GALAXY EVOLUTION and ENVIRONMENT

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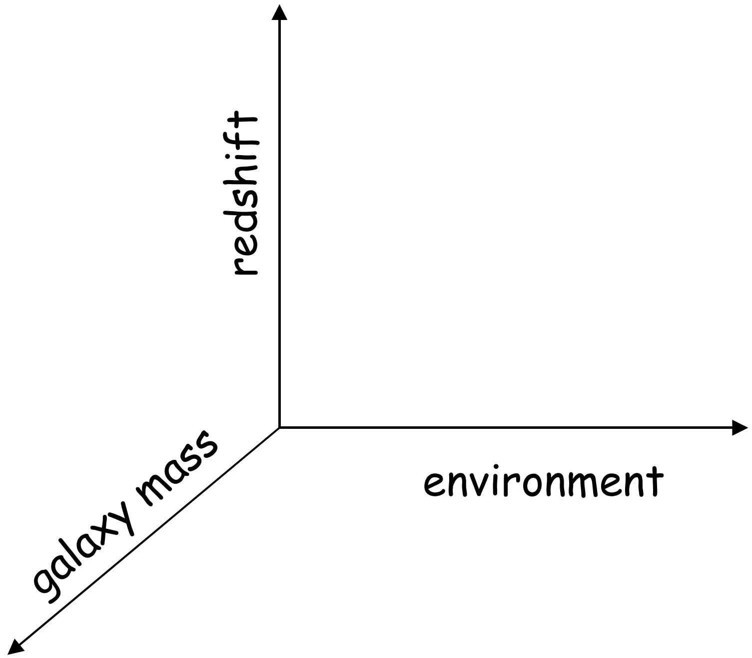
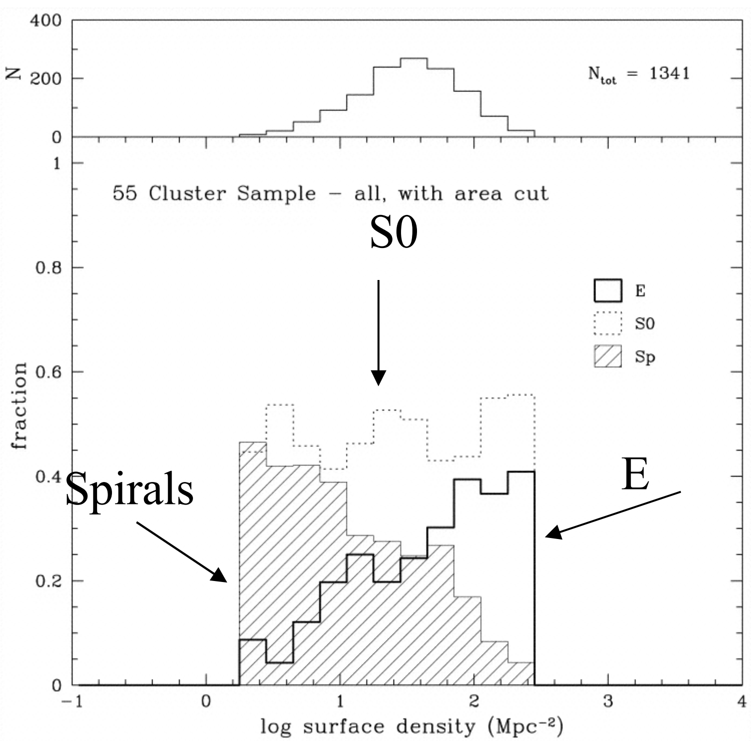

redshift
environment
galaxy mass

How to characterize environment?
One way is local galaxy density

MORPHOLOGY-DENSITY RELATION

Fraction of galaxies

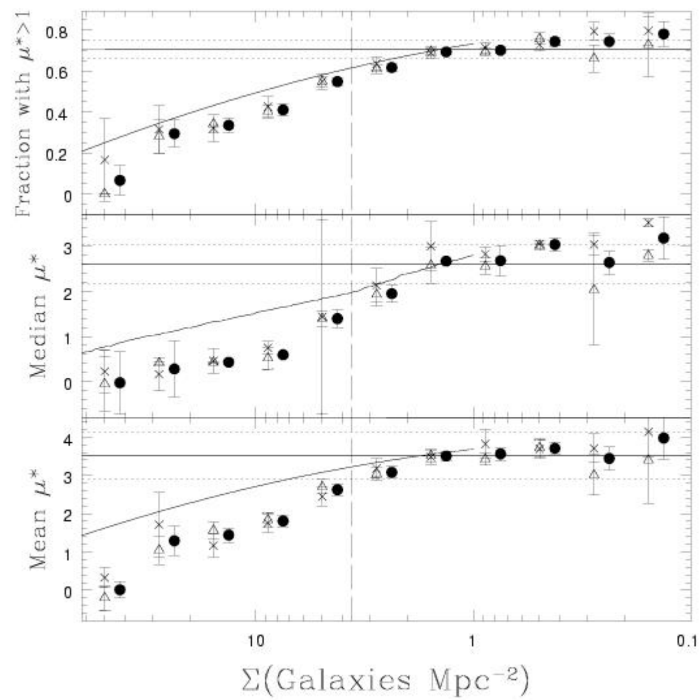


projected surface density (log)

Dressler et al. 1997

STAR FORMATION-DENSITY RELATION

~ Median SF



projected surface density (log)

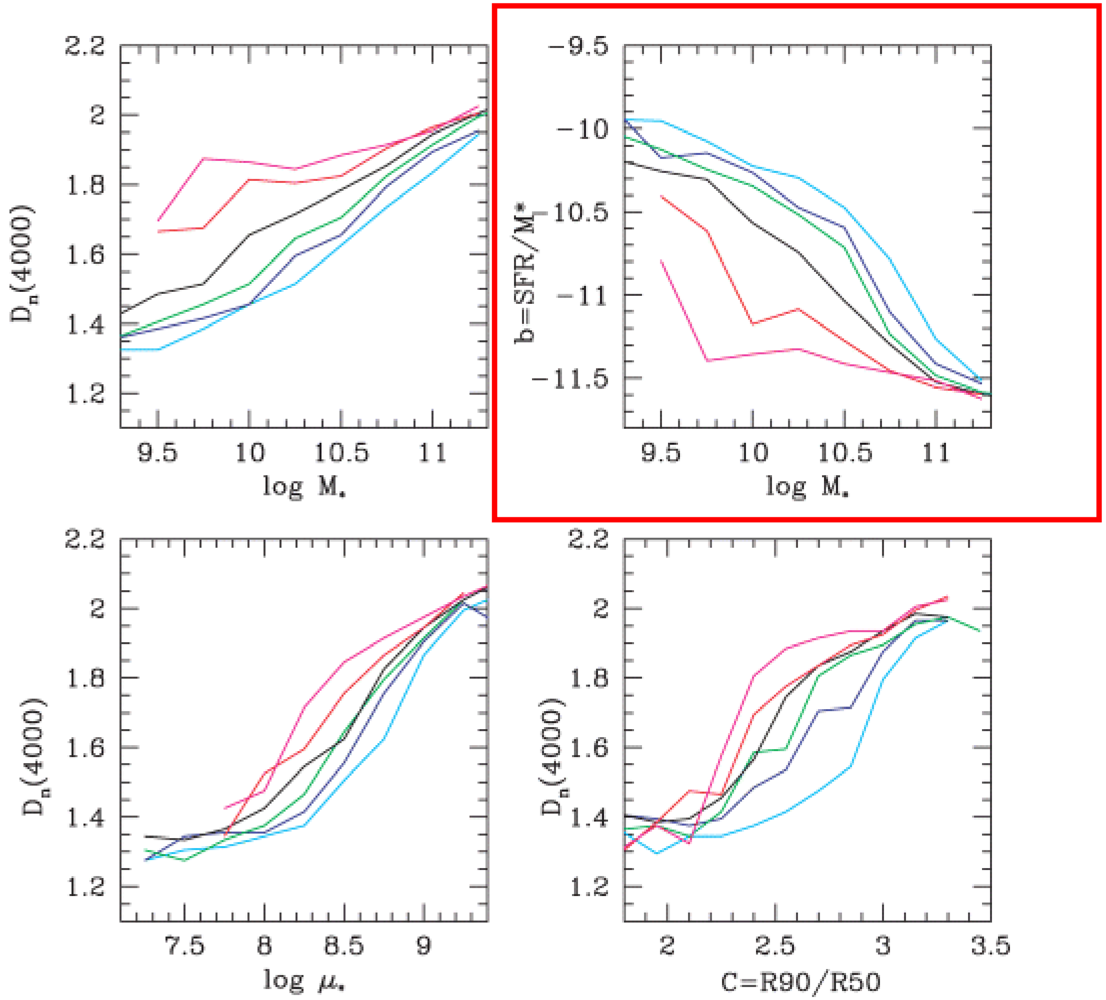
Lewis et al. 2002

Current star formation rate per unit galaxy stellar mass (M_*) vs M_*

Low redshift

At a given galaxy mass, SF varies with local density.

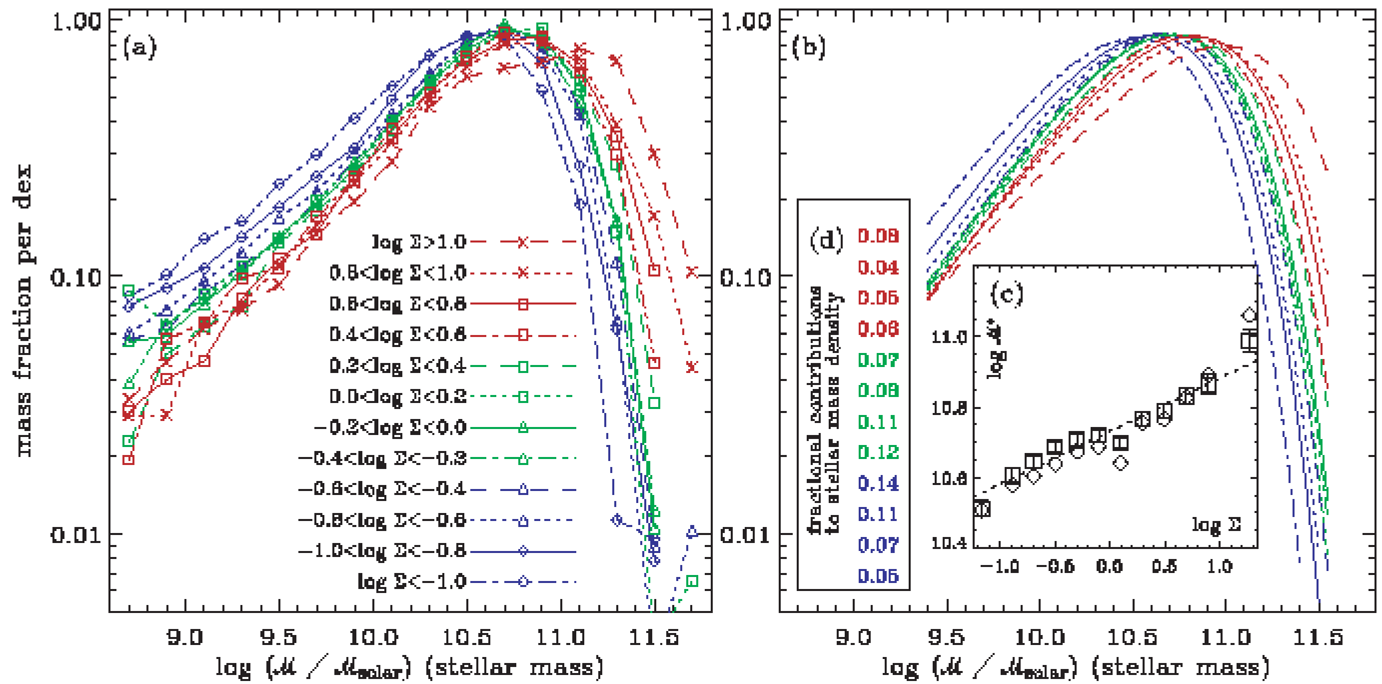
At each density, SF trend with galaxy mass.



Kauffmann et al. 2004

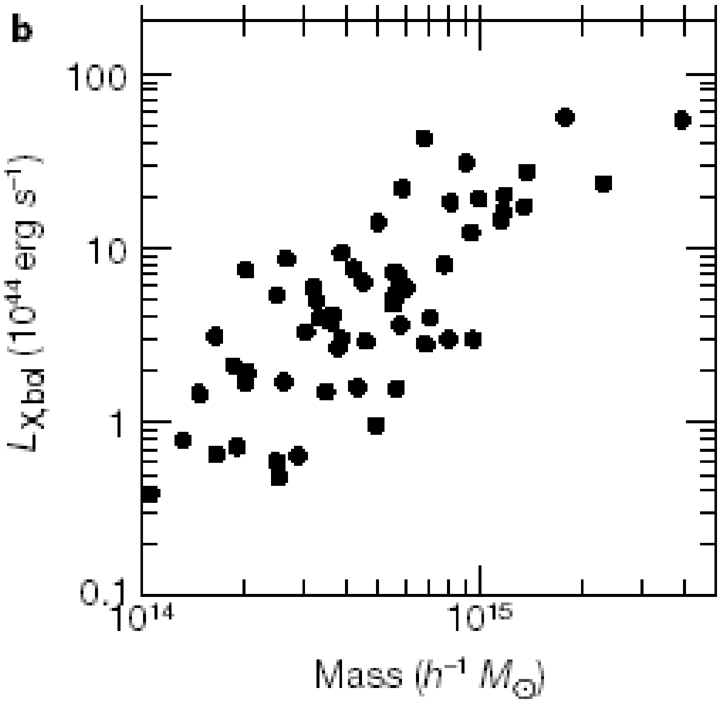
Galaxy stellar mass function itself varies with density

Mass fraction per dex



Log M (stellar mass)

Baldry et al. 2006



Borgani & Guzzo 2001

Measuring cluster masses

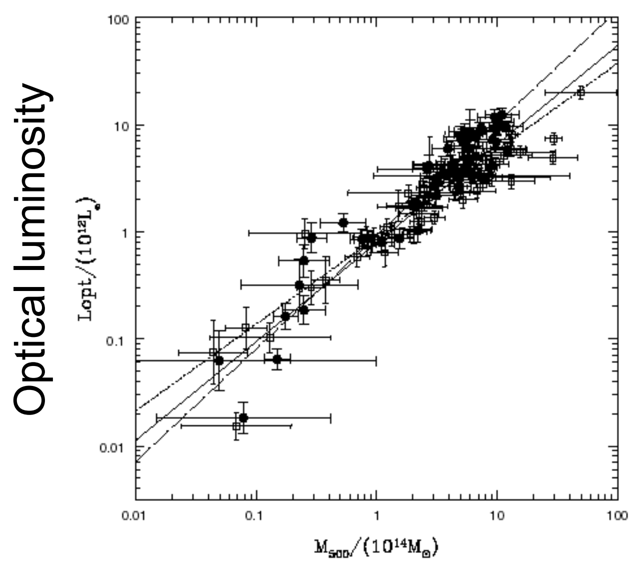
Cluster velocity dispersion

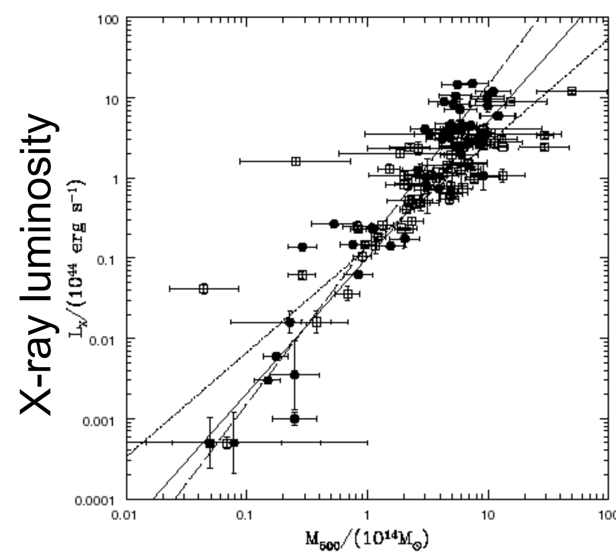
X-ray luminosity

Cluster total luminosity/richness

Weak-lensing

Sunyaev-Zeldovich





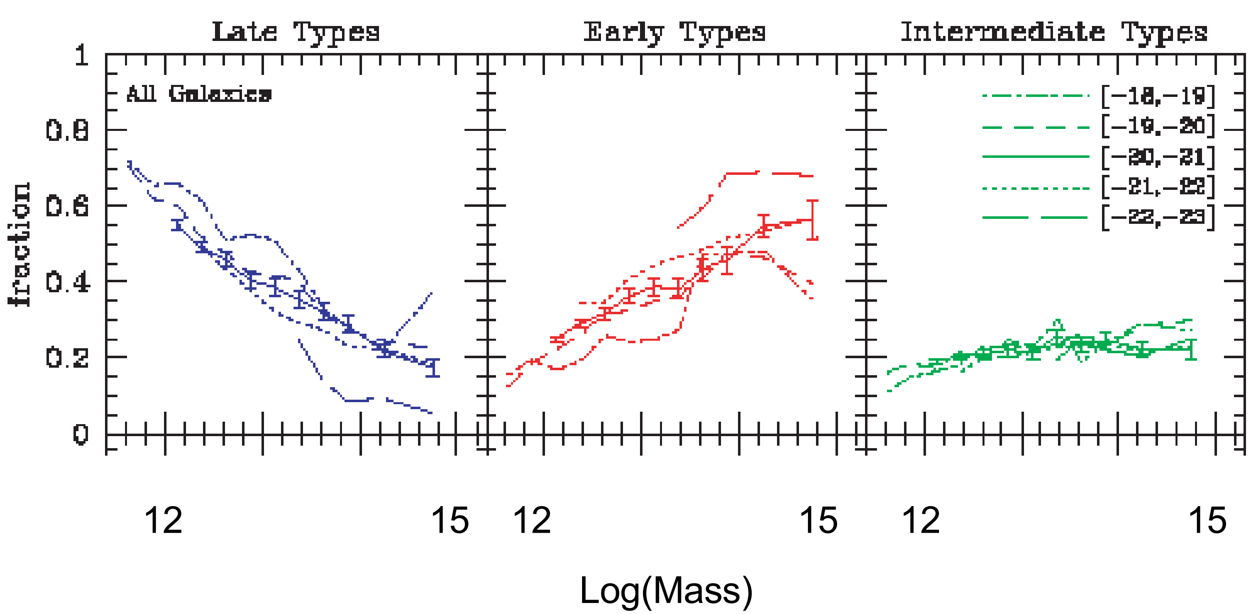
Virial mass

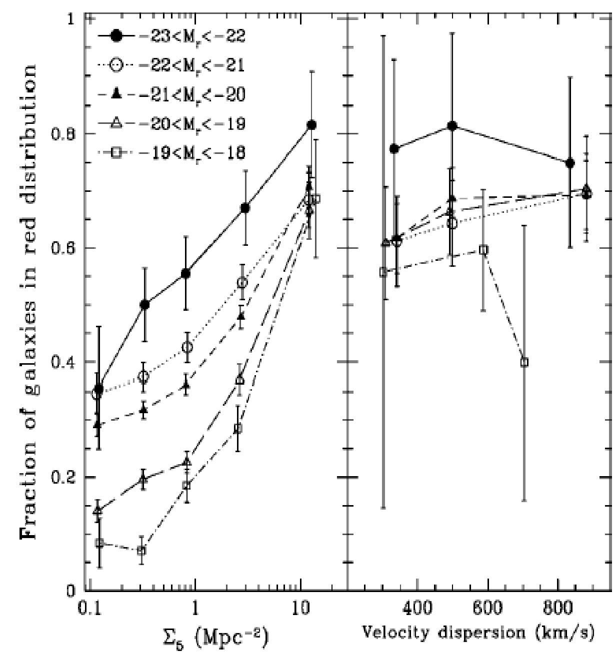
Popesso et al. 2005

A number of attempts, confusing in the beginning, even more confusing recently

Richer, more centrally concentrated, relaxed clusters have fewer star-forming/late-type galaxies.

Early attempts with (e.g. Zabludoff & Mulchaey 1998, Biviano et al. 1997) and without (e.g. Smail et al. 1998, Andreon & Ettori 1999) success.

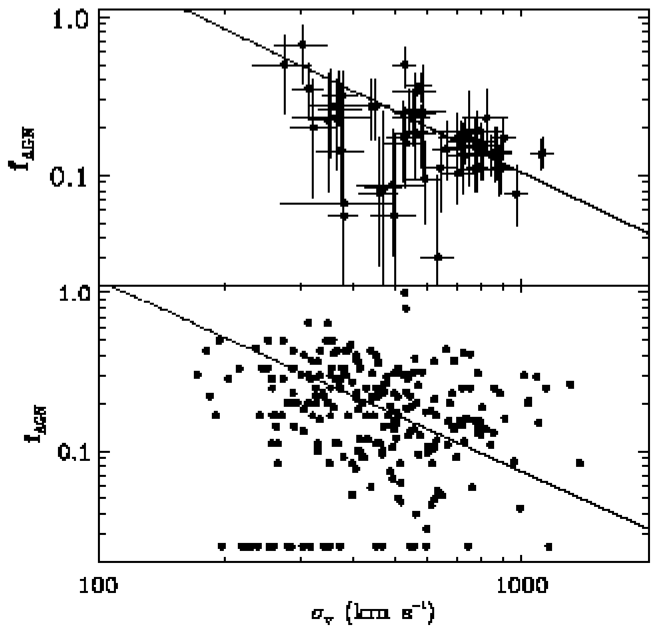




Red galaxy fraction versus velocity dispersion

Weinmann et al. 2006

Balogh et al. 2004



Popesso & Biviano 2007

AGN % --- cluster sigma

Several studies in the last few years at low-redshift but still far from understanding

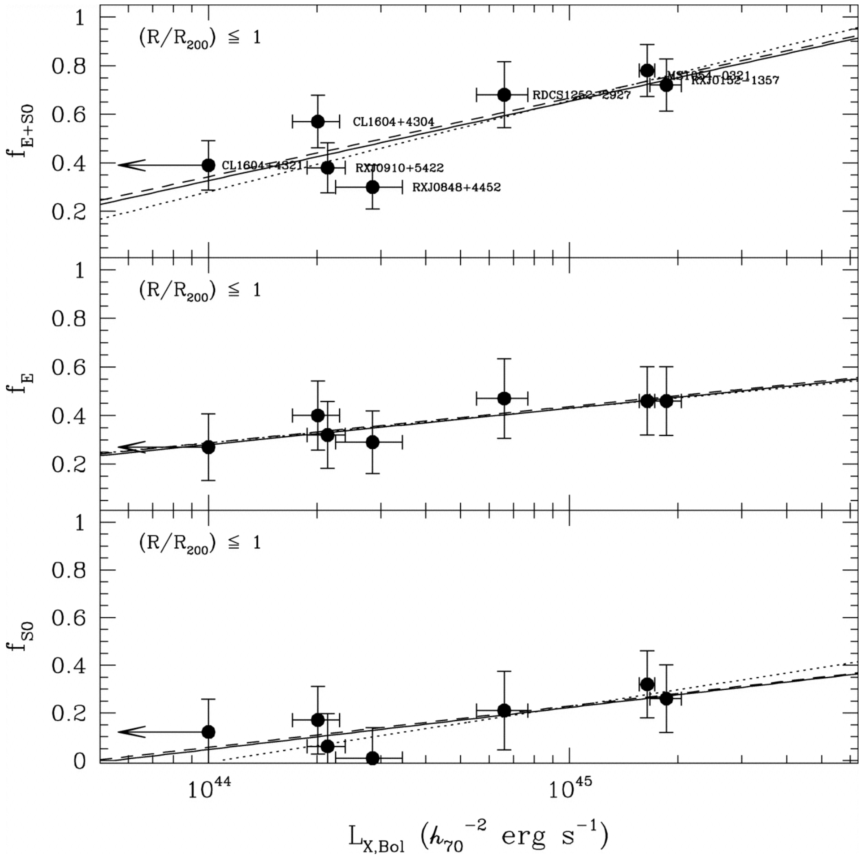
High redshift correlations

Early-type galaxy fraction versus X-ray luminosity

f(E+S0)

f(E)

f(S0)

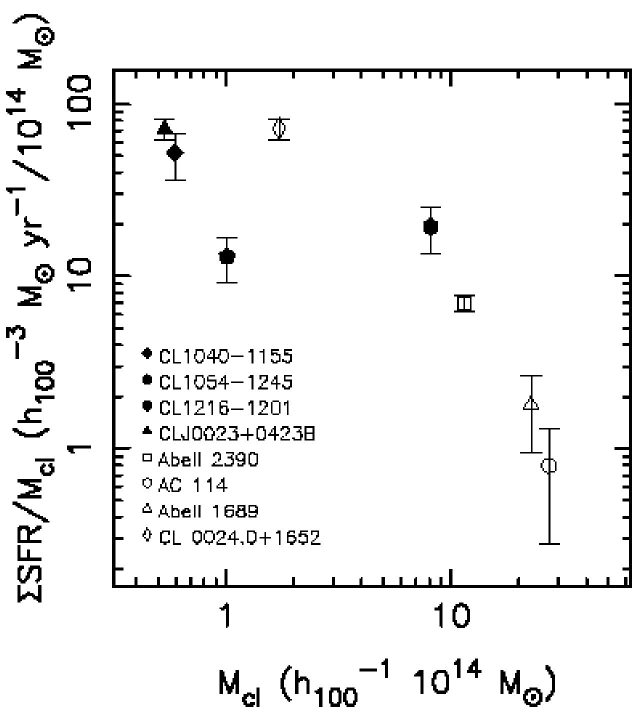


L_X

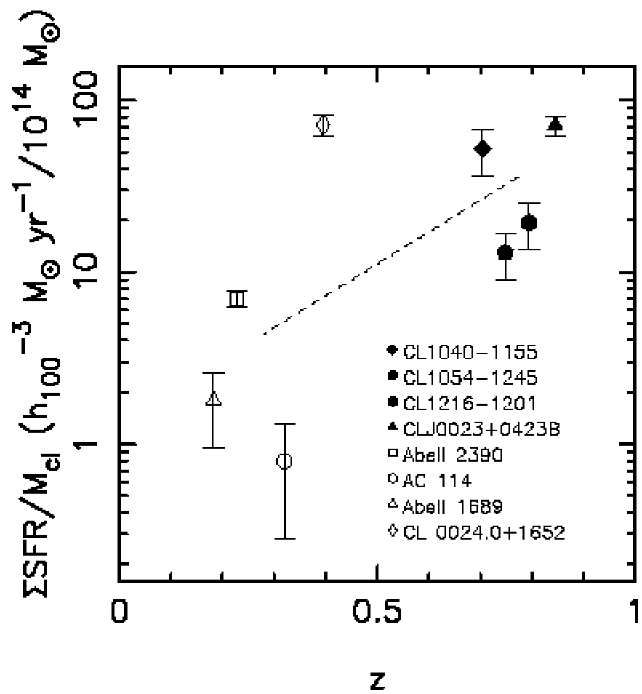
Postman et al. 2005

Integrated cluster SFR per unit of cluster mass

Very hard to discriminate evolution and dependence on “cluster mass”



Cluster mass



Redshift

Finn et al. 2005, Homeier et al. 2005

see Popesso et al. 2007: significant anticorrelation SFR/Mass – sigma at low-z

STAR FORMATION AND….

- LOCAL DENSITY: several correlations with local density, at high- and low-z -- easy to measure, hard to interpret

- SYSTEM MASS, LOW-Z: presence + lack of correlations with system mass, apparently contrasting results

- SYSTEM MASS, HIGH-Z: large samples with range of masses start to be available

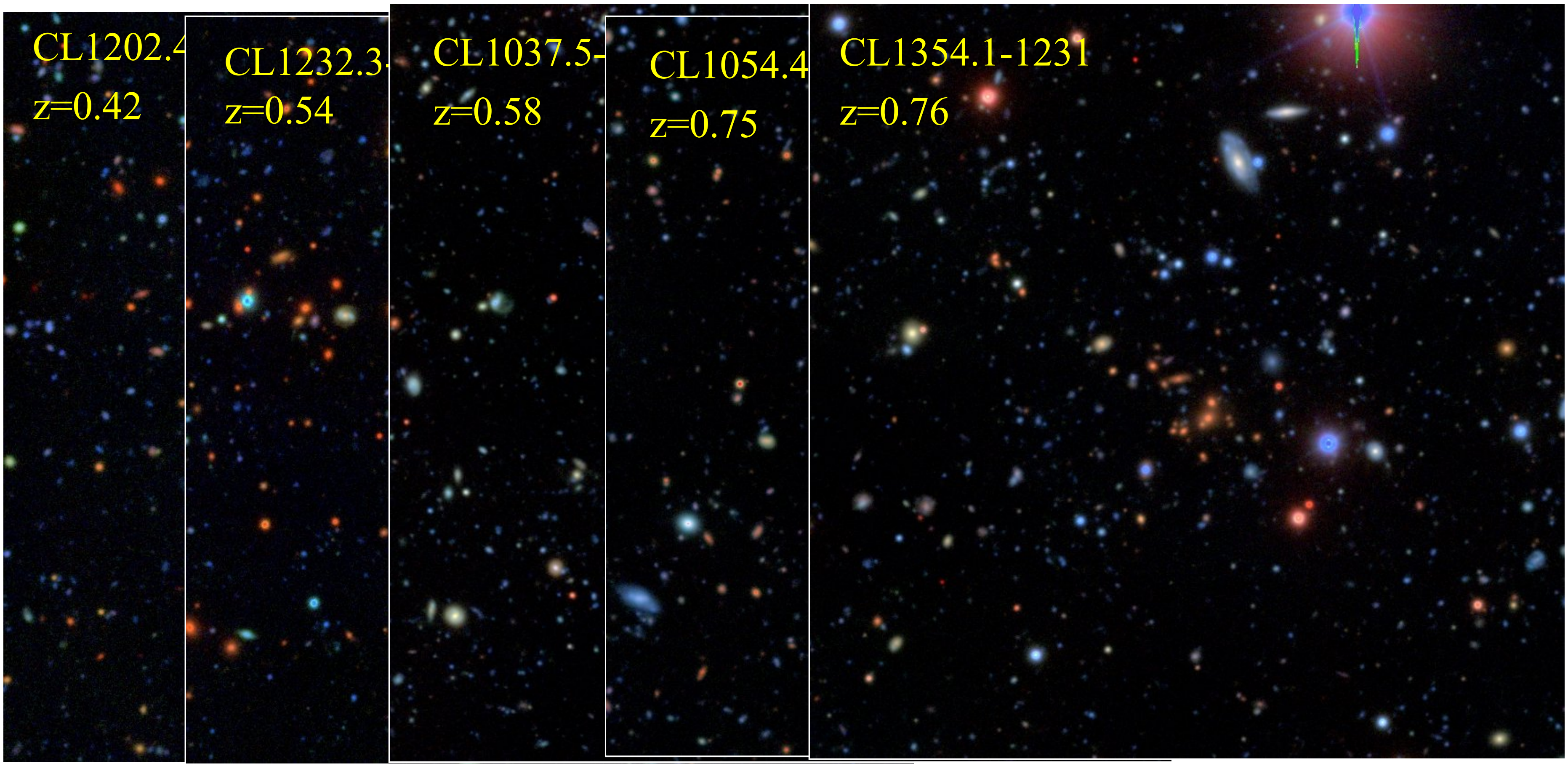
- RELATION LOCAL DENSITY-SYSTEM MASS?
  still unexplored

The ESO Distant Cluster Survey

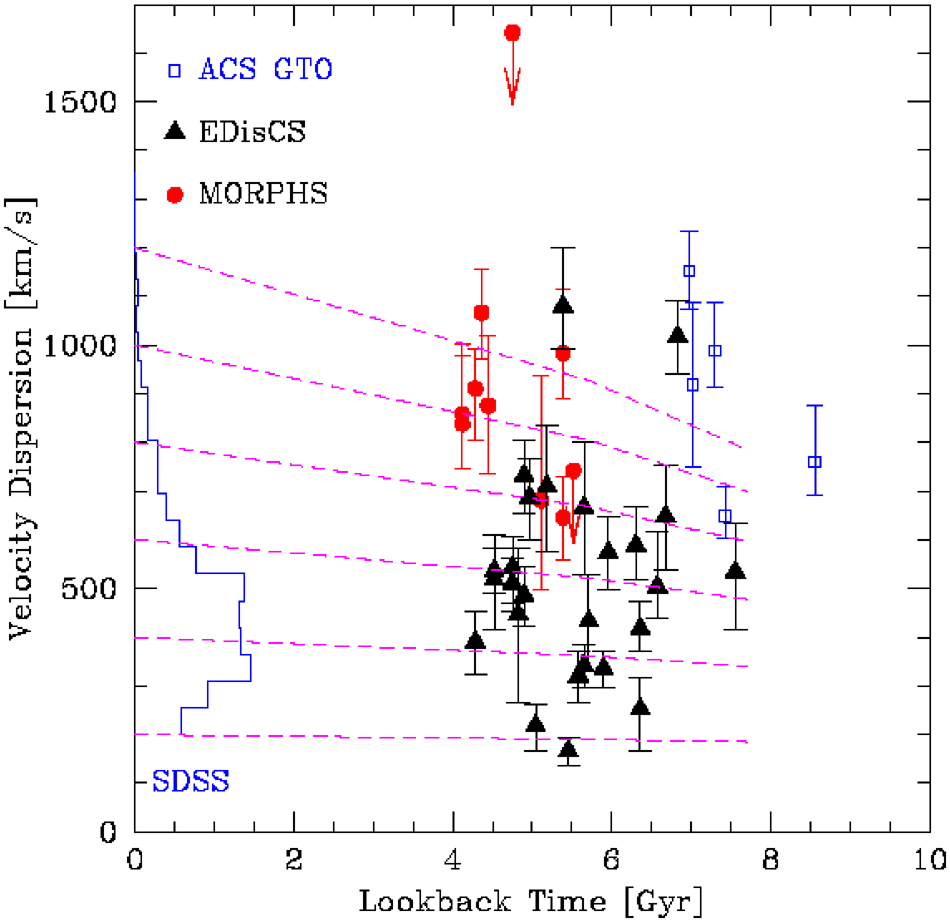
(EDisCS --- P.I. Simon White)

20 fields with clusters at z=0.42-0.96

Optically selected – VLT deep imag. + spectroscopy, ACS/HST, XMM, Spitzer….



Matching high-z and low-z cluster samples



Milvang-Jensen et al. 2007 submitted

Spectroscopy: the sample

Halliday et al. 2004 and Milvang-Jensen et al. 2007

For this work, 16 clusters, 10 groups, + 84 galaxies in poor groups and 162 in the "field".

Cluster name	$z_{cluster}$	$\sigma_{cluster} \pm \delta\sigma_{cluster}$	No. of members
(1)	(2)	(3)	(4)
Cl1232	0.5414	$1080\ ^{+119}_{-89}$	54
Cl1216	0.7943	$1018\ ^{+73}_{-77}$	67
Cl1411	0.5200	$861\ ^{+265}_{-124}$	26
Cl1138	0.4800	$751\ ^{+65}_{-93}$	48
Cl1354	0.7621	$703\ ^{+78}_{-156}$	21
Cl1301	0.4828	$678\ ^{+88}_{-91}$	37
Cl1353	0.5882	$625\ ^{+163}_{-107}$	22
Cl1037A	0.4200	$604\ ^{+91}_{-90}$	37
Cl1054-11	0.6972	$589\ ^{+78}_{-70}$	49
Cl1227	0.6356	$571\ ^{+96}_{-53}$	22
Cl1103C	0.9598	$566\ ^{+180}_{-66}$	7
Cl1059	0.4562	$508\ ^{+70}_{-44}$	41
Cl1037B	0.5775	$507\ ^{+205}_{-146}$	19
Cl1202	0.4243	$505\ ^{+135}_{-74}$	21
Cl1054-12	0.7498	$504\ ^{+113}_{-65}$	36
Cl1018	0.4733	$488\ ^{+69}_{-57}$	33
Cl1040	0.7043	$418\ ^{+55}_{-46}$	30
Cl1103A	0.6255	$369\ ^{+34}_{-104}$	14
Cl1103B	0.7031	$288\ ^{+112}_{-162}$	11
Cl1420	0.4960	$272\ ^{+140}_{-61}$	27
Cl1119	0.5499	$173\ ^{+37}_{-21}$	21
total			643

In high-z clusters, groups and field

- Ongoing star formation and cluster mass
- Morphologies and cluster mass
- Star formation histories and cluster mass
- Star formation and local density

- A possible theoretical scenario

How many galaxies are forming stars in clusters at z=0.8? Can we quantify the evolution z=0.8 to z=0?

Galaxies with EW(OII)>3 Å in emission

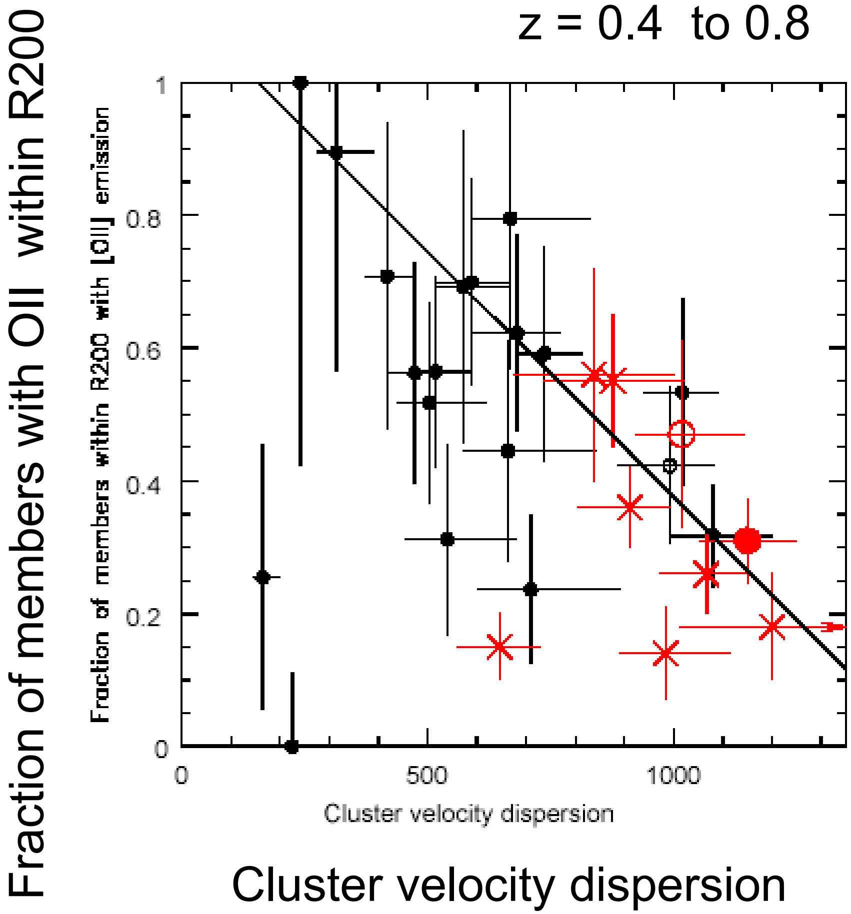
- within $R_{200} \sim R_{vir}$
- corrected for completeness
- to appropriately evolving galaxy magnitude limits
- no bias in galaxy sample
- good spectral quality and sufficient number of spectra per cluster

Fraction of star-forming galaxies vs cluster velocity dispersion

Fraction of cluster members with [OII] emission (= % of galaxies with ongoing SF**)**

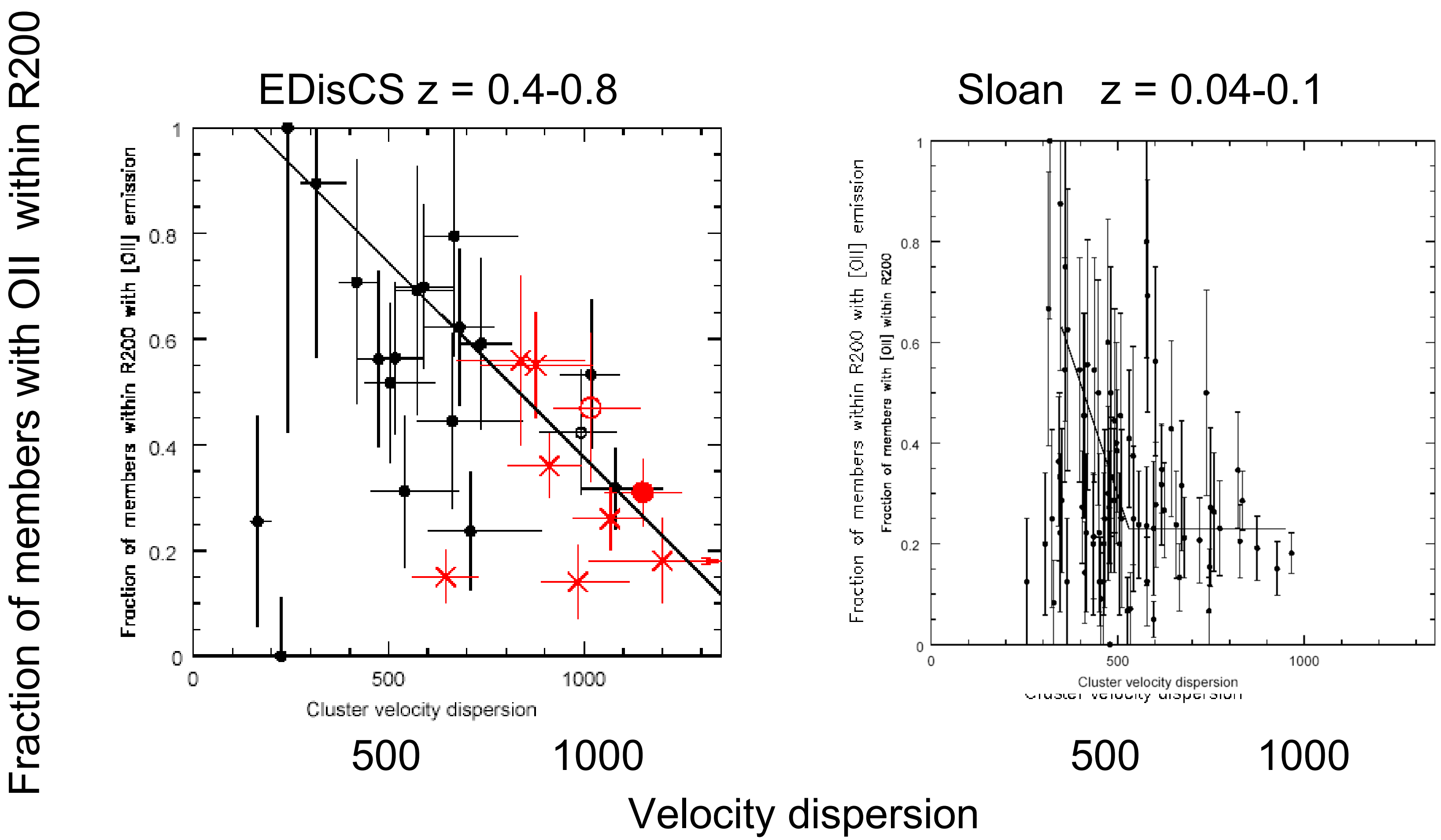
vs.

Cluster velocity dispersion



Poggianti et al. 2006

Evolution with z of the % of SF-ing galaxies



This might explain why it has been difficult to detect and quantify evolution…..

[OII] strength in different environments

The % of starforming galaxies changes with environment and z

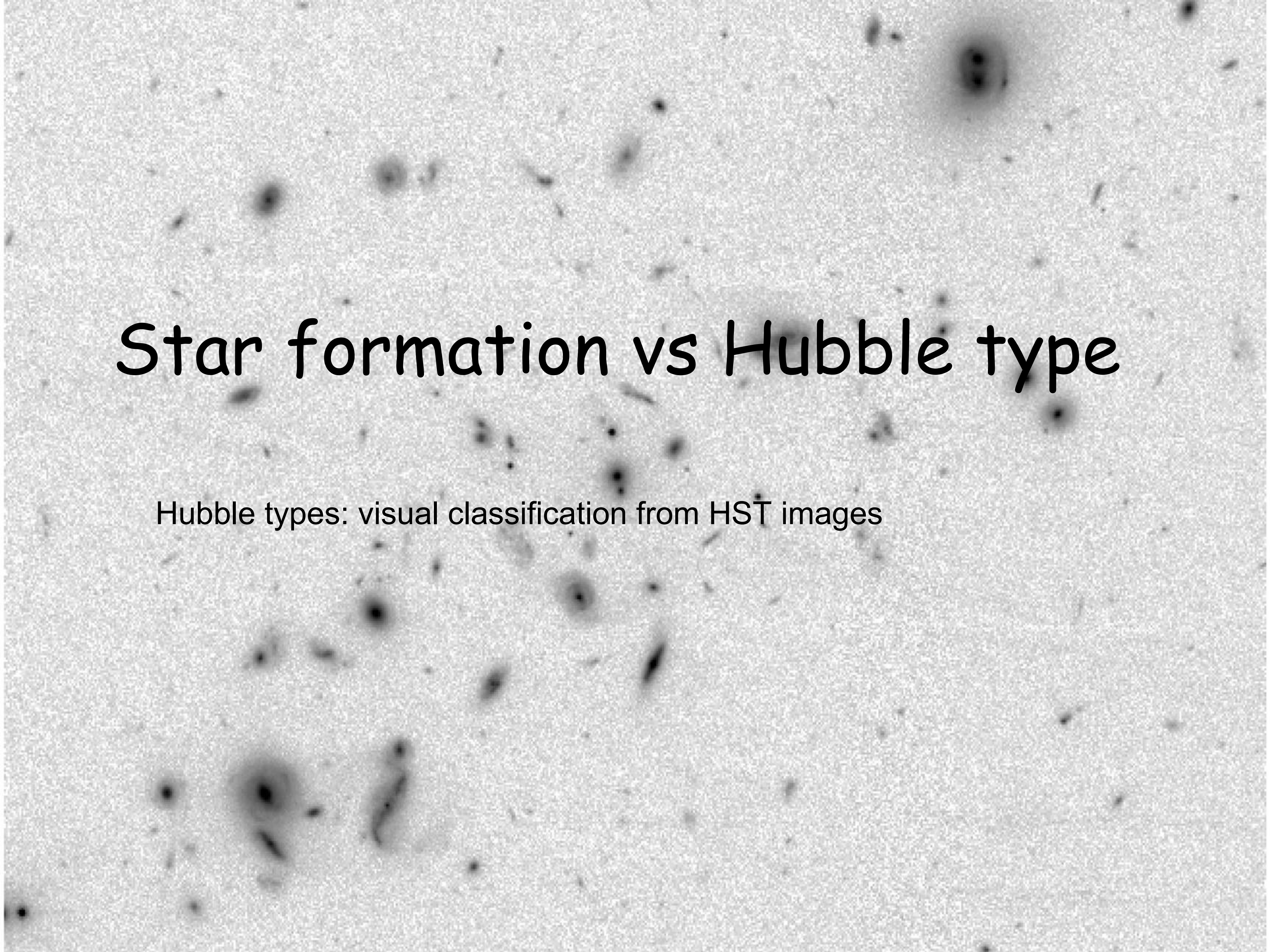
Does the SF activity in SFing galaxies change with environment?

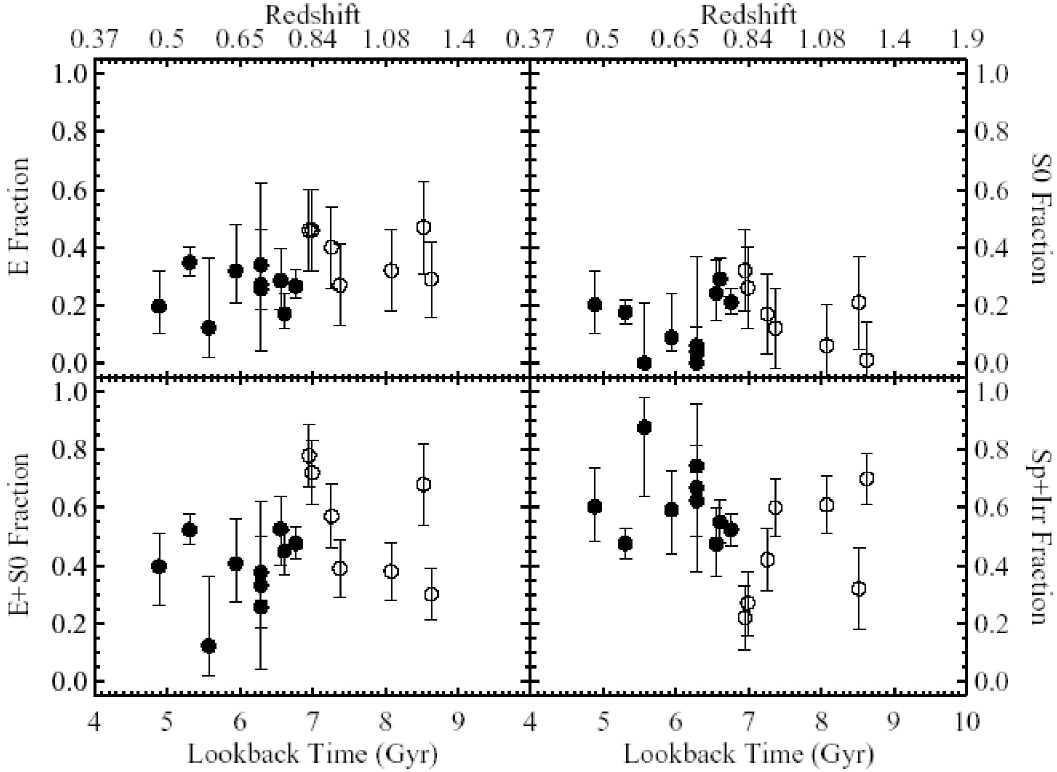
At z=0.4-0.8 it does.

Poggianti et al. 2006

Star formation vs Hubble type

Hubble types: visual classification from HST images



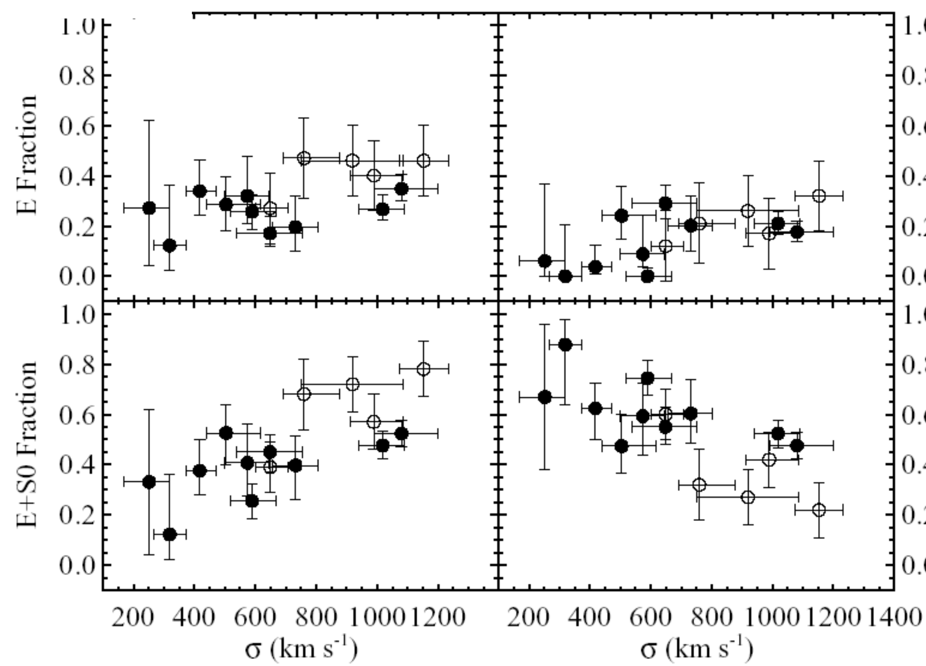


Desai et al. 2007

(Dressler et al. 1997, Fasano et al. 2000, Postman et al. 2005, Smith et al. 2005)

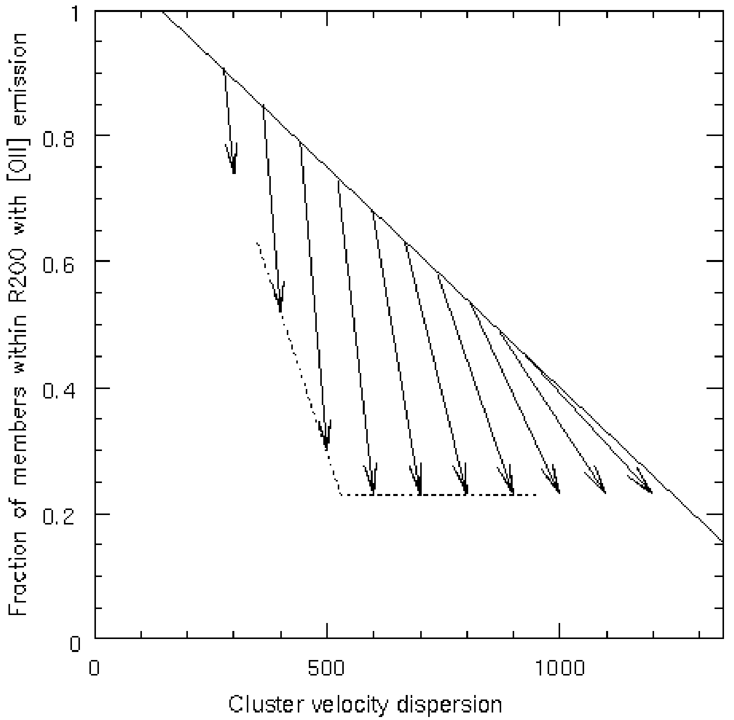
Morphological fractions vs redshift

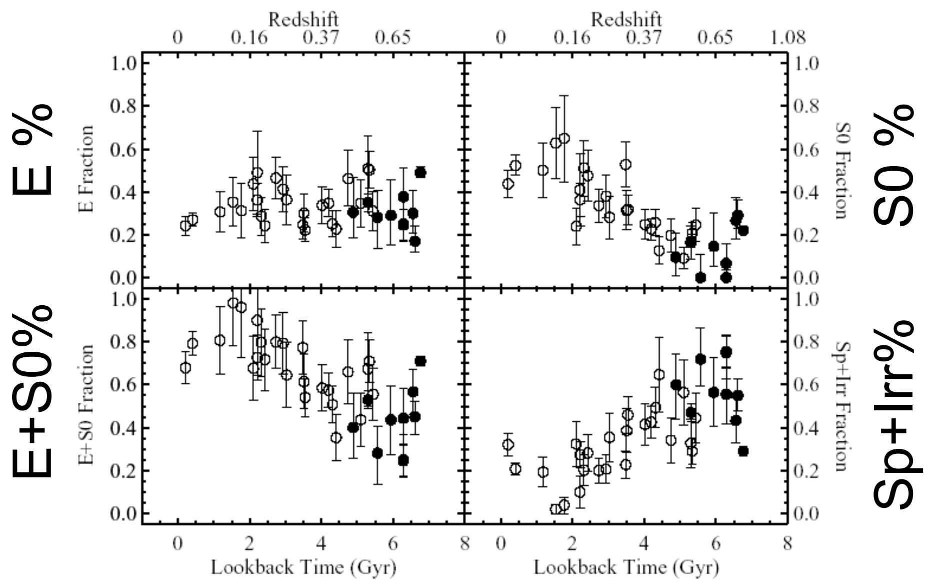
Downsizing (Smail et al. 1998, Poggianti et al. 2001, De Propris et al. 2003, Holden et al. 2007)



Morphologies vs cluster velocity dispersion at high-z

STAR-FORMATION and MORPHOLOGY

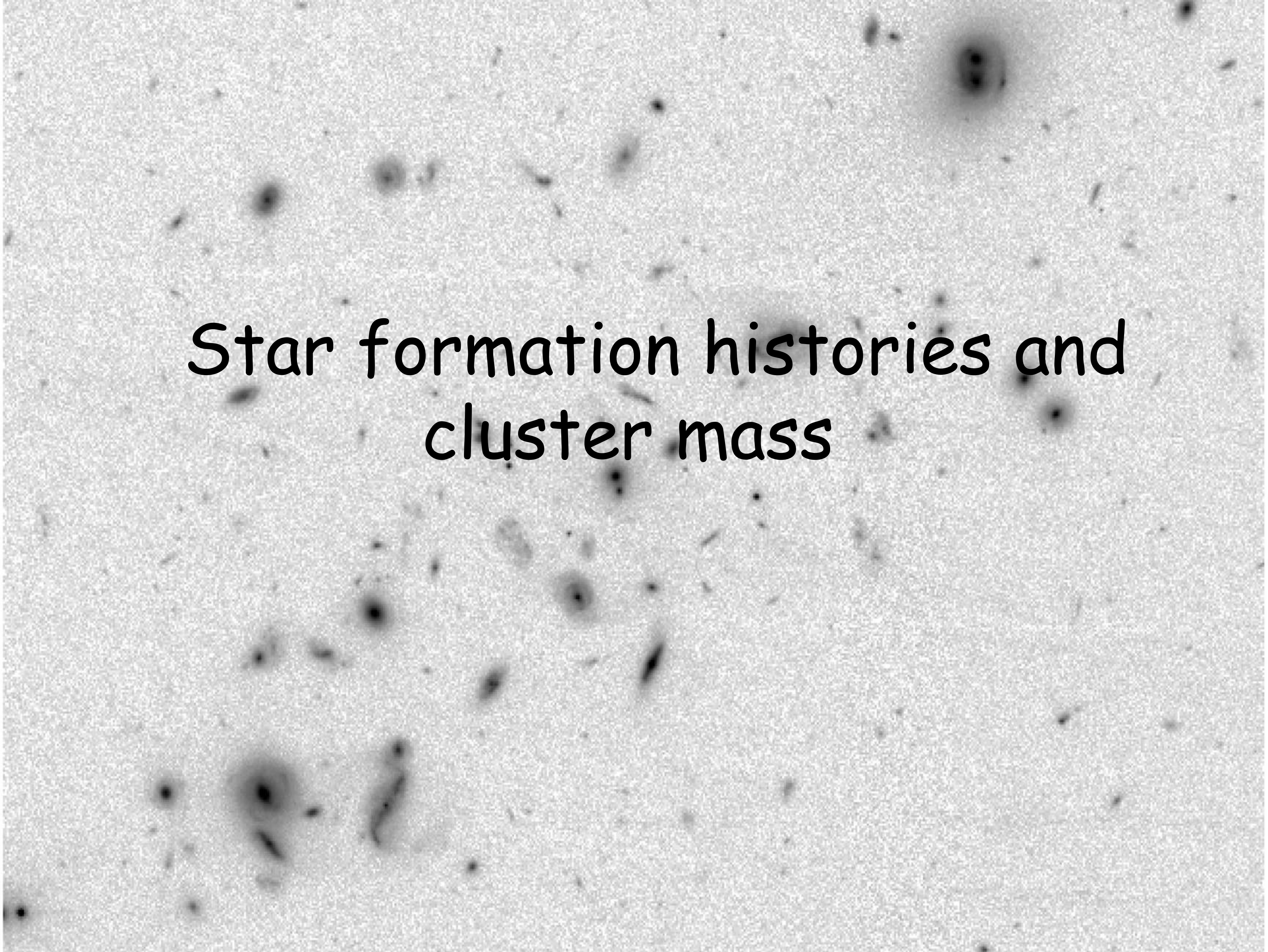


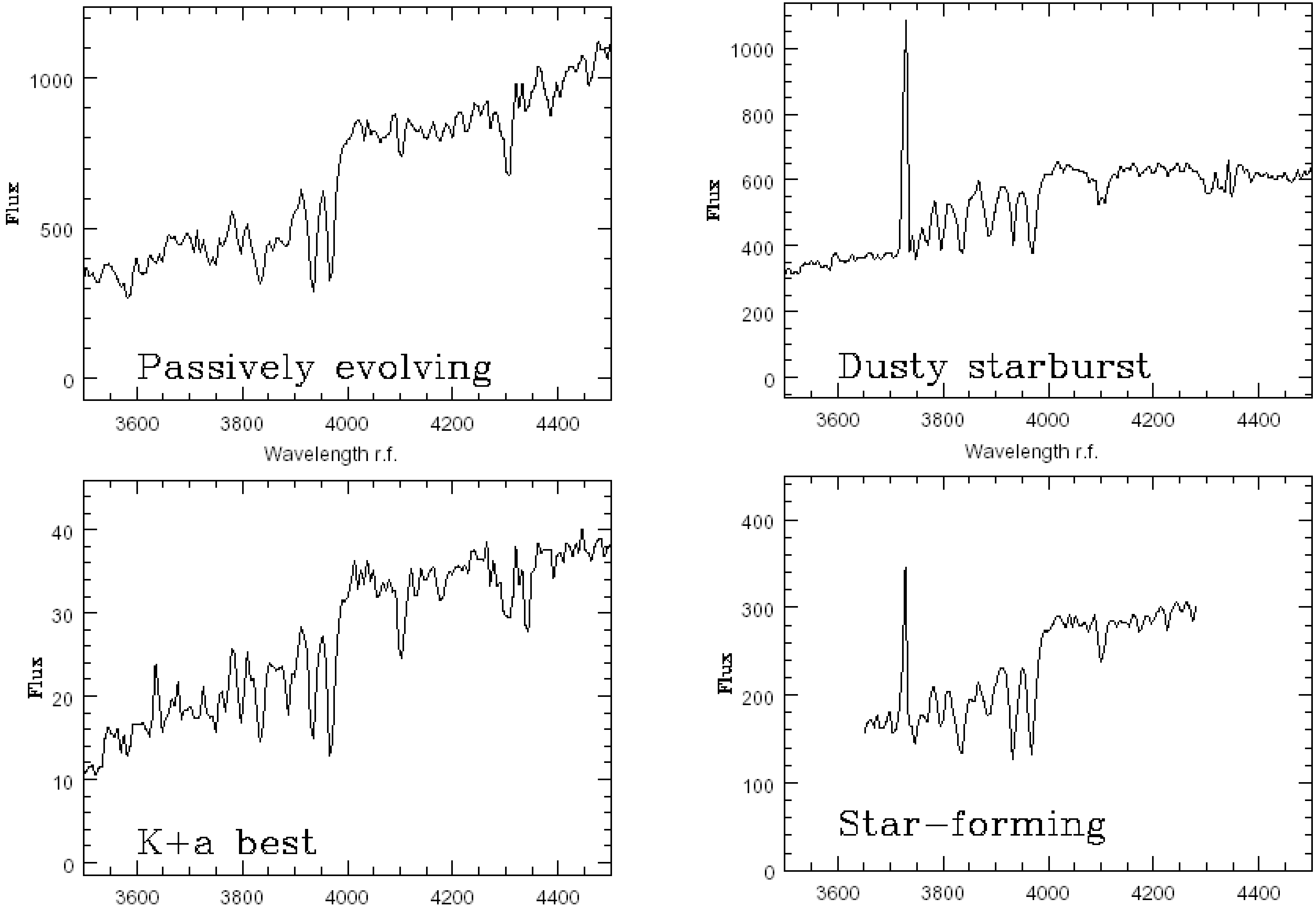


Observed spiral % ~ observed SF-ing % at all z's

Observed early-type % ~ observed passive % at all z's

Star formation histories and cluster mass





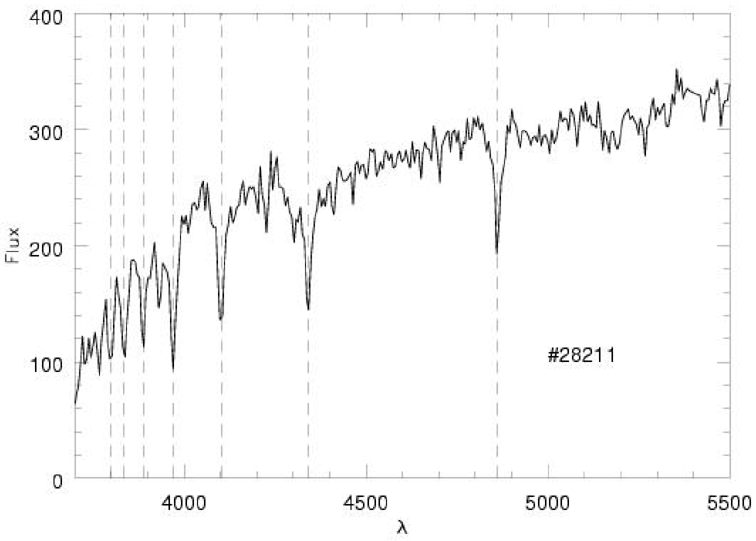
Poggianti et al. 2008b in prep.

POST-STARBURST GALAXIES IN PREVIOUS STUDIES

MORPHS clusters at z=0.4-0.5

starbursts 22% star—forming 10% post-starburst 25% passive 43%

Dressler et al. 1999, Poggianti et al. 1999



Post-starburst galaxies in clusters:

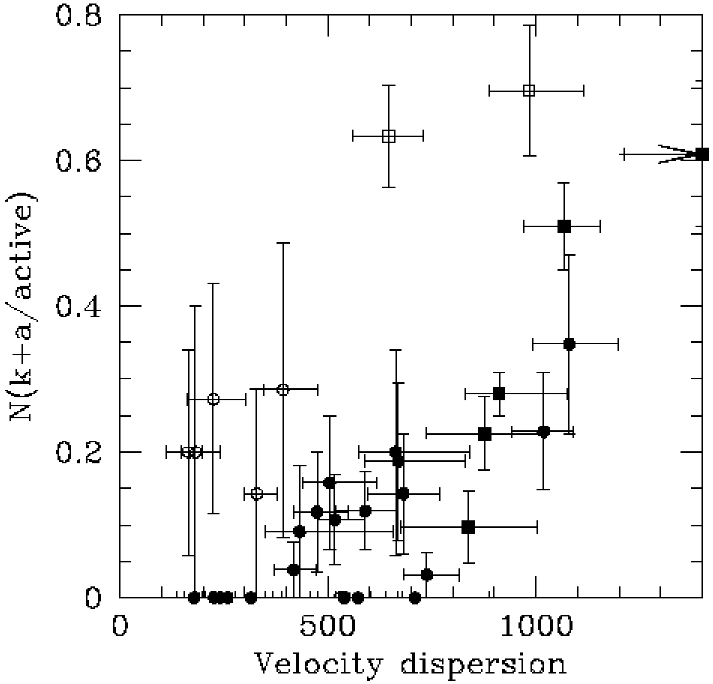
SF truncation in dense environments

In Coma, post-starbursts are **dwarf galaxies**

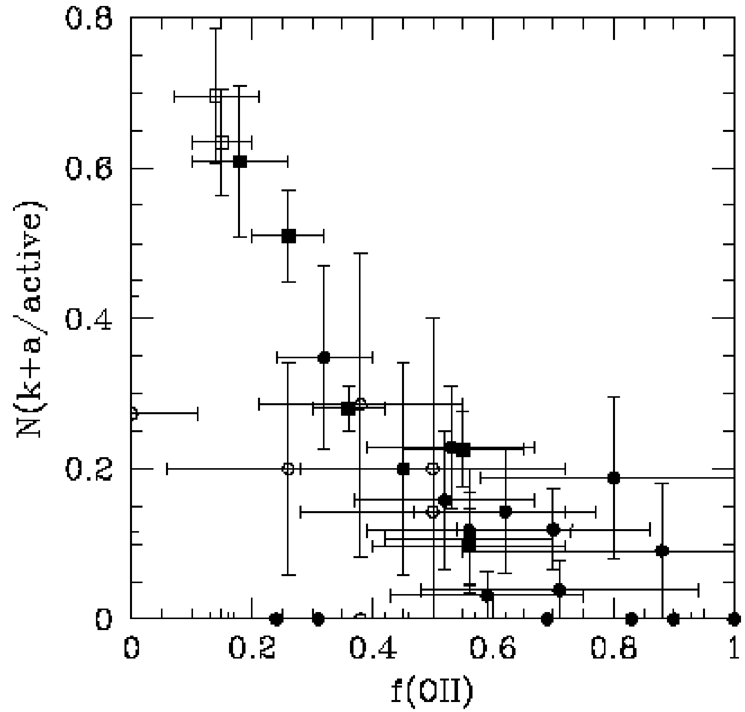
Relation with cluster substructure

Poggianti et al. 2004

In EDisCS clusters: **6% post-starburst**



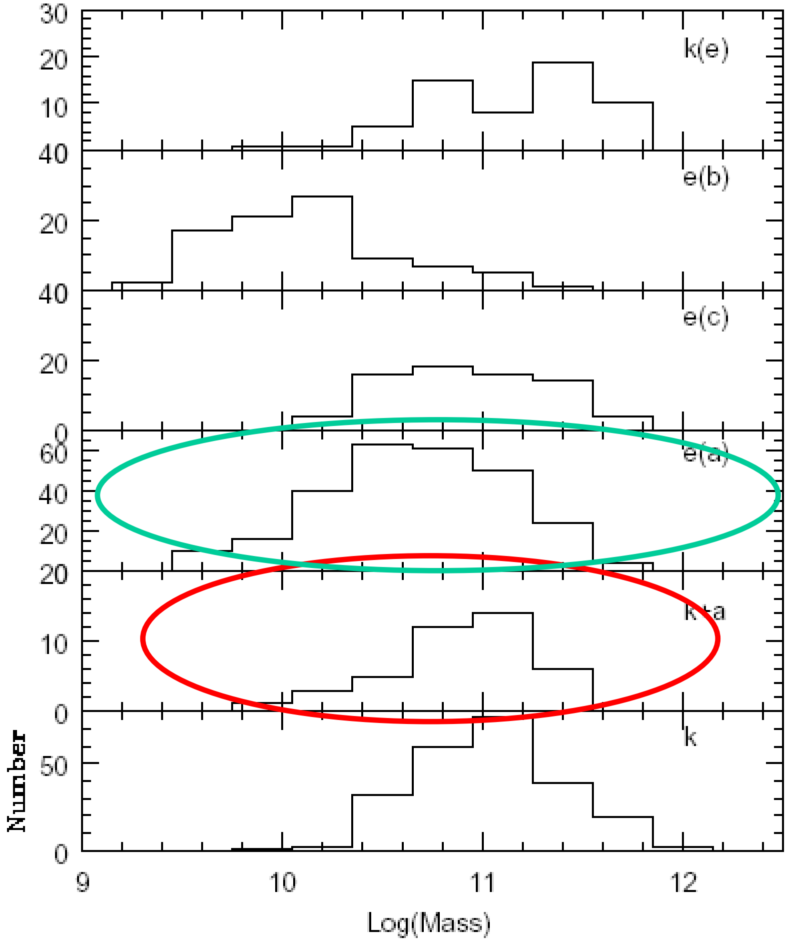
Post-starburst % among active



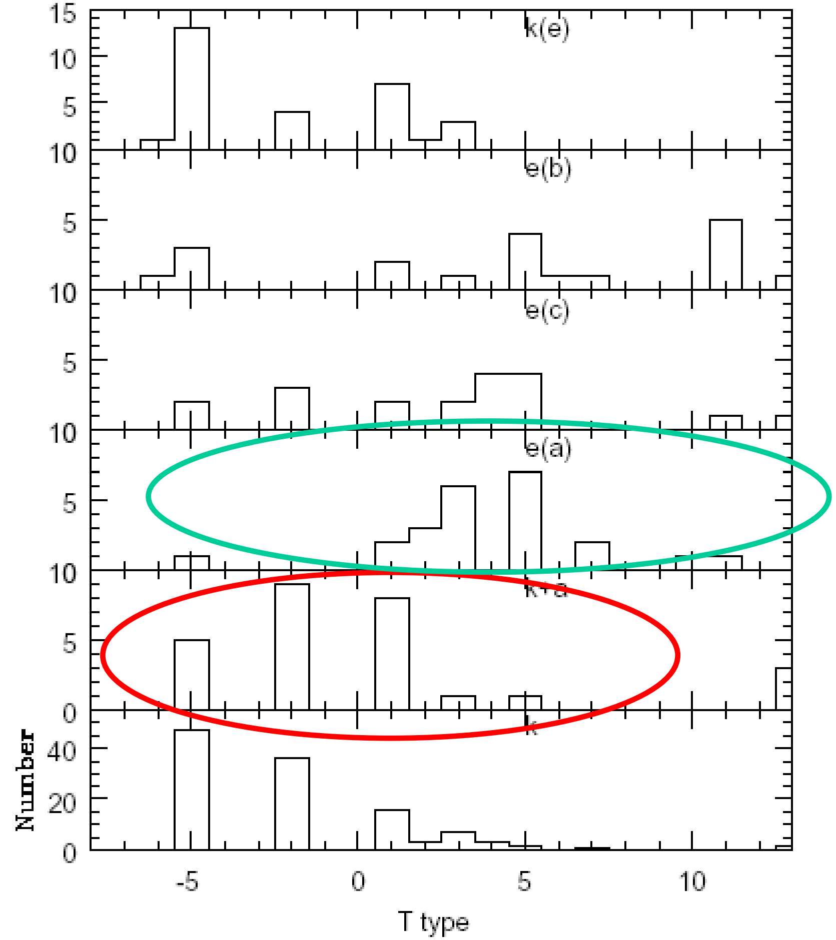
Dusty starburst % among emission

GROUPS LOW-OII	22±7	50±9
CLUSTERS	17±2	29±4
GROUPS HIGH-OII	0	45±10
POOR GROUPS	3±1	45 ±8
FIELD	7±1	15±6

MASS DISTRIBUTIONS

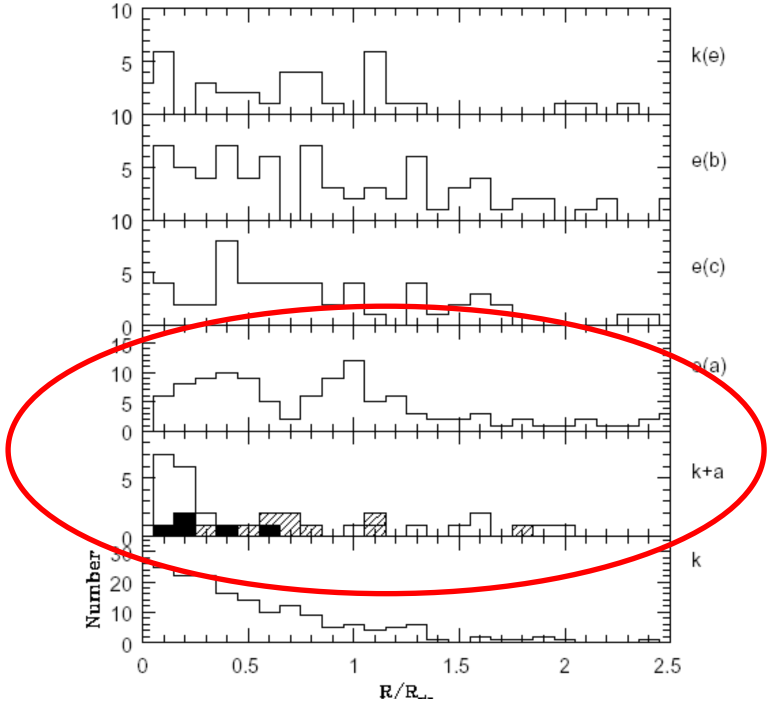


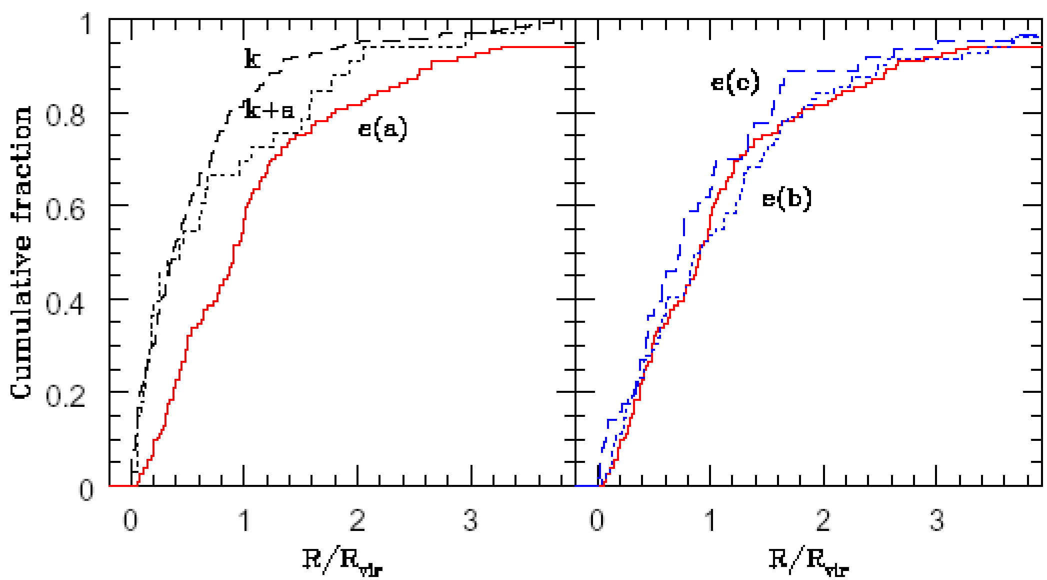
HUBBLE TYPES



Poggianti et al. 2008b in prep.

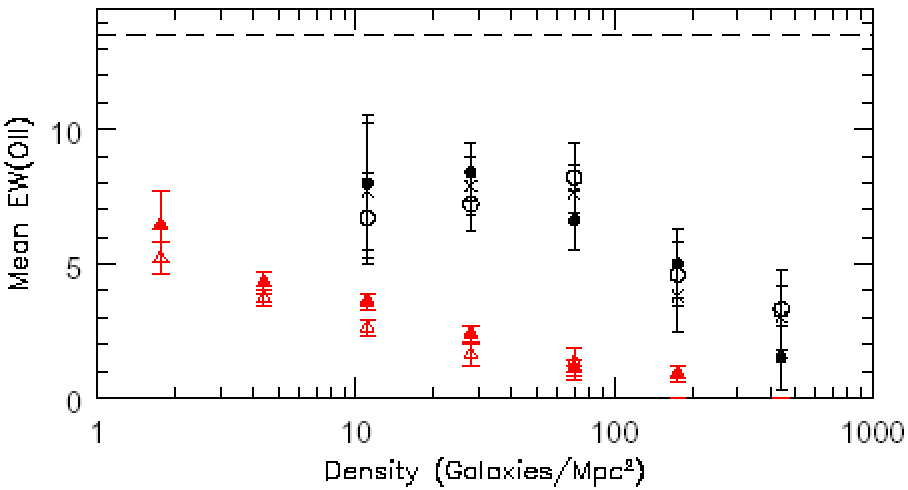
Radial distributions

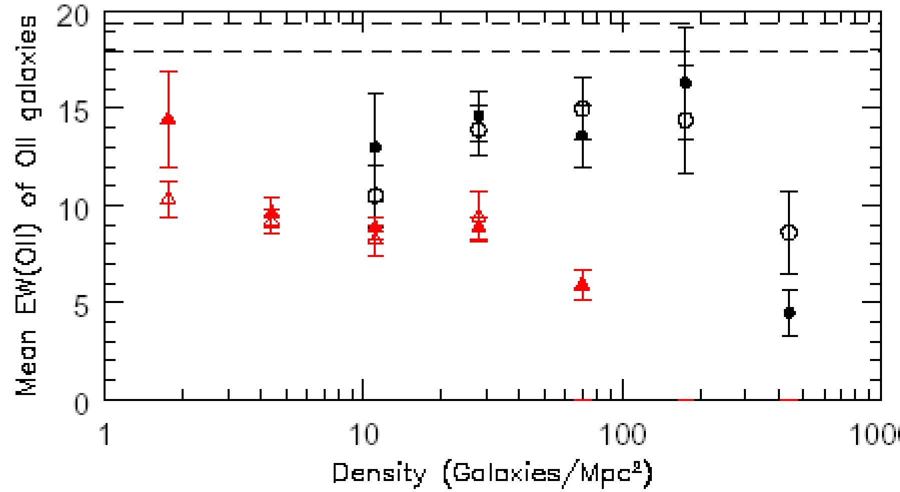


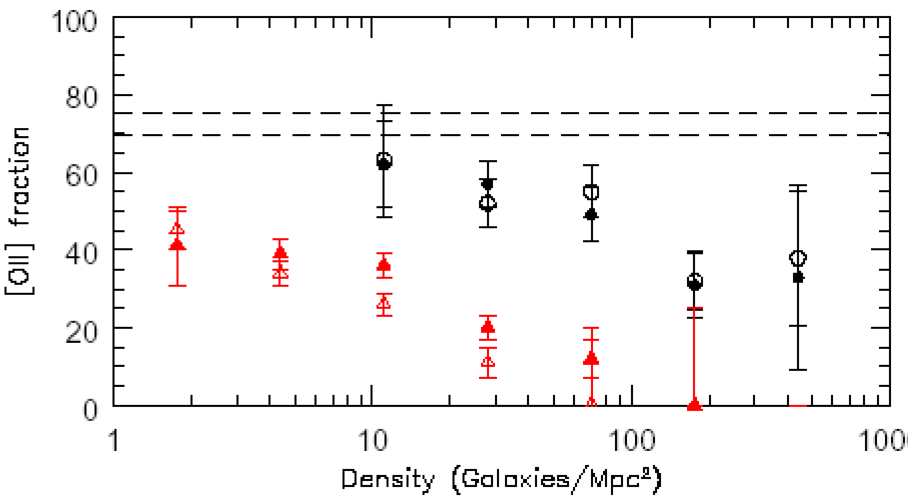


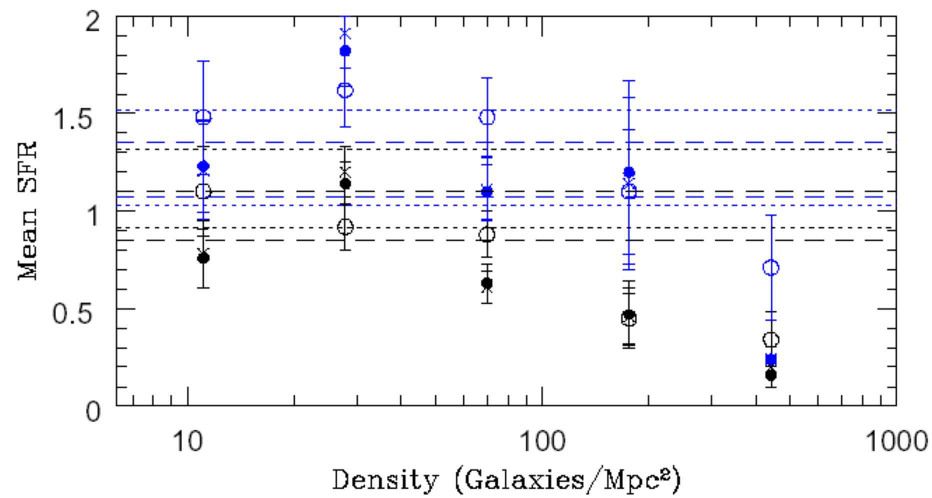
Star formation and local density in high-z clusters

Star formation and local density





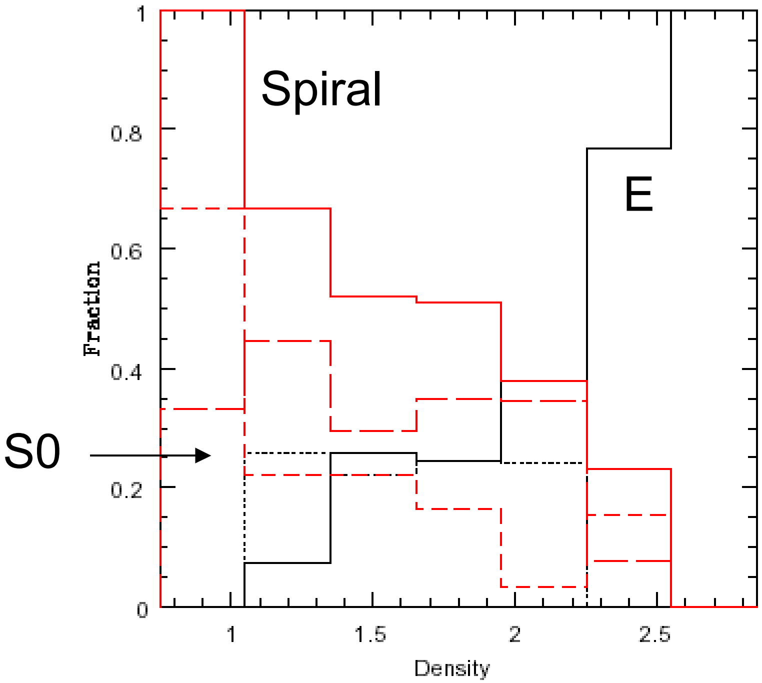


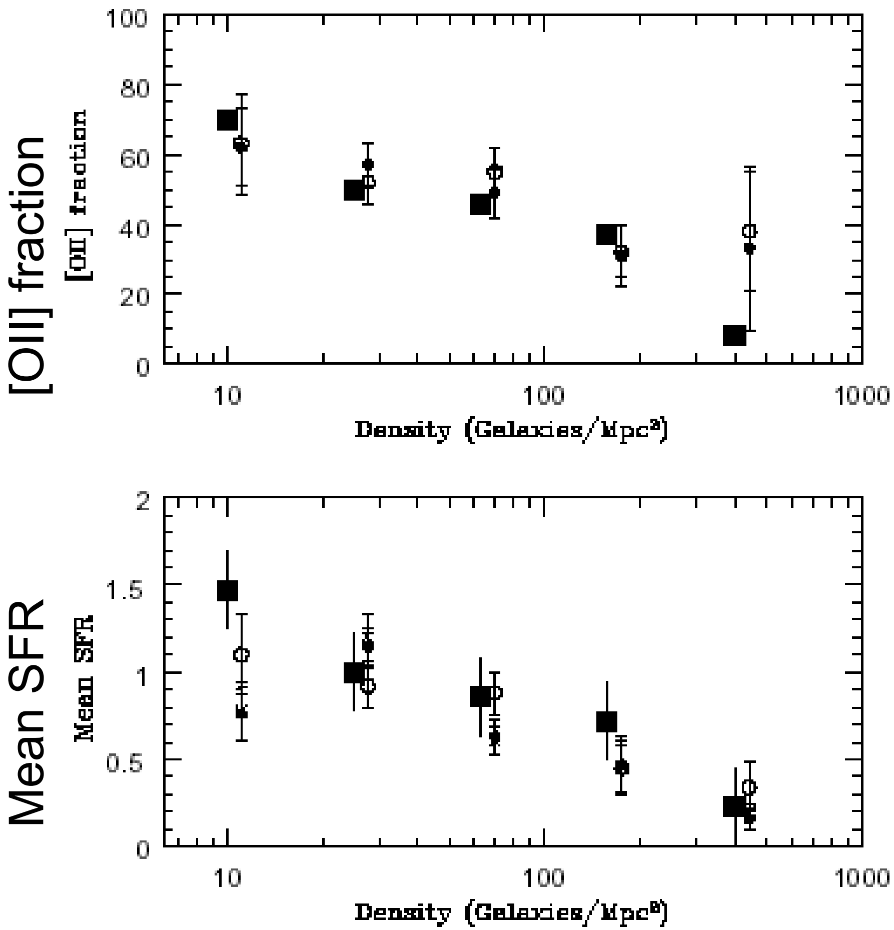


Caveat: AGN contamination

Poggianti et al. 2008a in prep.

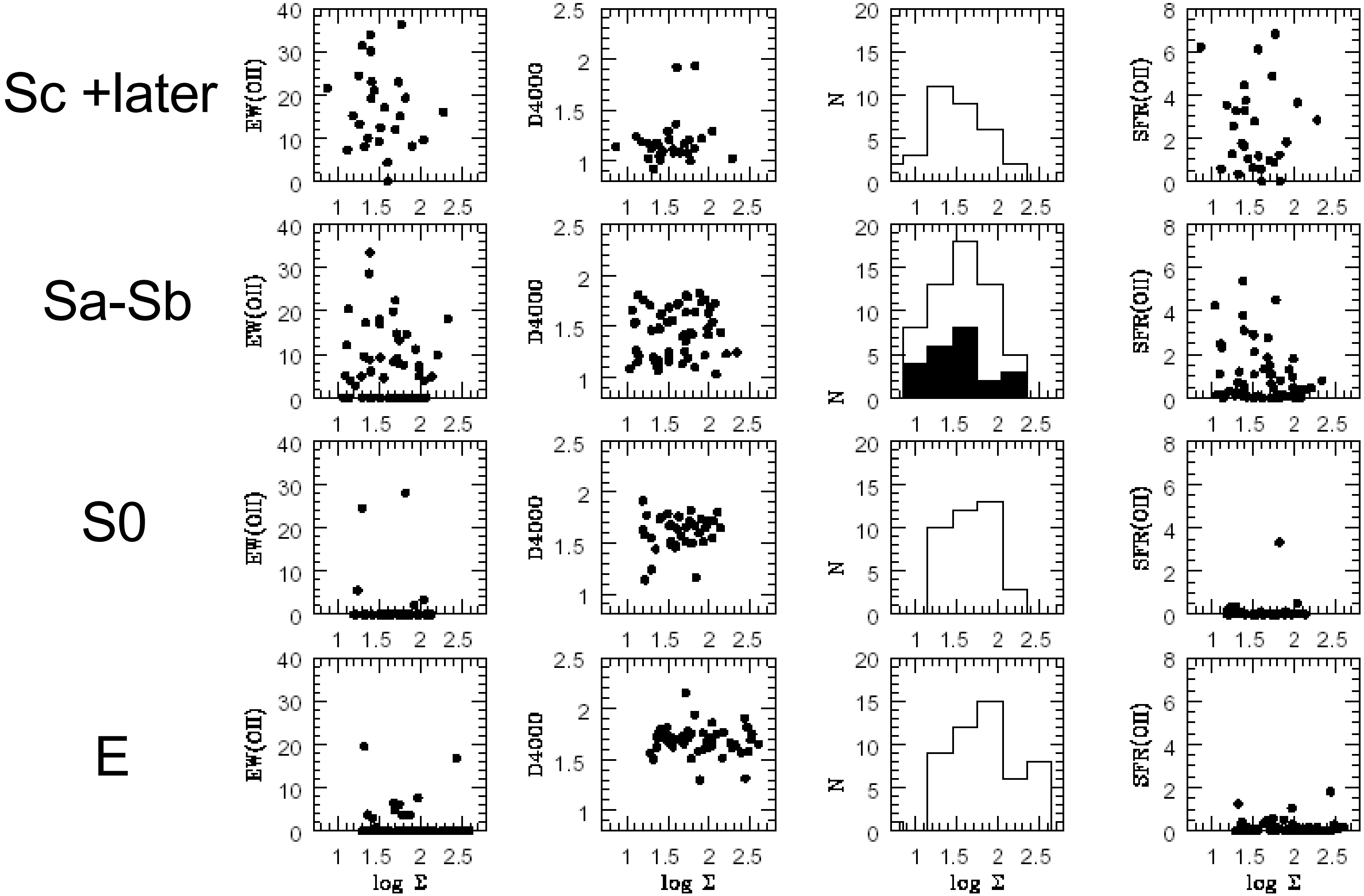
SF-density or Morphology-density?





Poggianti et al. 2008a in prep.

For a given Hubble type, no trend of SF with local density…



Poggianti et al. 2008a

The origin of the observed trends:

star formation activity and structure growth

Origin of SF-mass relations

If SF grossly depends on the mass of the system, there should be a connection between the SF trends and the growth history of structures

Searching for the link…..

Press-Schechter (Bower 1991, Lacey & Cole 1993) for mass fraction

Millennium Simulation (Springel etal 05,De Lucia et al. 2005) for galaxy fraction

A POSSIBLE SCENARIO

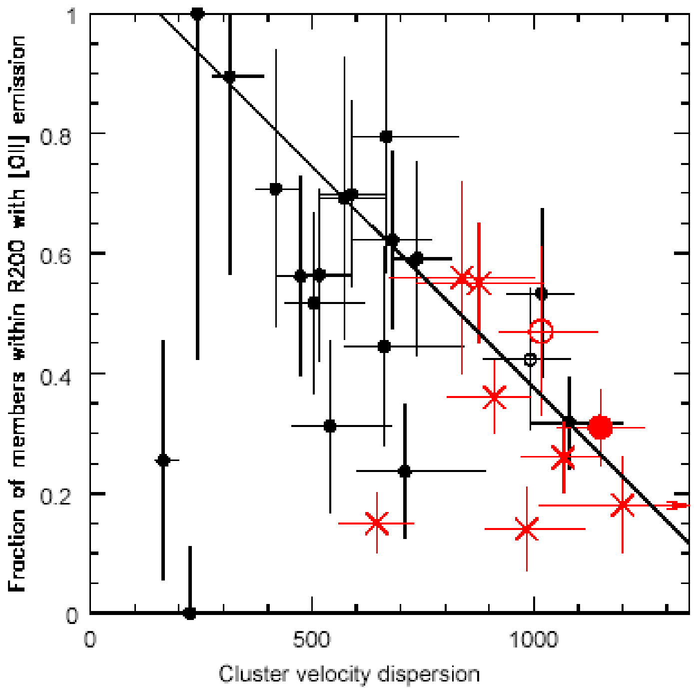
Two families of passive galaxies:

"Primordial" passive galaxies completed their SF at z>2
When primordial galaxies finished forming stars (z>2), the most massive systems were groups (M < 10^14)

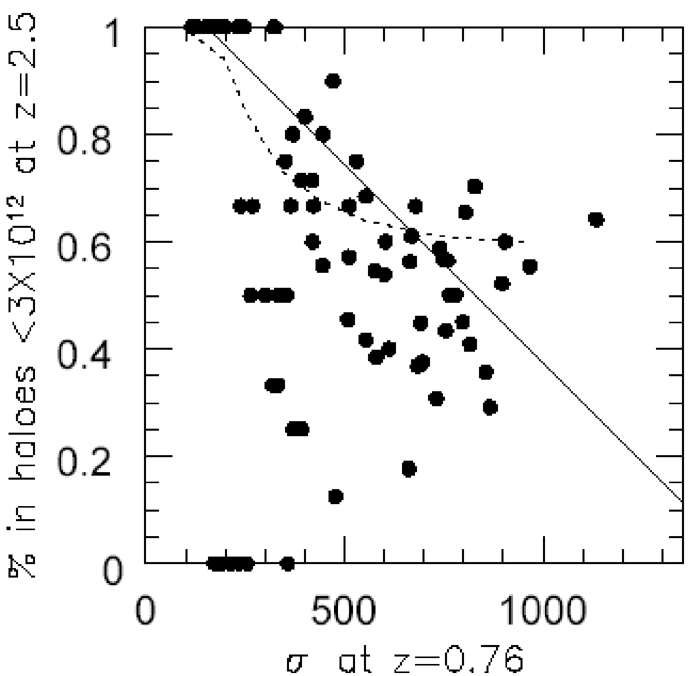
"Quenched" galaxies that stopped forming stars after they entered the dense environment for the first time. 500 km/s at z=0 corresponds to M~10^14 = reference mass for quenching. Below this mass, only SOME systems efficiently quench. 3 Gyr reasonable quenching timescale

Poggianti et al. 2006

A POSSIBLE SCENARIO



- The fraction of passive galaxies at high-z is determined by the fraction of mass/galaxies that were already in groups with M > 3 X 10^12 at z=2.5, + 30% quenched galaxies in most massive systems, and some groups.

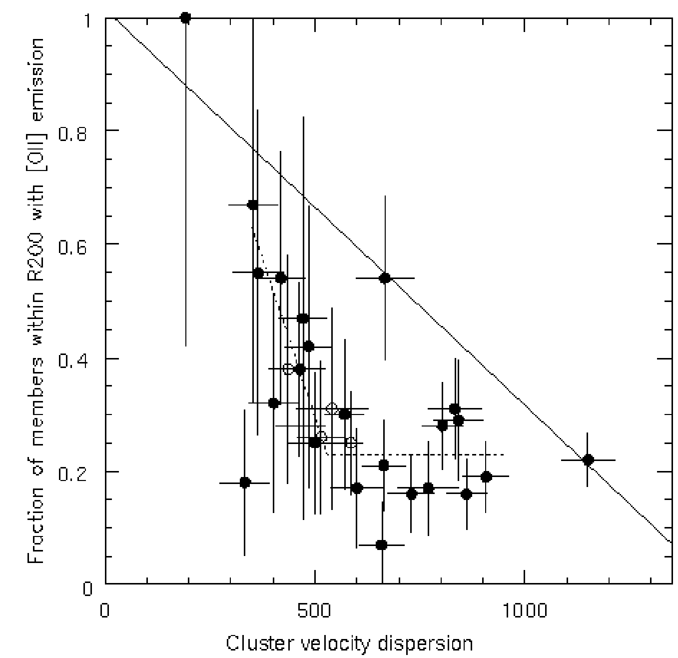


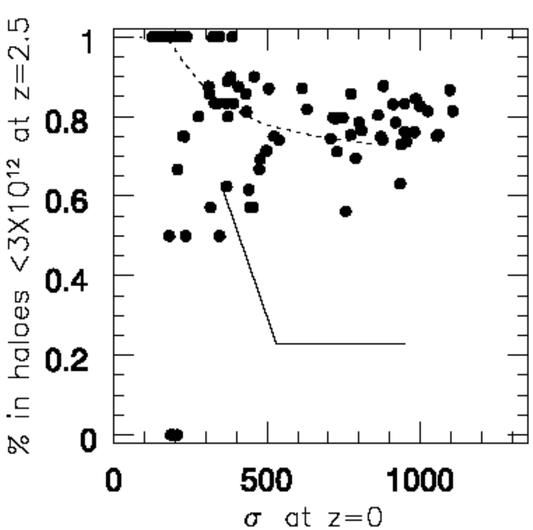
Poggianti et al. 2006

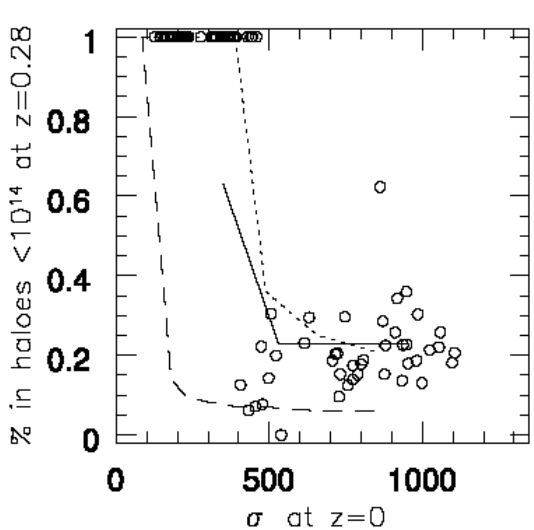
A POSSIBLE SCENARIO

- The fraction of passive galaxies observed at low-z agrees with the fraction of galaxies in clusters with M > 10^14 at z~0.28, i.e. 3 Gyr before z=0

- Of the 80% passive galaxies at low-z, 20% are primordial passive galaxies and 60% are quenched galaxies







Poggianti et al. 2006

SUMMARY

- **[OII]-sigma relation: <u>at high-z</u> the proportion of star forming galaxies largely depends on the mass of the system**

- **Strong evolution in the star forming fraction between z=0.8 and z=0**

- **Evolution of the star forming fraction consistent with the evolution of spirals**

- **Post-starburst galaxies at high-z: a massive cluster (and mini-cluster) phenomenon. Dusty starbursts universally found - but prefer group environment, related to mergers?**

- **Possible "simple" link between star formation activity in galaxies and history of growth of clusters and groups. <u>Primordial</u> and <u>quenched</u>: two channels, different epochs and timescales, two typical halo masses, two morphologies. (The two channels of ICM metal enrichment?)**