CLUSTERS OVER A HUBBLE TIME:
bridging the low- and high-z universes

Bianca M. Poggianti

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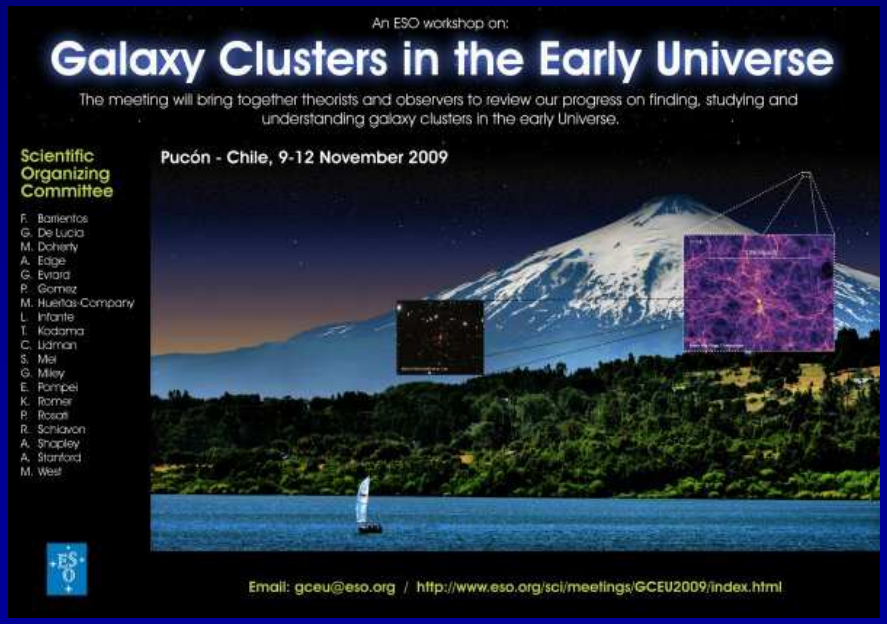
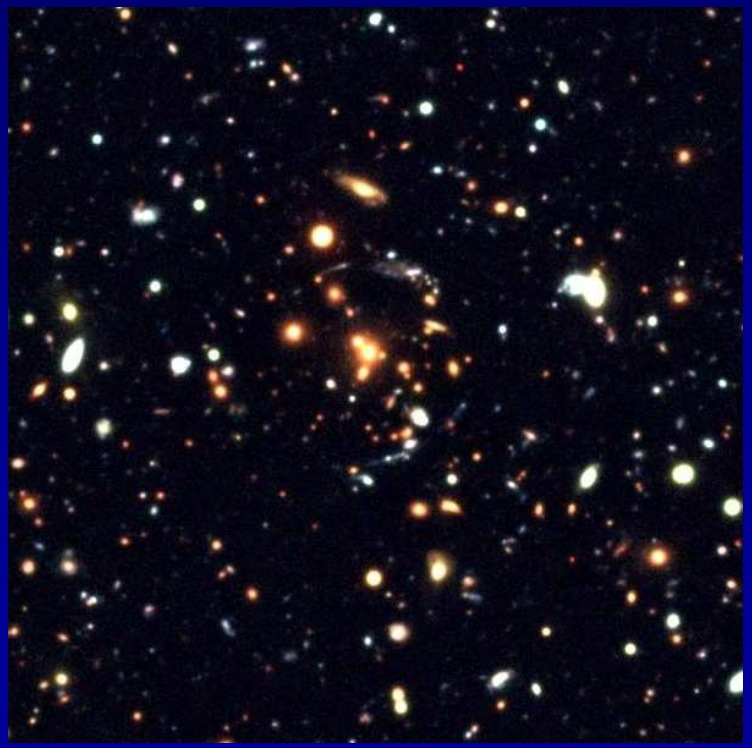


The ESO Distant Cluster Survey
(EDisCS)

P.I. S. White (MPA-Garching, D)
A. Aragón-Salamanca (Nottingham, UK)
P. Best (ROE, Scotland)
D. Clowe (U. Arizona, USA)
J. Dalcanton (U. Washington, USA)
P. Jablonka (Lausanne, CH)
R. Pello (OMP, F)
B. Poggianti (Padova, I)
D. Zaritsky (U. Arizona, USA)
G. De Lucia (MPA, D)
V. Desai (SSC, USA)
C. Halliday (Padova, I)
B. Milvang-Jensen (Copenhagen, DK)
G. Rudnick (Arizona, USA)
R. Saglia (Munich, D)
L. Simard (U. Victoria, C)
J. Varela (Padova, I)
J. Fritz (Padova, I)
B.Vulcani (Padova, I)

20 fields with 19 clusters, 10+ rich groups, poor groups and field galaxies at z=0.42-0.96



WIde-field Nearby Galaxy-cluster Survey

WINGS

A multiwavelenght wide-field survey of 77 X-ray selected clusters at z=0.04-0.07

Daniela Bettoni

Mauro D'Onofrio
Giovanni Fasano (co-PI)
Alessandro Omizzolo
Bianca M. Poggianti (co-PI)

Antonio Cava
Jacopo Fritz
Chiara Marmo
Ezio Pignatelli
Tiziano Valentinuzzi
Jesus Varela

+Alan Dressler
Warrick Couch
Per Kjaergaard
Mariano Moles
David Woods

+external collaborators at
Trieste, Granada, Tenerife

TWO FAMILIES OF PASSIVE GALAXIES IN CLUSTERS TODAY

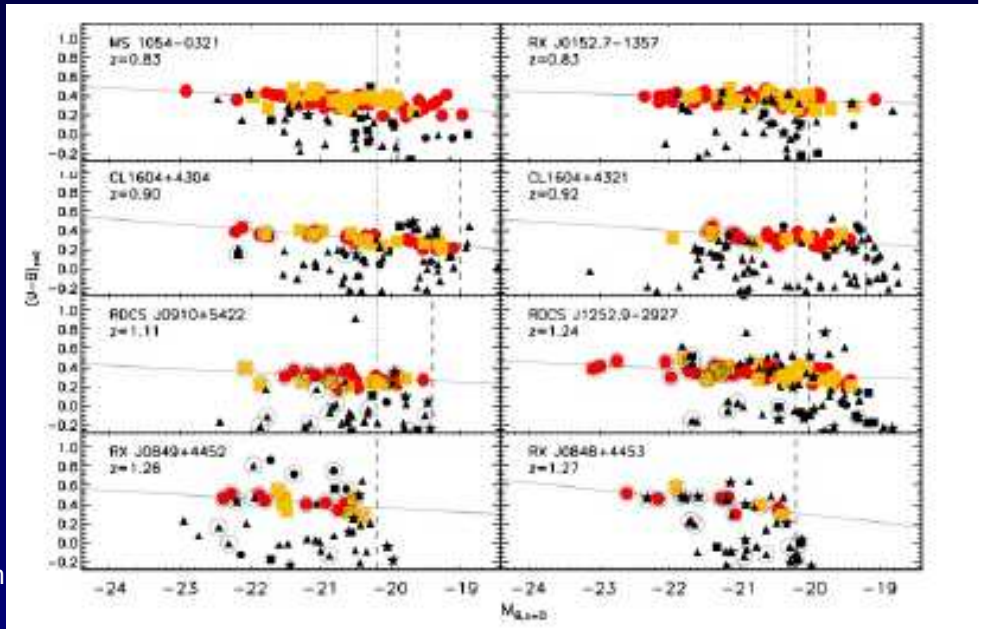
Primordial passive galaxies that finished forming stars, were red and were essentially fully assembled in mass at ≥2-3

Quenched/declining galaxies that stopped star formation at later epochs

PRIMORDIAL PASSIVE GALAXIES

Colour-magnitude studies of massive red cluster galaxies out to z=1.5 and beyond

(Aragon-Salamanca et al. 1993, Rakos et al. 1995, Stanford et al. 1995, 1996, 1997, 1998, Schade et al. 1996, 1997, Ellis et al. 1997, Lopez-Cruz 1997, Kodama et al. 1998, Barger et al. 1998, van Dokkum et al.1998, 1999, 2000, 2001, Gladders et al. 1998, de Propris et al. 1999, Terlevich et al. 1999, 2001, Vazdekis et al. 2001, Andreon 2003, Merluzzi et al. 2003; Rosati et al. 1999, Lubin et al. 2000, Stanford et al. 1998, 2002, Kajisawa et al. 2000, van Dokkum et al. 2000, Blakeslee et al. 2003, 2006, Andreon et al. 2004,2006,2008°,b, Rettura et al. 2009, Demarco et al. 2007, Mei et al. 2006°, b, Homeier et al. 2006, mei et al. 2009)



ACS team z=0.8-1.3 Mei et al. 2009

Fundamental Plane, Mass-to-Light ratios and Mg-sigma relation

(van Dokkum & Franx 1996, Kelson et al. 1997, 2000, 2001, van Dokkum et al. 1998, Bender et al. 1996, 1998, Ziegler & Bender 1997, Ziegler et al. 2001, Holden et al. 2004, 2005,van Dokkum et al. 2007)

Spectral features (Lick indices) Kelson et al. 2001, 2006, Tran et al. 2007, Jorgensen et al. 2005, Sanchez-Blazquez et al. 2009

Bright-end of K-band (mass) luminosity function

(De Propris et al. 1999, Kodama & Bower 2004, Toft et al. 2004, Strazzullo et al. 2006, De Propris et al. 2007)

FROM STAR-FORMING TO PASSIVE

0.0 z 0.5

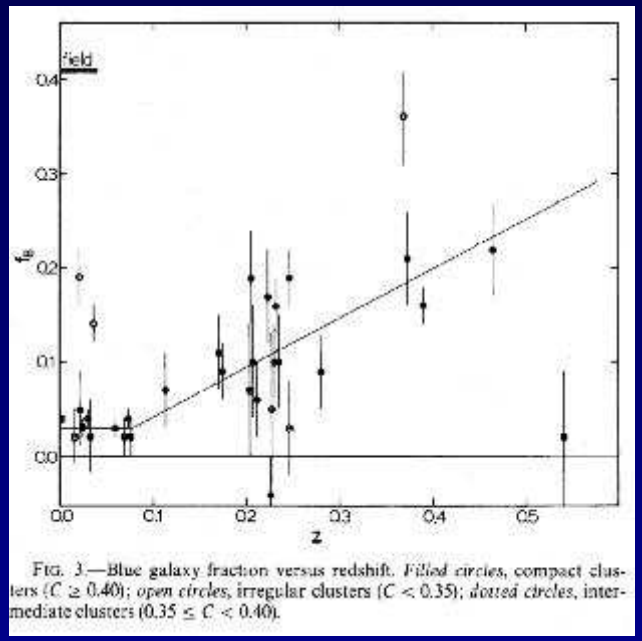


FIG. 3.—Blue galaxy fraction versus redshift. *Filled circles*, compact clusters ($C \geq 0.40$); *open circles*, irregular clusters ($C < 0.35$); *dotted circles*, intermediate clusters ($0.35 \leq C < 0.40$).

Fraction of blue galaxies versus redshift

Butcher-Oemler 1984, Kodama & Bower 2001

<u>Spectroscopy confirmed a widespread SF activity in distant clusters</u>:

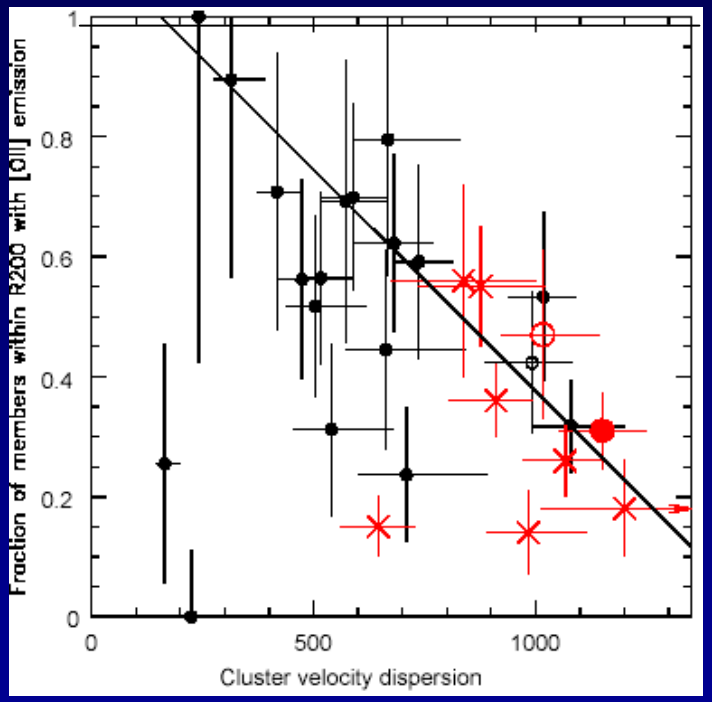
at z=0.4-0.5, star-forming fraction =30-50%, compared to nearby similar clusters that contain few galaxies with ongoing or recent SF

Dressler & Gunn 1982, 1983, Couch & Sharples 1987, Poggianti et al. 1999, Dressler et al. 1999, Ellingson et al. 2001, Balogh et al. 1997….

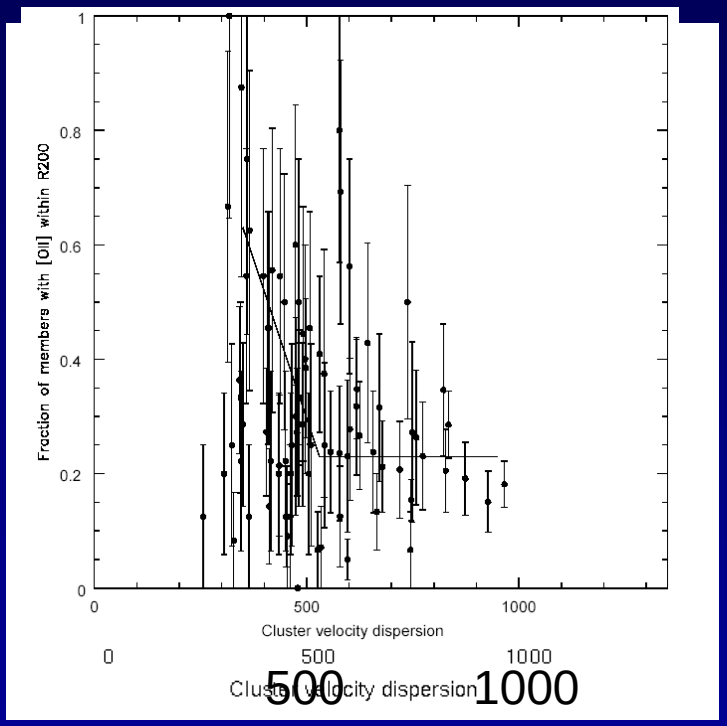
From star-forming to passive: evolution of the % of SF-ing galaxies

Fraction of members with OII within R200

EDisCS z = 0.4-0.8



Sloan z = 0.04-0.1



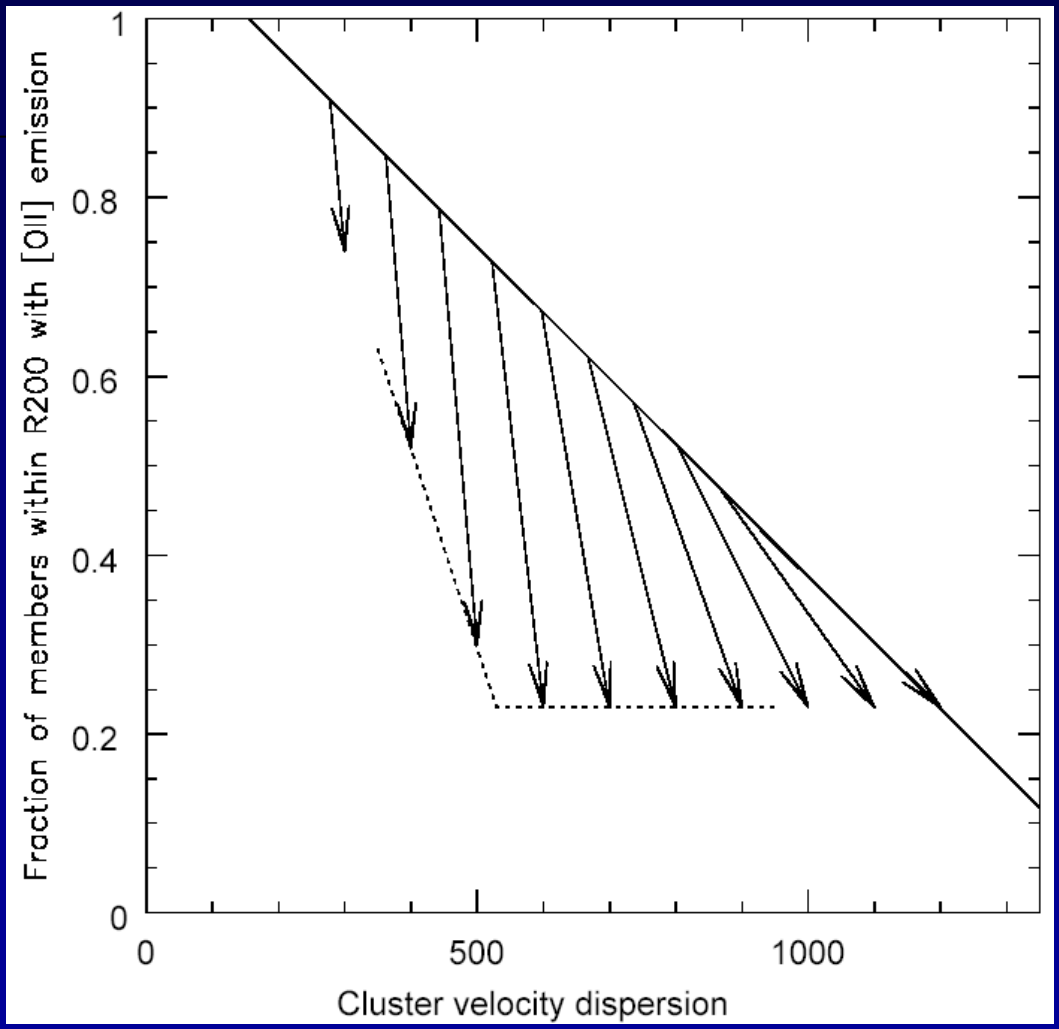
500 1000

Velocity dispersion

Poggianti et al. 2006

From star-forming to passive: evolution of the % of SF-ing galaxies

Fraction of members with OII within R200



Poggianti et al. 2006

TWO FAMILIES OF PASSIVE GALAXIES IN CLUSTERS TODAY

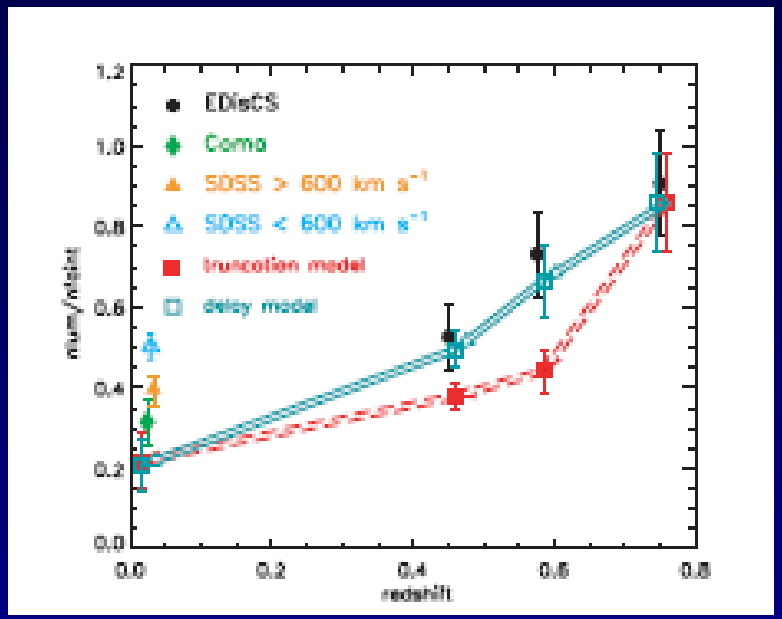
Primordial passive galaxies that finished forming stars, were red and were essentially fully assembled in mass at ≥2-3 – the most massive

Quenched/declining galaxies that stopped star formation at later epochs – less massive, following downsizing

STAR FORMATION DOWNSIZING: the cluster view

EDisCS De Lucia et al. 2004, 2007

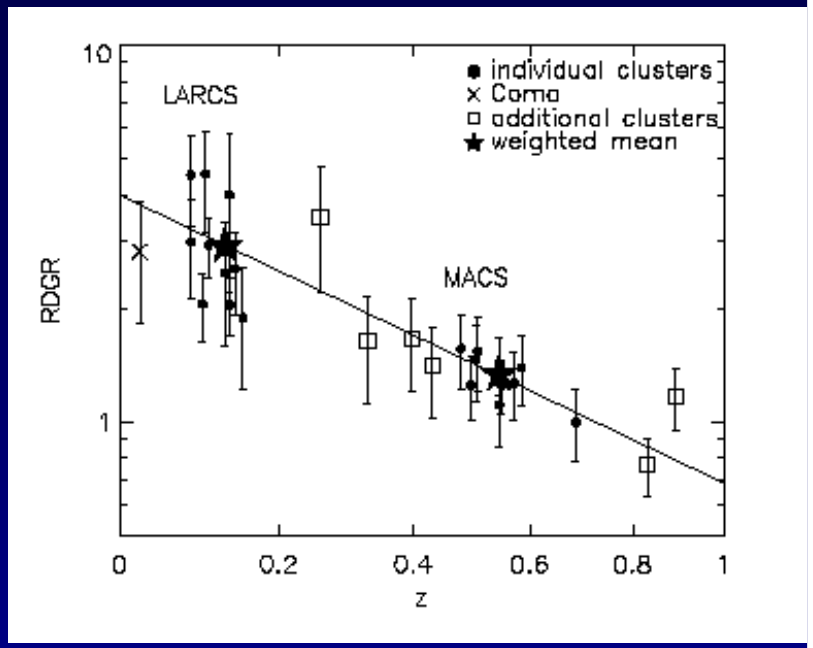
Red sequence luminous-to-faint ratio



0.0 redshift 0.8

MACS+LARCS Stott et al. 2007

Red sequence faint-to-luminous ratio



0.0 redshift 1

A deficiency of red galaxies at faint magnitudes in distant clusters compared to nearby clusters.

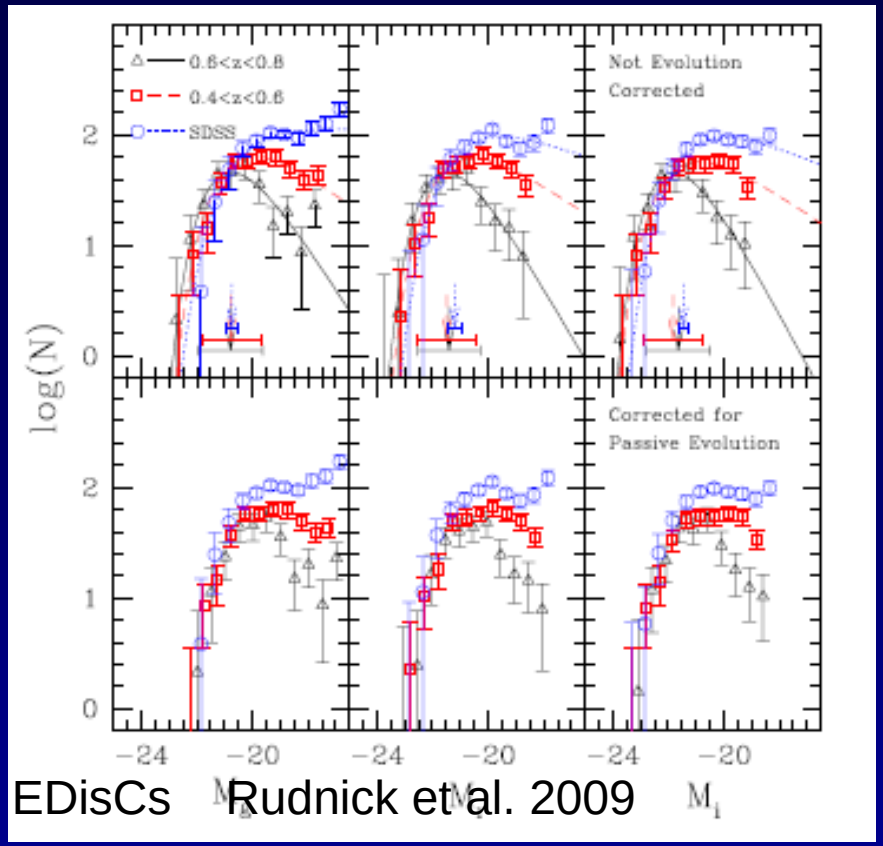
Progressive build-up of the red sequence at faint magnitudes

also Gilbank & Balogh 2008, Lu et al. 2009

also De Propris et al. 2003, 2004, Holden et al. 2007 Smail et al 1998, Kajisawa et al. 2000, Nakata et al. 2001, Kodama et al. 2004

STAR FORMATION DOWNSIZING: the cluster view

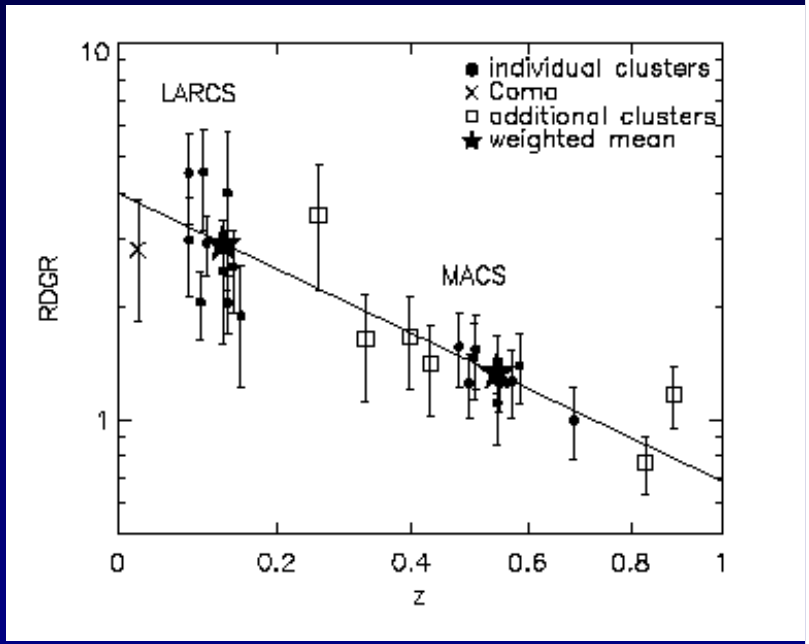
Red sequence luminous-to-faint ratio



EDisCs Rudnick et al. 2009

Red sequence faint-to-luminous ratio

MACS+LARCS Stott et al. 2007



0.0 redshift 1

A deficiency of red galaxies at faint magnitudes in distant clusters compared to nearby clusters.

Progressive build-up of the red sequence at faint magnitudes

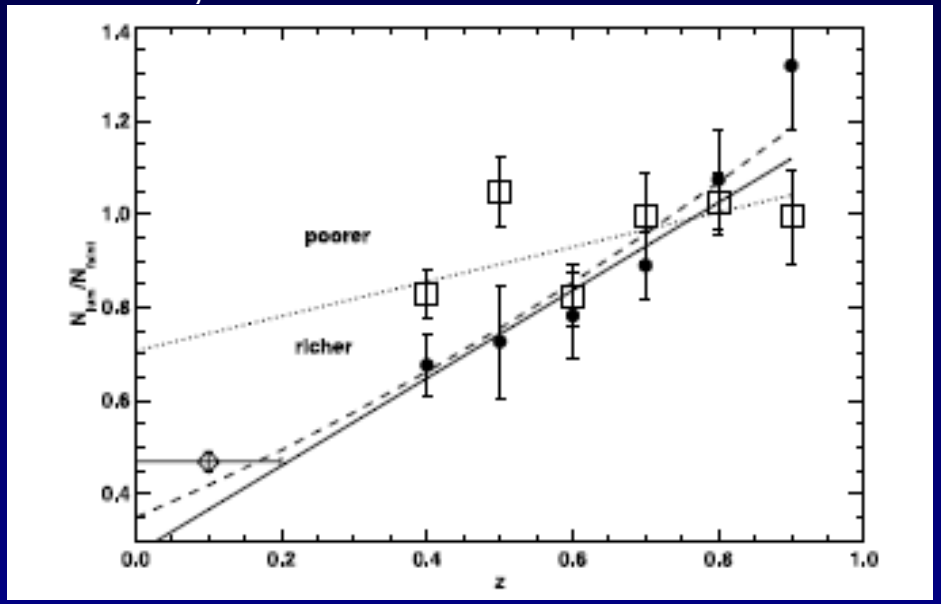
also Gilbank & Balogh 2008, Lu et al. 2009

also De Propris et al. 2003, 2004, Holden et al. 2007 Smail et al 1998, Kajisawa et al. 2000, Nakata et al. 2001, Kodama et al. 2004

STAR FORMATION DOWNSIZING: the cluster view

RCS, Gilbank et al. 2008

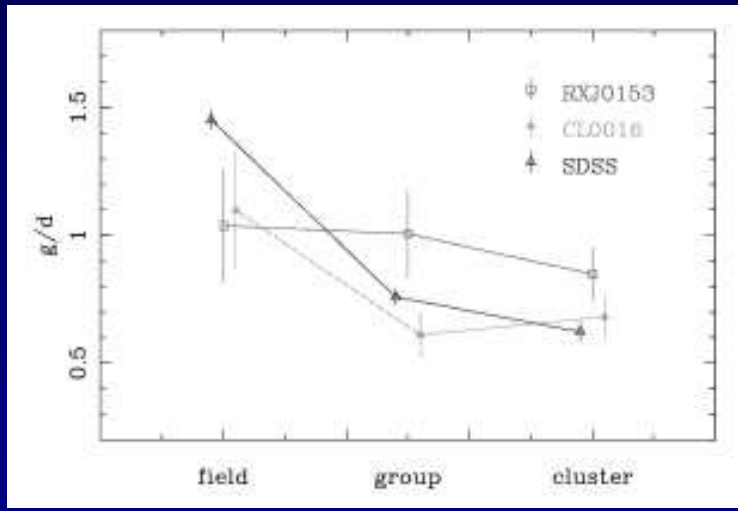
Red sequence luminous-to-faint ratio



0.0 redshift 1.0

PISCES Tanaka et al. 2005, 2007, Koyama et al. 2008, ,Kodama et al. 2004

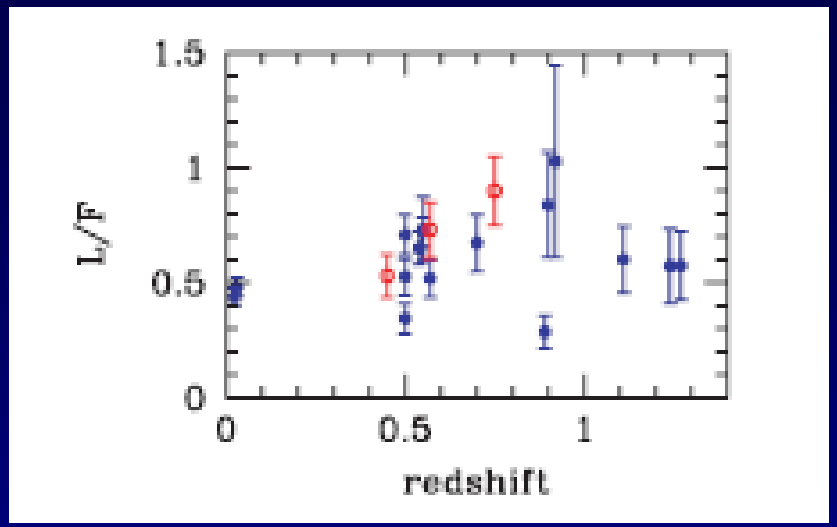
Red sequence luminous-to-faint ratio



Richness dependence of downsizing effect, star formation ended earlier in more massive clusters

STAR FORMATION DOWNSIZING: the cluster view

Red sequence luminous-to-faint ratio



0.0 redshift 1.3

In contrast: No trend with redshift of luminous-to-faint red ratio, and of faint end slope of red luminosify function

Andreon 2008

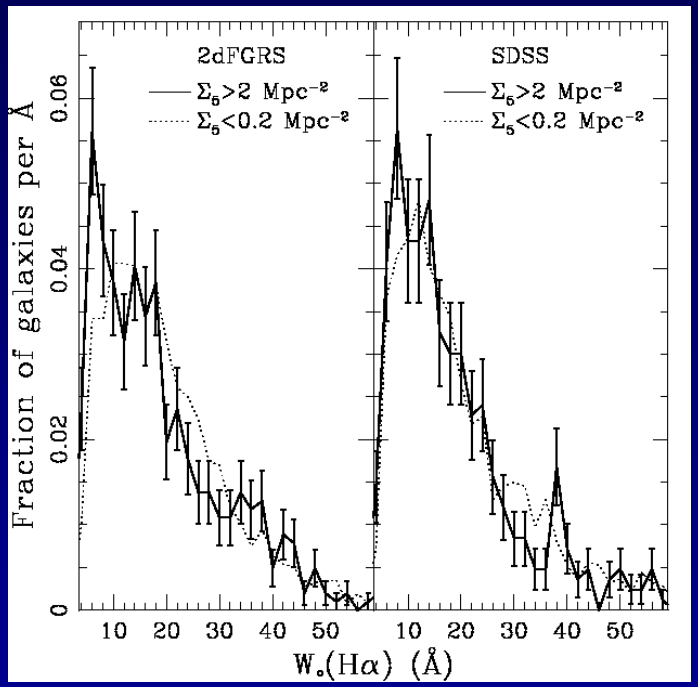
TWO FAMILIES OF PASSIVE GALAXIES IN CLUSTERS TODAY

Primordial passive galaxies that finished forming stars, were red and were essentially fully assembled in mass at ≥2-3 – the most massive

Quenched/declining galaxies that stopped star formation at later epochs – less massive, following downsizing - likely due to a combination of intrinsic and environmental effects

SFR in star-forming galaxies: does it depend on environment?

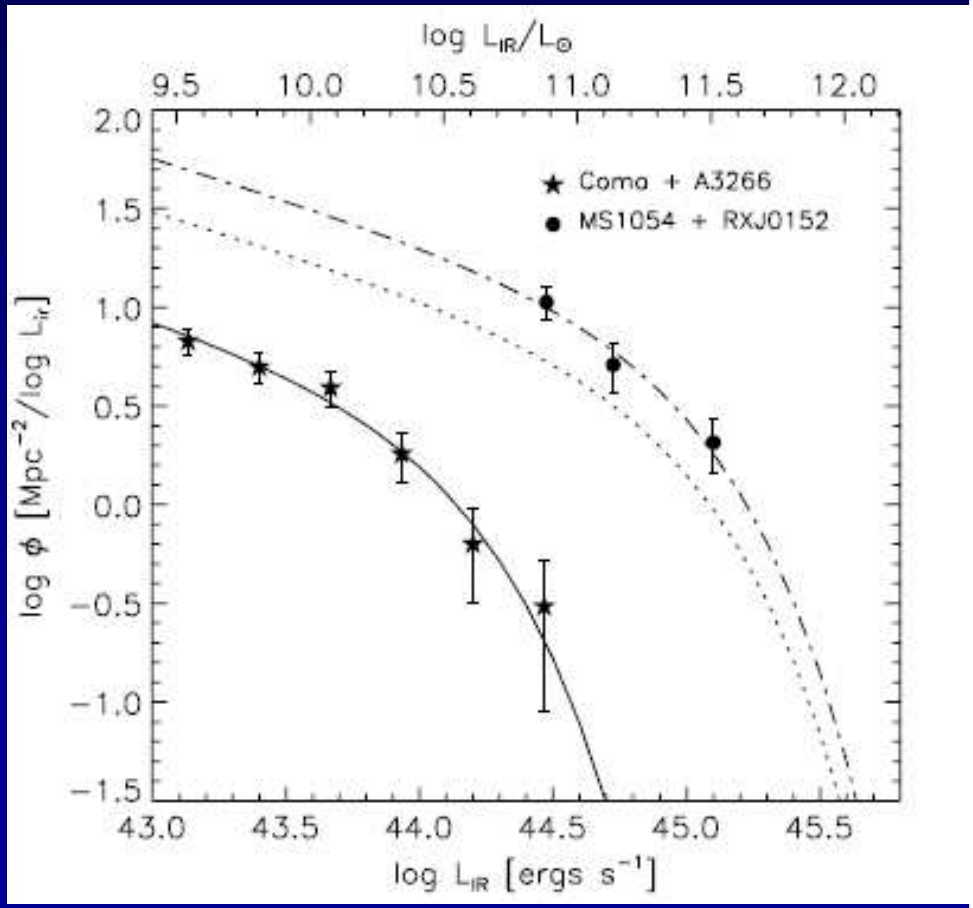
on local density?



Fraction of galaxies

Halpha equivalent width

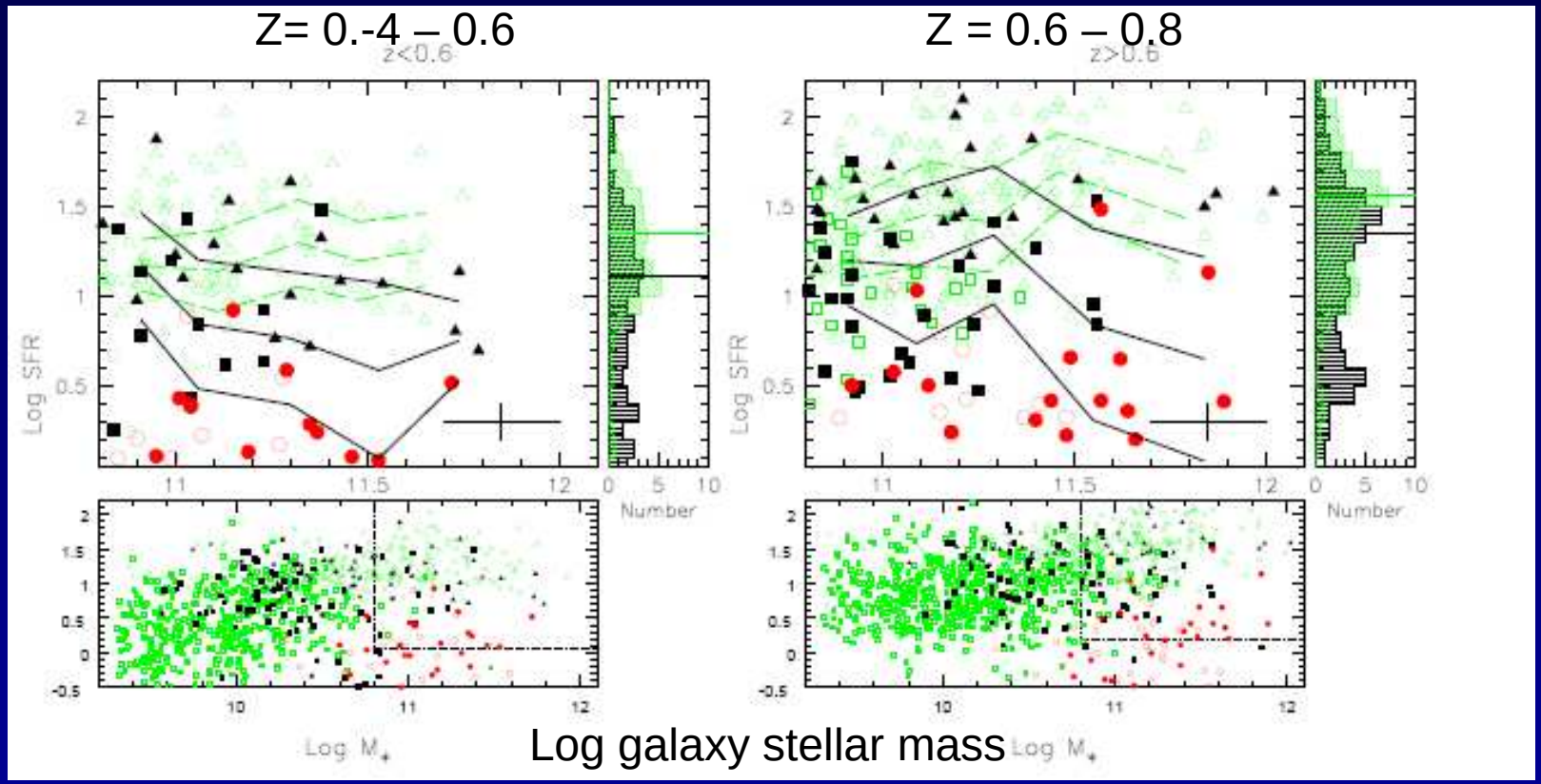
Balogh et al. 2004a, also Rines et al. 2005, Bai et al. 2006, 2007, 2009 + Weinmann et al. 2006, Cassata et al. 2007…



Bai et al. 2009

THE SFR-MASS RELATION IN CLUSTERS, GROUPS AND FIELD

EDisCS Vulcani et al. submitted



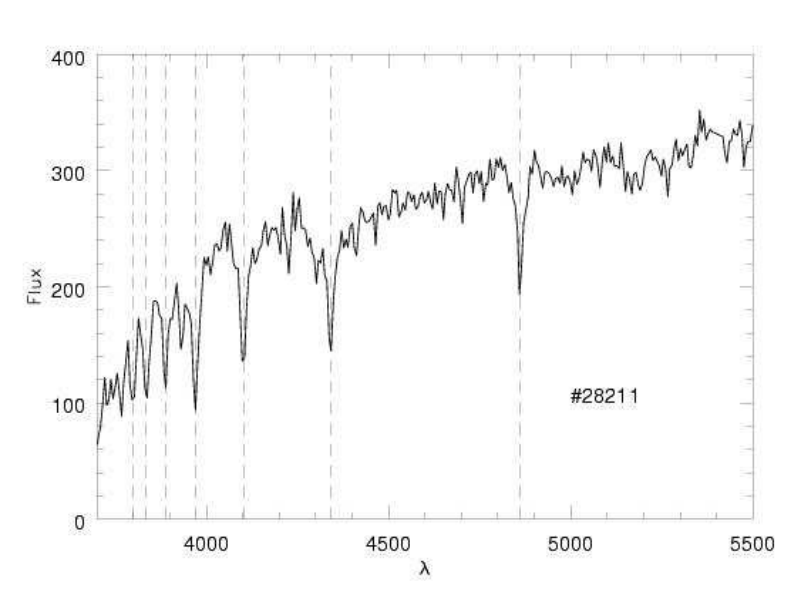
Lower median SFR in cluster star-forming galaxies of a given mass then in the field -- Groups like the field??

Average SFR in star-forming galaxies varies with galaxy environment at a fixed galaxy stellar mass

POST-STARBURST SPECTRA IN DISTANT CLUSTERS

strong Balmer absorption and no line detected in emission

SF ended **abruptly** sometime during the last Gyr



Larger % in distant clusters than in field at similar z's, supporting a mechanism truncating SF in clusters

(Couch & Sharples 1987, Dressler et al. 1999, Poggianti et al. 1999, Tran et al. 2003,2004, Ma et al. 2009, Poggianti et al. 2009 – but Balogh et al. 1999)

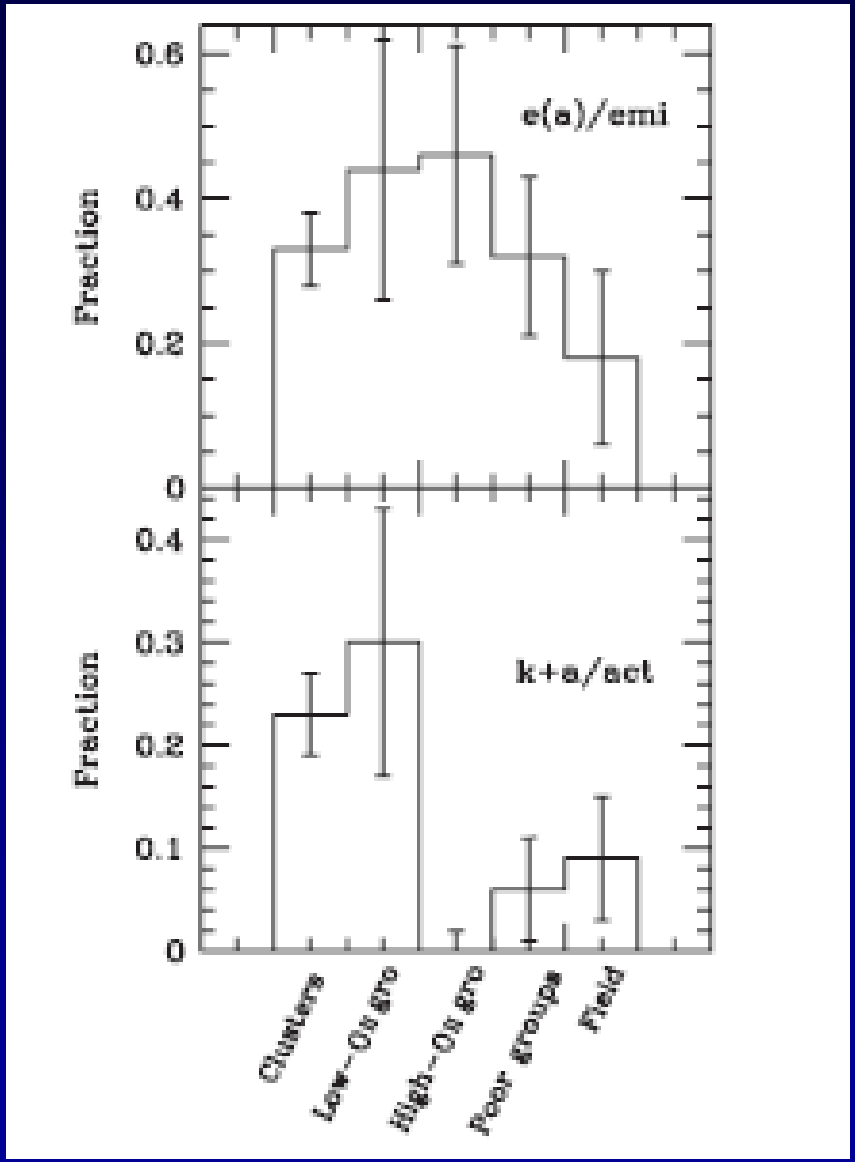
Evidence for ICM origin in Coma where rare among bright galaxies, but common (15%) among dwarfs (Poggianti et al. 2004)

At z=0.4-0.8, post-starburst galaxies more frequent in more massive clusters and in *some* of the groups…

…those groups with a low OII fraction for their sigma

Poggianti et al. 2009a

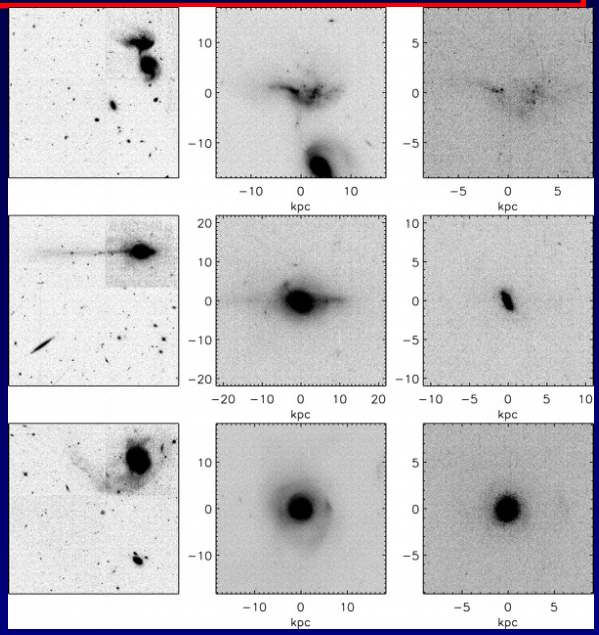
However, even in clusters, post-starburst fraction may not be sufficient to account for the evolution of the red fraction (De Lucia et al. 2009)



Probable different origin in different environments

In the field at z=0, rare and mostly associated with mergers

(Zabludoff et al. 1996, Yang et al. 2004, 2008, Goto 2005, Nolan et al. 2007, Yamauchi et al. 2008, Goto et al. 2008)



At z=0.8, k+a's prefer overdense regions – At low-z, underdense regions – High-z k+a's can be progenitors of red galaxies at same z – At low-z, they can't (Yan et al. 2009 DEEP2)

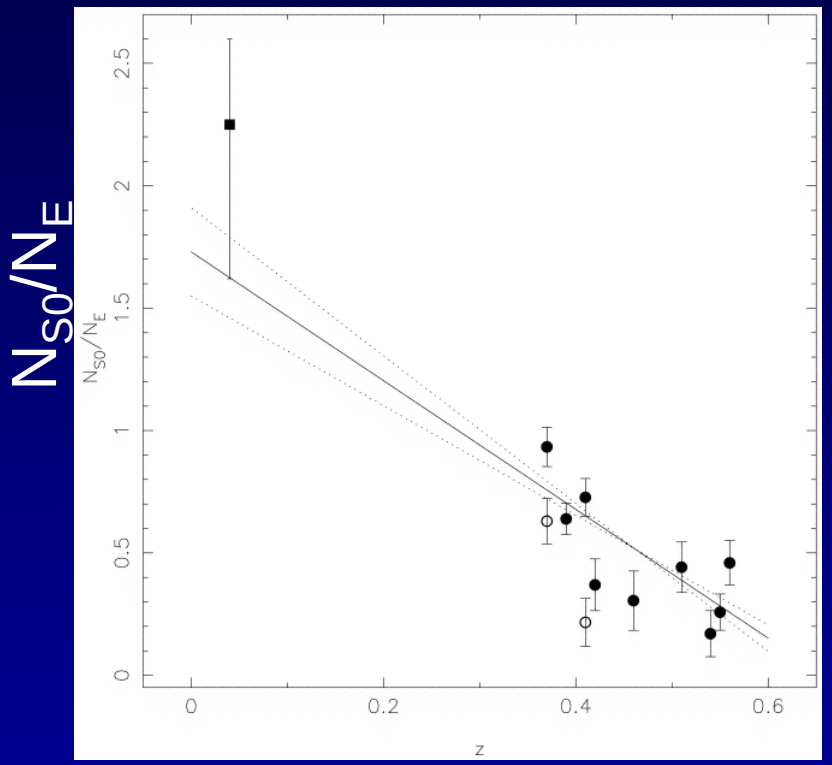
Evolution of frequency also in the field: a factor of 230 between 0.07 and 0.7 - How relevant for the evolution of the star-forming fraction and of the cosmic SF history? (Wild et al. 2009 – 40% of red sequence growth rate)

TWO FAMILIES OF PASSIVE GALAXIES IN CLUSTERS TODAY

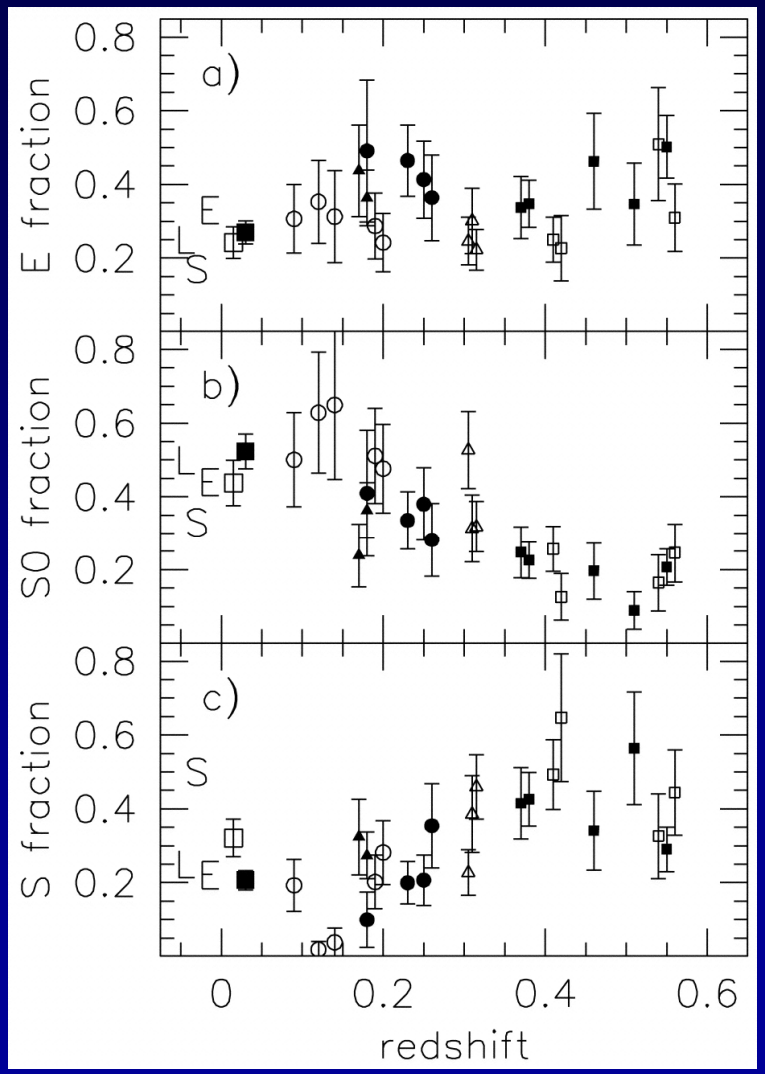
Primordial passive galaxies that finished forming stars, were red and were essentially fully assembled in mass at ≥2-3 – the most massive – mostly and most of the ellipticals

Quenched/declining galaxies that stopped star formation at later epochs – less massive, following downsizing - likely due to a combination of intrinsic and environmental effects – (some of today's) S0s

MORPHOLOGICAL EVOLUTION IN CLUSTERS: S0s GALAXIES



Dressler et al. 1997

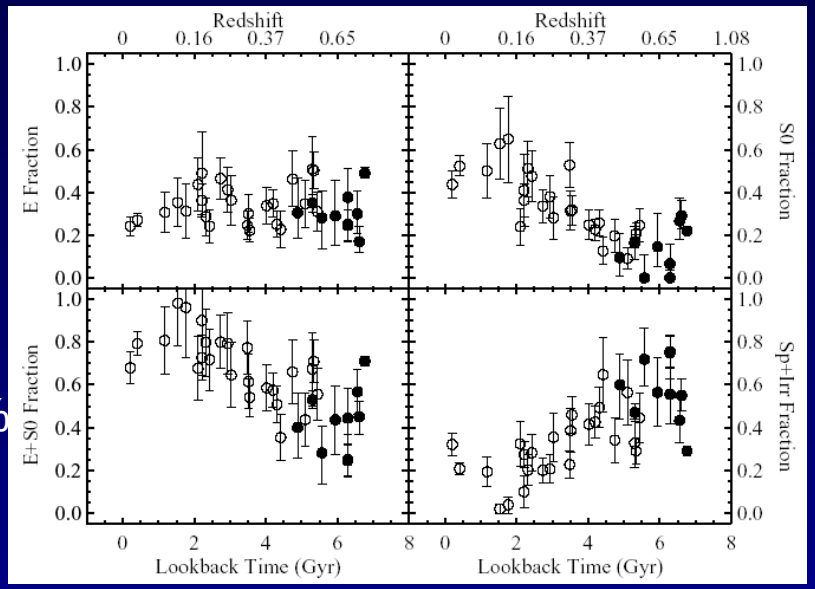


Fasano et al. 2000

MORPHOLOGICAL EVOLUTION IN CLUSTERS: from spiral to S0 GALAXIES

E %

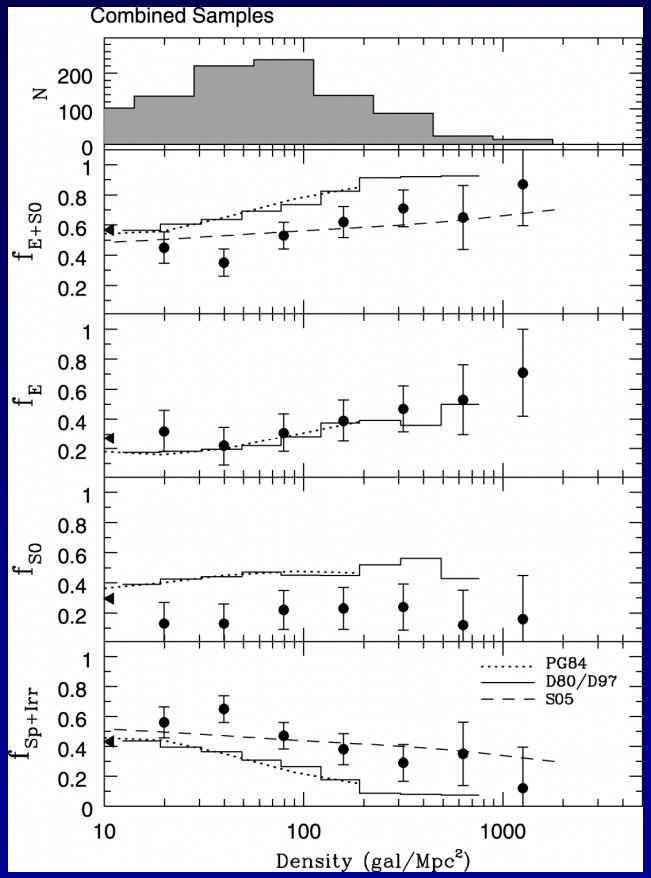
E+S0 %



S0 %

Sp+Irr %

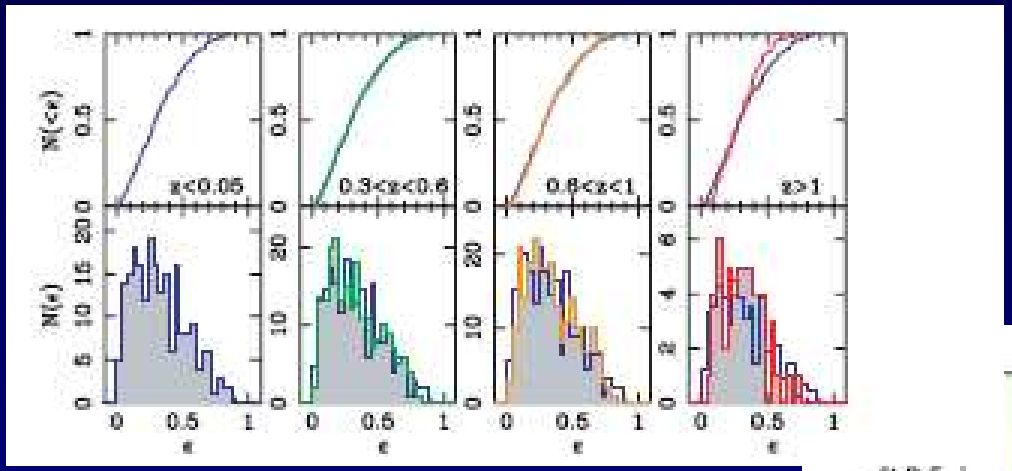
Desai et al. (2007)

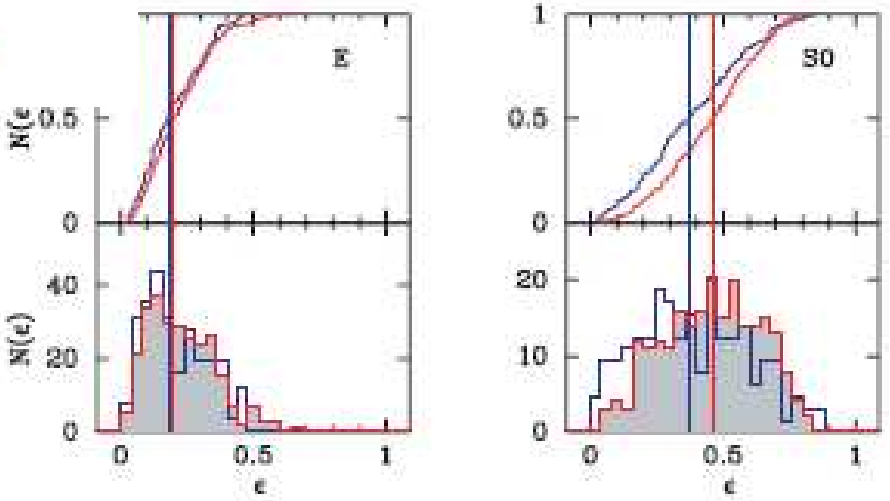


Postman et al. 2005,
also Smith et al. 2005

Also Treu et al. 2003, Moran et al. 2007, Simard et al. 2009

S0 EVOLUTION STILL DEBATED



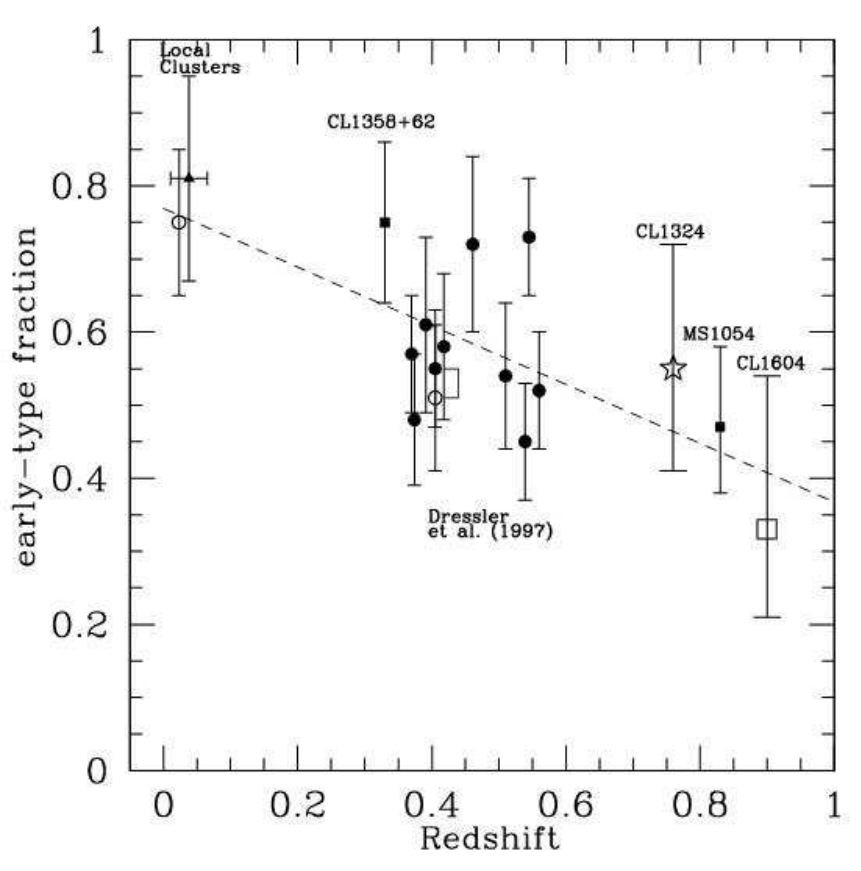


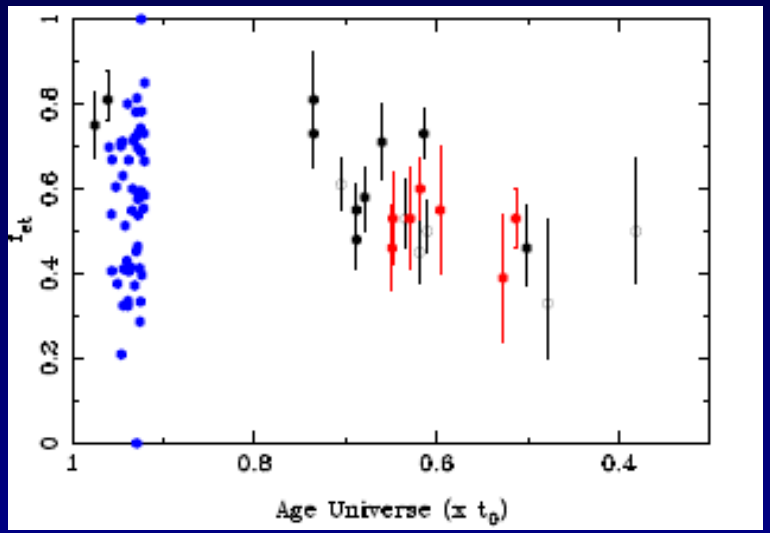
No evolution in the ellipticity distribution of cluster early-type galaxies

Holden et al. 2009

also Andreon 1998, Fabricant et al. 2000

Evolution of early-type fraction

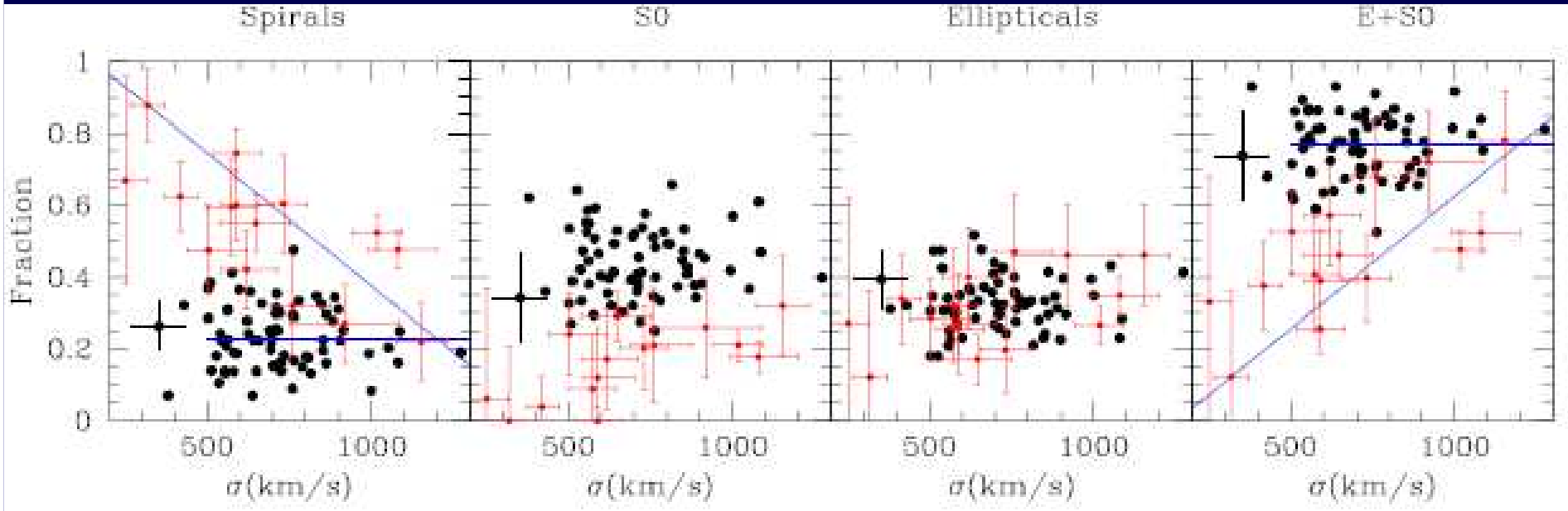




Lubin et al. 2003, van Dokkum et al. 2000

Simard et al. 2009

Evolution of the morphological fractions



AS FOR THE STAR-FORMING FRACTION, THE STRONGEST EVOLUTION BETWEEN z=1 AND TODAY APPEARS TO HAPPEN IN GALAXIES IN LOW-MASS CLUSTERS

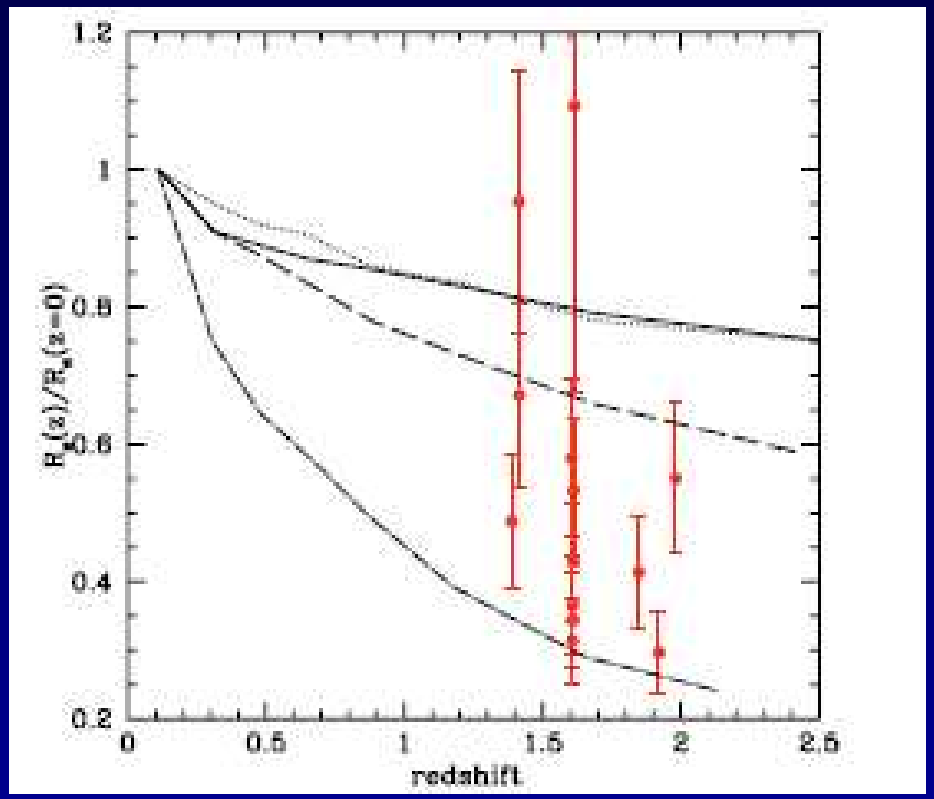
WINGS + EDisCS Poggianti et al. 2009b ApJ Letter

THE EVOLUTION OF MASSIVE GALAXY SIZES

A population of high-z massive galaxies with small effective radii compared to low-z massive galaxies

(Daddi et al. 2005, Trujillo et al. 2006, 2007, 2009, Toft et al. 2007, Zirm et al. 2007, Buitrago et al. 2008, Cimatti et al. 2008, van Dokkum et al. 2008, 2009, Saracco et al. 2009, van der Wel et al. 2009)

Size evolution due to minor mergers?

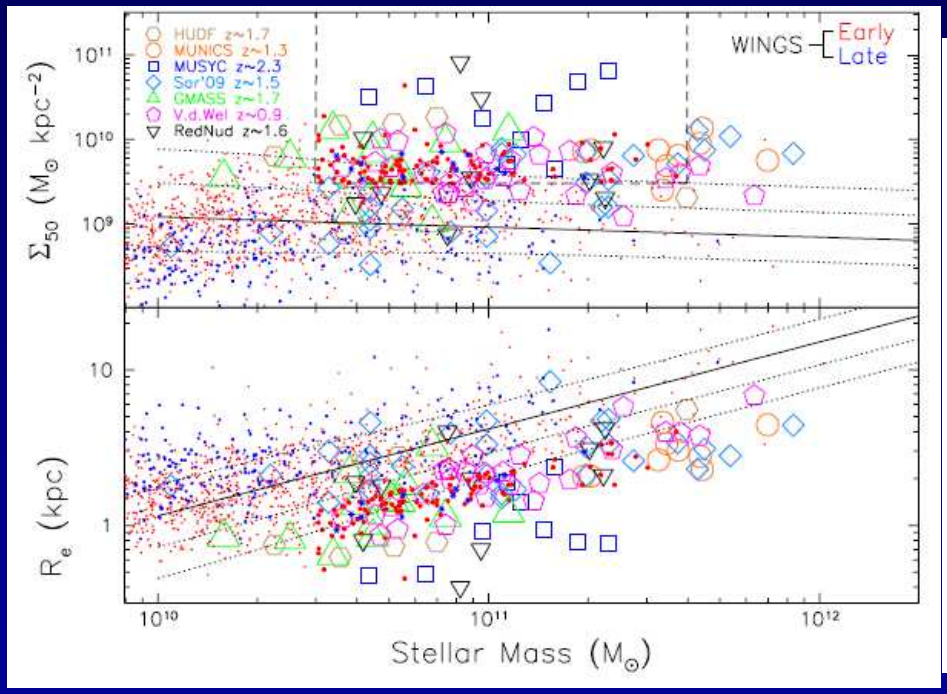


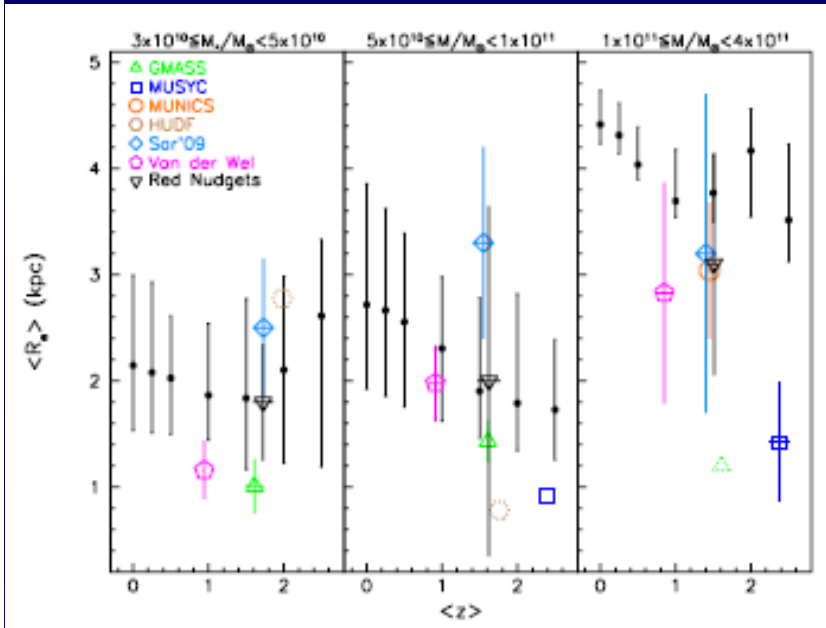
Cimatti et al. 2008

See Rettura, Raichoor, Stott….talks

THE EVOLUTION OF MASSIVE GALAXY SIZES
low-z clusters

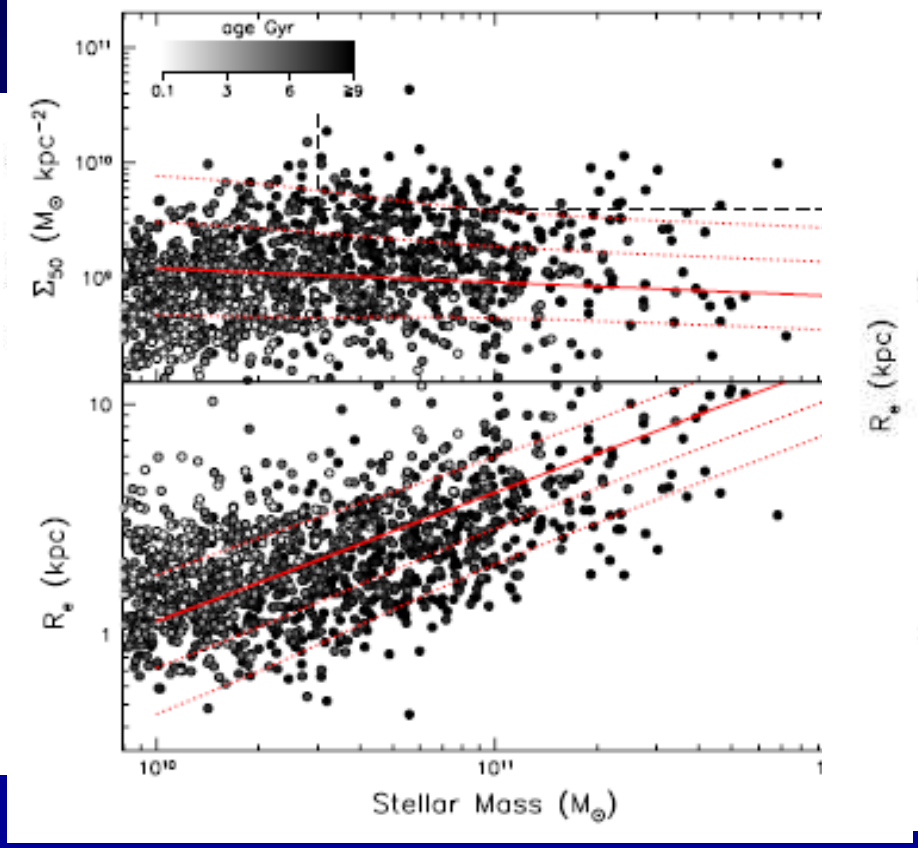
Median Re vs z for 3 galaxy mass bins

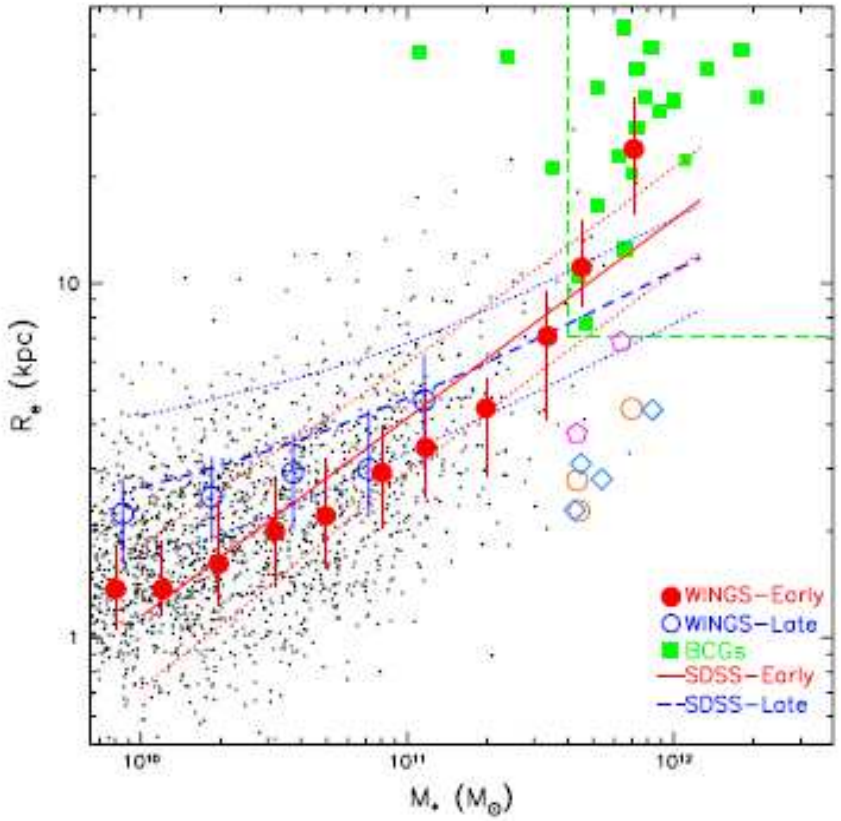




WINGS Valentinuzzi et al. 2009

THE EVOLUTION OF MASSIVE GALAXY SIZES
low-z clusters





WINGS Valentinuzzi et al. 2009

Questions for the z≥1 studies

1) Witness the formation of the “primordial” population, and unveil the physical processes involved – also by characterizing “environment” in detail and by measuring the timescales involved

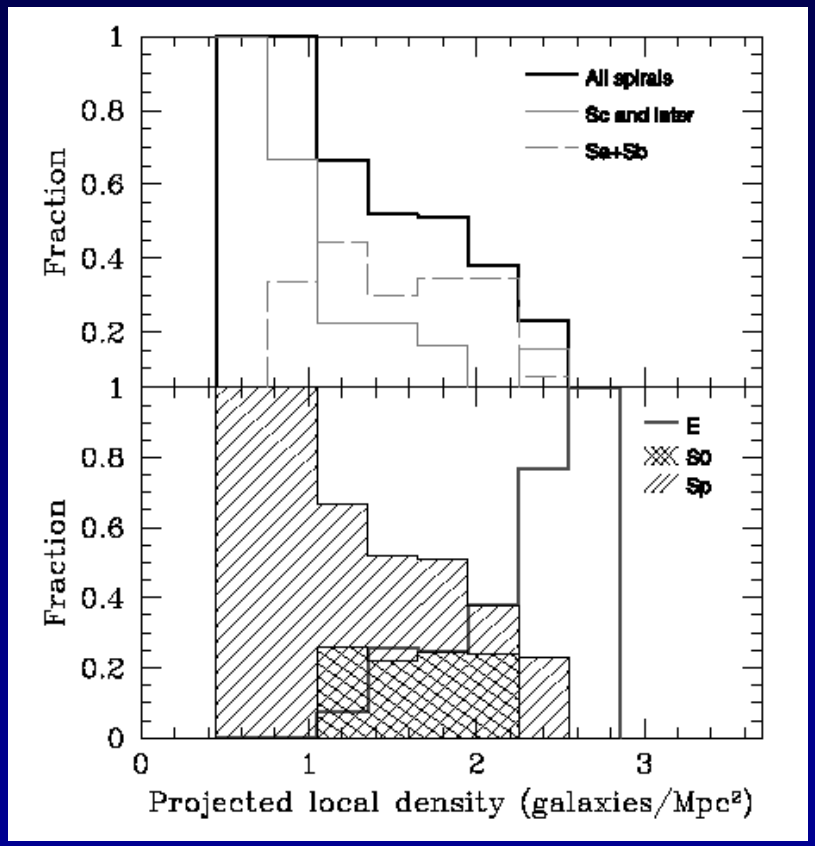
2) Measure the galaxy-mass segregation with environment at high-z, allowing to discriminate between mass and environment

3) Assess how the formation of galaxy structure and the first phases of the galaxy stellar history proceed at early epochs, and how they are linked

4) Achieve a complete census of the size-mass distribution of all galaxies at high-z, regardless of their stellar age

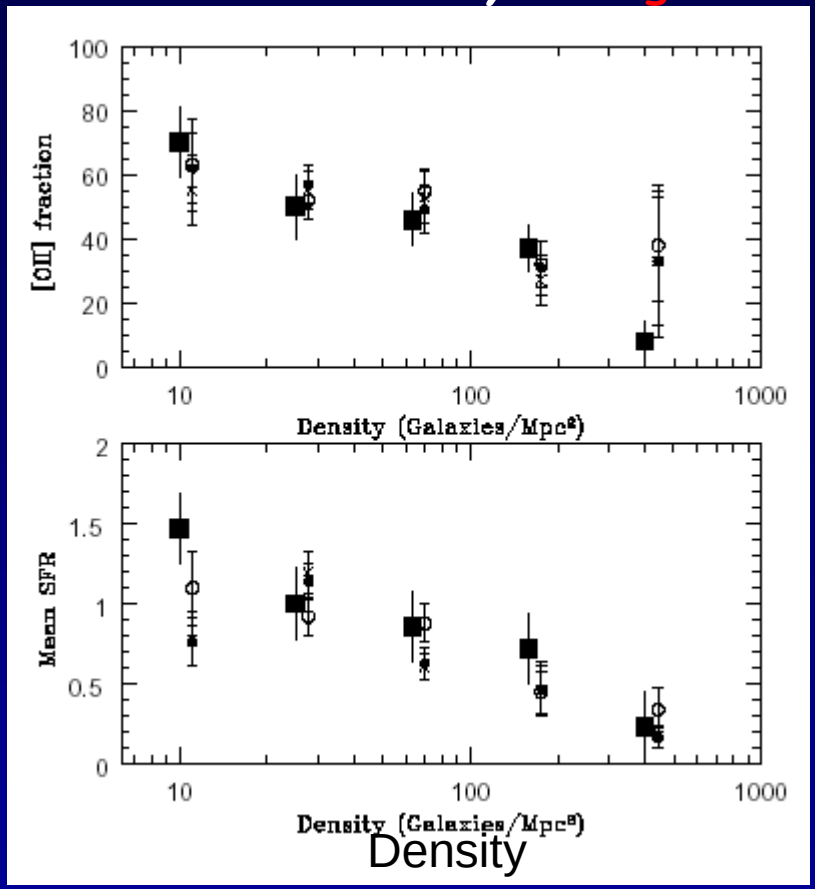
SF-density = Morphology-density in high-z clusters

For a given Hubble type, ***no trend of SF with local density*** at high-z…



SFing %

Mean SFR



EDisCS Poggianti et al. 2008