# L'EVOLUZIONE DELLE DIMENSIONI DELLE GALASSIE E LA LORO DIPENDENZA DALL'AMBIENTE

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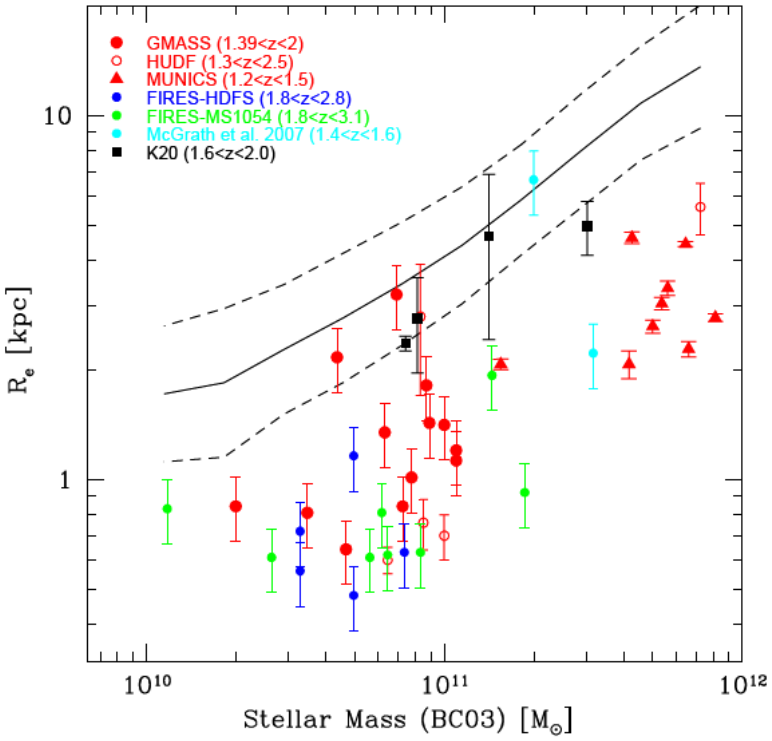
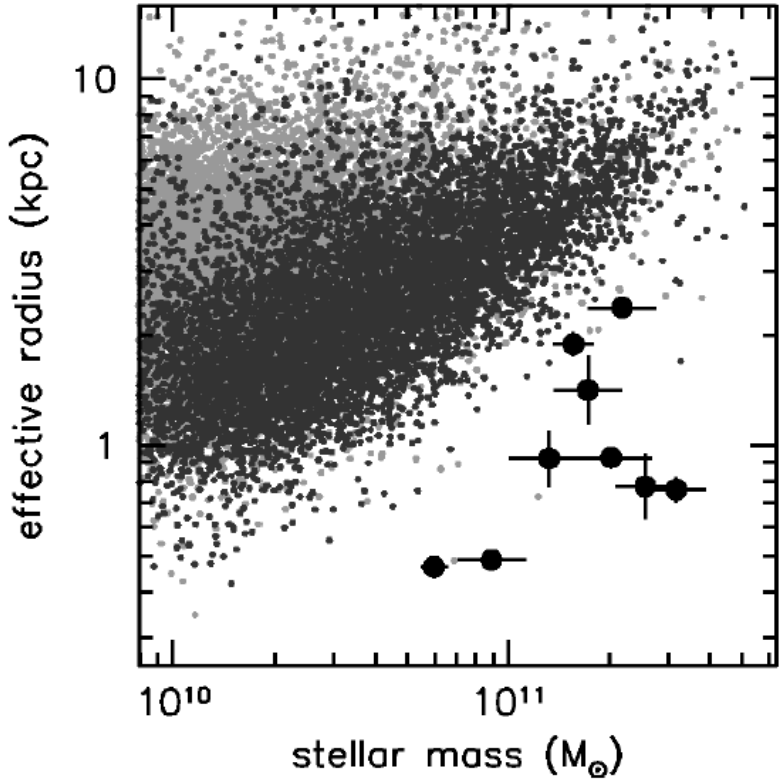
# MASSIVE COMPACT GALAXIES AT HIGH REDSHIFT

Many authors find high-z (z>1-3), massive ($M_*>10^{10}$-$10^{11}$ $M_{sol}$) galaxies with small sizes ("compact", $R_e$<1-2-3kpc)




**Cimatti et al. 2008**



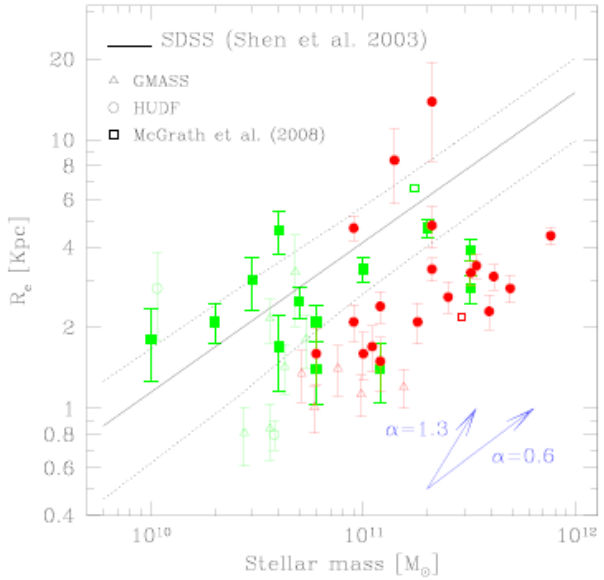

**Van Dokkum et al. 2008**

(Daddi+ 2005, Trujillo+ 2006, Toft+ 2007, Zirm+ 2007, Buitrago+ 2008, Cimatti+ 2008, van Dokkum+ 2008, Damjanov+ 2011, Ryan+12, +)

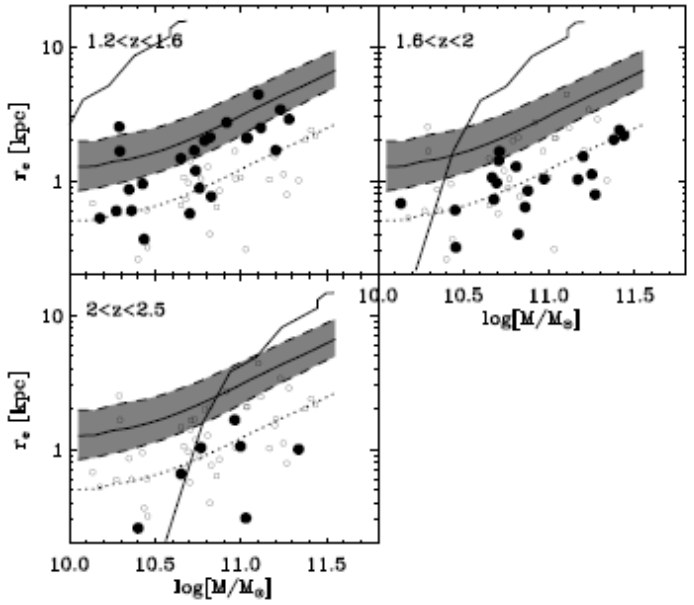
# SELECTION AND LOCAL COMPARISON

In most cases, high-z galaxies **are selected to be already passive (old stars) at that z** – in a few cases, morphologically selected to be early-type galaxies (van der Wel+ 2008, Saracco+ 2009, Cassata+ 2011, 2013)

Most high-z works use as local comparison the median mass-size relation for n › 2.5 galaxies (Shen+ 2003), finding high-z points to lie mostly below local relation



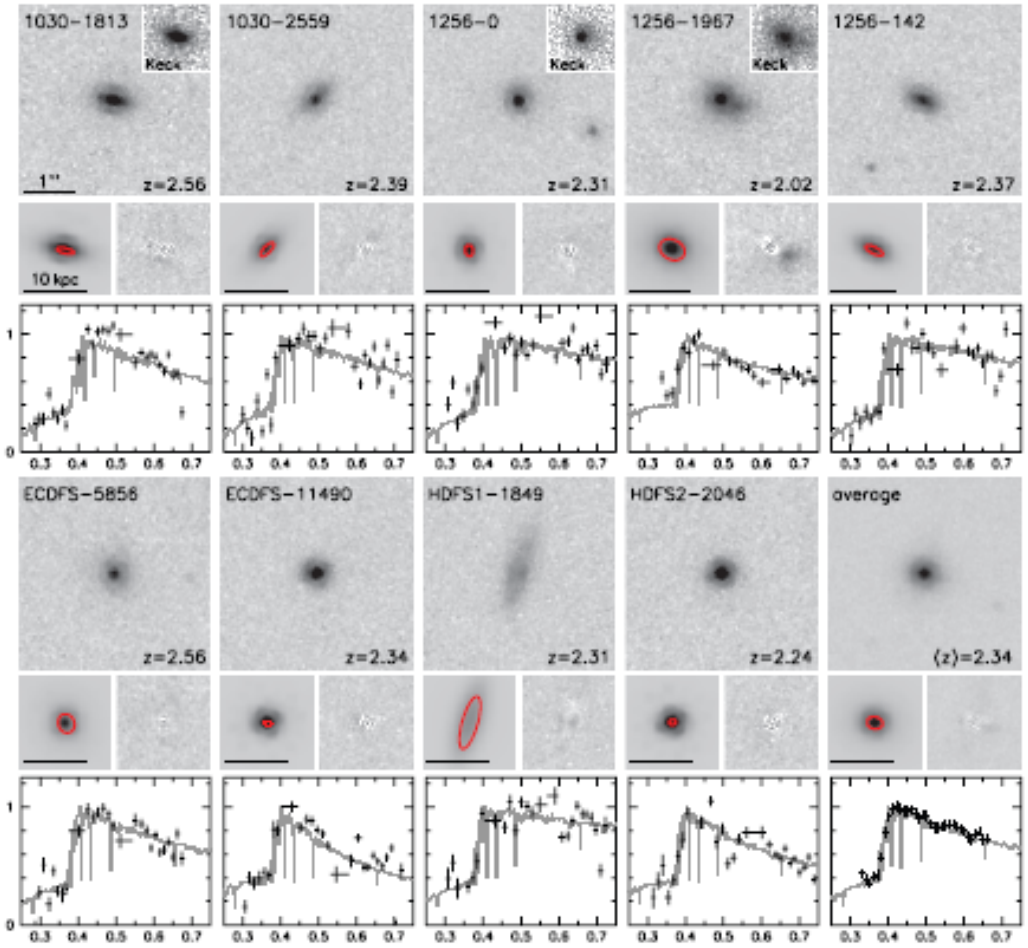

Saracco et al. 2009

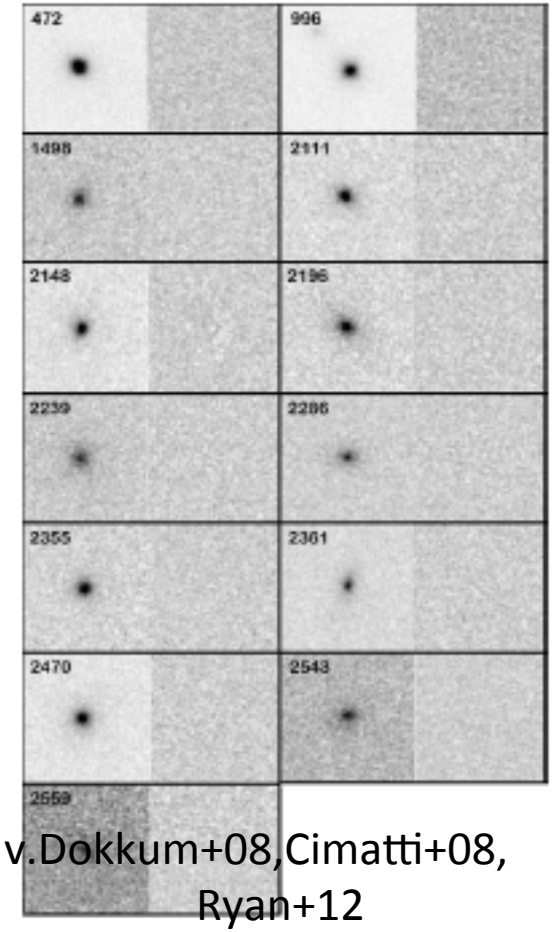



Cassata et al. 2011

# ELLIPTICALS OR DISKS?

The majority of massive high-z galaxies (even passive and massive) have disks



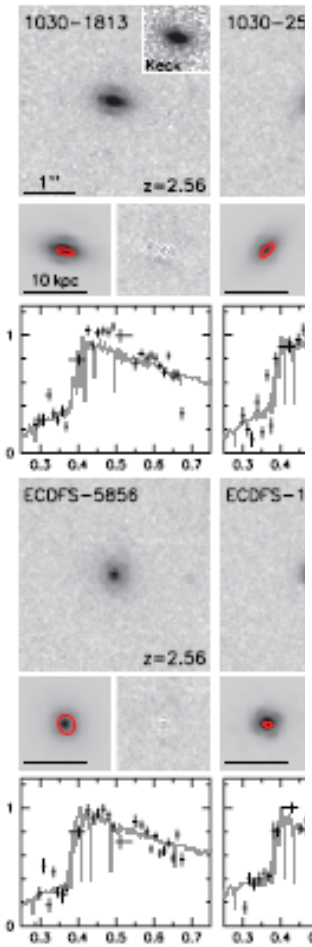



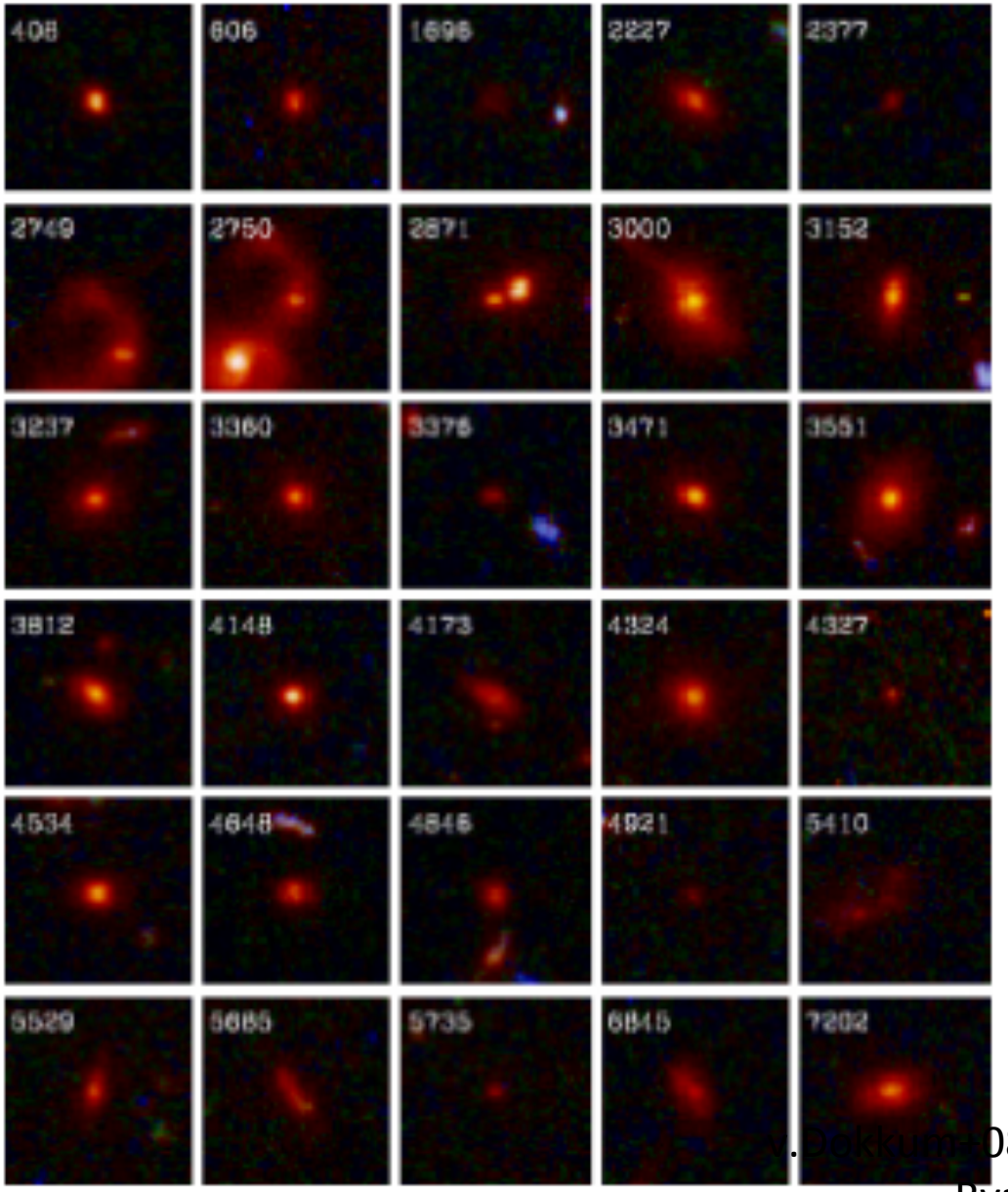

v.Dokkum+08,Cimatti+08, Ryan+12

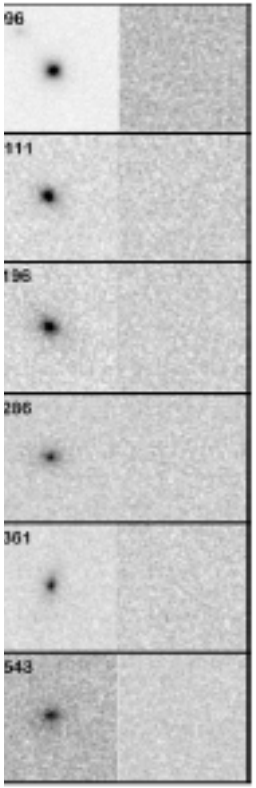
The majority

massive)

have disks



. Dekkum+08,Cimatti+08,
Ryan+12

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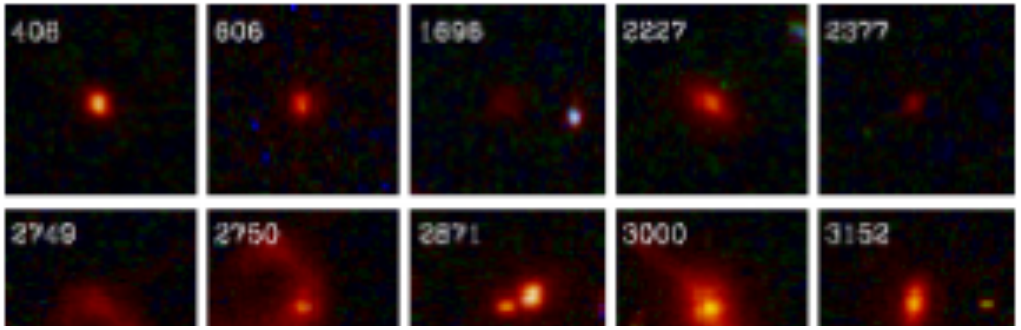


massive)

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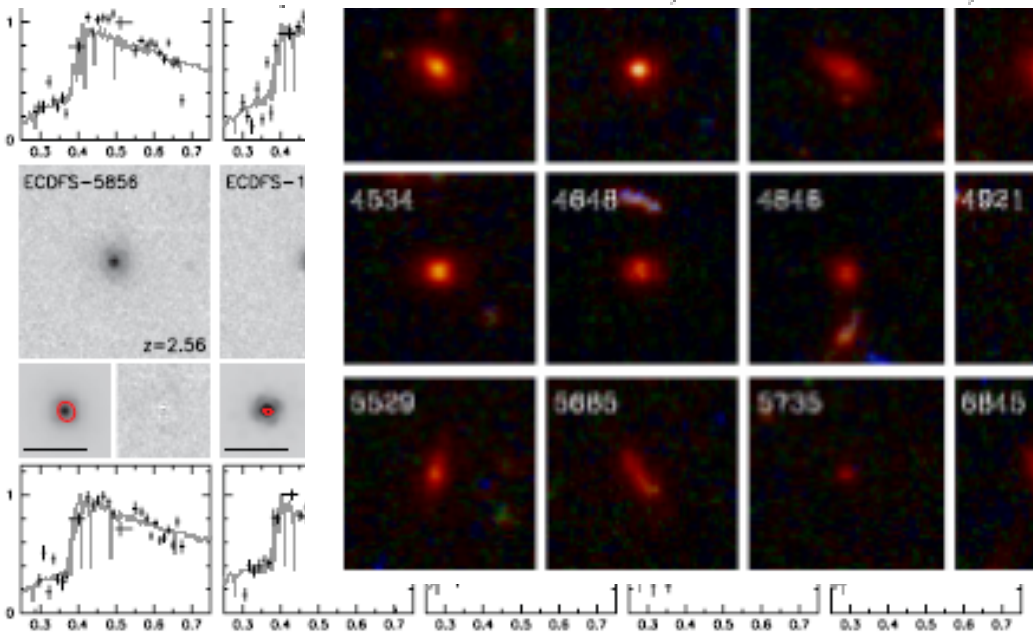
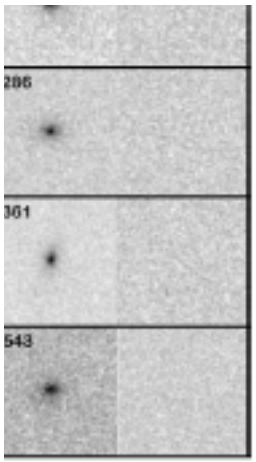
doi:10.1088/0004-637X/730/1/38

# THE MAJORITY OF COMPACT MASSIVE GALAXIES AT $z \sim 2$ ARE DISK DOMINATED

ARJEN VAN DER WEL[1], HANS-WALTER RIX[1], STIJN WUYTS[2], ELIZABETH J. MCGRATH[3], ANTON M. KOEKEMOER[4], ERIC F. BELL[5], BRADFORD P. HOLDEN[6], ADAY R. ROBAINA[7], AND DANIEL H. MCINTOSH[8]




. Dokkum+08,Cimatti+08, Ryan+12

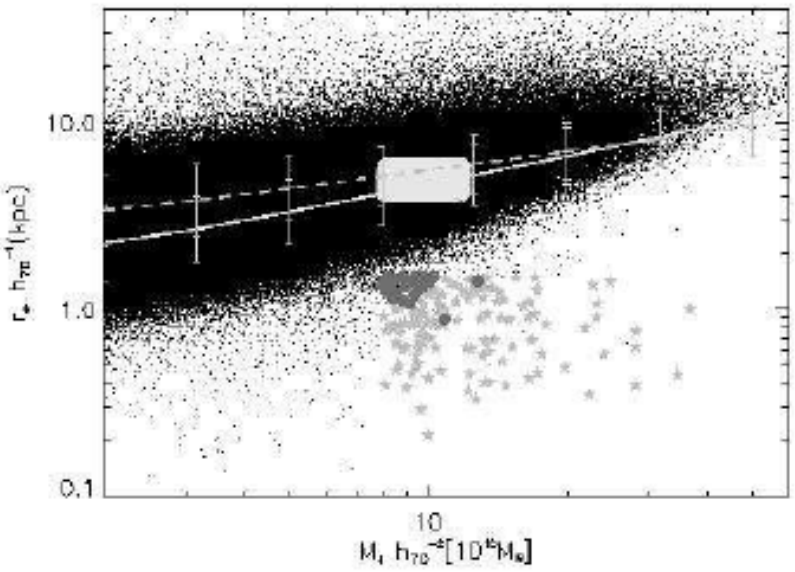
C2 images of the nine spectroscopically confirmed quiescent $z > 2$ galaxies from Kriek et al. (2006). Each panel spans 3.8″ ×

# GENERAL FIELD AT LOW-Z

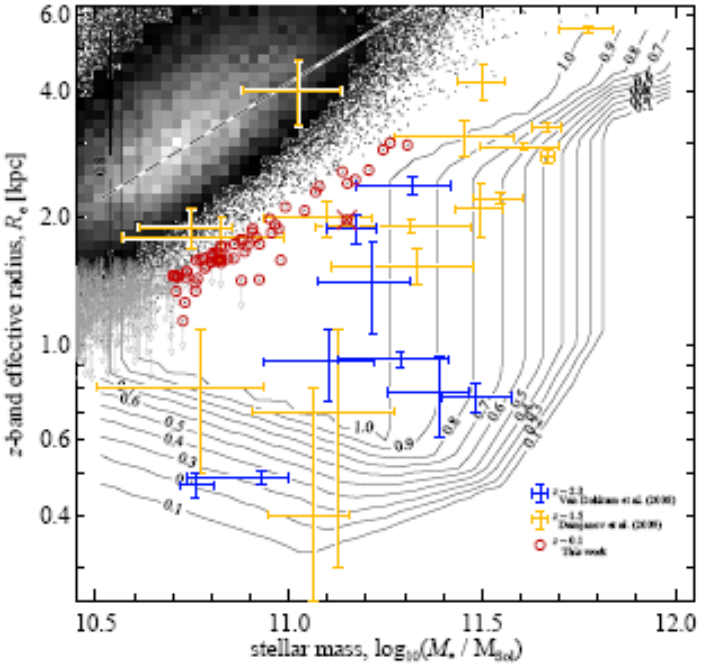
Trujillo et al. (2009) and Taylor et al. (2010) searched for massive compact galaxies at low-z – both found very few such galaxies in the general field at low-z

Almost none of the massive compact high-z galaxies have “survived”?

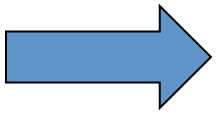
see also Trujillo+2014 NGC1277




Trujillo et al. 2009




Taylor et al. 2010



## EVOLUTION IN GALAXY SIZES?

## FACTORS 3 TO 6 INVOKED

- Major mergers
- Expansion for mass loss due to an AGN or stellar wind (Fan+ 2008, Damjanov+ 2009)
- **Minor dry merging** (Naab+ 2009, Hopkins+ 2009, Oser+ 2012) – adding stellar mass to the outer parts of the galaxies, without the formation of new stars

Problems: minor mergers (especially dry) not frequent enough for size evolution since $z \geq 1$ (Newman+ 2012, Nipoti+ 2012, Cimatti+ 2012)

## WHY IMPORTANT?

Role of in-situ star formation (high-z) vs. growth via accretion (lower z) – neither simply "monolithic collapse", nor single binary merger of disk galaxies

Galaxy mass and size seem to be two key elements that determine a galaxy evolutionary history

# WIde-field Nearby Galaxy-cluster Survey

# WINGS

A wide-field survey of 77 X-ray selected clusters at z=0.04-0.07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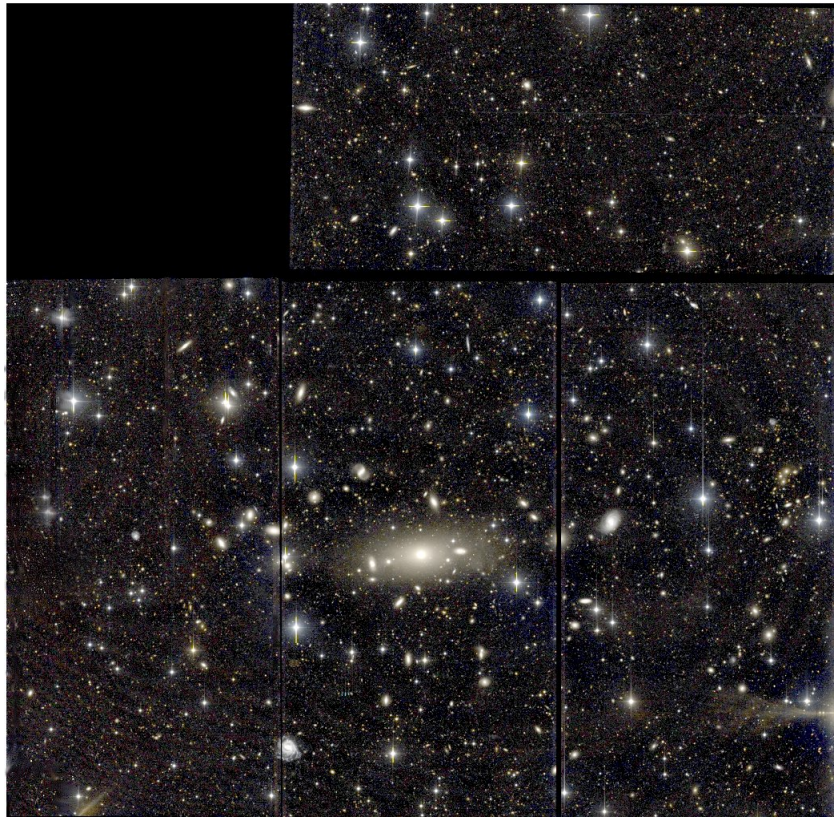
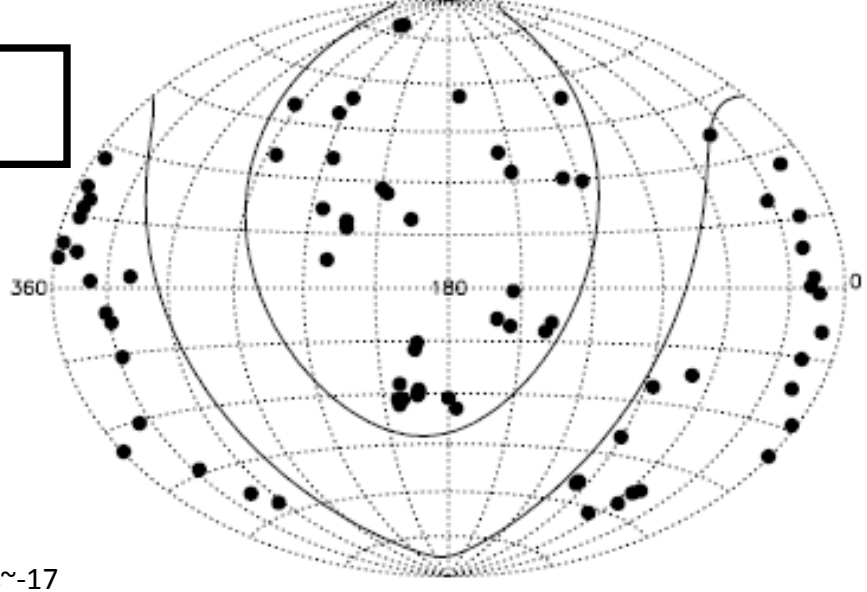
Antonio Cava
Jacopo Fritz
Tiziano Valentinuzzi
Jesus Varela
Alessia Moretti
Benedetta Vulcani

+Mariano Moles
Alan Dressler
Warrick Couch
Per Kjaergaard

+external collaborators at
Trieste, Granada, Tenerife, ESO

# THE WINGS DATASET




Sigma=500-1200+, Log $L_X$=43.3-44.7

B and V deep photometry

FOV 1.2-2.7Mpc, res. 0.7-1.6kpc, $M_V$~-13
400.000 gal phot., 40.000 surf.phot + morph

Optical fibre spectroscopy

48 clusters, 6500 spectra, 100-200 galaxies/cluster, down to $M_V$~-17

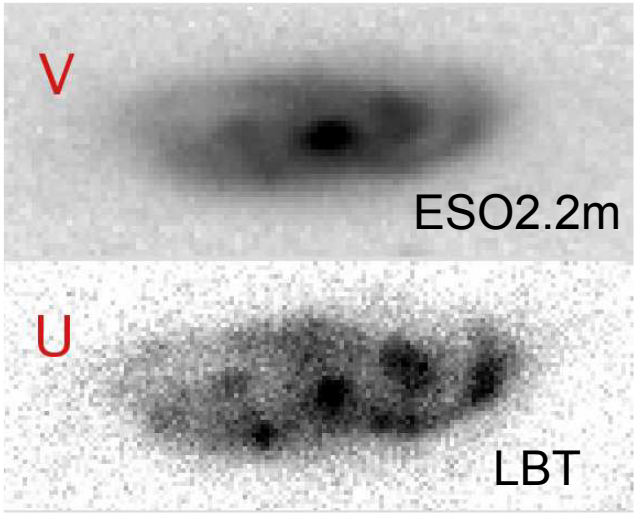
Near-IR deep photometry

J and K, 36 clusters – galaxy masses, SED + struct.props

u, V and B on a 1deg sq. with Omegacam, + AAOMEGA spectroscopic follow-up

Ongoing -

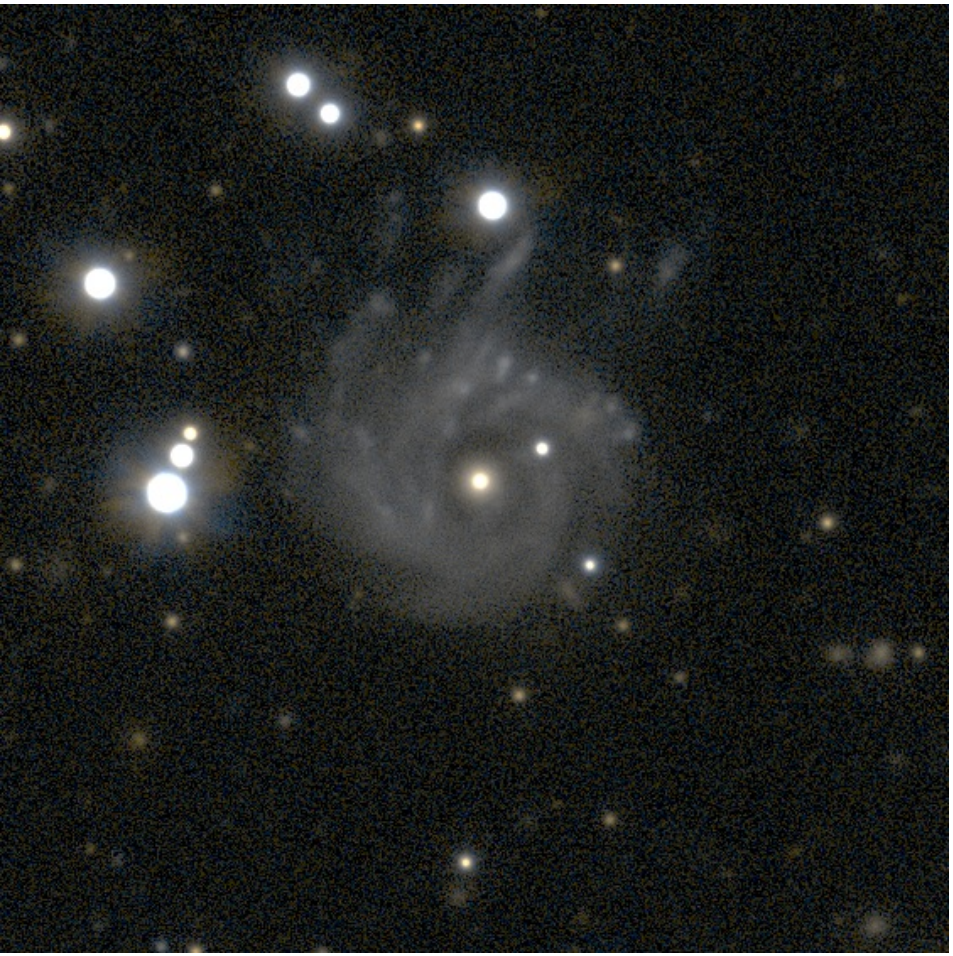
U-band with INT, LBT & Bok

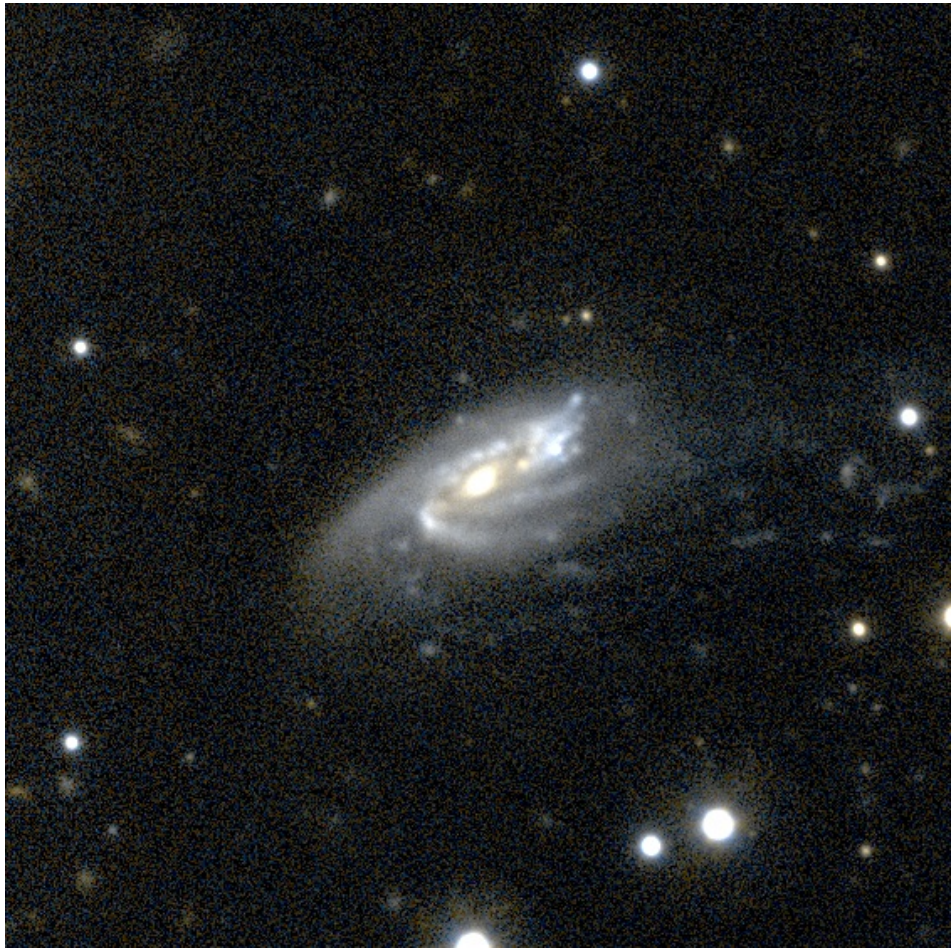



**Large effort: 114 telescope nights, 28 refereed pubs so far, all wide-field – ALL PUBLIC on VO (Moretti+ 2014)**

WFC/INT, WFC/ESO2.2, WYFFOS/WHT, 2dF/AAT, WFCAM/UKIRT, 90prime/Bok, LBC/LBT, Omegacam/VST, AAOMEGA/AAT,GMOS/ Gemini,VIMOS/VLT

# JELLYFISH GALAXIES WITH OMEGACAM





In prep.

# Padova-Millennium Galaxy and Group Catalogue (PM2GC)

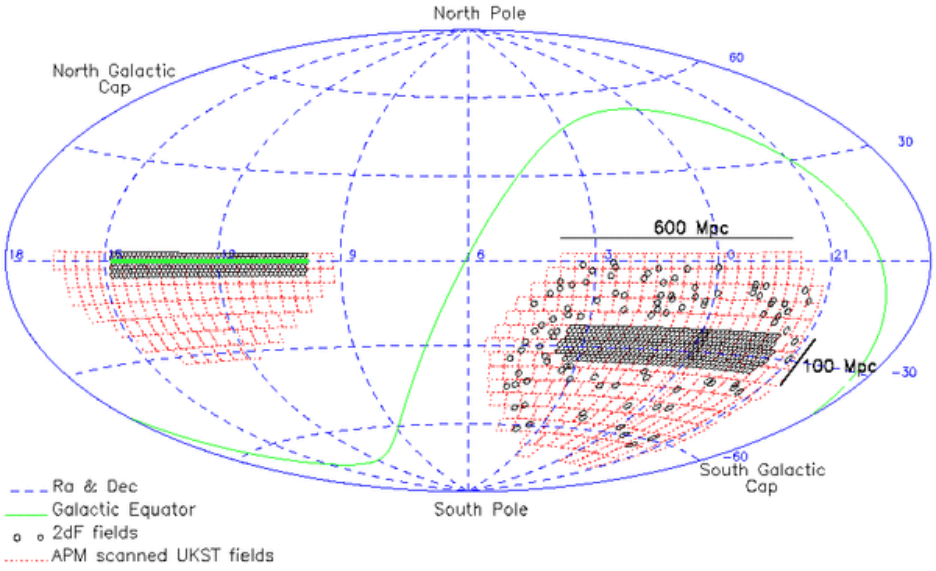
Rosa Calvi – Bianca M. Poggianti + WINGS collaborators

## A general field galaxy sample at z=0.04-0.1

Based on the Millennium Galaxy Catalogue (PI Simon Driver, Liske et al. 2003), a 38 deg^2 equatorial survey

B-band imaging with WFC/INT

AAT/2dF redshift survey combined with 2dFGRS and SDSS: spectroscopic completeness in the area 96% to B=20

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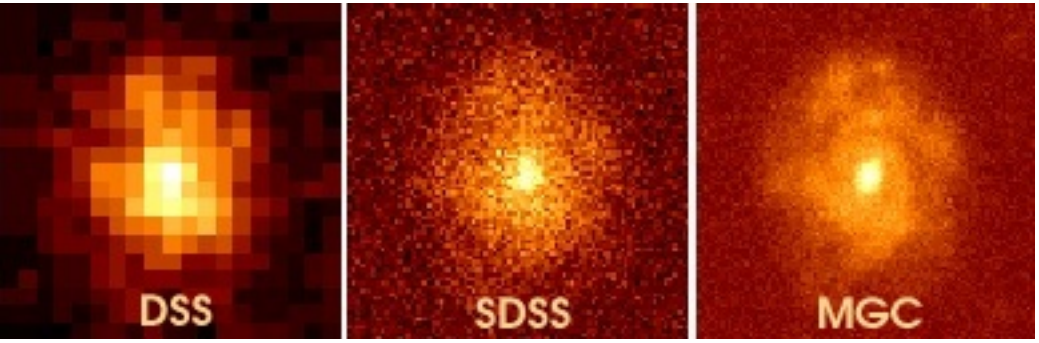



ADVANTAGES compared to SDSS:

Better imaging quality

Spectroscopic completeness (14% of all, 27% of our compacts missing in SDSS)

Group catalogue (groups, binaries and singles) and environment characterization (FOF algorithm)

- Galaxy morphologies
- Galaxy stellar masses
- SFHs and stellar populations from spectral analysis

Calvi et al. 2011, 2012, 2013

# LOW-Z RESULTS IN GALAXY CLUSTERS

## WINGS -- Valentinuzzi et al. 2010a,b

1. In nearby clusters, a significant population of compact galaxies with masses and sizes similar to high-z galaxies

   12% in B-band of all galaxies with $3 \times 10^{10} < M < 4 \times 10^{11}$ (all types and colors) – BCGs excluded!

# LOW-Z RESULTS IN GALAXY CLUSTERS

## WINGS -- Valentinuzzi et al. 2010a,b

2. Importance of selection effects

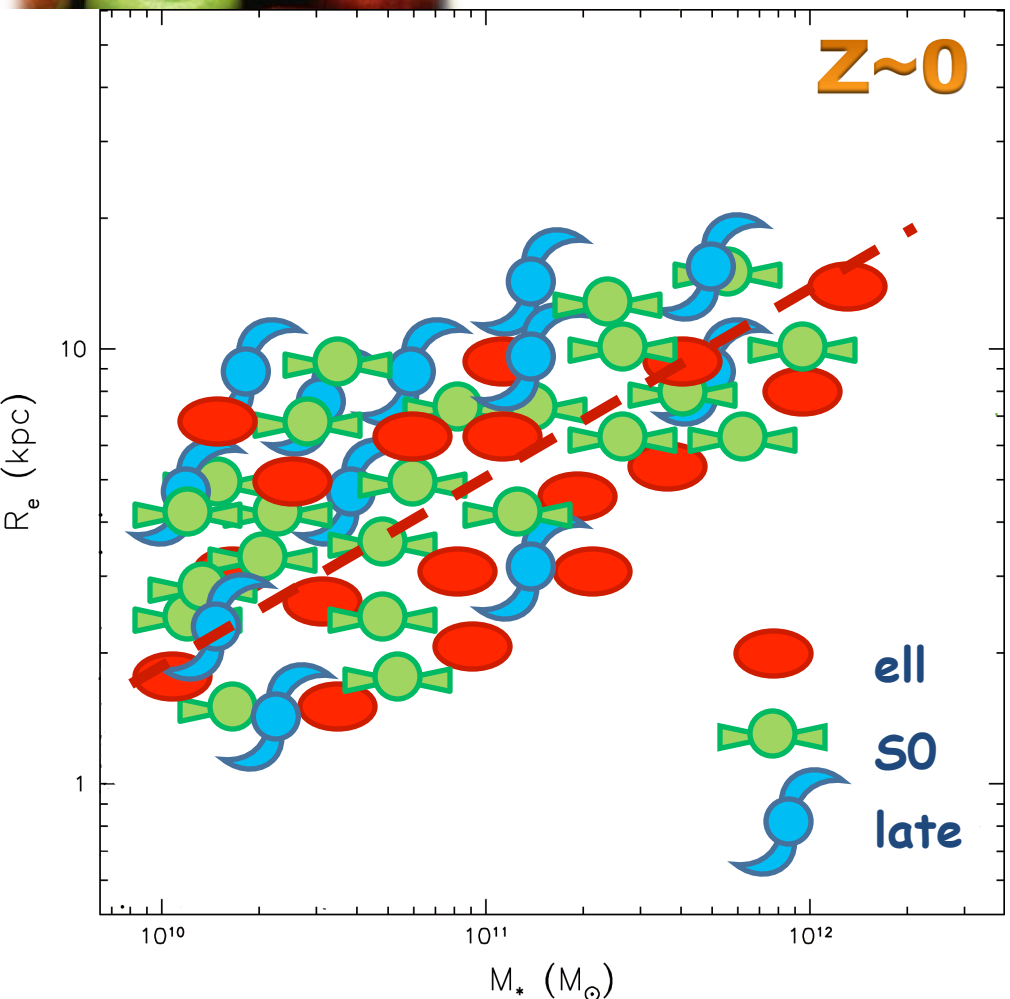
As time goes by, **more and more galaxies are added to the passive population** – Those that are added later have on average **larger sizes** than those that were already old/early

In fact, at a given mass, galaxy sizes depend on stellar population ages: **galaxies that stopped forming stars sooner are smaller** (also Saracco+ 2009, van der Wel 2009, Cappellari+2012 + others)

**Selecting galaxies to be old results in selecting the most compact ones.**

# MATCHING HIGH-Z and LOW-Z POPULATIONS

How to identify local descendants? – every method is imperfect (passivity,morphology, number density…)




***use as local comparison ONLY those galaxies whose lum.wei. age is so old that they already looked passive at high-z***

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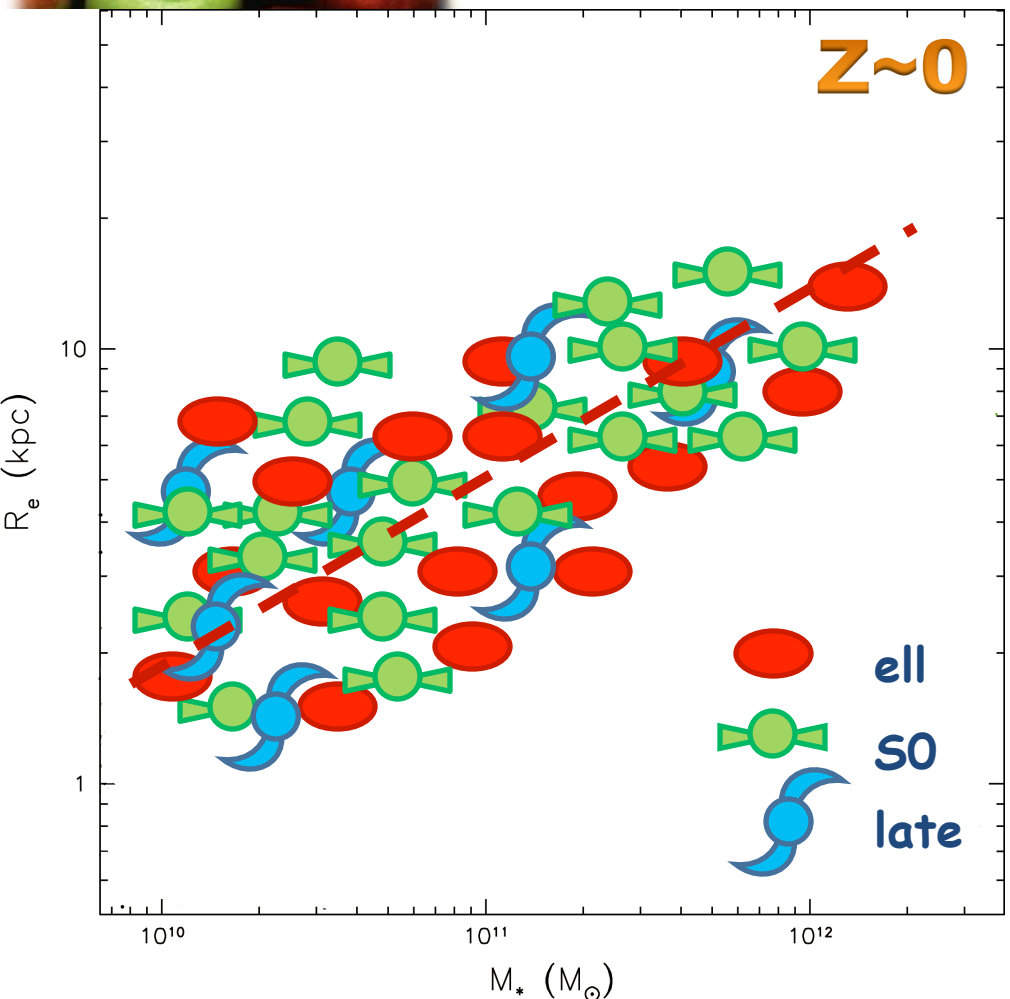


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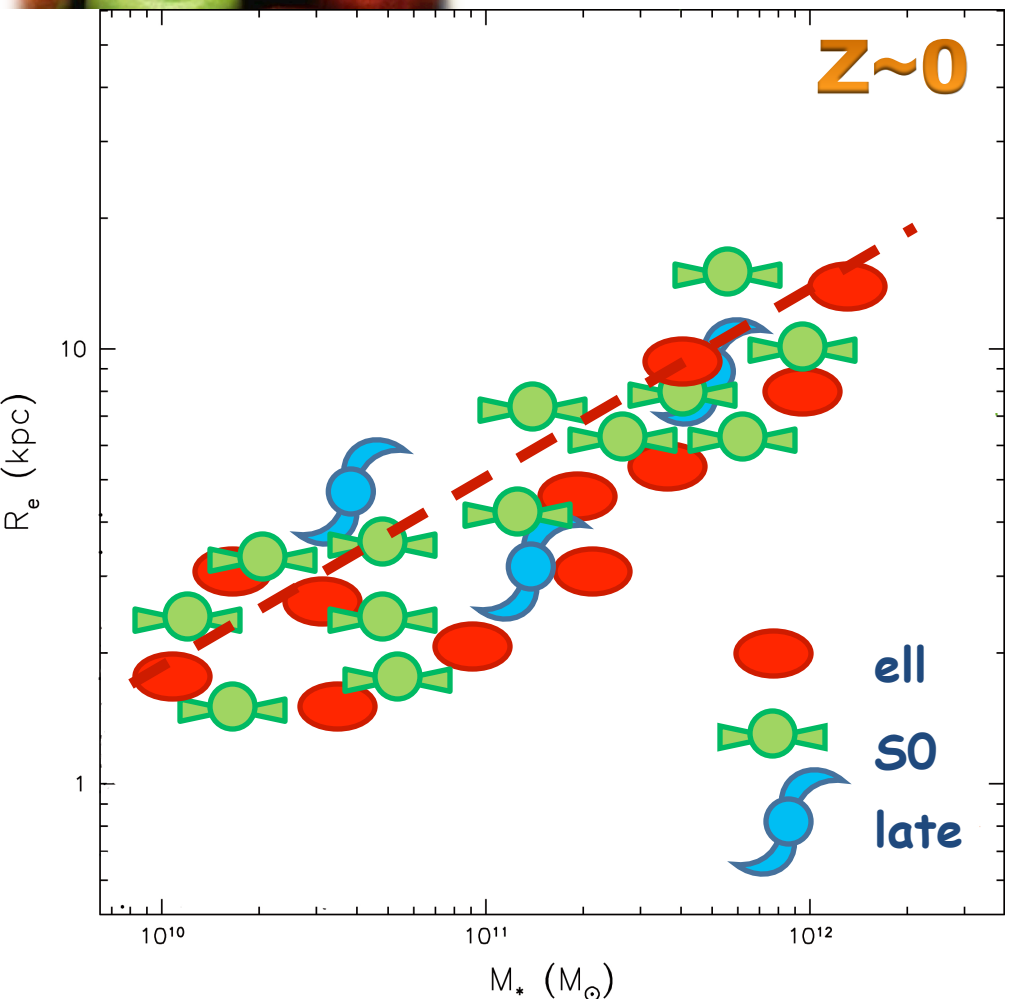


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# PROPERTIES OF LOW-Z COMPACT MASSIVE GALAXIES

After inspecting each candidate, 44 galaxies / 995 in PM2GC

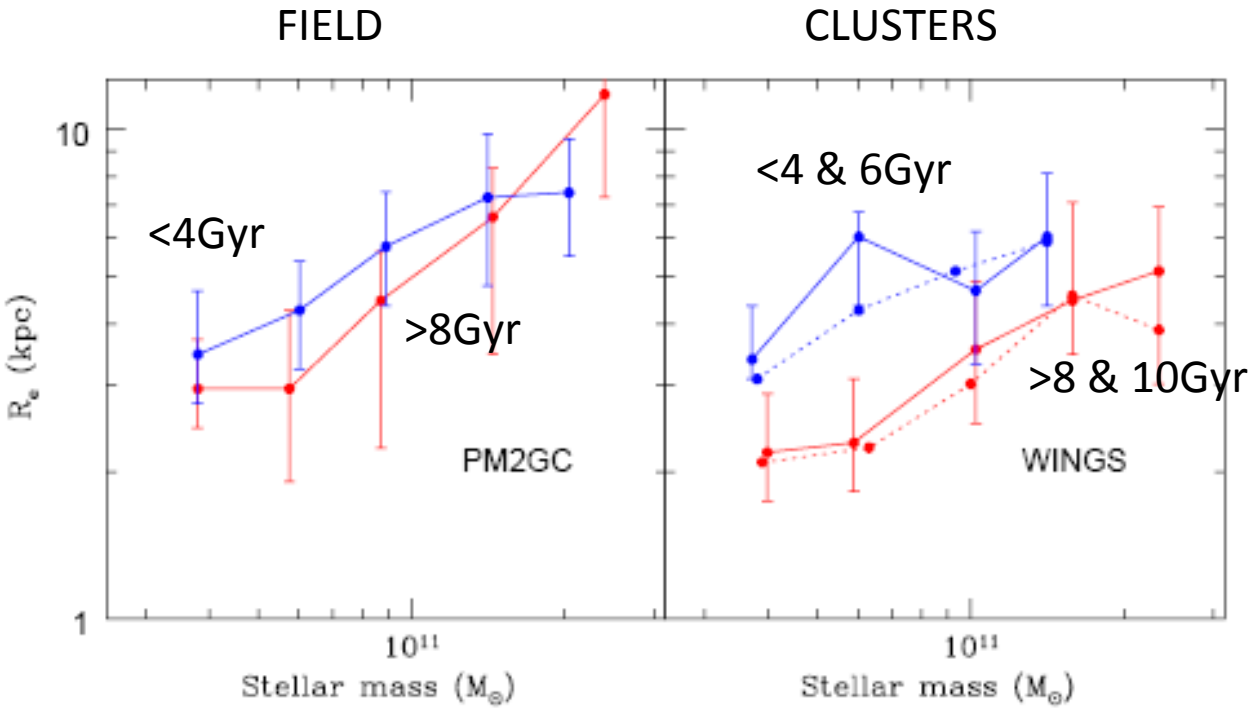
Compact fraction M>3X10^10: 4.4±0.7% in PM2GC, 11.8±1.7% in WINGS B-band (in >500km/sec PM2GC "groups" 14±7)

using literature values (masses and sizes) in PM2GC 3.7±0.7%

| | PM2GC | | WINGS B-band | |
|---|---|---|---|---|
| Quantity | Value | RMS error | Value | RMS error |
| SDGs | 44 | 7 | 51 | 11 |
| $\langle R_e \rangle$ | 1.45 | 0.26 | 1.57 | 0.34 |
| $\langle n \rangle$ | 2.8 | 0.6 | 3.1 | 0.8 |
| $\langle b/a \rangle$ | 0.48 | 0.13 | 0.65 | 0.16 |
| $\langle M_* \rangle$ | $6.0\times10^{10}M_\odot$ | $1.9\times10^{10}M_\odot$ | $9.1\times10^{10}M_\odot$ | $3.6\times10^{10}M_\odot$ |
| $\langle V_{abs} \rangle$ | -20.87 | 0.42 | -20.68 | 0.38 |
| $\langle Lw-age \rangle$ | 5.45 | 1.87 | 9.64 | 2.10 |
| $\langle Mw-age \rangle$ | 9.25 | 1.08 | 11.95 | 1.39 |
| Ellipticals frac. | 22.7% | 7.2% | 29.1% | 7.8% |
| S0s frac. | 70.5% | 12.7% | 62.0% | 10.7% |
| Late-type frac. | 6.8% | 3.9% | 8.8% | 4.4% |

Poggianti et al. 2013a

# MASS-SIZE RELATION AS A FUNCTION OF LUMINOSITY-WEIGHTED AGE




Older LW galaxies are smaller

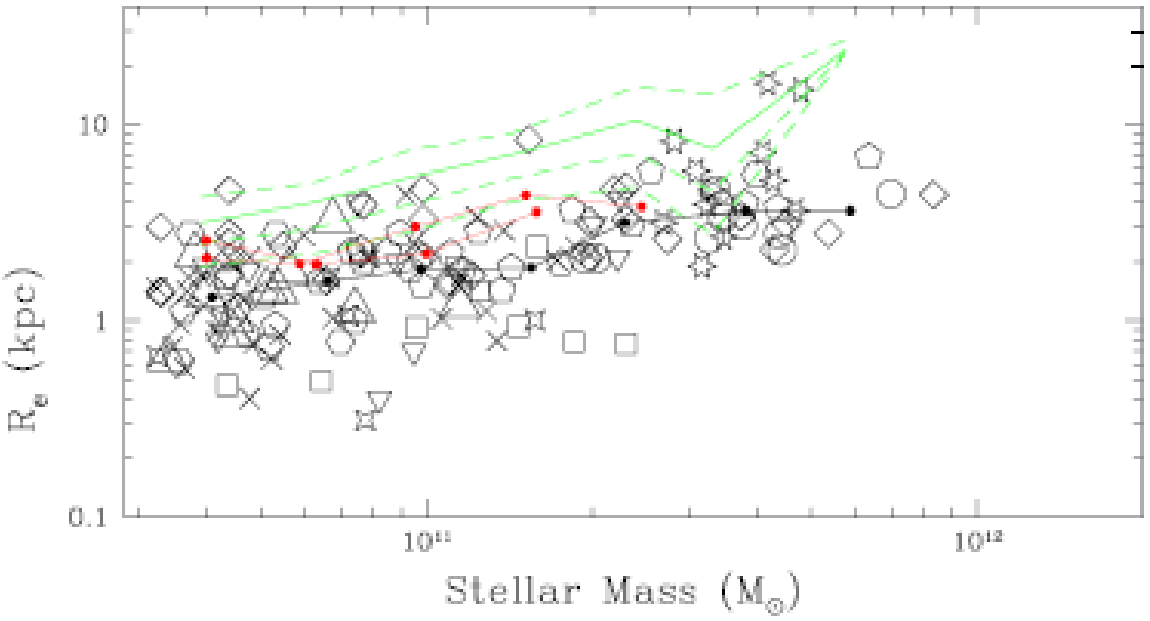
Effect stronger in clusters than in the field

Most works find same effect (van der Wel et al. 2009, Saracco et al. 2009, Williams et al. 2010, Cappellari et al. 2012 – but see Trujillo et al. 2011)

Galaxy LW ages depend on galaxy stellar mass, galaxy size and environment.

Poggianti et al. 2013a

# THE AMOUNT OF SIZE EVOLUTION




Half of the observed evolution of the median mass-size relation is due to the progenitor bias:

Considering only galaxies with OLD LW ages at low-z, average evolution a factor ~1.6 (instead of 3.1)

MILD EVOLUTION IN SIZE

Poggianti et al. 2013a

# SIMULATIONS

Millennium Simulation + semianalytic model (De Lucia & Blaizot 2007):

60% of all galaxies that at z=2 are massive (>$10^{11}$) *and* passive end up in clusters above $10^{14}$ Msun by z=0

Studying massive galaxies at high-z means to a large extent studying the progenitors of today's cluster galaxies

40% of all galaxies that at z=2 are massive (>10^11) *and* passive are **BCGs** of clusters above 10^14 Msun by z=0

For BCGs large evolution in both size and mass required (Valentinuzzi+ 2010b, Bernardi+ 2009 and many others) …. they have been excluded here

Poggianti et al. 2013a

# HOW MANY OF THE DISTANT COMPACTS HAVE REMAINED COMPACT UNTIL TODAY?

*number density* of compact galaxies

Previous works:

Taylor+10: strong evolution in ND (>5000) for extremely compact galaxies – local comparison disk-free red sequence SDSS

Cassata+10, 13: evolution in ND driven both by size growth of compact galaxies and – mostly -appearance of new early-type galaxies with larger size

Saracco+10: negligible evolution in ND for early-type galaxies

Carollo+13: no change in ND over $0.2 < z < 1$ for passive early-types for $M < 10^{11}$, 30% decrease at higher masses

Poggianti et al. 2013b

# THE EVOLUTION OF THE NUMBER DENSITY OF COMPACT GALAXIES

CANDELS Barro et al. 2013, GOODS-S + UDS fields – GALFIT on HST/WFC3 H-band images, masses from model using Bruzual & Charlot 2003

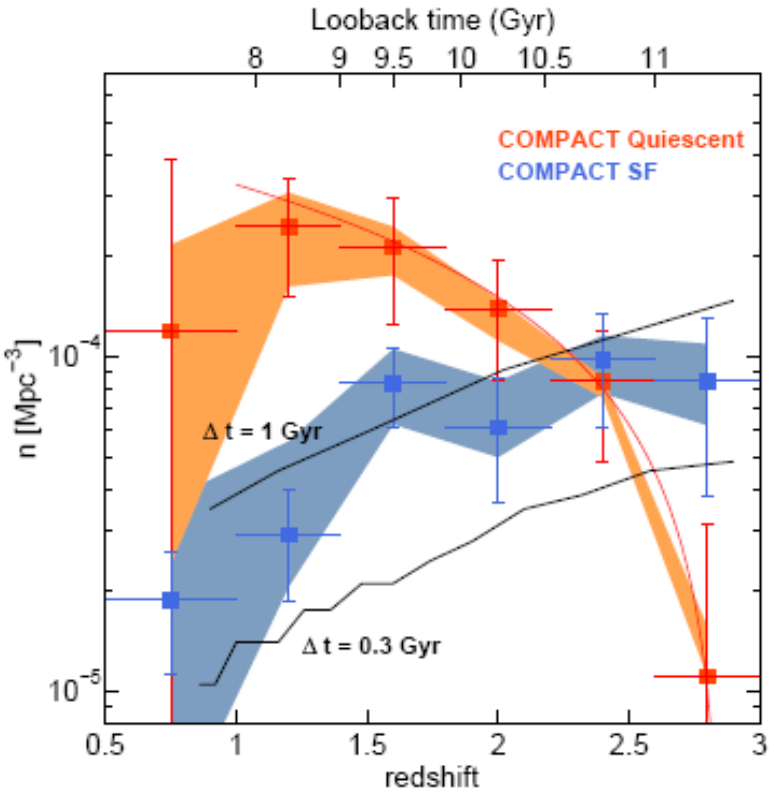
$M \geq 10^{10}$ Msun

Compactness criterion:

Log $M/r_e^{1.5} \geq 10.3$ Msun $kpc^{-1.5}$

QUIESCENT/STARFORMING

sSFR <> 10^-0.5 Gyr^-1

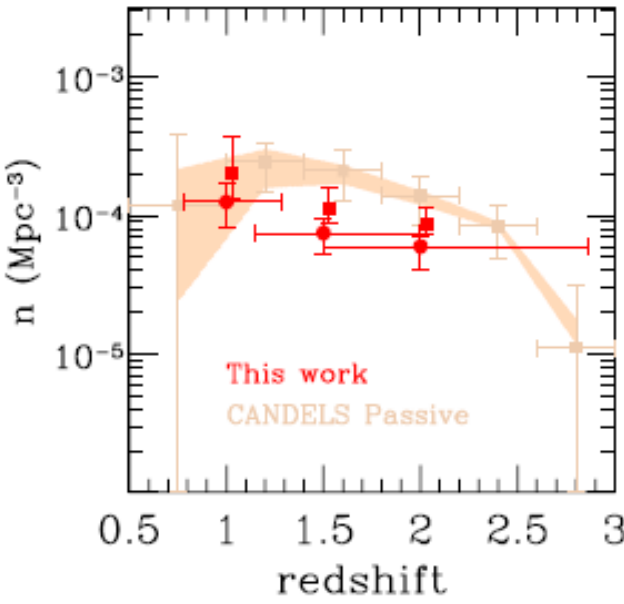



Barro et al. 2013

# HOW MANY OF THE DISTANT COMPACTS HAVE REMAINED COMPACT UNTIL TODAY?

*number density* of compact galaxies

PM2GC vs CANDELS at z=1-3: **upper limit** factor ~2 to evolution of the number density -- at most half of the high-z compact galaxies have evolved in size. Evolution may be stronger (upper limits 2 to 5) for ultracompact galaxies (≥0.4 dex below local mass-size relation, 20% of high-z population)



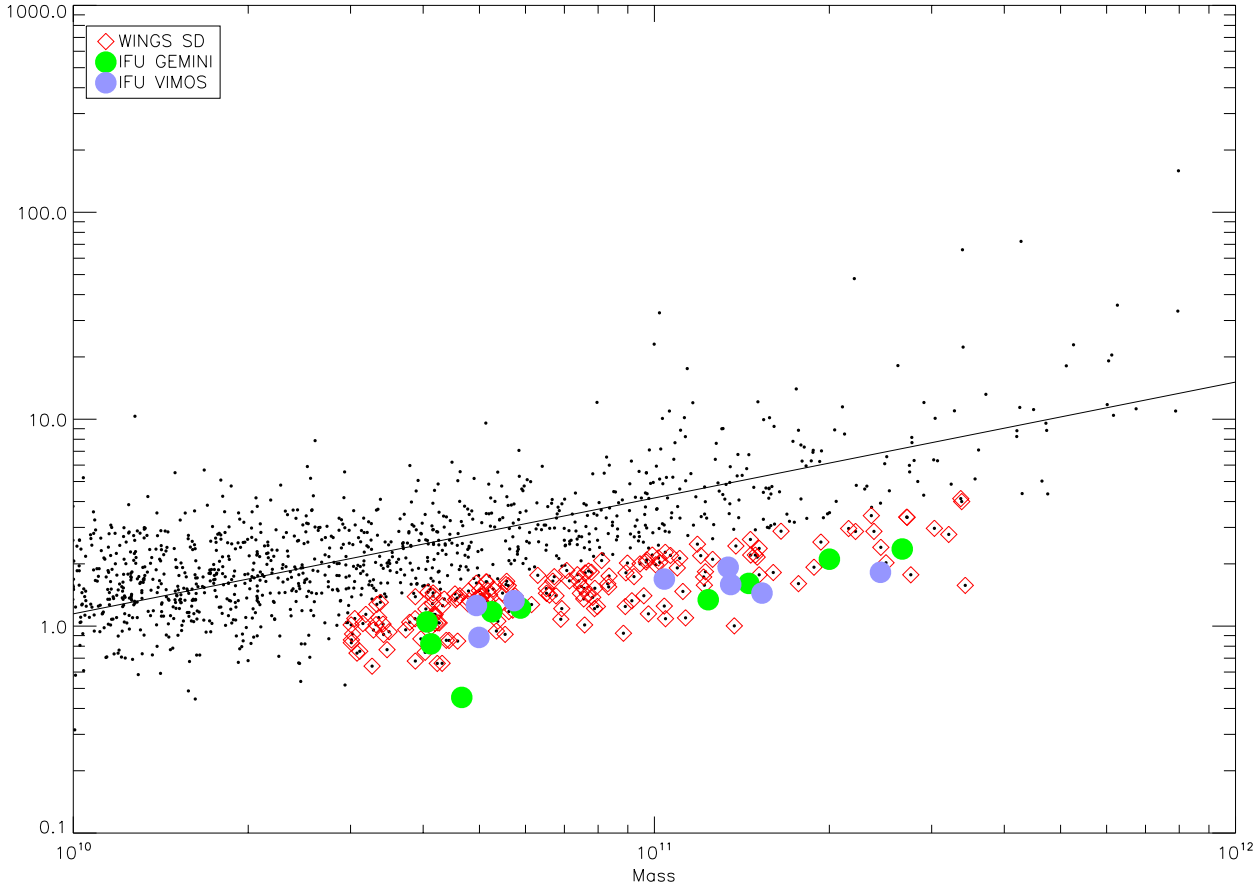

Poggianti et al. 2013b

STUDYING THE RELICS: IFU VIMOS/VLT and GMOS/GEMINI DATA FOR 18 COMPACT LOCAL GALAXIES

in collaboration with Michele Cappellari

DETAILED KINEMATICS, MASS AND STELLAR POPULATION STUDY IN PROGRESS

Effective radius (kpc)




Galaxy stellar mass

Moretti et al. in prep.

STUDYING THE RELICS: IFU VIMOS/VLT and GMOS/GEMINI DATA FOR 18 COMPACT LOCAL GALAXIES

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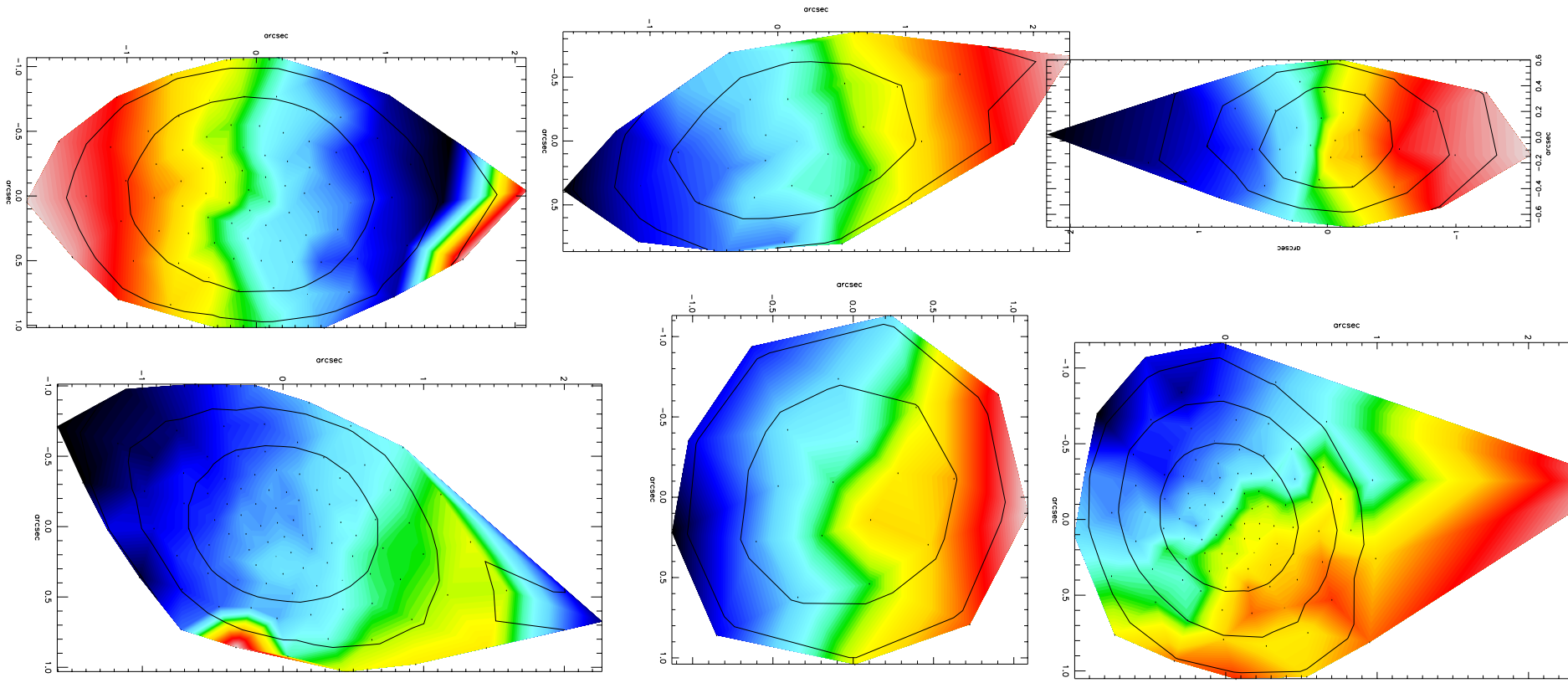


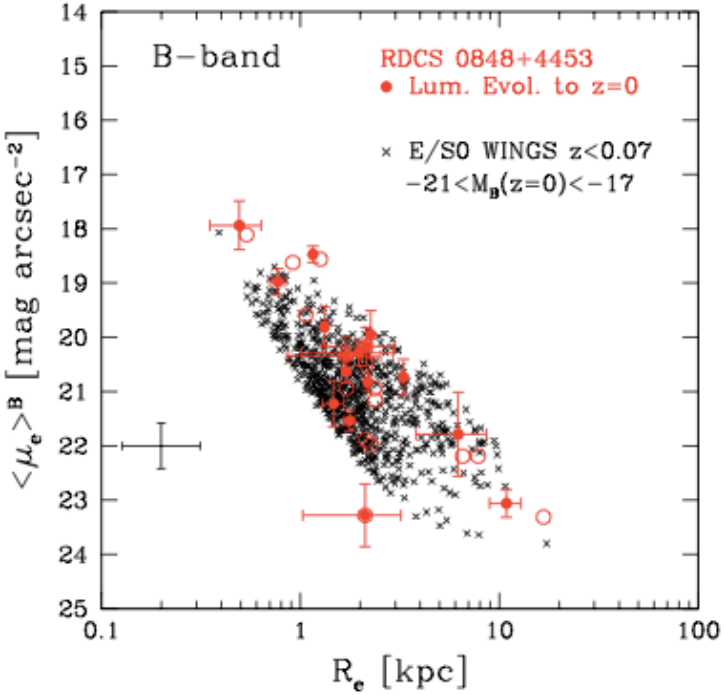

Moretti et al. in prep.

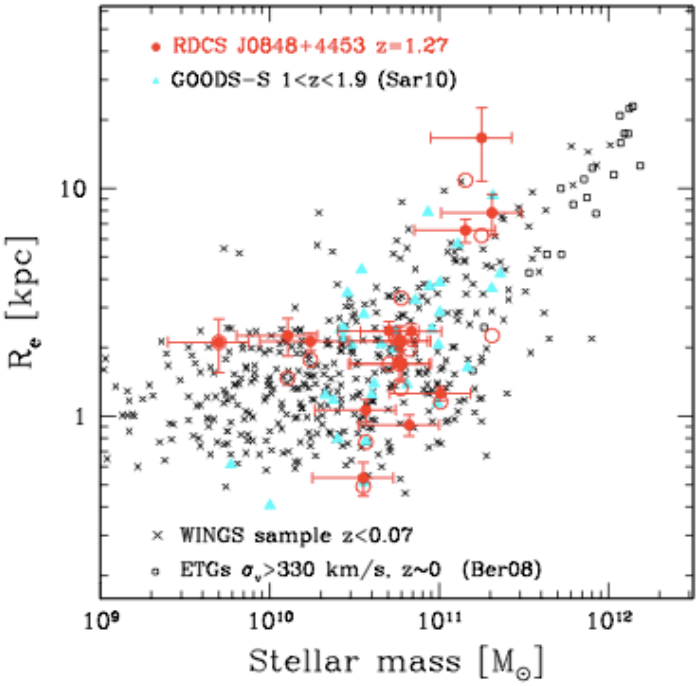
# EVOLUTION OF CLUSTER ELLIPTICAL SCALING RELATIONS

## Saracco+2014 in press

Combined analysis of size-surface brightness and size-mass relation of morphologically-selected ellipticals in clusters at z~1.3 and in WINGS+Coma:

no significant evolution in size and no significant growth in mass is allowed since z~1.3 – only passive evolution



THERE ARE COMPACT MASSIVE GALAXIES AT LOW REDSHIFT

OUR RESULTS SUGGEST EVOLUTION OF SIZES OF INDIVIDUAL GALAXIES IS MILD (in the mass range 3X10^10-4X10^11)

EXCEPT FOR TODAY' S BCGs

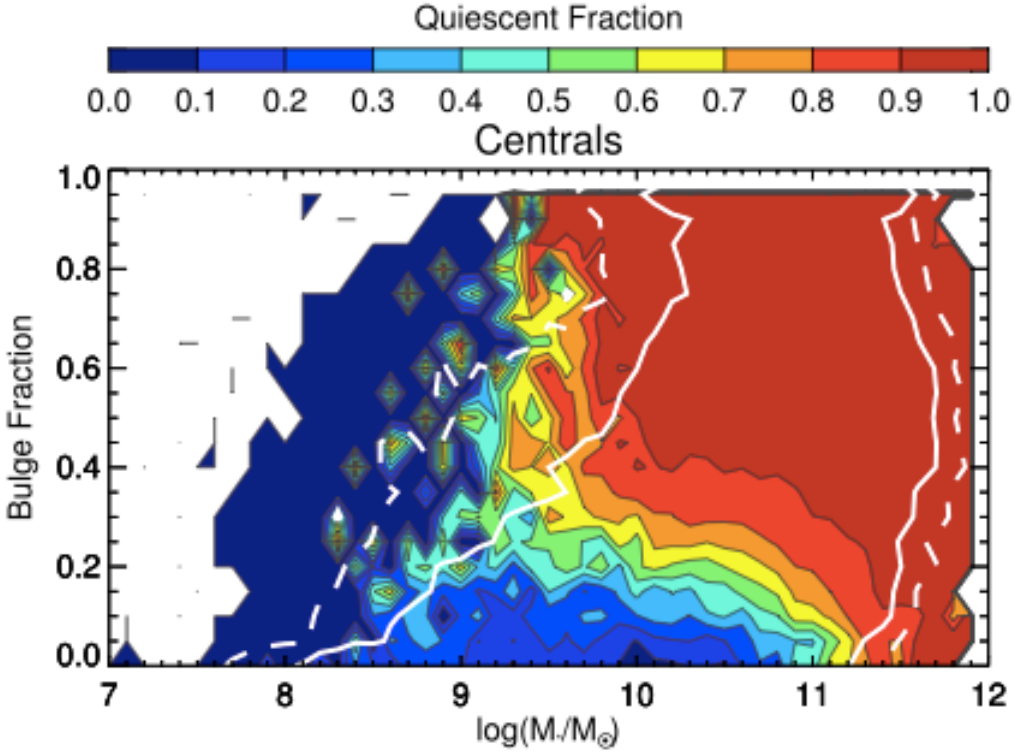
ENVIRONMENTAL DEPENDENCE: COMPACT GALAXIES MORE FREQUENT IN CLUSTERS THAN IN FIELD AT LOW-Z

COMPARING WITH CANDELS, ALSO NUMBER DENSITY EVOLUTION IS MILD:
≥ 50% of high-z compact galaxies have remained compact until today

L’evoluzione in size delle galassie early-type, che alcuni danno per acquisita, necessita di una rivalutazione critica.

L’aspetto forse piu’ interessante e’ capire perche’ la size e’ uno dei parametri chiave.

L’eta’ delle popolazioni stellari delle galassie  dipende dalla size – anche la frazione di galassie quiescent (=passive) dipende dalla size. In Omand+2014 troviamo che la dipendenza della quiescent fraction da $M/R^{1.5}$ e’ guidata dalla dipendenza da B/T, la prominenza del bulge.




Omand, Balogh & Poggianti 2014