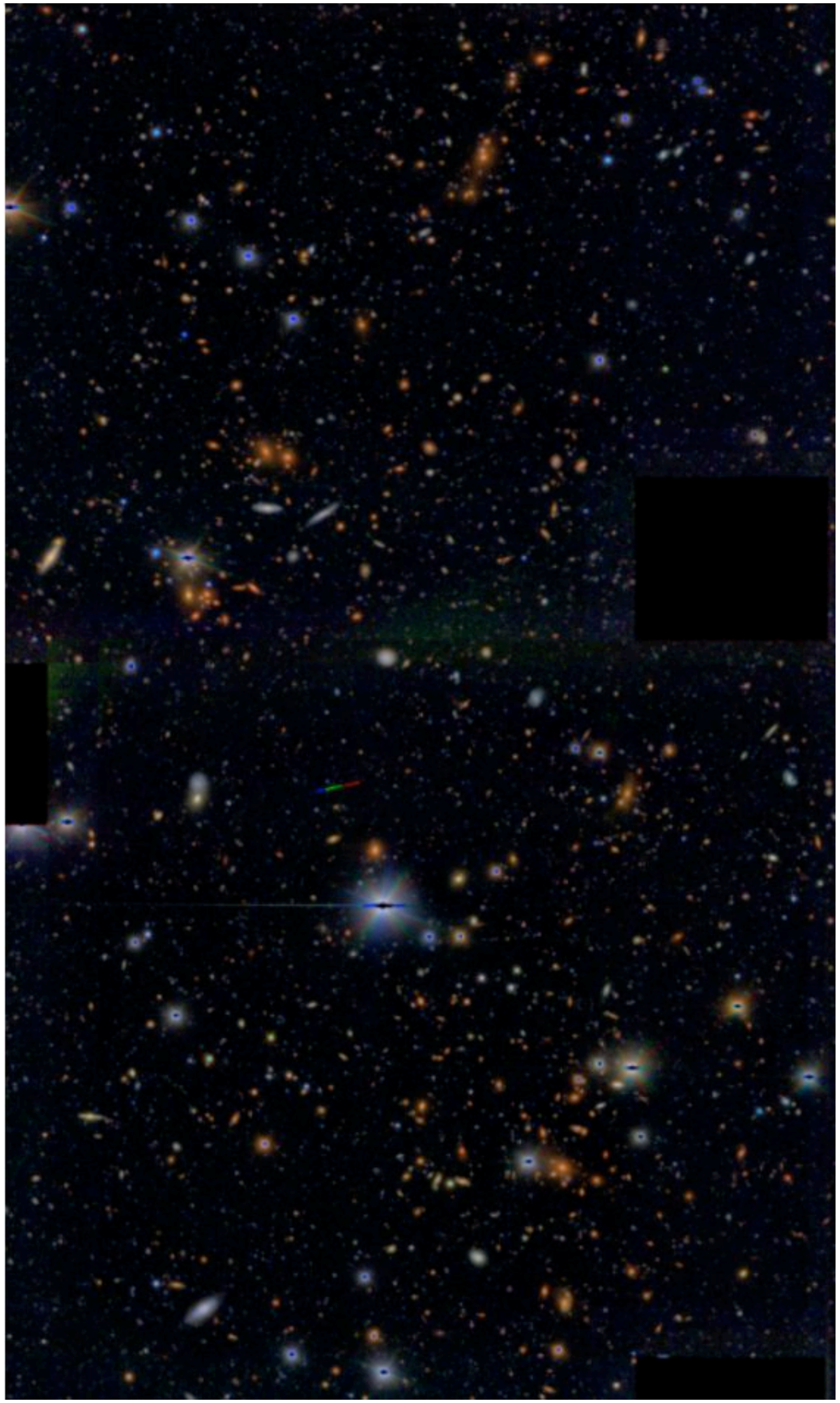
Tran, Saintonge et al, in prep.

A group of groups

- 4 galaxy groups at z~0.37
- will merge into a massive cluster by z~0
- HST, MIPS & Chandra imaging + >600 redshifts

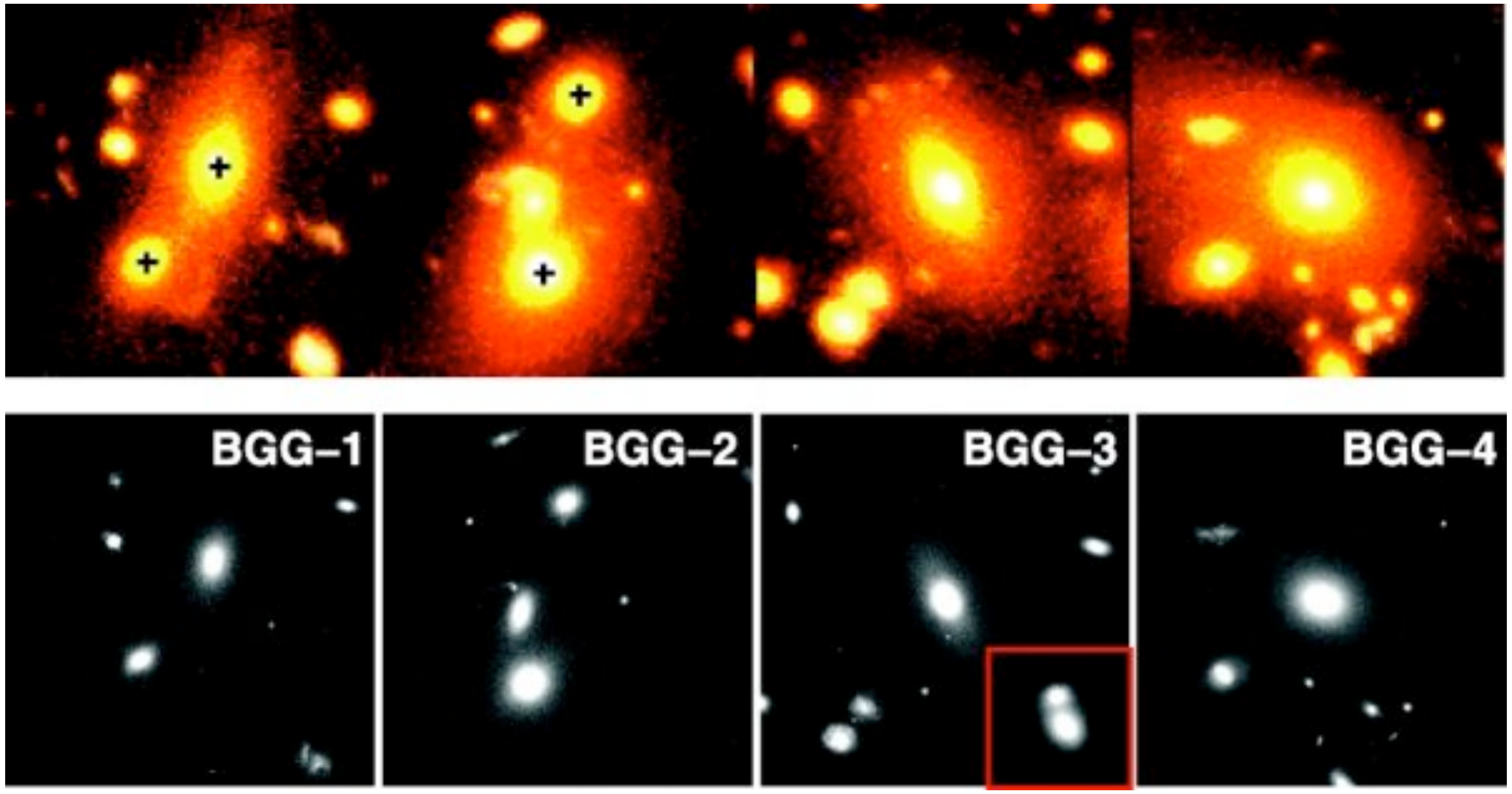


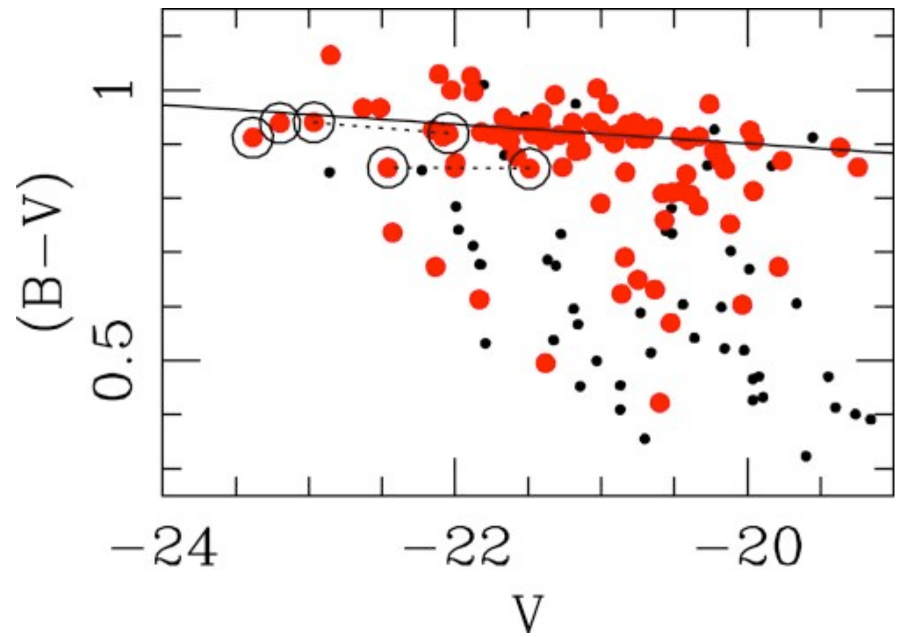
grayscale: NVSS / contours: Chandra



VLT/VIMOS BVR image

Evidence for late assembly of massive cluster galaxies



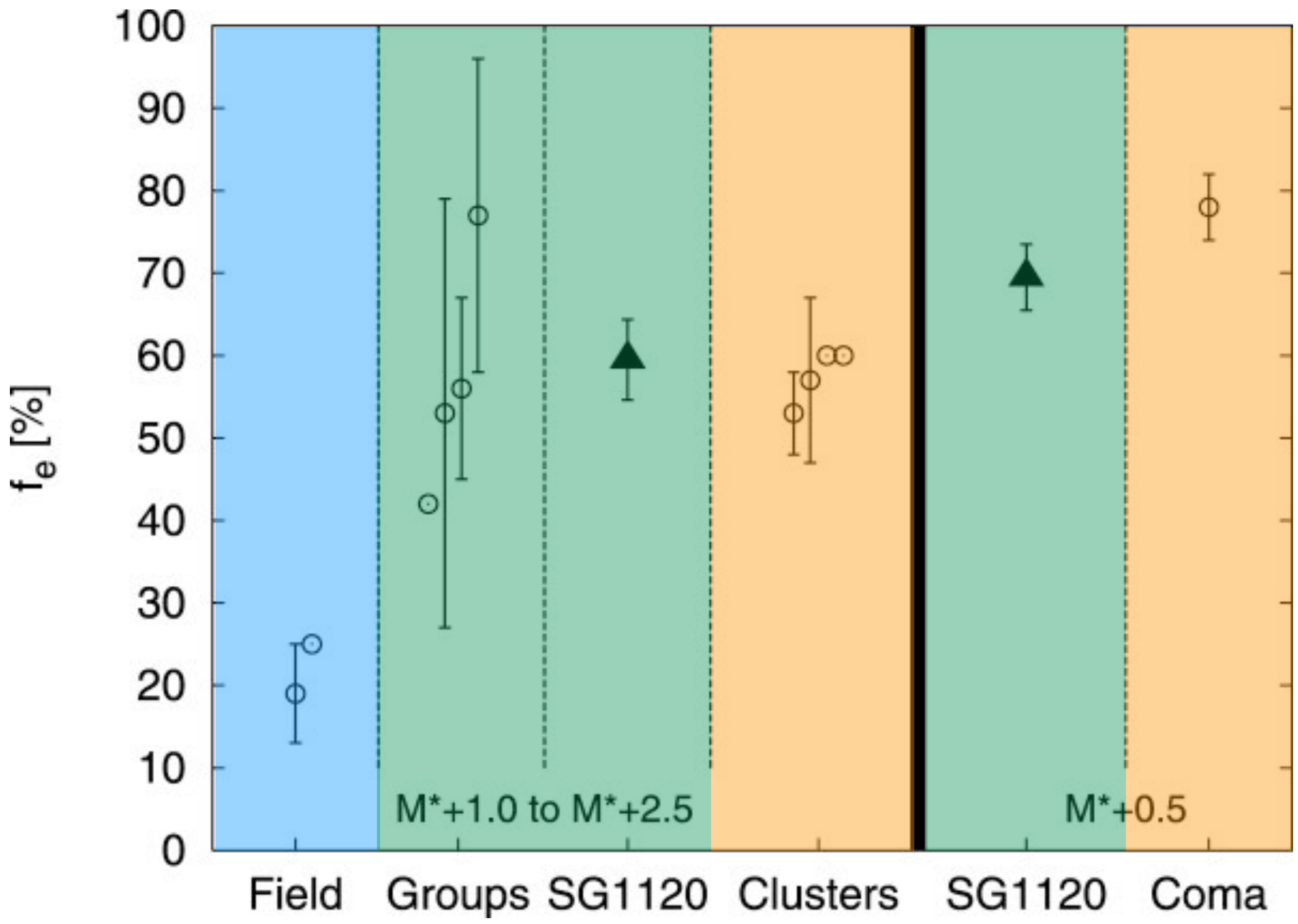


Tran et al. (2008)

BGGs of the four z~0.37 groups in order of increasing stellar mass

- no recent SF: dry red mergers
- group environment critical for this process

Forming early-type galaxies in groups



- f_e [SG1120] ~ f_e [Coma]
- S0/E ratio = 0.5, similar to clusters at same z

Kautsch et al. (2008)

see also: Wilman et al. (2008)

MIPS fraction vs environment

- both field and groups are significantly enhanced over the cluster,
  - fraction of dusty star-forming members (f_{SFR}):
    - FIELD: 32%
    - GROUPS: 33%
    - CLUSTER: 6%
- in lower density regions of the groups, f_{SFR} is in excess in the groups over the field: group-induced bursts of star formation
- L* of the IR luminosity function at z=0.4 consistent for field and cluster, but group in excess over both

for details and figures, see: Tran, Saintonge et al, 2009 (coming soon)

Conclusions

“redshift” study:

The fraction of dusty, star-forming members in clusters was ~4 times larger at $z=0.8$

“environment” study:

The fraction of dusty, star-forming galaxies in groups and in the field is ~5 times larger than in clusters at $z=0.4$ (and even enhanced in groups vs field)

“combined” conclusion:

The group environment is crucial in establishing the properties of cluster galaxies - interactions and infall of groups on clusters is responsible for bursts of dusty star formation.