Observing the link between halo assembly and galaxy evolution

Daniele Pierini

Max-Planck-Institut für extraterrestrische Physik

in collaboration with (particularly):
H. Böhringer (MPE), F.G. Braglia (UBC), A. Finoguenov (MPE), S. Giodini (MPE), G.W. Pratt (CEA), D. Wilman (MPE), S. Zibetti (MPIA)

Layout

Introduction

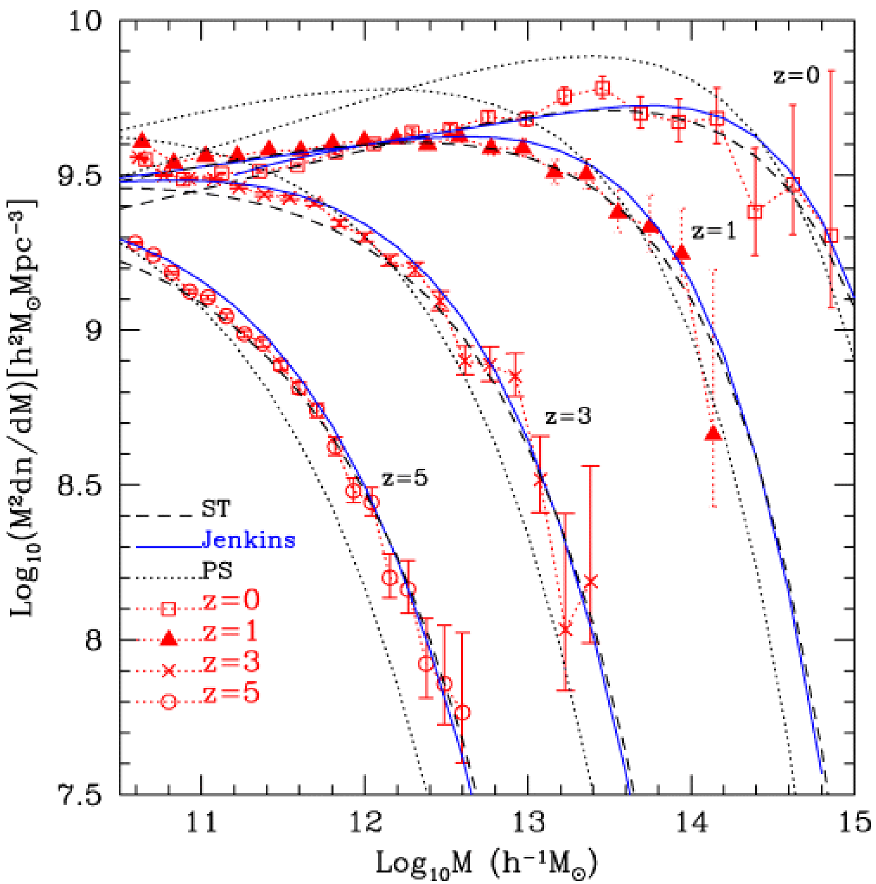
Massive clusters of galaxies at intermediate z: halo assembly and galaxy populations

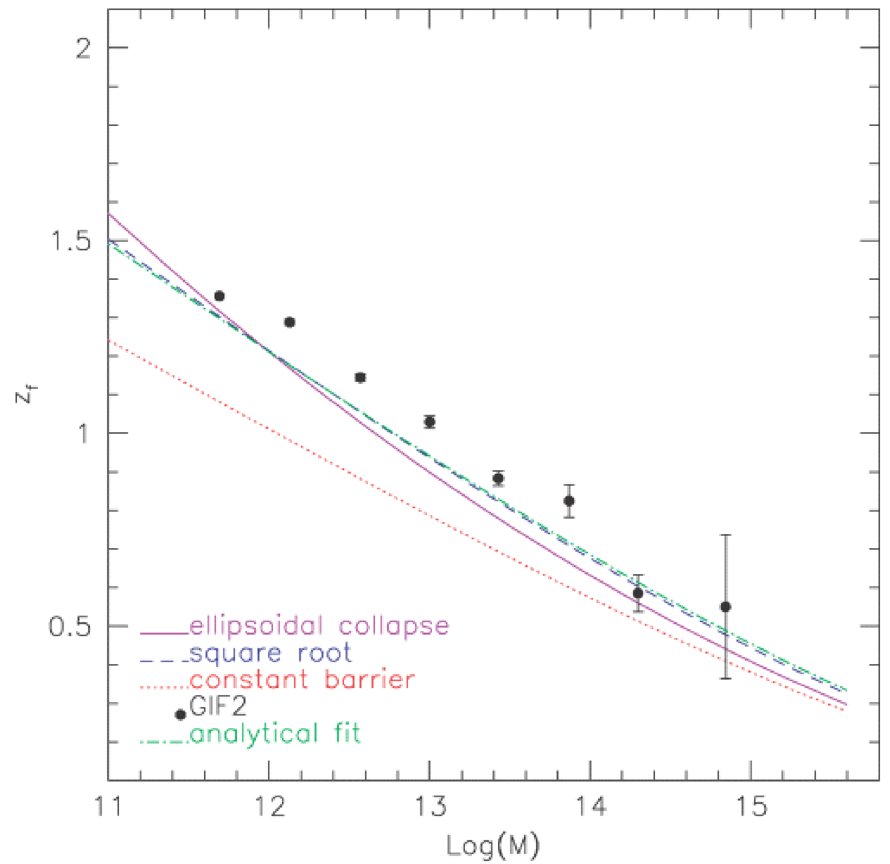
Groups as drivers of (massive) galaxy evolution

Fossil groups: laboratories for sharpened tests of CDM universes and baryon physics

Conclusions and outlook

Dark matter halos: assembly time I.

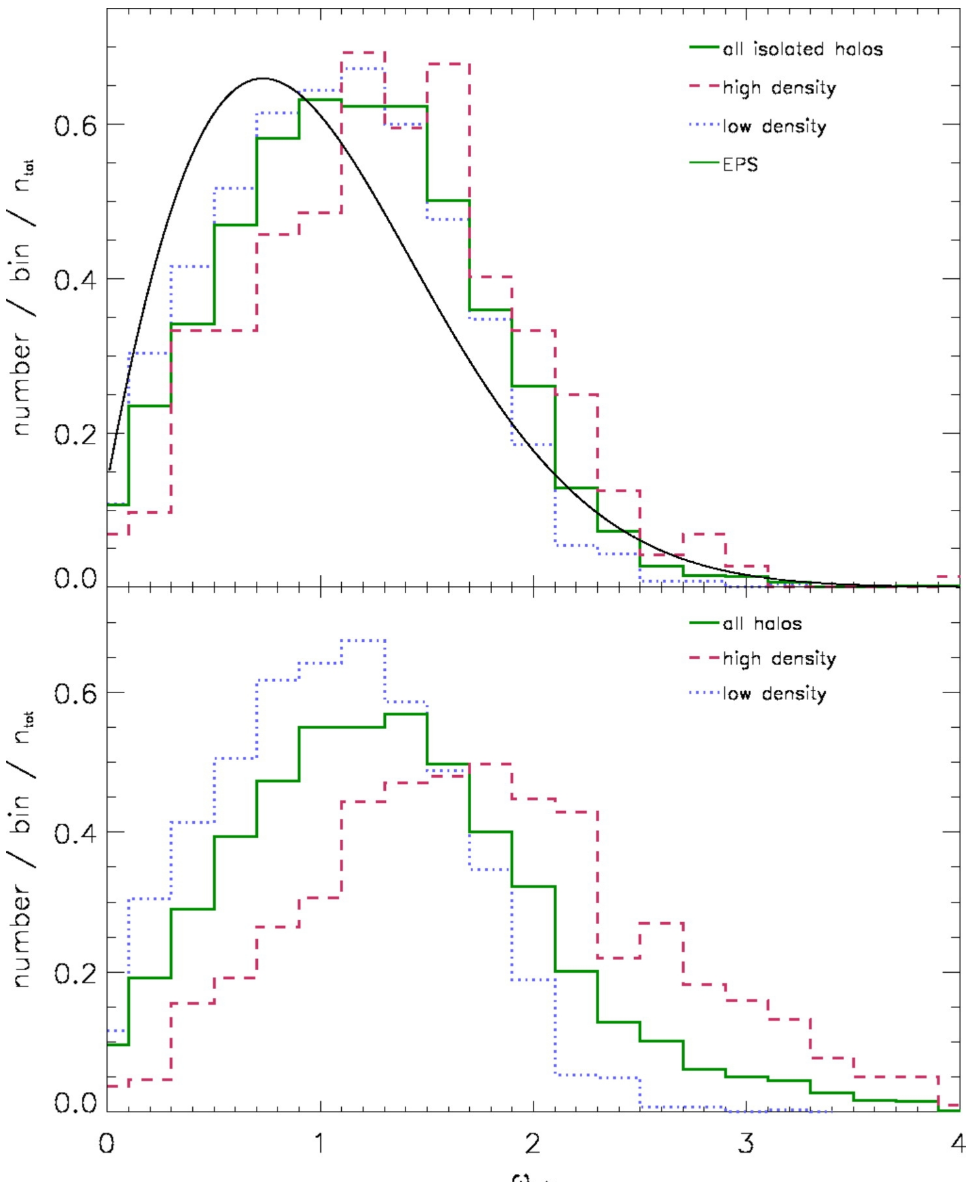




In the standard cold dark matter (CDM) scenario (White & Rees 1978), structure in our Universe formed hierarchically.

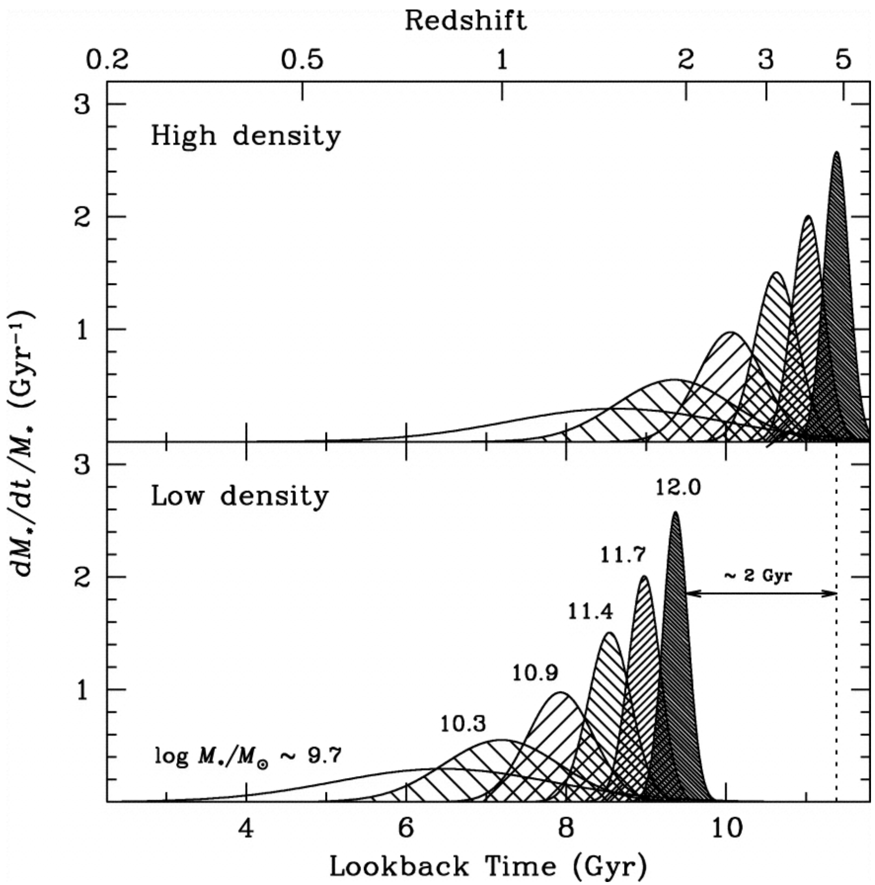
Massive halos are expected to have formed more recently (Press & Schechter 1974; Gao et al. 2004; Giocoli et al. 2007).

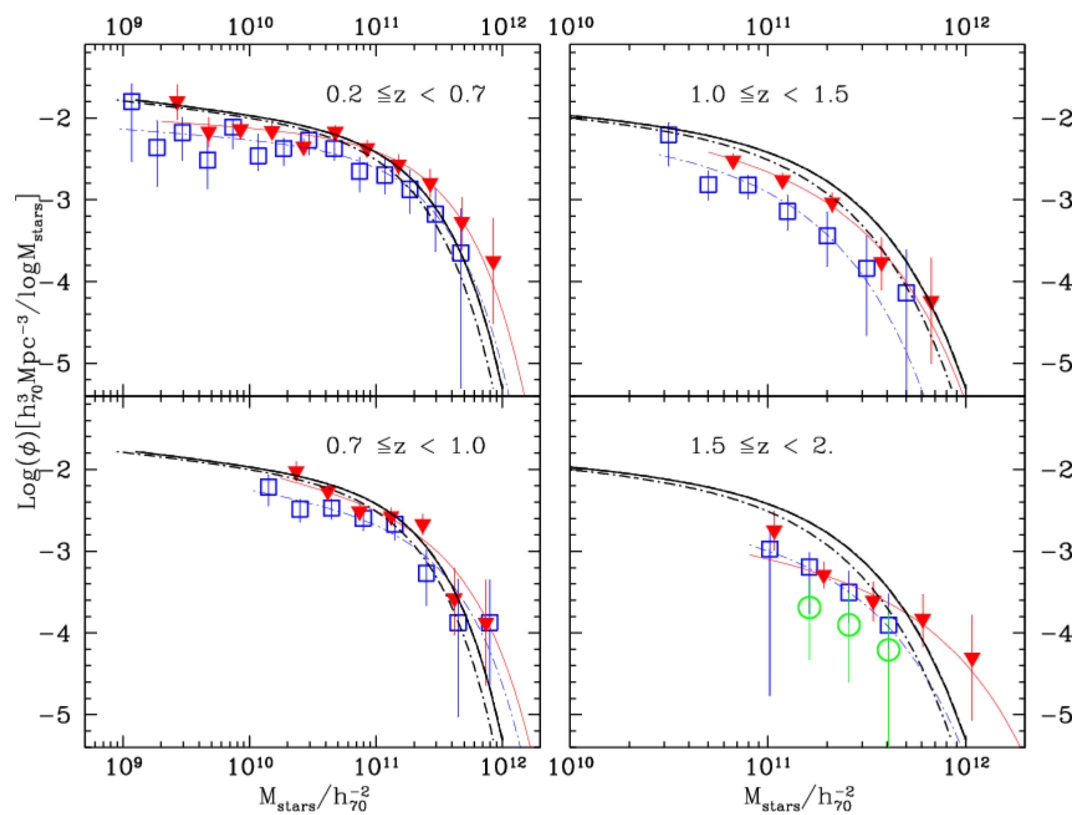
Dark matter halos: assembly time II.



The mass assembly histories of galaxy-sized CDM halos depend also on environment (Maulbetsch et al. 2007).

Galaxies: stellar mass build-up

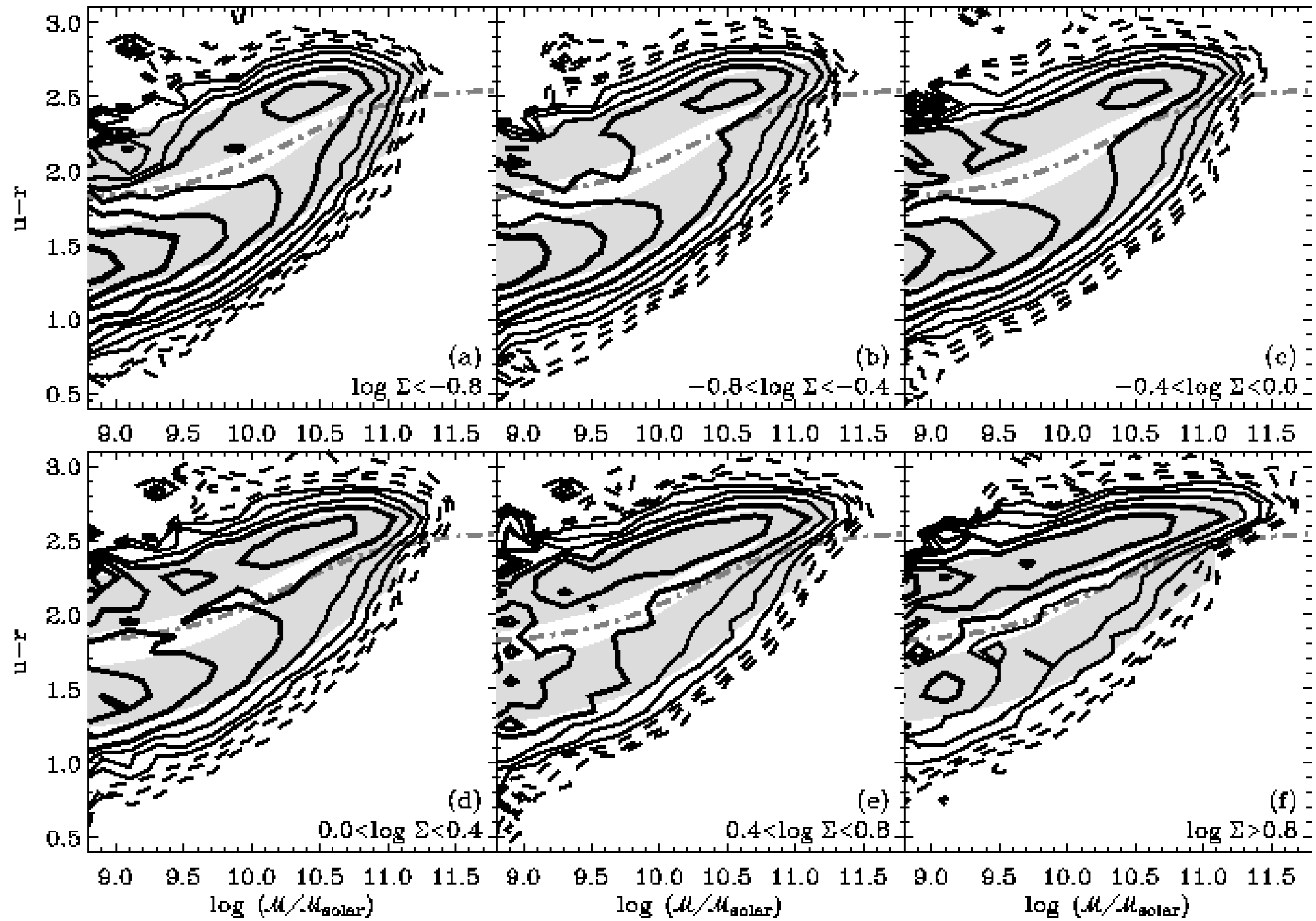




Analysis of the stellar populations in early-type galaxies at z=0 reveals that most of their stars were formed at 3<z<5 (1<z<2) in high (low) density environments, significant stellar mass growth at z<1 being limited to low mass objects (Thomas et al. 2005).

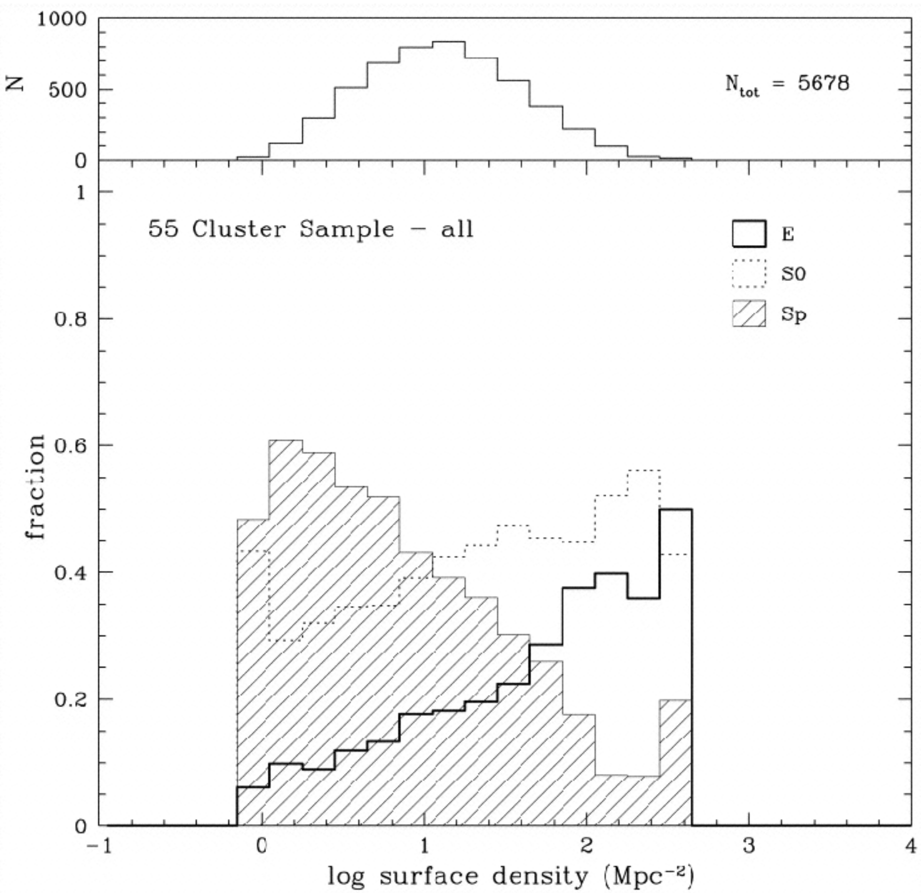
Massive galaxies are already in place at z~2 (Fontana et al. 2004).

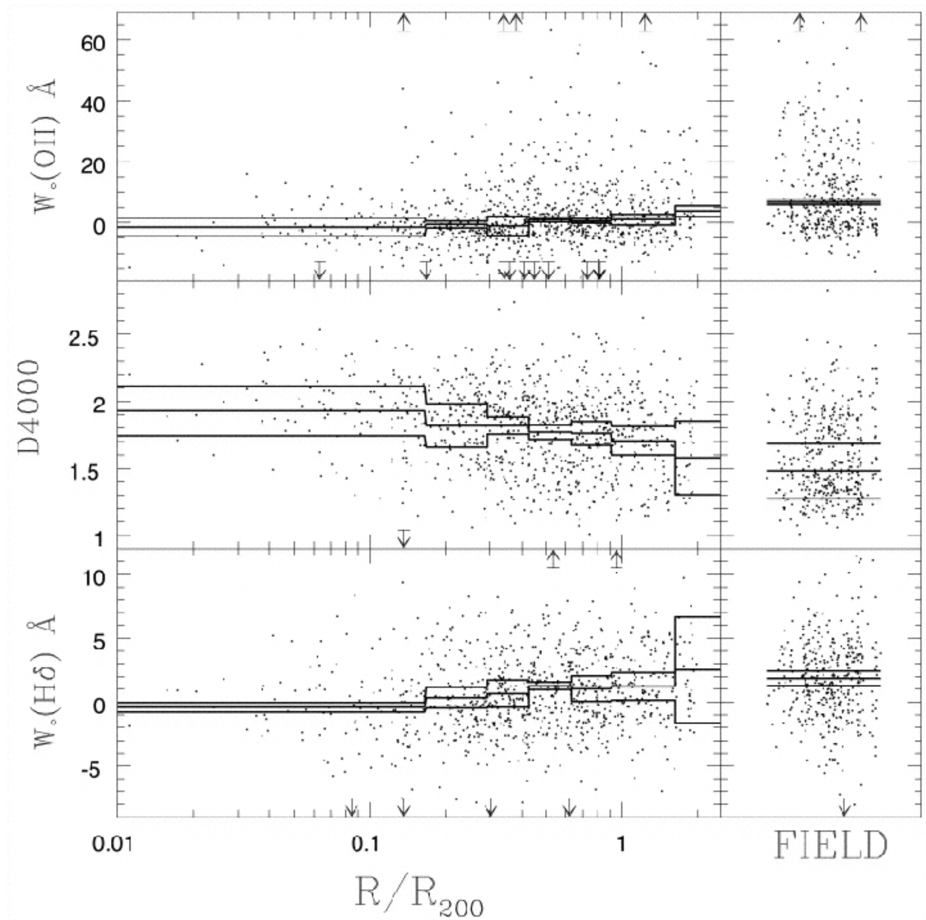
Galaxies in different environments I.



The observed galaxy bi-modality vs stellar mass and environment is qualitatively reproduced by semi-analytical models based on N-body simulations incorporating feedback from star formation and AGN (Baldry et al. 2006).

Galaxies in different environments II.





Existence of a relationship between morphology and density (Dressler 1980; Dressler et al. 1997) or cluster-centric distance.

Existence of a relationship between star formation mode and cluster-centric distance or environment (Balogh et al. 1999).

Some open questions I.

What feedback? How? When? Where?

Quasar mode (early, impulsive) vs radio mode (intermittent) – (Kauffmann & Haehnelt 2000; Di Matteo, Springel & Hernquist 2005; Bower et al. 2006; Croton et al. 2006; Sijacki & Springel 2006; Puchwein, Sijacki & Springel 2008)

Supernova mode (distributed winds) or starburst mode (localized super wind) – (Mac Low & Ferrara 1999; Springel & Hernquist 2003; Croton et al. 2006)

Pressure driven or momentum driven winds – (Aguirre et al. 2001; Veilleux, Cecil & Bland-Hawthorn 2005; Oppenheimer & Davé 2006; Dalla Vecchia & Schaye 2008)

Some open questions II.

What baryon processes in what halos?

Gravitational (tidal) interactions (galaxy-galaxy, galaxy-cluster, harassment) – (Spitzer & Baade 1951; Richstone 1976; Farouki & Shapiro 1981; Merritt 1983; Icke 1985; Merritt 1984; Miller 1986; Byrd & Valtonen 1990; Moore et al. 1996, 1998, 1999)

Hydrodynamic interactions between a galaxy ISM and the ICM (ram pressure, viscous stripping, thermal evaporation) – (Gunn & Gott 1972; Nulsen 1982; Cowie & Songaila 1977)

Starvation – (Larson et al. 1980; Balogh et al. 2000; Bekki et al. 2002)

Preprocessing – (Mihos 2004; Fujita 2004; Dressler 2004)

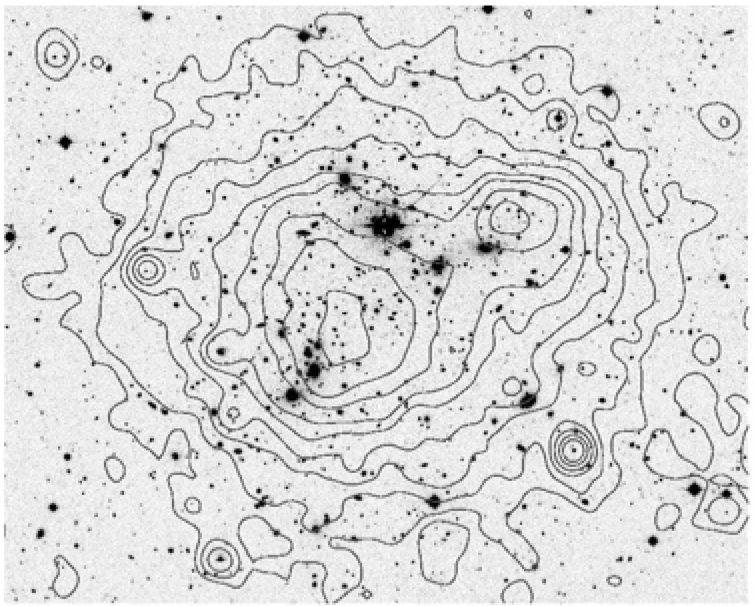
X-ray selected clusters at $z \leq 0.3$

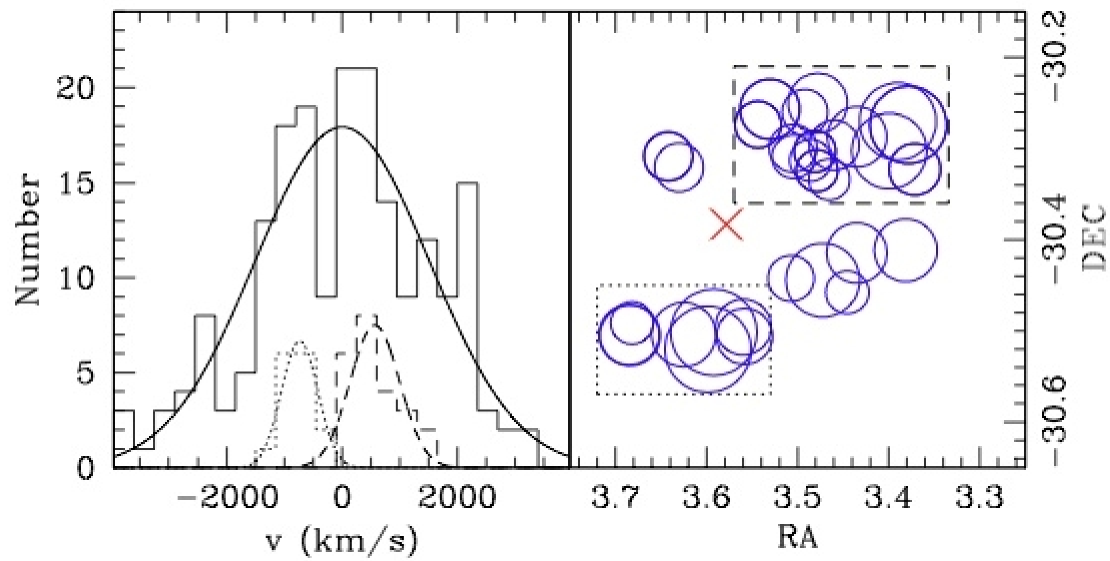
REXCESS: the representative XMM-Newton cluster structure survey: 33 galaxy clusters at $0.055 \leq z \leq 0.183$ with $L(0.1 \div 2.4$ keV$) > 0.44 \times 10^{44}\ h_{70}^{-2}$ erg s^{-1} (Böhringer et al. 2007)

DXL: an unbiased, flux-limited, almost volume-complete sample of 13 distant ($z \sim 0.3$), X-ray luminous clusters from the REFLEX survey, observed with XMM-Newton (Zhang et al. 2006)

Data: X-ray spectro-imaging cashed; wide-field optical imaging almost complete; on-going multi-object spectroscopy

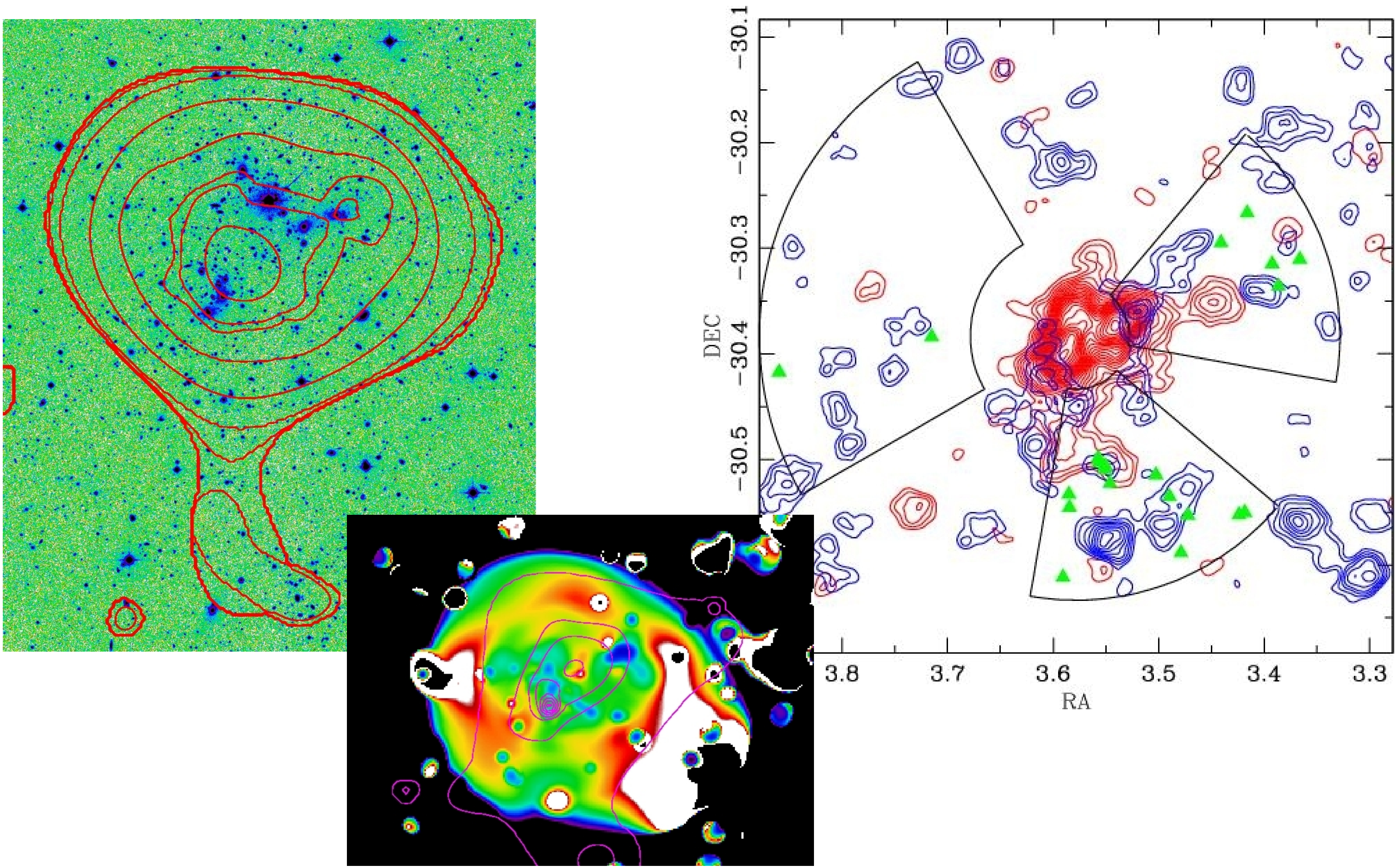
Abell 2744: the “trainwreck” cluster



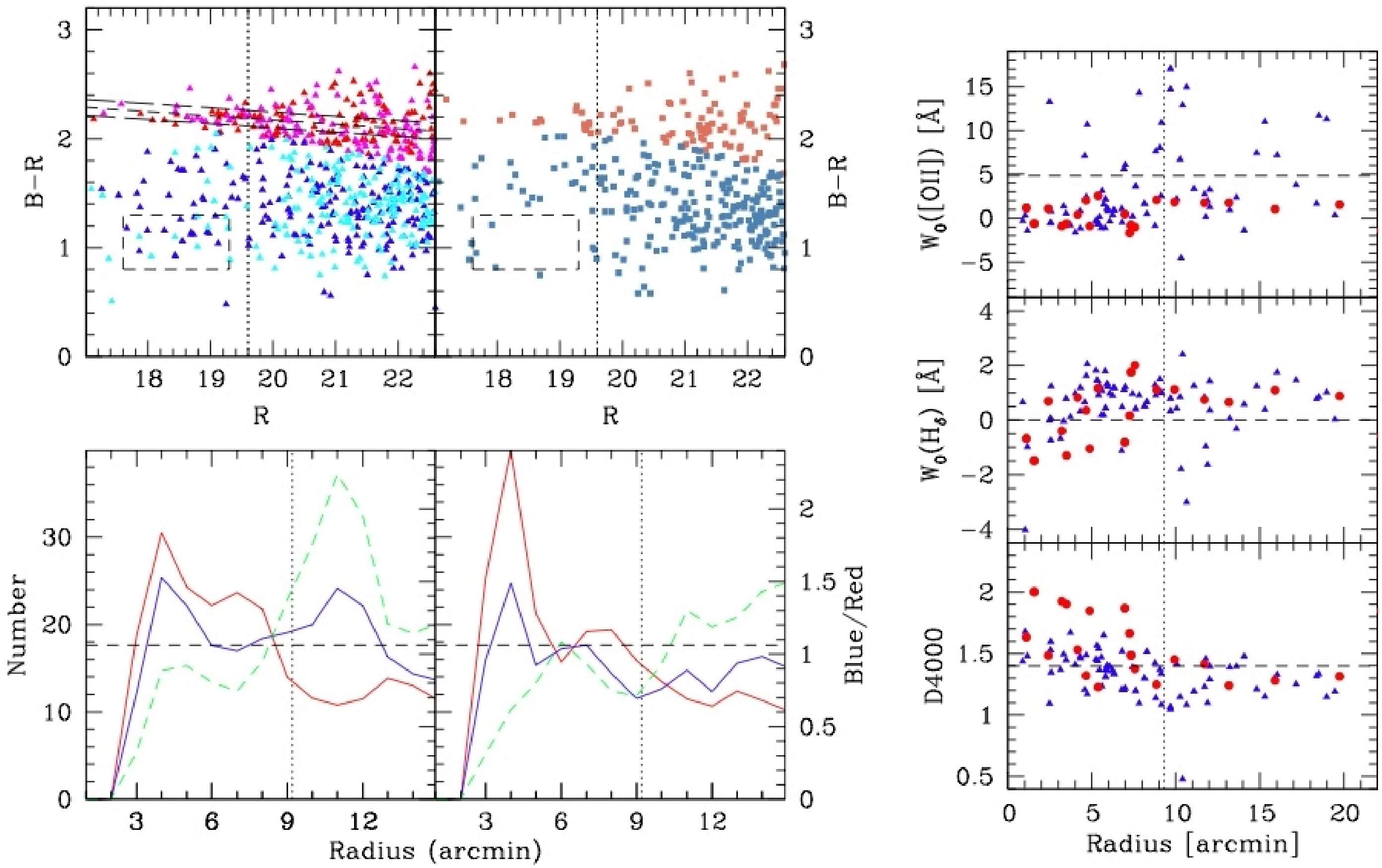


Clear evidence of substructure (X-ray surface brightness and entropy maps, multiple BCGs, Dressler & Shectman test; 2D distribution of photometric members) in this DXL merging cluster (Böhringer, Braglia, DP, et al. 2006; Braglia, DP, Böhringer 2007).

A2744: filamentary structure



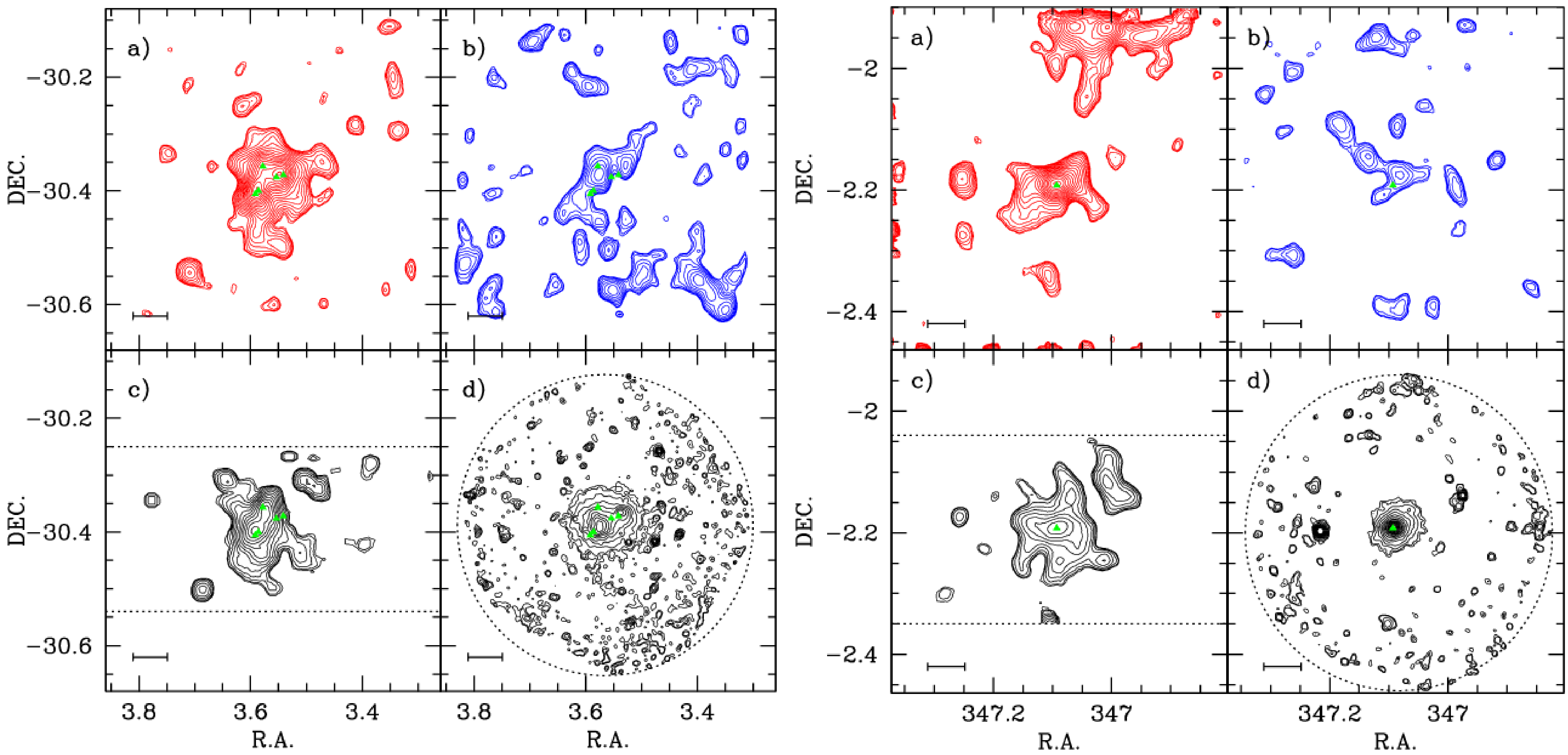
A2744: substructure & stellar pop's



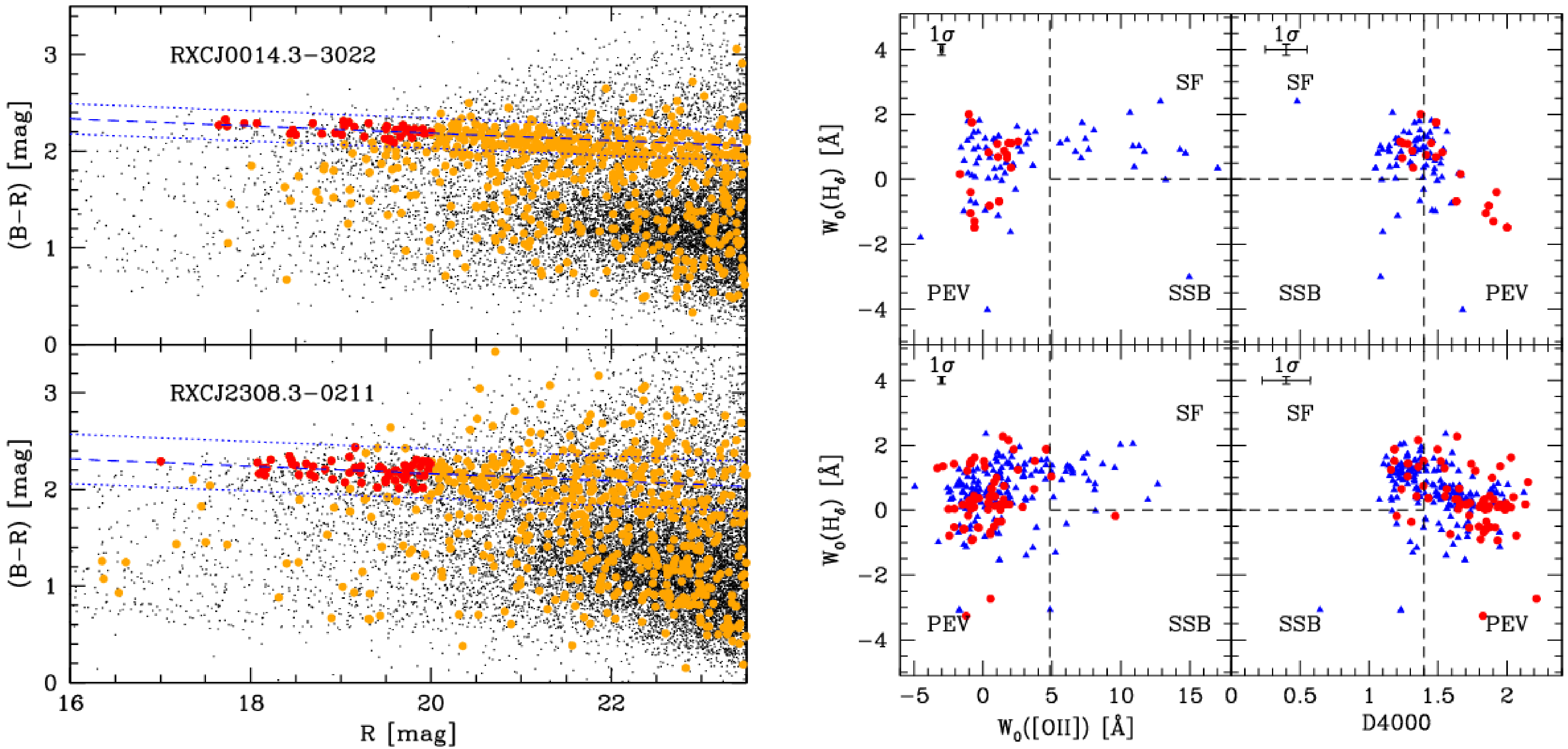
Increased star formation activity wrt the field along filaments and beyond R_{200} : harassment or infalling group?

Similar findings in a few superclusters and clusters (Kodama et al. 2001; Porter & Raychaudhury 2007; Fadda et al. 2008)

Halo assembly & galaxy pop's I.



Halo assembly & galaxy pop's II.



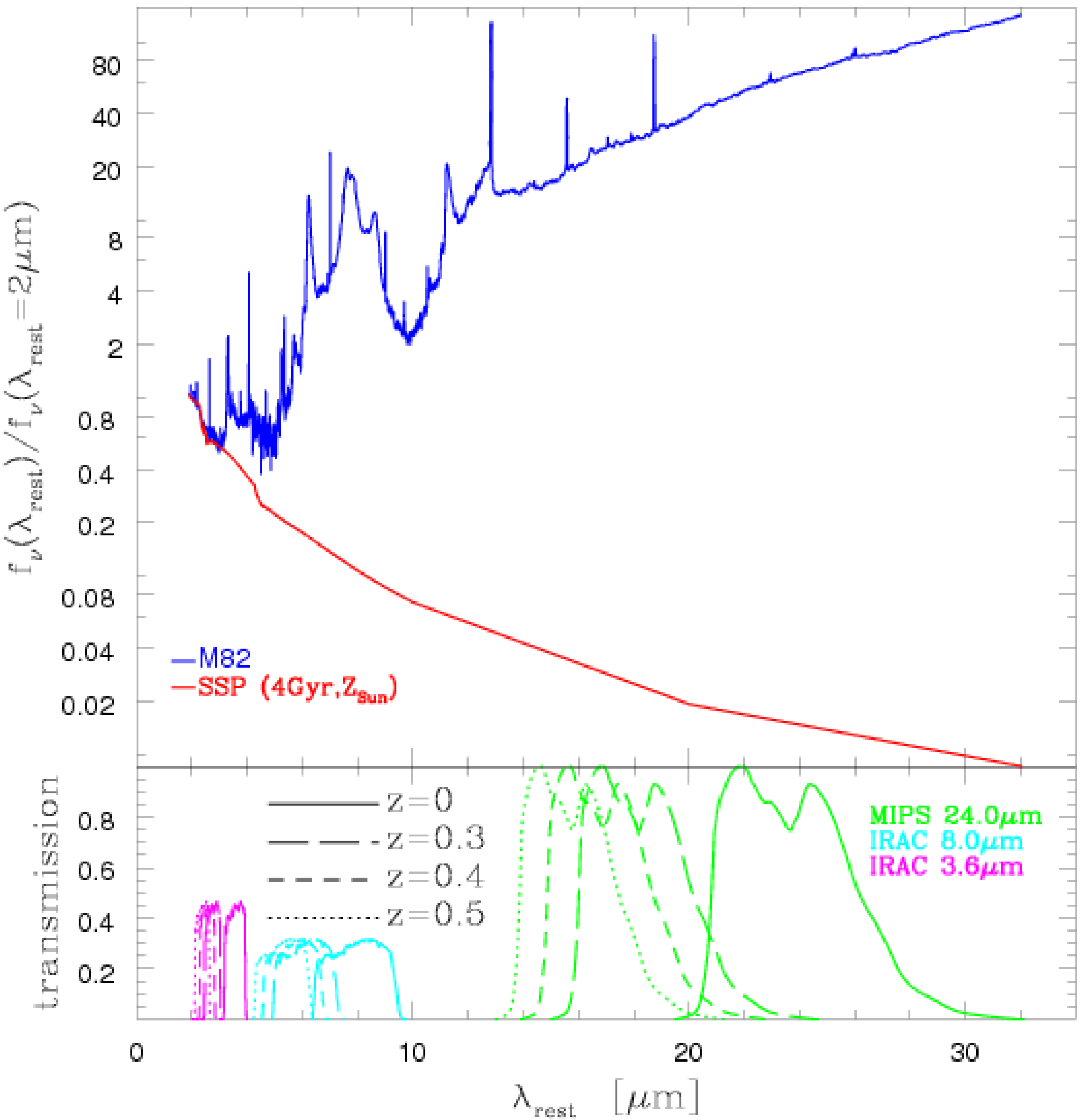
The DXL massive clusters A2744 (RXCJ0014.3-3022, merger) and A2537 (RXCJ2308.3-0211, relaxed, cool-core) exhibit different galaxy populations (Braglia, DP, et al. 2009): a link between halo assembly and star formation activity (cf. Zapata et al. 2009)?

Optically selected groups at z~0.4

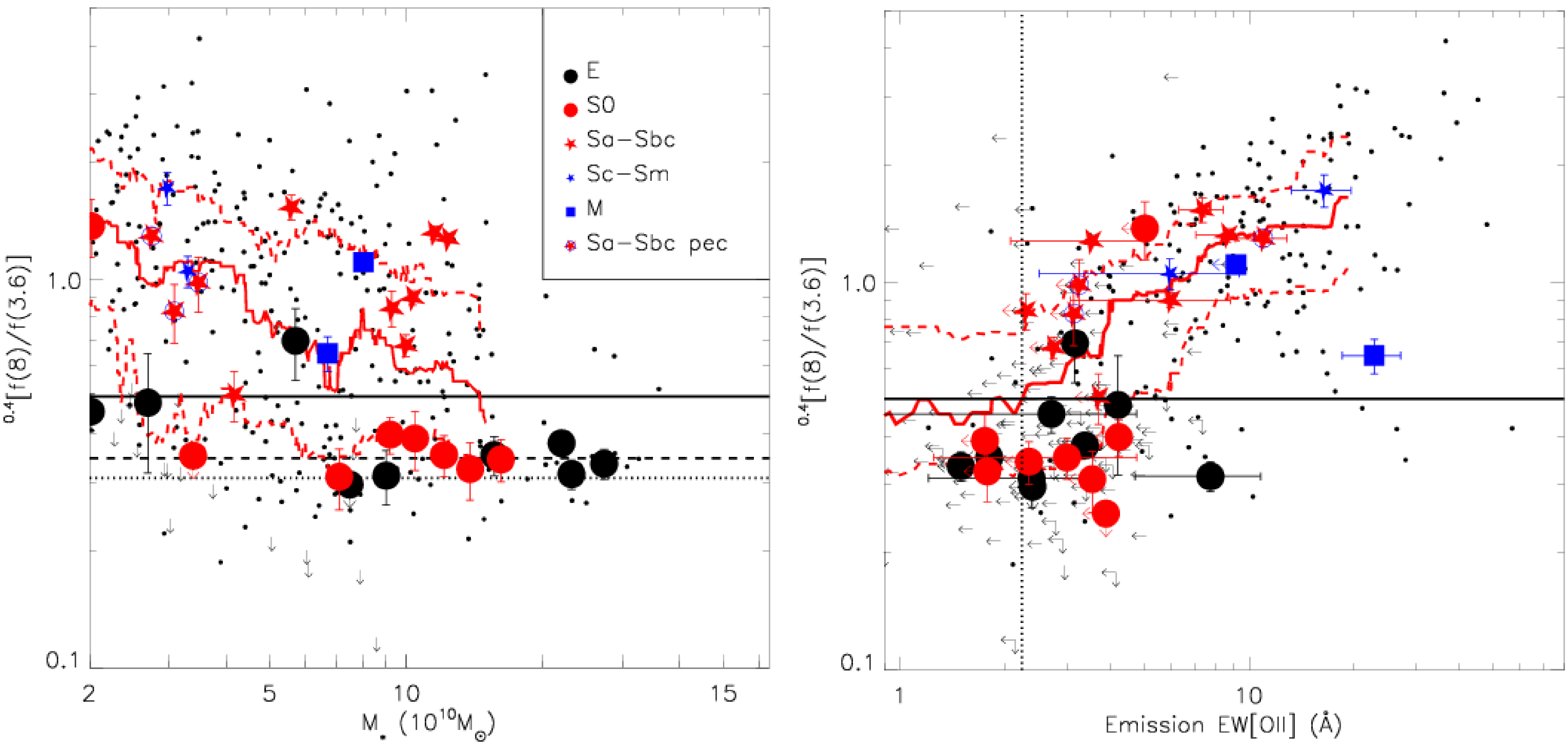
A sample of 333 galaxies in/around groups at $0.3 \leq z \leq 0.48$, complete in stellar mass down to log[M]=10.3, with Spitzer IRAC photometry, selected from CNOC2 (Wilman, DP, et al. 2008)

Out of this sample, 78 galaxies belong to groups (Carlberg et al. 2001; Wilman et al. 2005) with a velocity dispersion less than 500 km s^{-1} (80% of the selected CNOC2 groups)

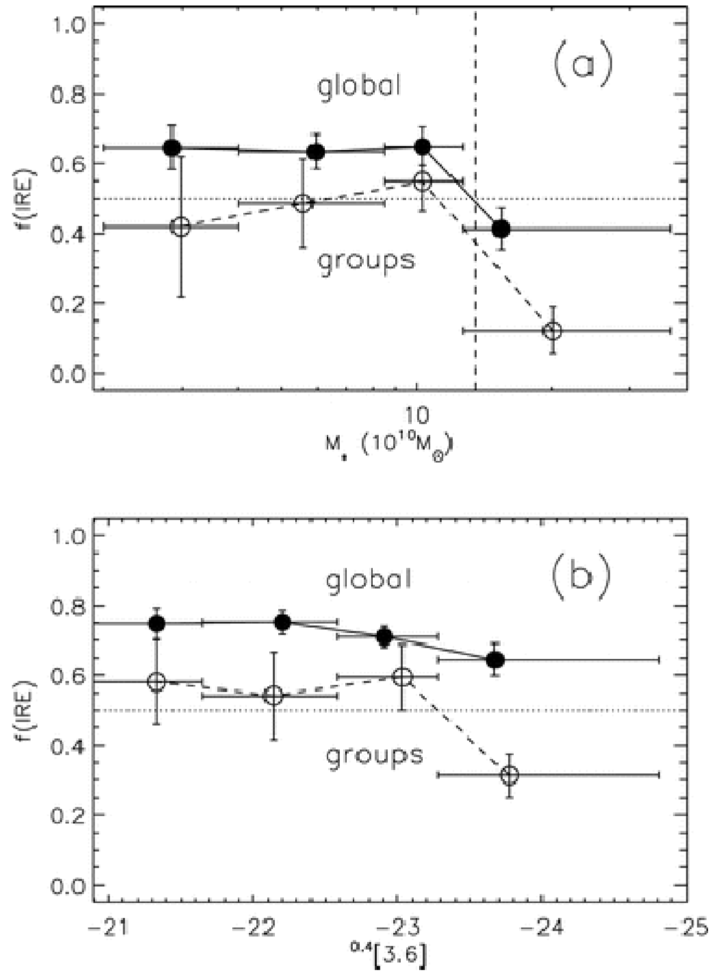
Obscured star formation in groups I.



Obscured star formation in groups II.

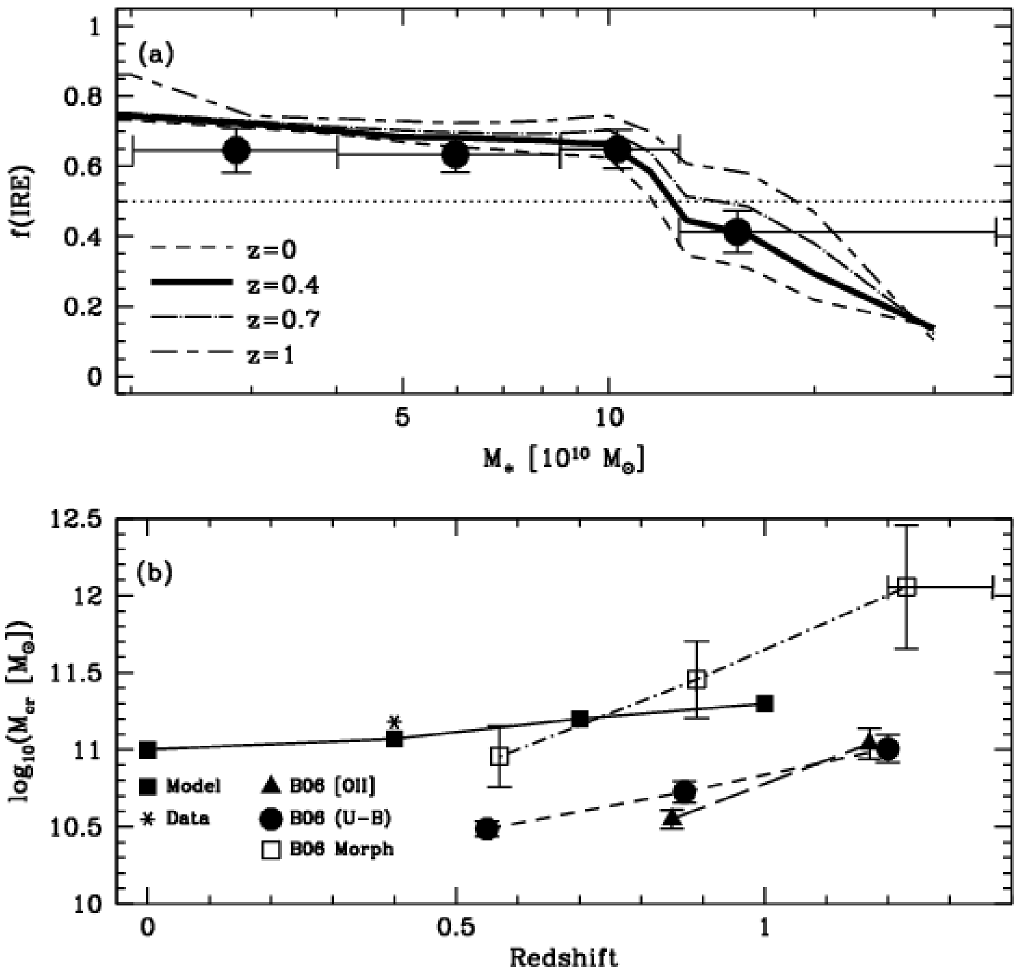


Groups: massive galaxy evolution I.



Suppression of star formation in groups, especially at log[M]≥11 (confirmed for coeval COSMOS X-ray selected groups by Giodini, Böhringer, Finoguenov, DP, et al. in preparation)

Groups: massive galaxy evolution II.



Use of a mock galaxy catalog (Bower et al. 2006) shows that the mass-dependent evolution of the fraction of star forming galaxies can be driven solely by cosmic structure growth.

Stellar/baryon mass fraction I.

91 X-ray selected groups at 0.1≤z≤1 from the COSMOS survey (Finoguenov et al. in preparation)

27 nearby clusters (Lin, Mohr & Stanford 2003)

Total masses M_{500} derived from the M_{200} -L_X relation established from weak-lensing analysis (COSMOS, Leauthaud et al. 2010) or the M_{500} -T_X relation (nearby clusters, Lin et al. 2003)

Stellar masses derived from the rest-frame K-band luminosity for individual galaxies (COSMOS, Ilbert et al. 2009) or the galaxy ensemble (nearby clusters, Lin et al. 2003)

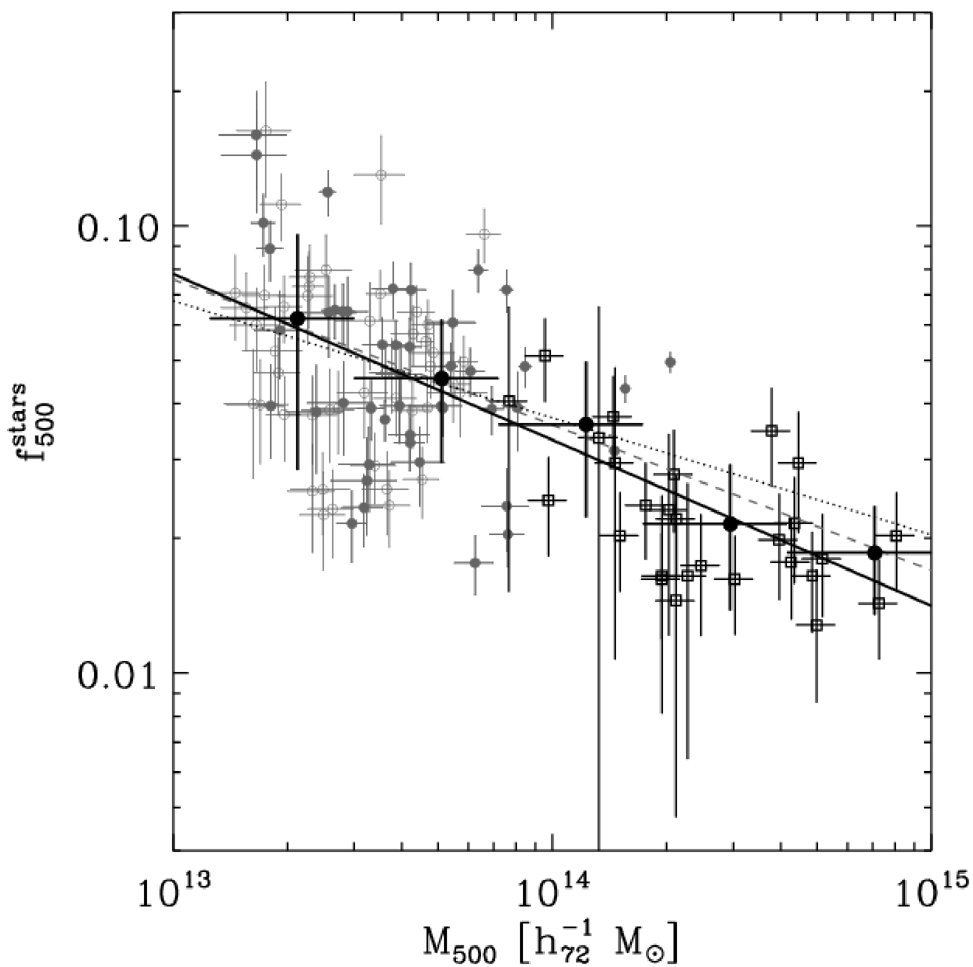
Hot gas mass fraction from the f^{gas} -M_{500} relation established for a representative sample of groups and clusters at z≤0.2, based on hydrostatic mass estimates (Pratt et al. 2009)

Stellar/baryon mass fraction II.

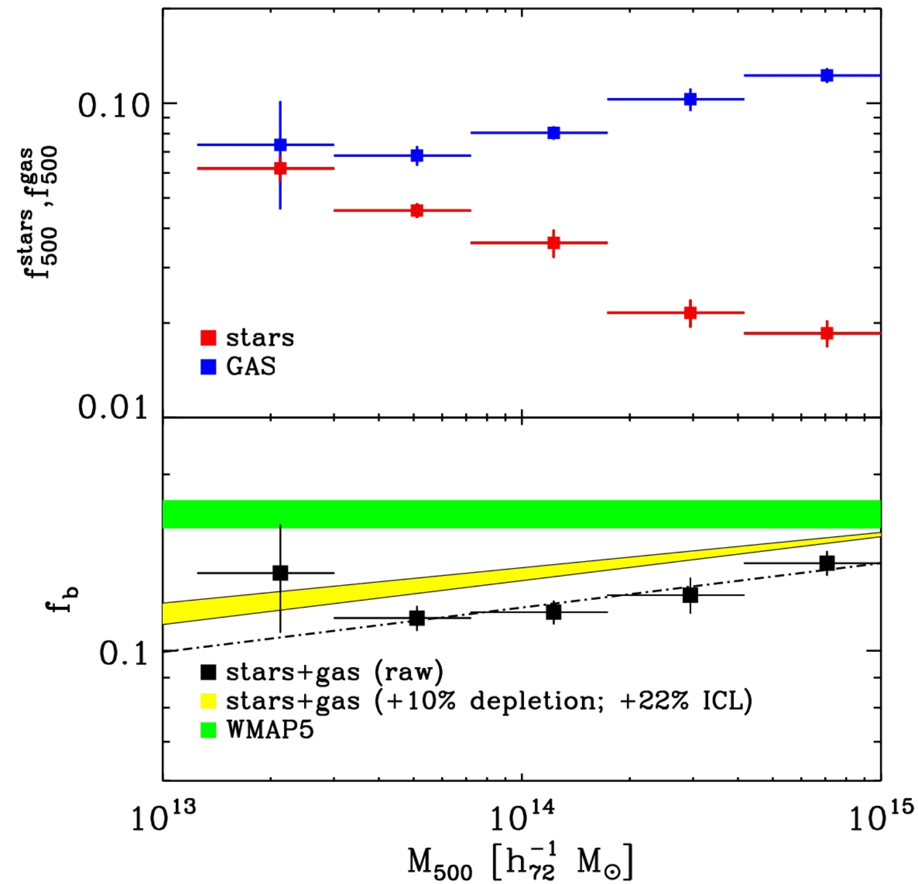
$f^{stars} \sim M_{500}^{-0.37(\pm 0.04)}$ (Giodini, DP, et al. 2009) consistent with the hierarchical build-up of stellar light in CDM universes (exponent ≥ -0.35, Balogh et al. 2009)

Mild evolution of this relation with z (statistics is limited)

Contribution from ICL both critical and controversial (cf. Zibetti et al. 2005; Gonzalez et al. 2007)



Stellar/baryon mass fraction III.



Significant discrepancy in f^b wrt WMAP5 (Dunkley et al. 2007) for low mass groups: evidence for feedback?

Radio-mode feedback is an energetically feasible explanation for gas removal (Giodini et al. 2010)

Fossil groups: puzzles & probes

Extended emission at $L_X > 10^{42}\ h_{50}^{-2}$ erg s^{-1} and a magnitude gap larger than 2 R-mag between the first two brightest members within $0.5R_{200}$ identify a FG (Jones, Ponman & Forbes 2000).

Numerous at the group mass scale (Vikhlinin et al. 1999)

A controversial halo assembly history: early assembly (D'Onghia et al. 2005; Dariush et al. 2007) vs final stage (La Barbera et al. 2009)

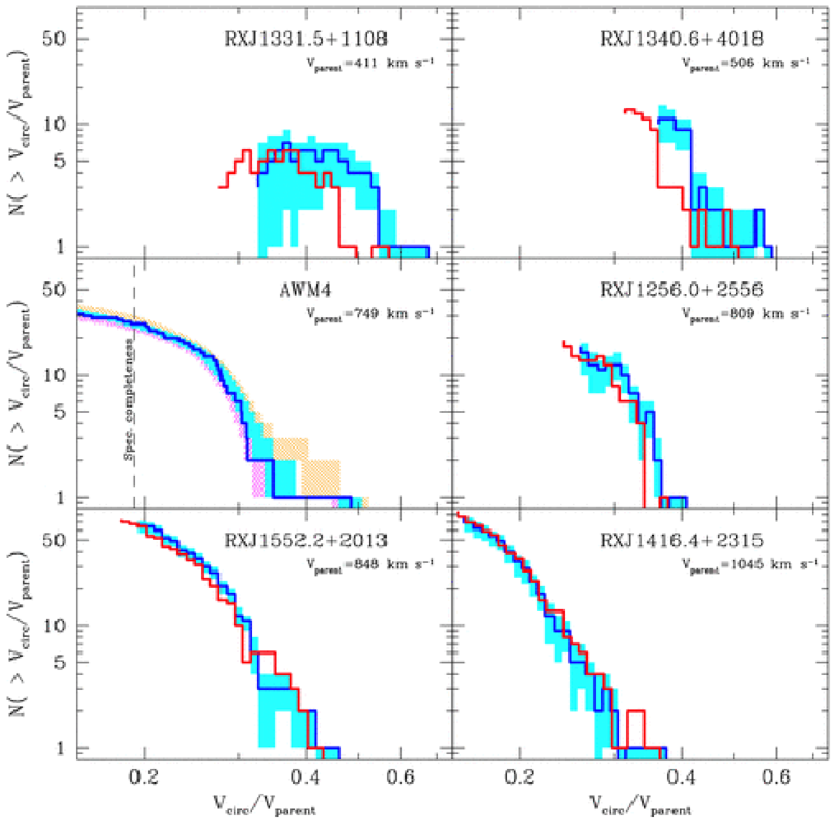
A transient phase (von Benda-Beckmann et al. 2008)?

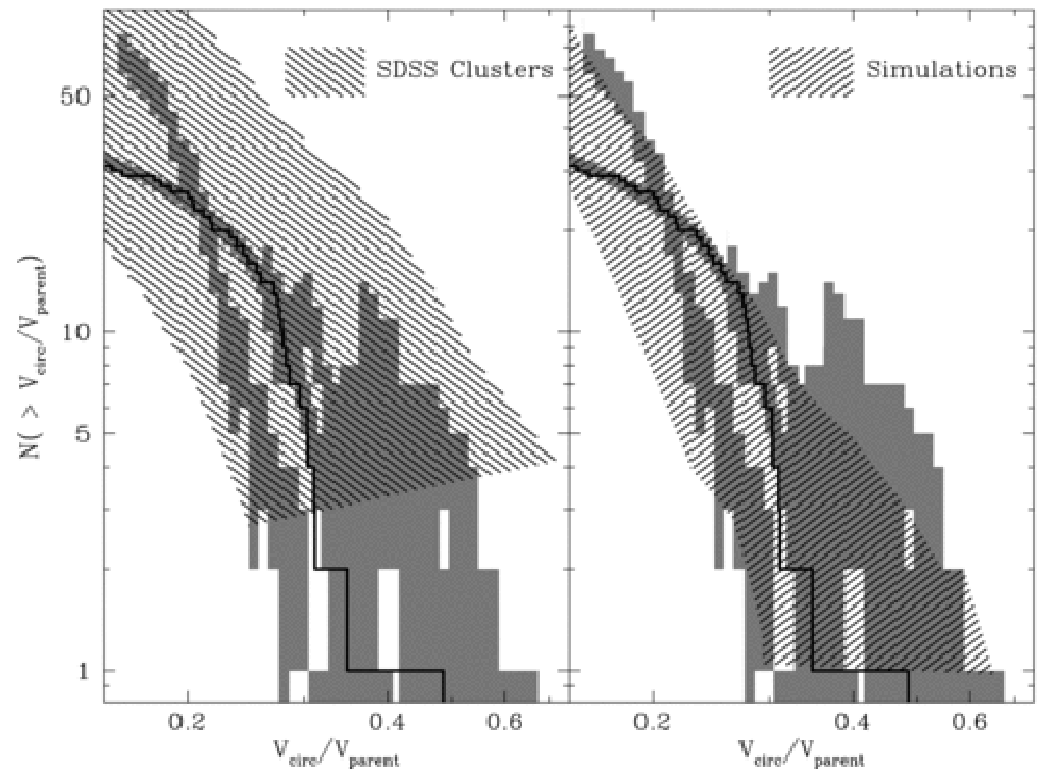
Distinct family of bound systems (D'Onghia & Lake 2004; Khosroshahi, Ponman & Jones 2007) or not (Sun et al. 2009)?

Ultimate examples of hydrostatic equilibrium in virialized systems (Vikhlinin et al. 1999)?

The least massive, baryonically closed systems (Mathews et al. 2005)?

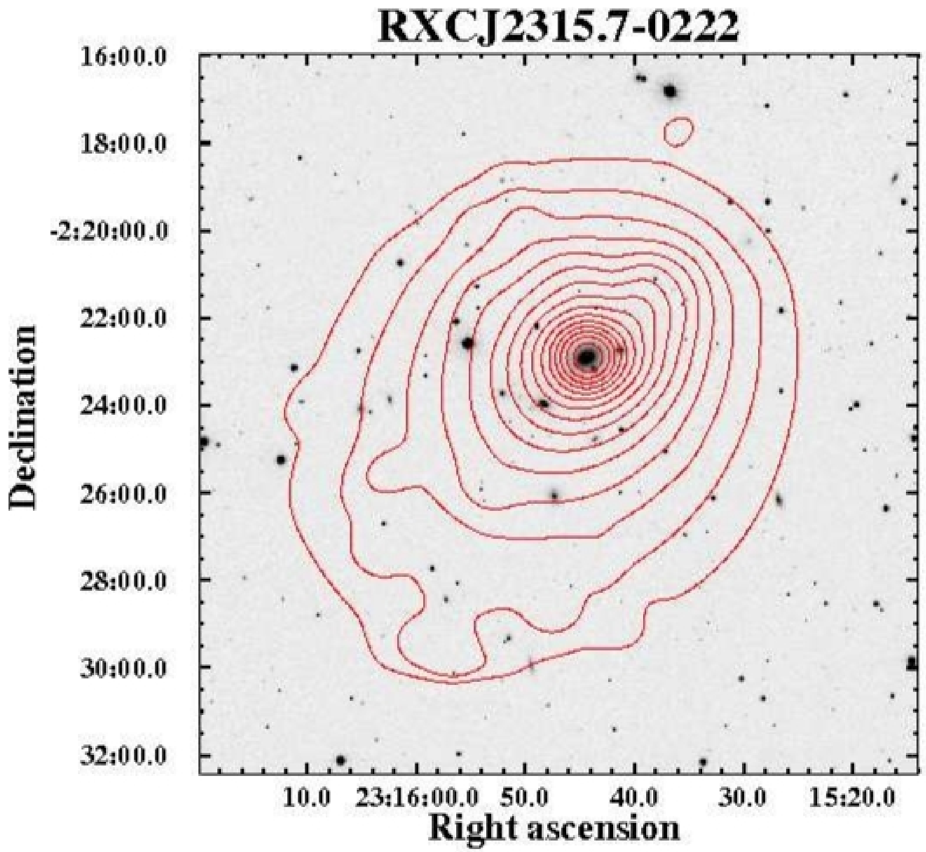
Fossil groups & the CDM paradigm

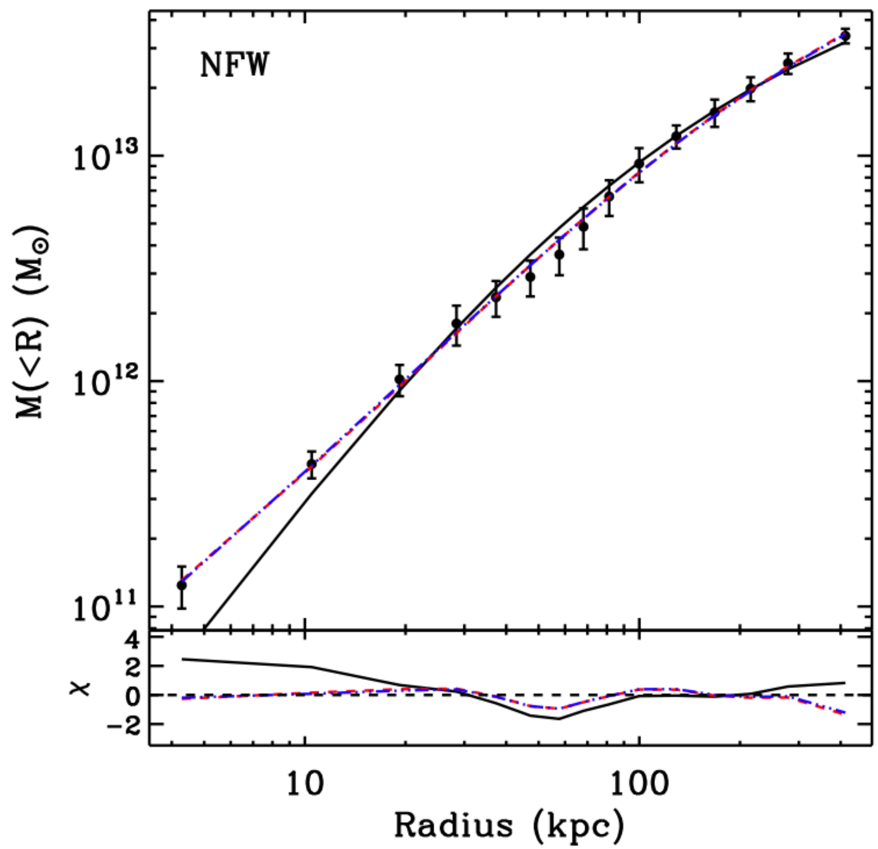




The substructure distribution functions of fossil systems (Zibetti, DP, Pratt 2009) are consistent with those of observed and simulated groups/clusters of similar masses (Desai et al. 2004; Sales et al. 2007), contrary to a previous claim (D'Onghia & Lake 2004). Further (spectroscopic) studies are needed.

FGs & the adiabatic contraction





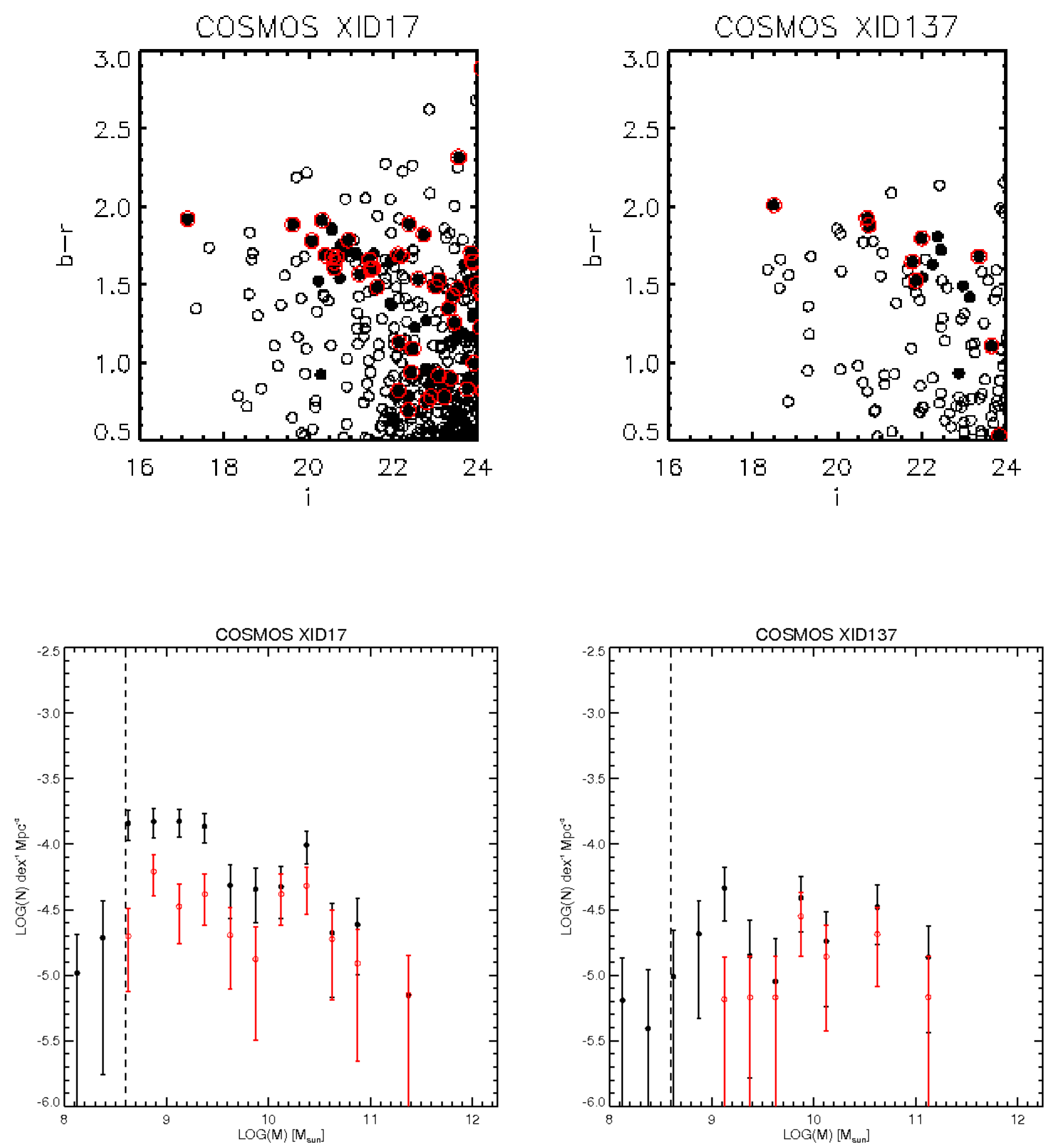
If undisturbed for a very long time (Vikhlinin et al. 1999), FGs offer a suitable test for AC models (e.g., Gnedin et al. 2004). Combining X-ray and optical data, a census of baryons is taken; likely AC has operated for a reasonable stellar IMF (Démoclès, Pratt, DP, et al. 2010). Large statistics is needed (cf. Tissera et al. 2009).

“Mature” fossil groups in COSMOS

Both are at z~0.4, with M_{500} ~1.6 & 8×10^{13} M_{o}; one is isolated, the other is part of a LSS (DP et al. in preparation).

They are dominated by passive (i.e., “red”) galaxies down to log[M]~10, at variance with coeval, similarly massive groups: more “mature” systems?

There is a lack of low-mass galaxies in the lighter, isolated FG: tidal interactions & no refill?



Conclusions and outlook

There is a link between galaxy properties and dynamical state or assembly time of clusters at intermediate redshifts.

Future study based on e.g. the REXCESS and DXL samples, but also SPT ones.

Infall regions, large-scale filamentary structures, and low-mass groups represent fundamental environments for understanding properties of galaxies and the ICM (preprocessing, preheating).

SDSS, Pan-STARRS, and COSMOS offer the opportunity to study this up to z~1.

Fossil systems are prospected as suitable laboratories for tests of LCDM predictions and gravitational/non-gravitational processes affecting galaxy evolution and the ICM at different epochs.

Statistics and information can be built up and systematics understood by using samples extracted from surveys like SDSS, Pan-STARRS, eROSITA, XDCP.

Analysis of multi-wavelength data and comparison with simulations are fundamental.