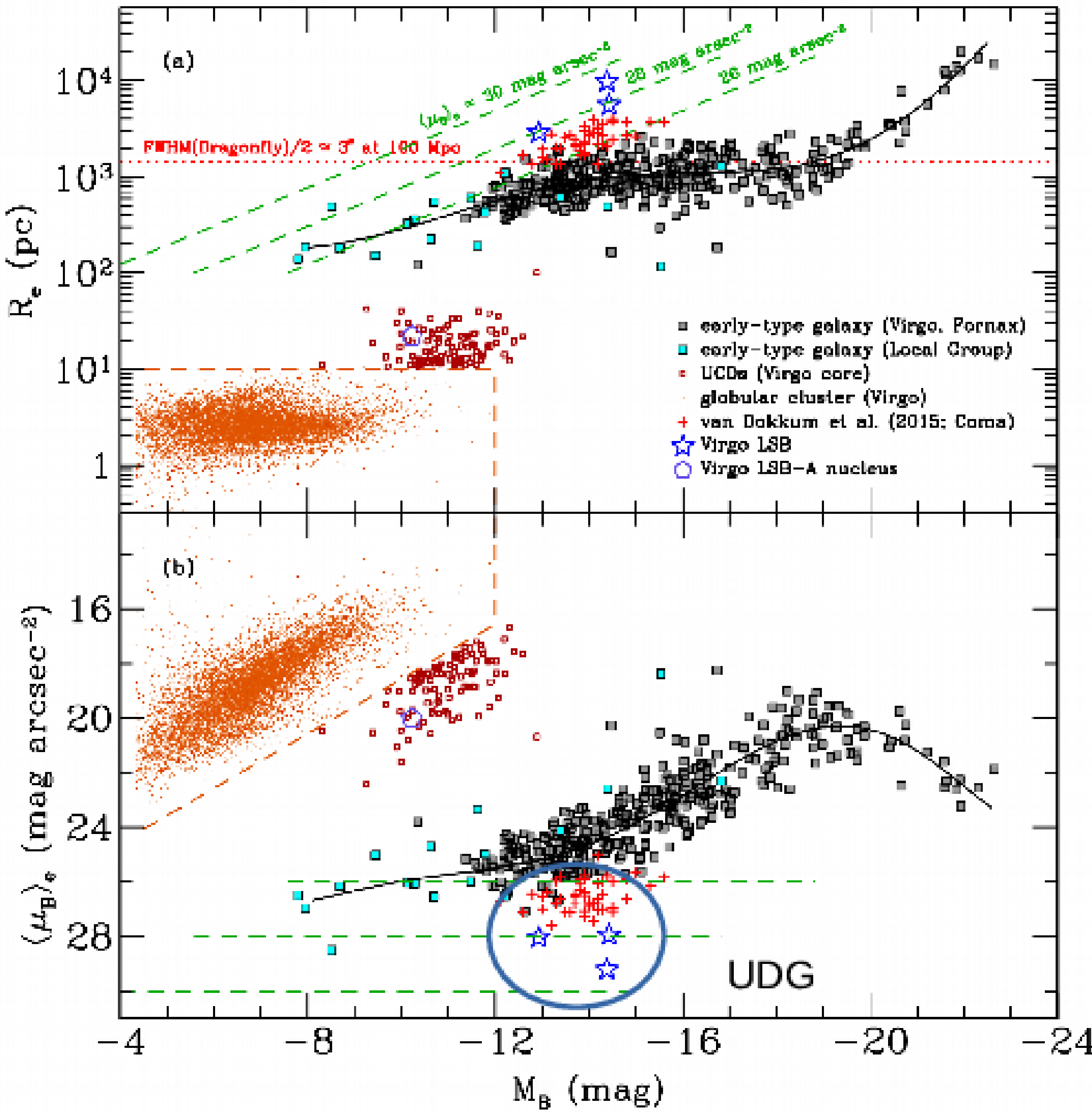
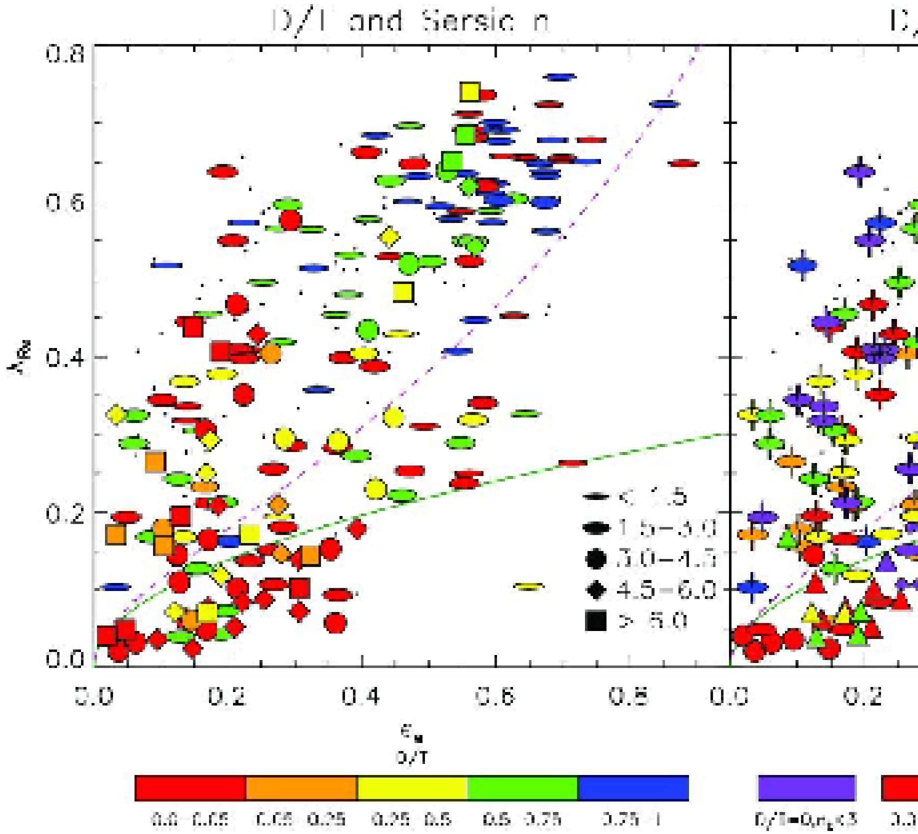
Scaling Relations

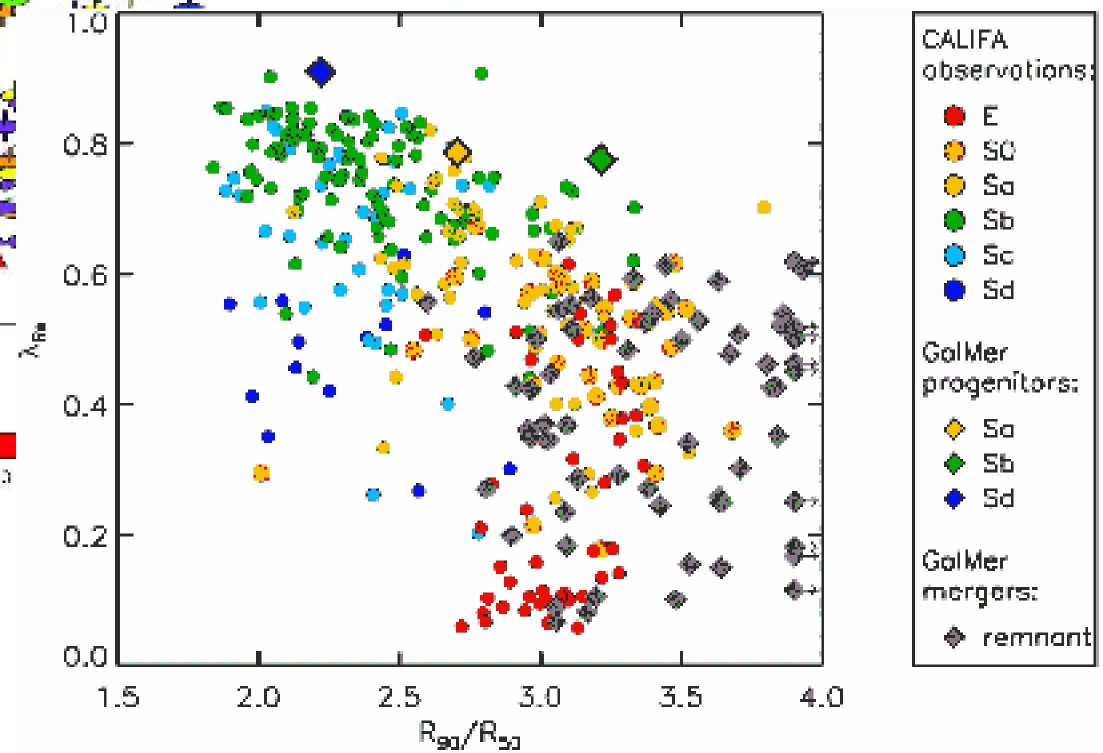


Mihos et al. 2015

Rotational Support in Galaxies

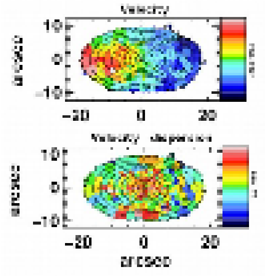


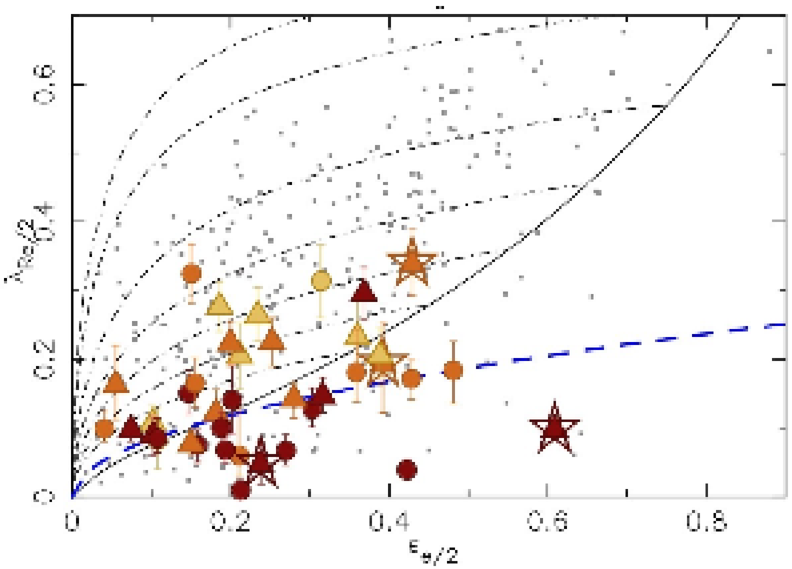
Krajnovic et al. (2012) (ATLAS3D)



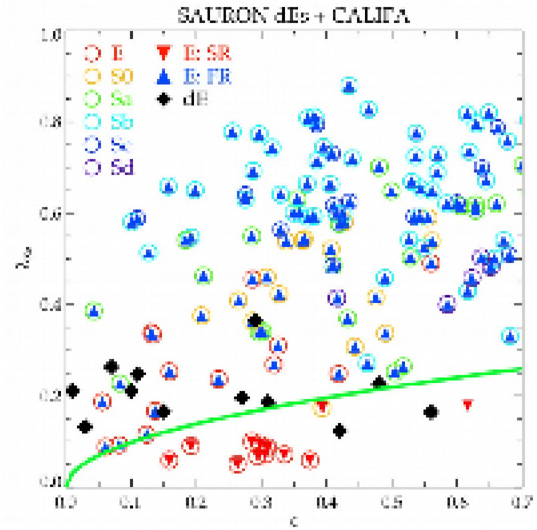
Spiral Galaxies: Querejeta et al. (2015),
to be published Falcon-Barroso+ 2017

Rotational Support in dwarf ellipticals





Toloba et al. 2015



Rys et al. 2013

- Dwarfs show both fast and slow rotators.
- Dwarf ellipticals tend to be less rotationally supported than their giant counterparts, and MUCH less than spirals.
- Radial cluster trend visible.

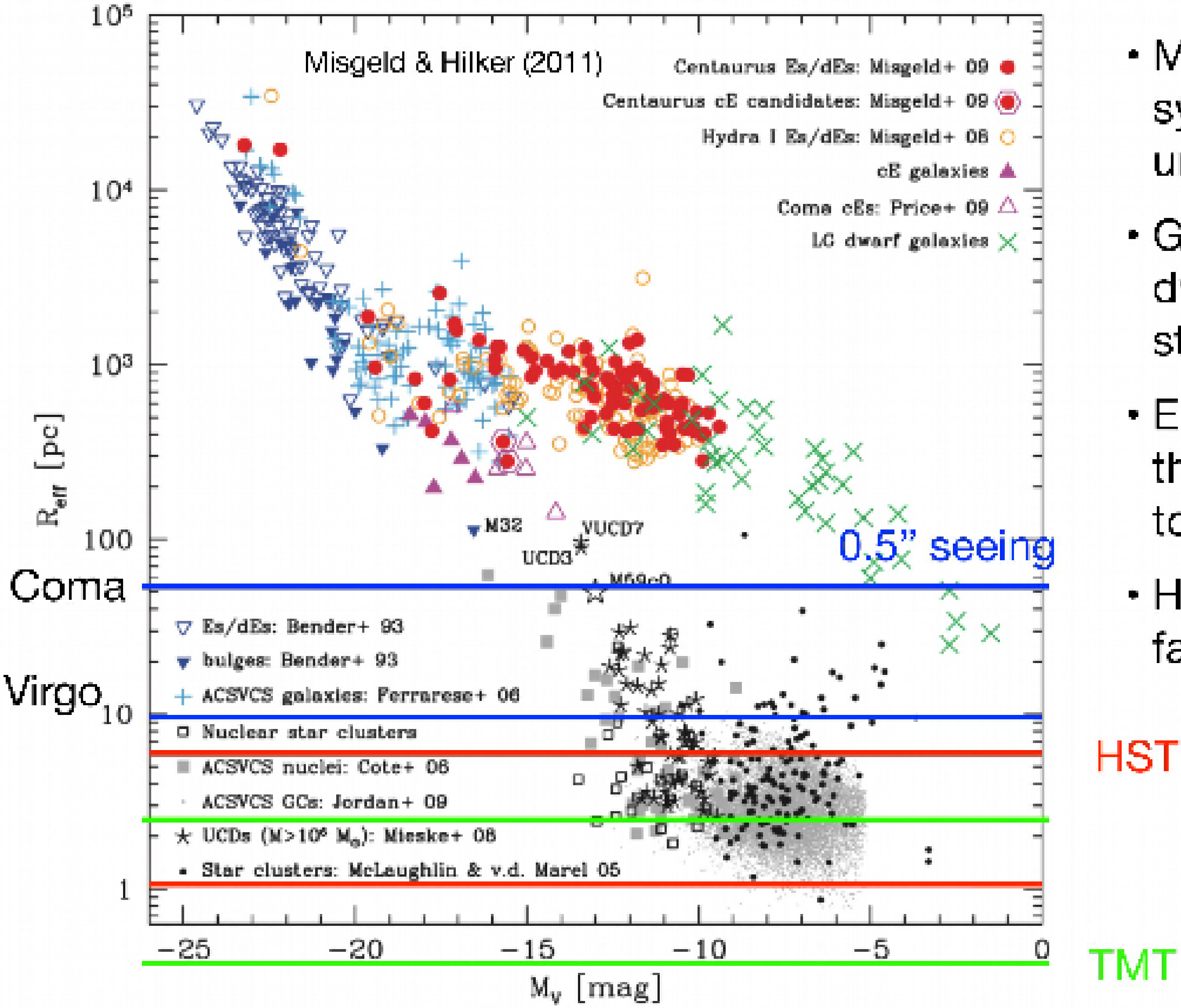
Compact Stellar Systems in the Nearby Universe

Eric Peng

The Local Neighborhood
(i.e., what we have to work with)

Credit: A. Colvin

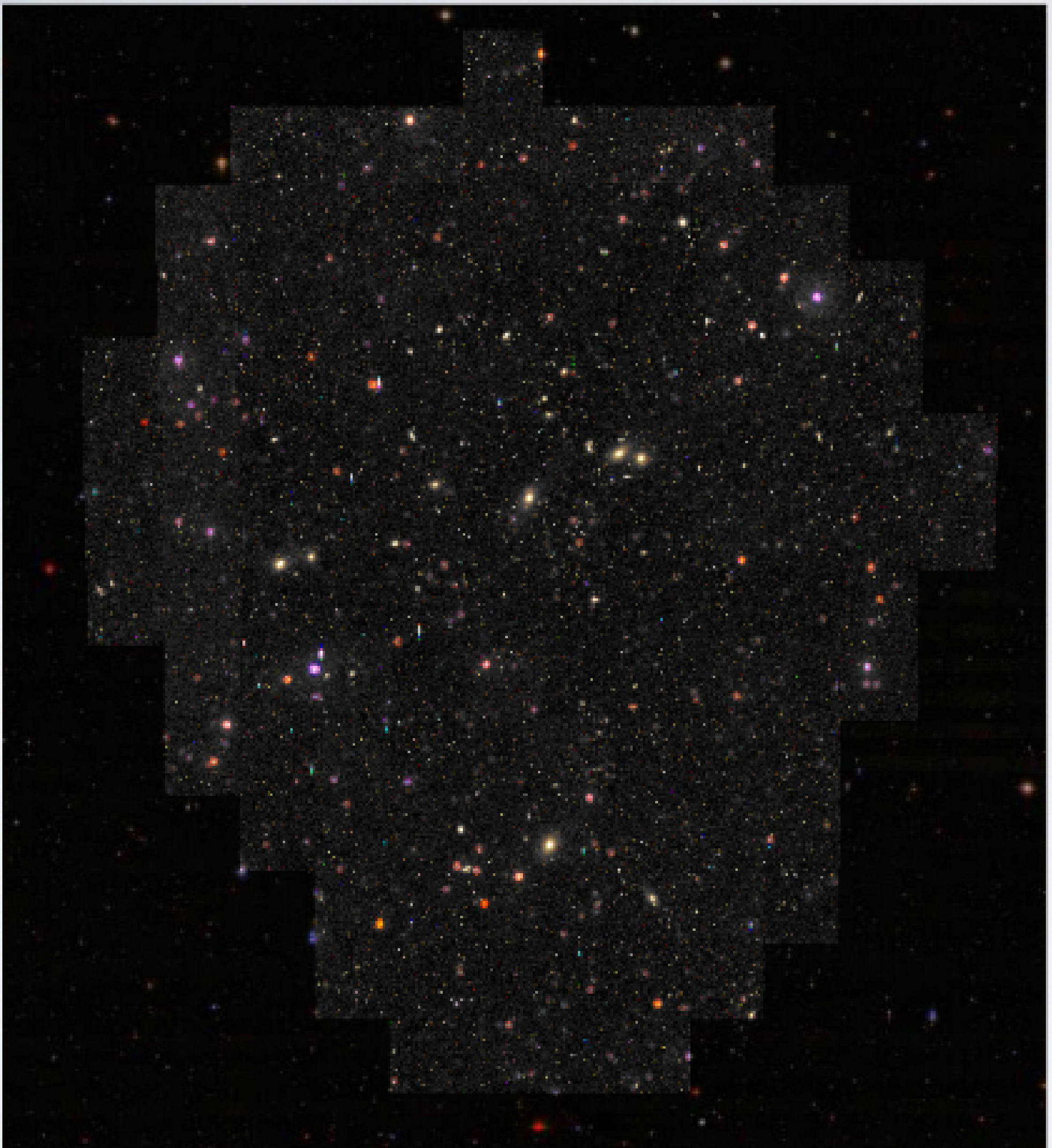
At the frontier of … spatial resolution



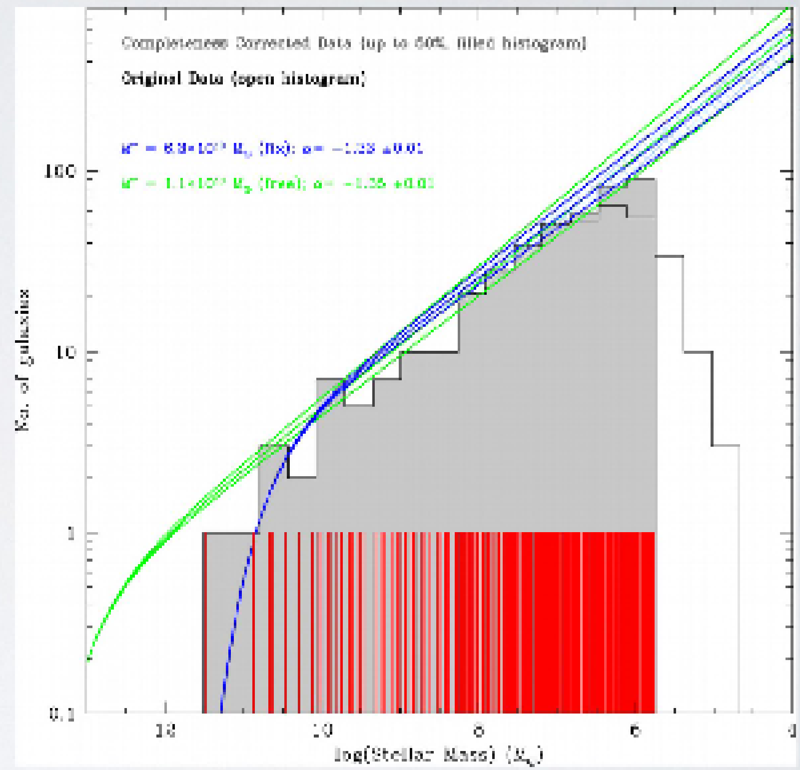
- Measuring sizes of stellar systems is important for understanding them
- Globular clusters and ultra-faint dwarfs are among the smallest stellar systems
- ELTs+AO will allow us to resolve the sizes of stellar systems down to GC size at 100 Mpc
- HST and current ground-based facilities can already do a lot

E. Peng, Ringberg 2017

The Virgo Cluster: low-mass stellar systems

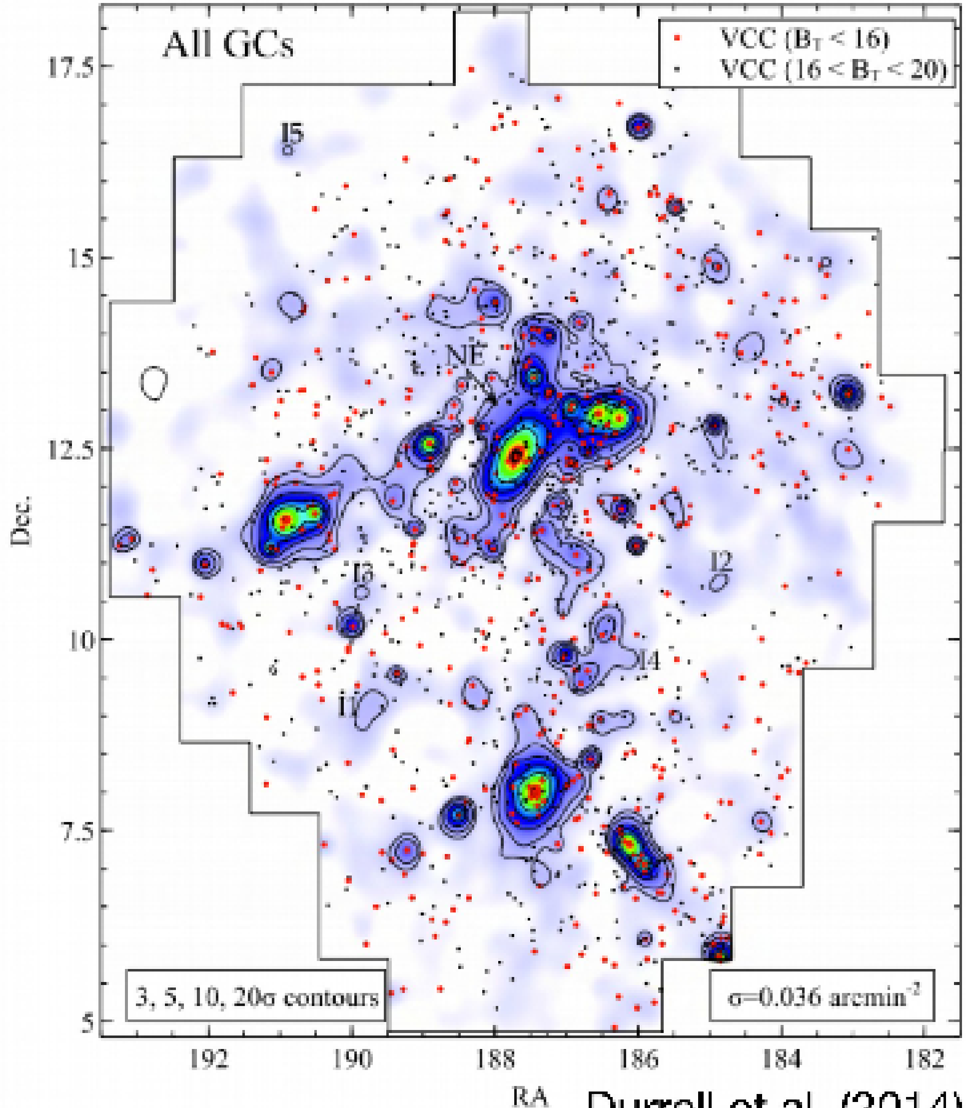


Next Generation Virgo Cluster Survey (NGVS; Ferrarese+12)



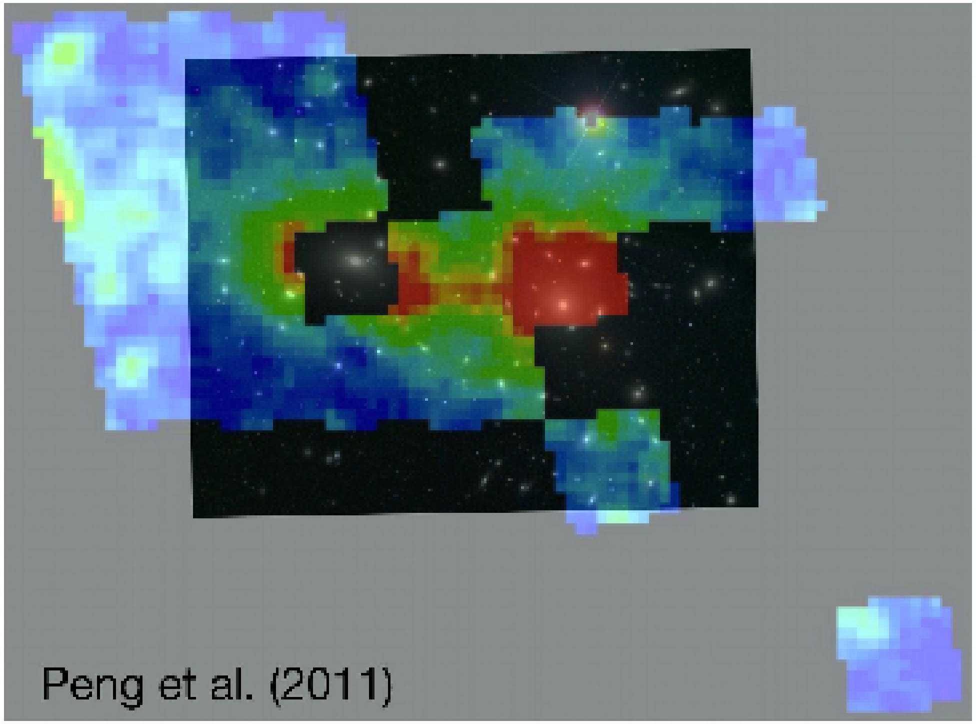
Complete sample of galaxies for $M_\star > 10^6\ M_\odot$ (Ferrarese+16)

~67,000 globular clusters across the entire Virgo Cluster



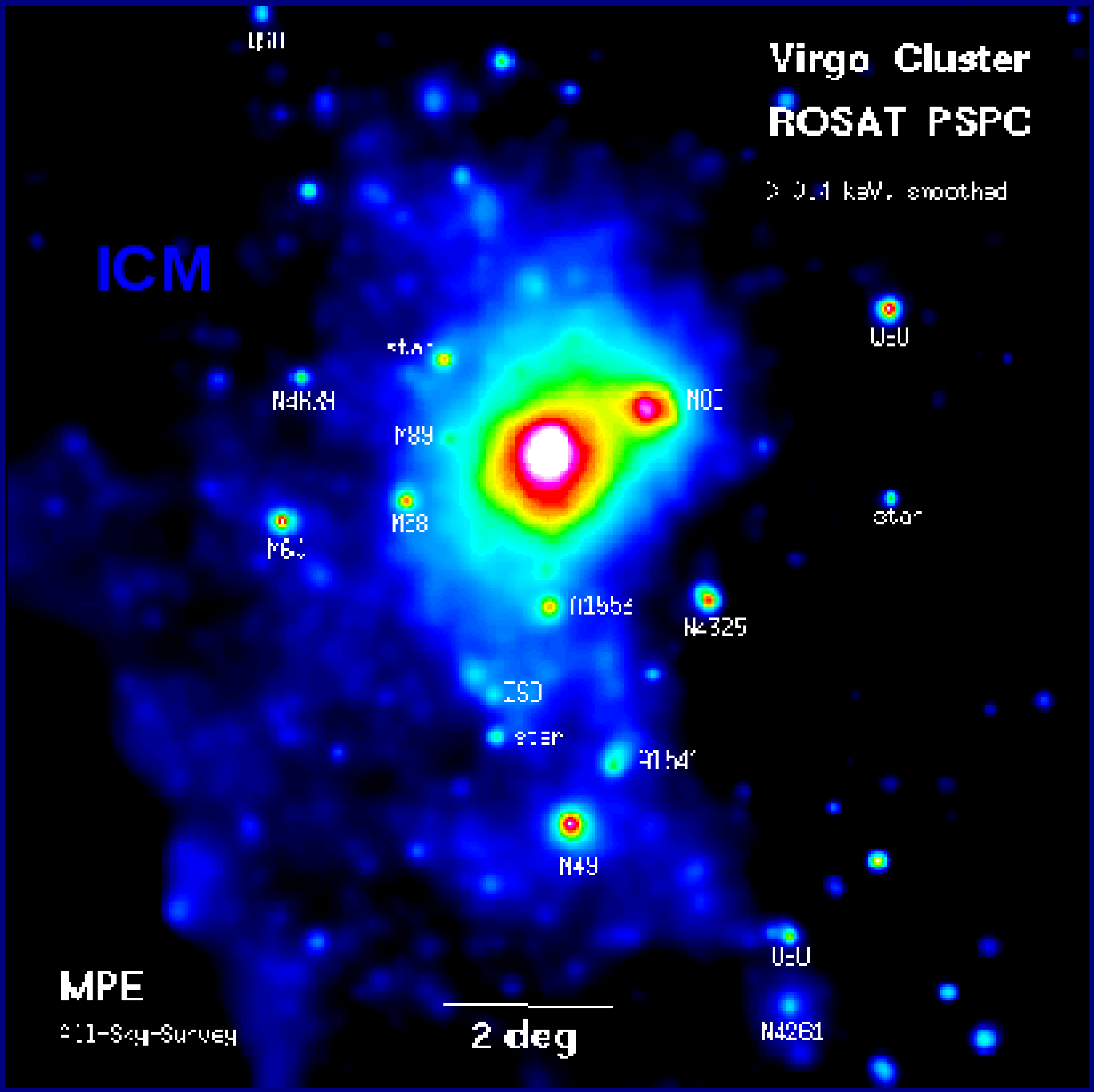
Durrell et al. (2014)

~70,000 GCs across Coma cluster core

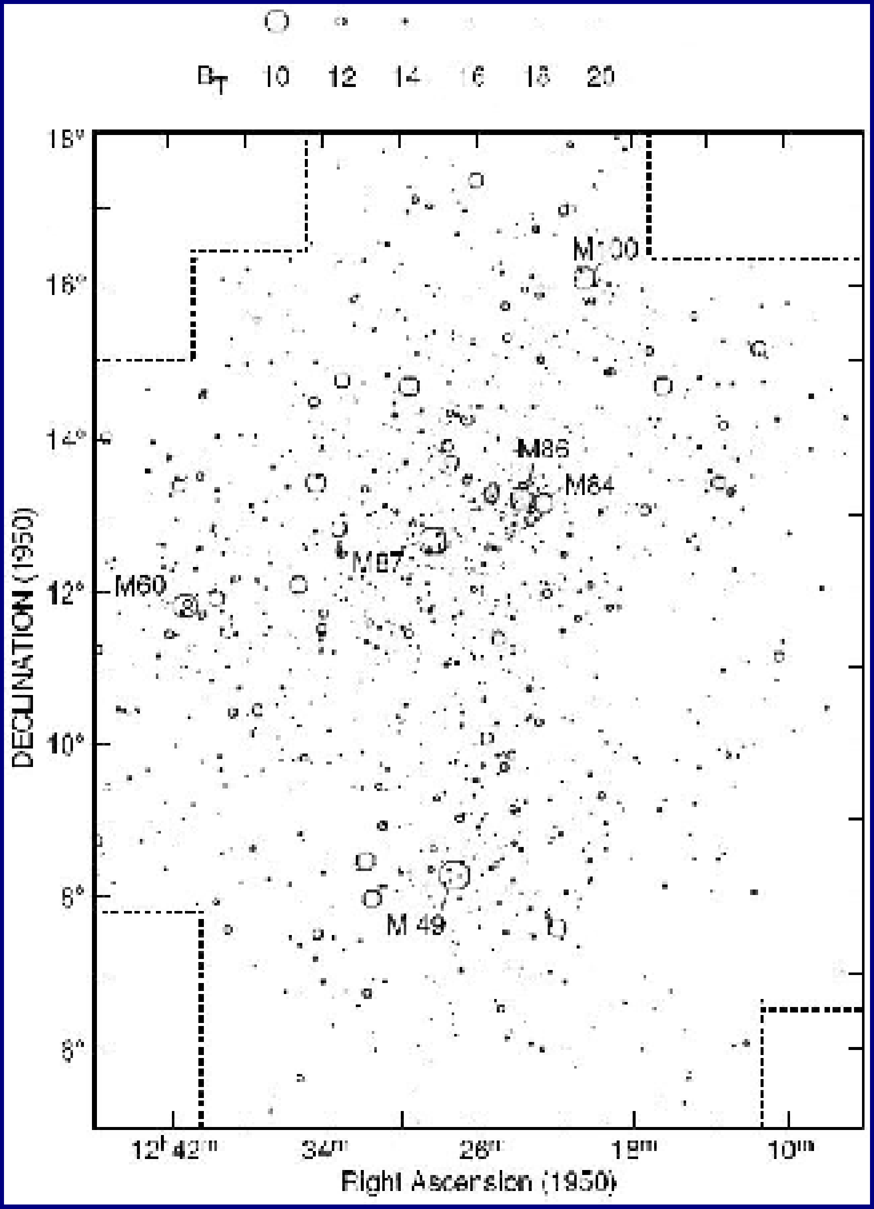


Using GCs we trace regions of low stellar mass density, reading history of interactions and accretion

The X-ray Structure of Virgo



Irregular, unrelaxed structure

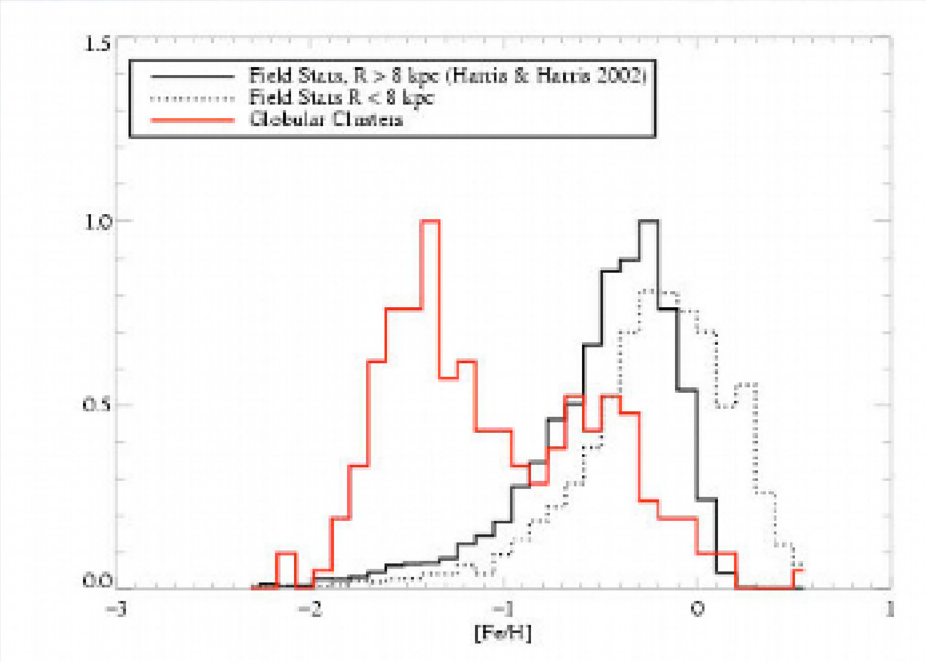


VCC: Binggeli, Sandage, & Tammann (1985)

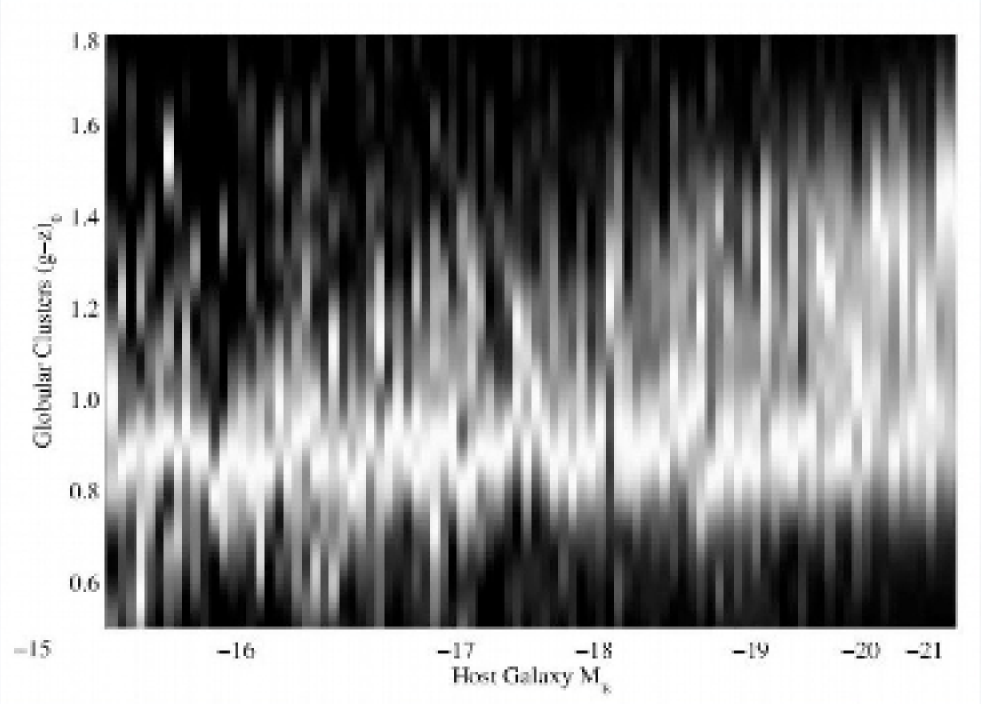
Globular clusters systems

Stars clusters are **not** faithful tracers of galactic star formation histories

Bimodal GC metallicity distributions



Harris & Harris (2004)



Peng et al. (2006)

All galaxies with GCs have metal-poor GCs

Metal-rich GCs are mostly in more massive galaxies

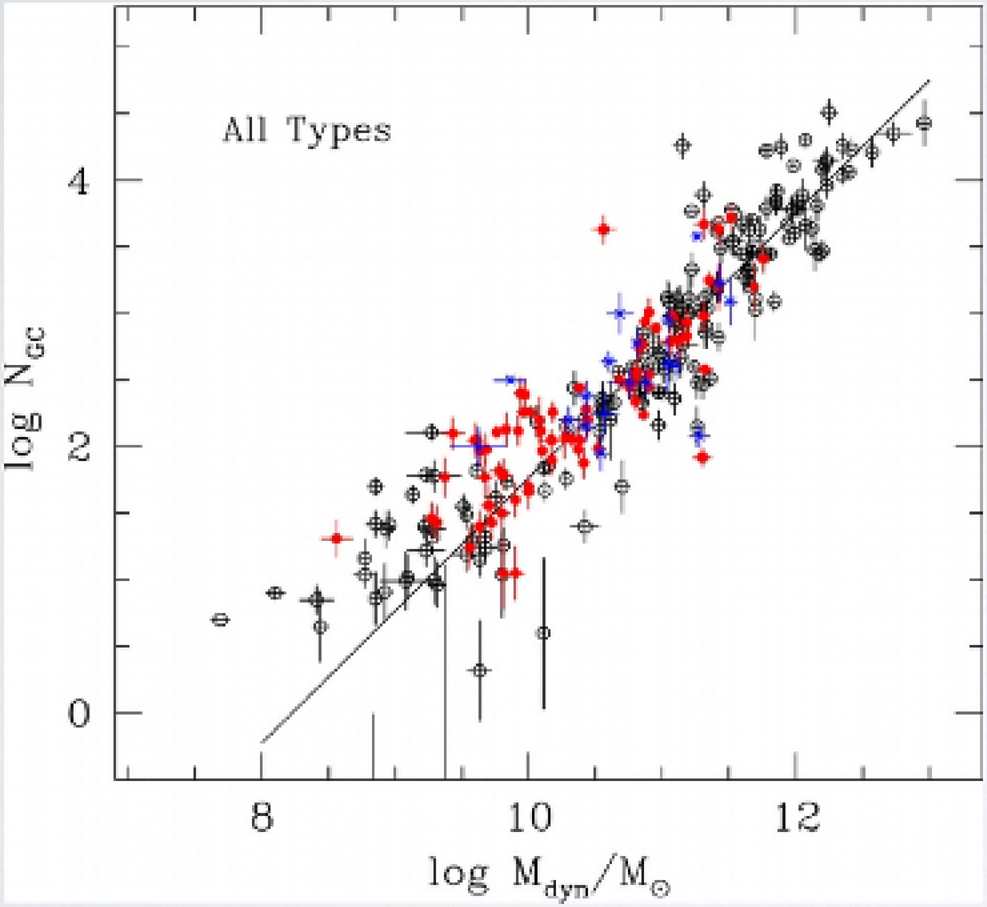
In nearly *all* galaxies, number of metal-poor GCs *outnumbers* metal-rich GCs

Massive GC populations in central cluster galaxies are ~2/3 metal-poor

Globular clusters systems

Stars clusters are **not** faithful tracers of galactic star formation histories

The number of GCs follows the dynamical mass

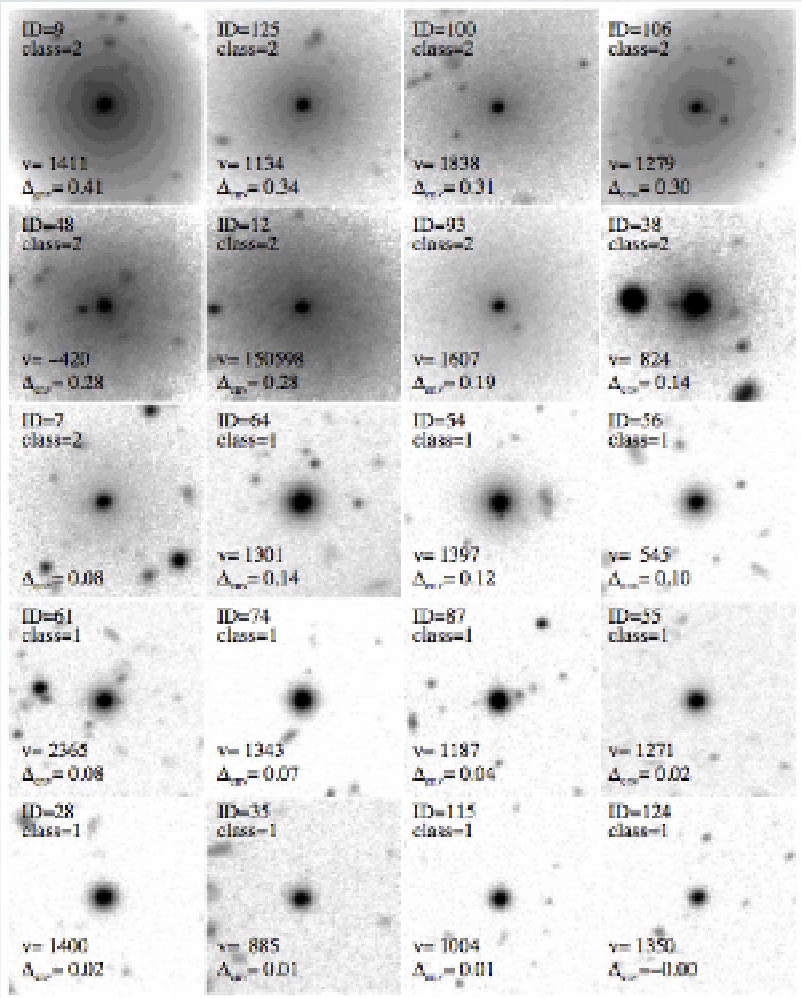


Harris et al. (2013)

GC “specific frequency” is not constant across galaxies, but tracks M/L

GC numbers are better than stellar mass as an indicator of dynamical mass

Ultra-Compact Dwarfs



Liu et al. (2015)

"UCD Morphological Sequence" seen around M87

Virgo cluster

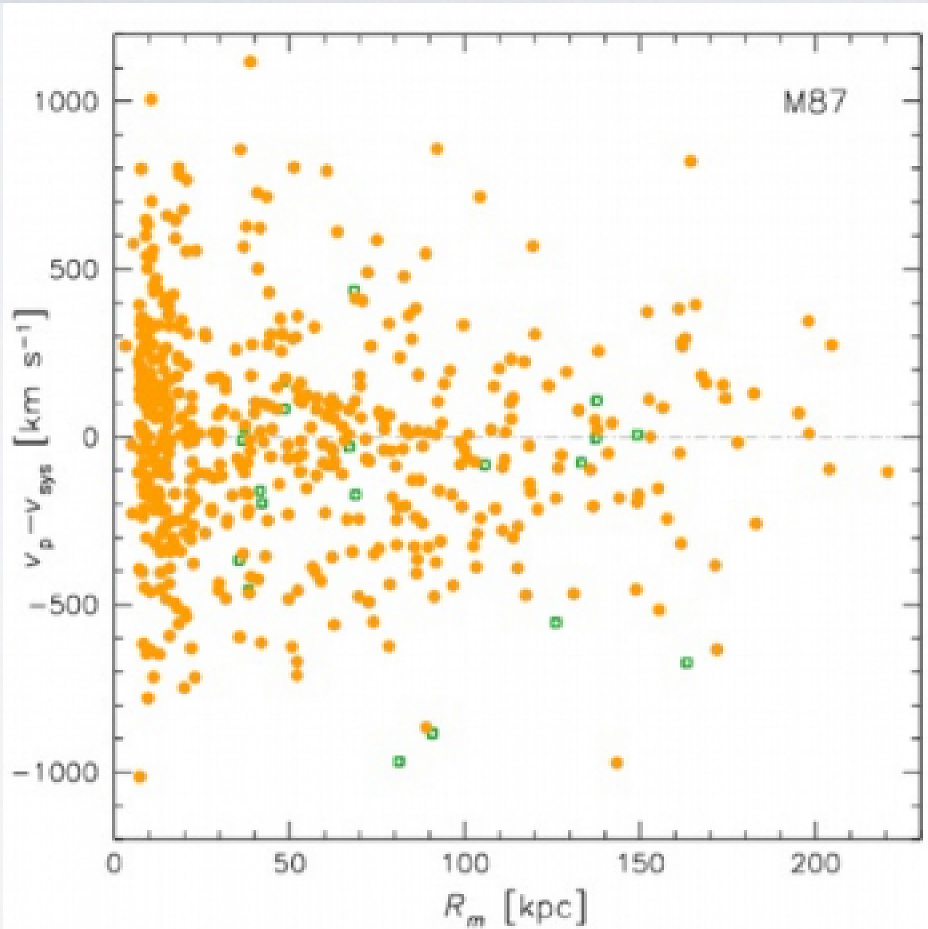
- All UCDs with r_h>10 pc in Virgo can be resolved using ground-based imaging with good seeing.
- Zhang et al. (2015) - A complete spectroscopic catalog of 92 UCDs around M87.
- Liu et al. (2015) - Photometric catalogs of UCDs around M87, M49, M60.
- Coming soon: a complete catalog of UCDs in the Virgo cluster.

Other Environments

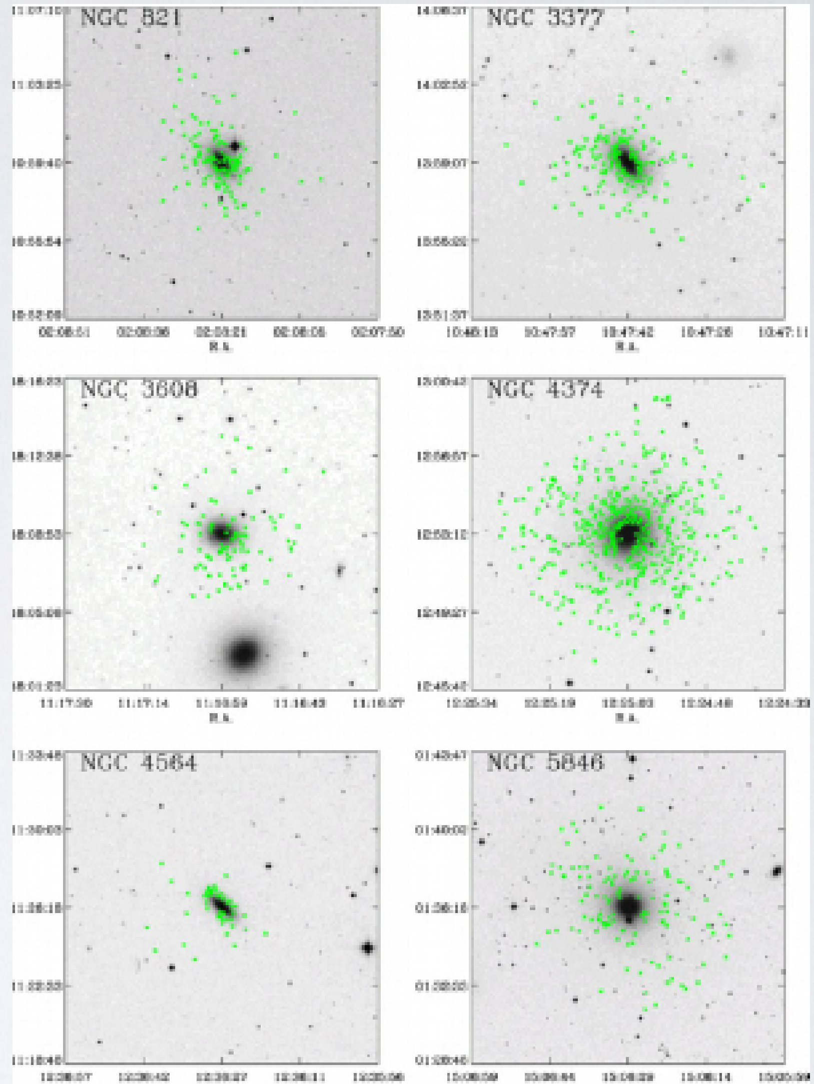
- Hilker+ - Fornax cluster
- Chiboucas+10, Madrid+10 - Coma cluster
- Misgeld+11 - Hydra I cluster
- Mieske+09 - Centaurus cluster
- Penny+ - Perseus cluster
- AIMSS project (Norris et al. 2014) - survey for "intermediate mass stellar systems" across all environments

What fraction of UCDs have "galactic" versus "star cluster" origins?

Discrete tracers of stellar kinematics



Romanowsky et al. (2012), also Forbes et al. (2017)



Coccato et al. (2009)

Tracing low surface brightness stellar populations in phase space

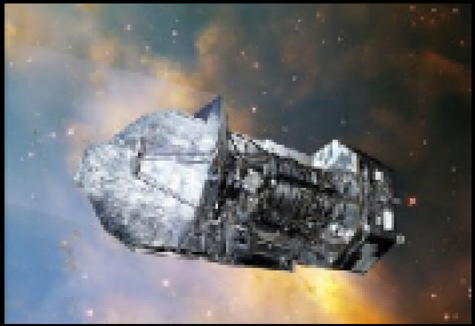
Environmental Transformations at Early Cosmic Times

Matteo Fossati

The tools

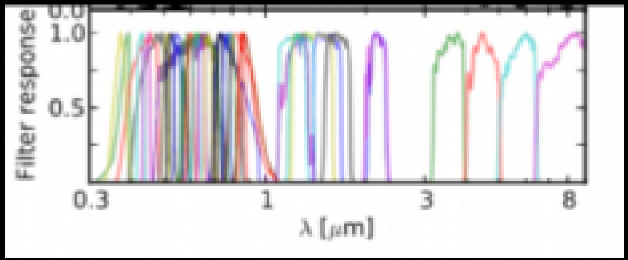
	Deep field surveys	Groups/Cluster surveys
Pros	Large range of environments Deep Multi-wavelength data	Pointed to specific (rare) haloes High galaxy number density per halo
Cons	Most massive haloes are rare Strategy —> Depth or Area?	Selection strategy (overdensity = cluster?) Identification of interlopers
	DEEP2, CANDELS, 3D-HST COSMOS, UDS, many more	GEEC2, GCLASS, GO-GREEN

Synergy of space and ground based facilities

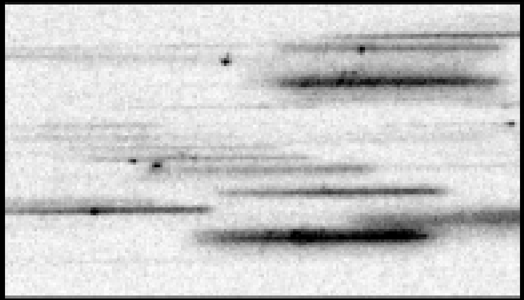
Hunting for redshifts

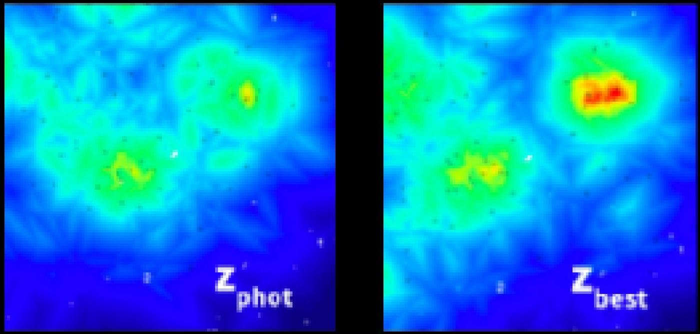
Photometric redshifts (e.g. Taniguchi+2007, Cardamone+2010, Whitaker+2011, Quadri+2012, ...)



No pre-selection
Poorer accuracy compared to spec-z
Redshift accuracy is field and magnitude dependent
Redshift accuracy is poorer at z>1 (exception NMBS)

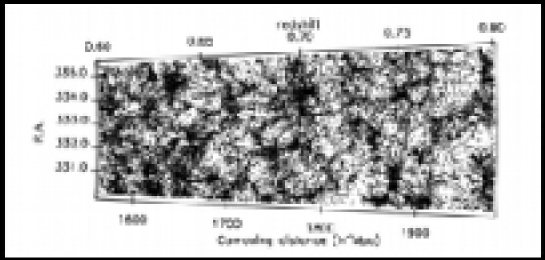
Slitless spectroscopy from space (e.g. 3DHST, Brammer+2012, Momcheva+2016)





No pre-selection
Deep (H<24mag)
Variable redshift accuracy
Less ideal in very dense fields

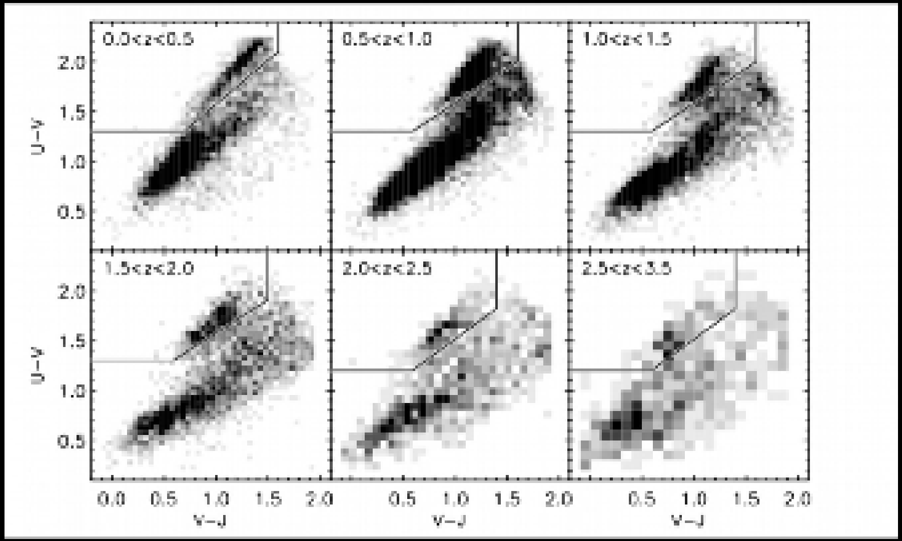
Multi-object spectroscopy from the ground (e.g. VIMOS, GMOS, IMACS, ...)



Highest redshift quality
Survey selection (Blue, star-forming targets)
Low number density and large area or
High number density on specific structures

Deep, complete, unbiased spectroscopic follow-ups are critical for an accurate characterization of the environment

The star-forming vs. quiescent dichotomy

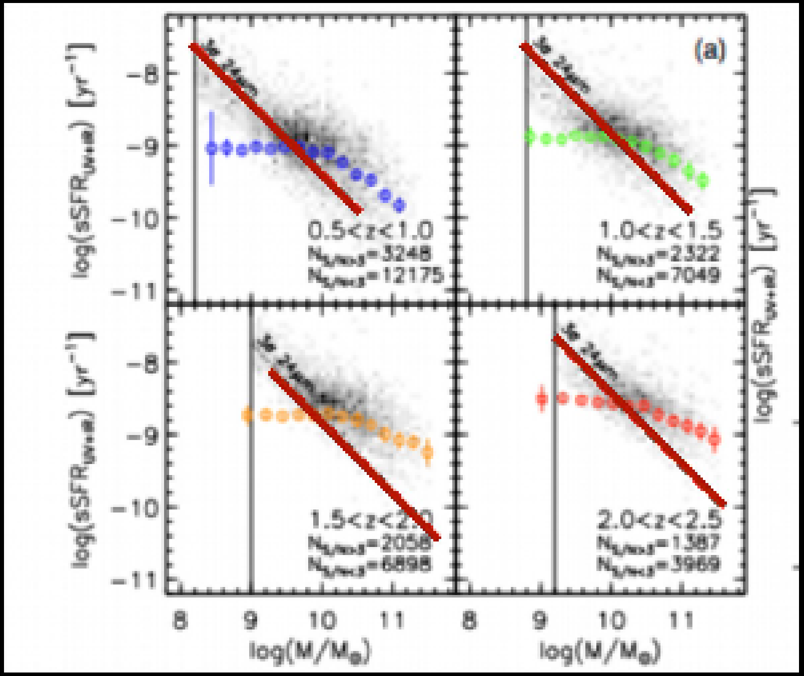


Whitaker+2011

Color-Color selection (UVJ, BzK diagrams)
Williams+2009, Whitaker+2011, ...

Weakly sensitive to dust extinction
Not a SFR based selection

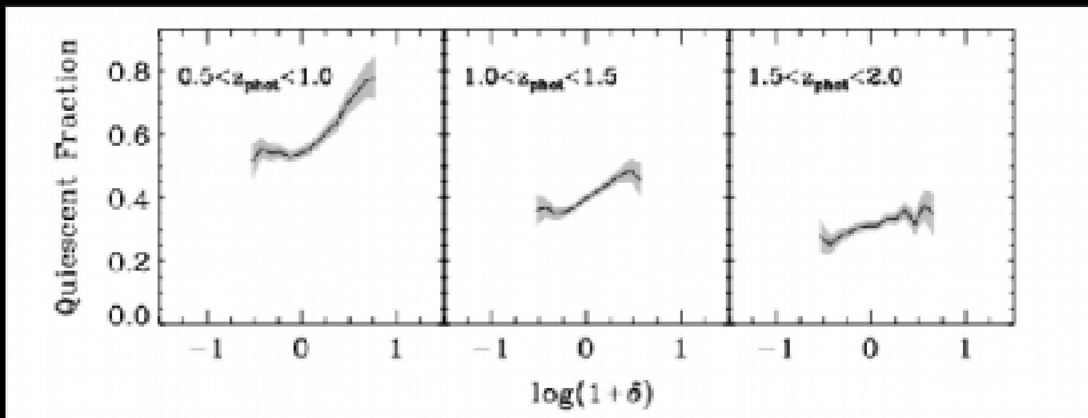
Spitzer/Herschel IR + UV star formation rates
Limited to bright IR/UV sources.
SED fitting SFR often used below the detection threshold



Whitaker+2014

Color-Color selection largely used at high-z. SFR indicators can lead to biases if they have a different origin for different galaxy populations

Passive fraction as a function of cosmic time I

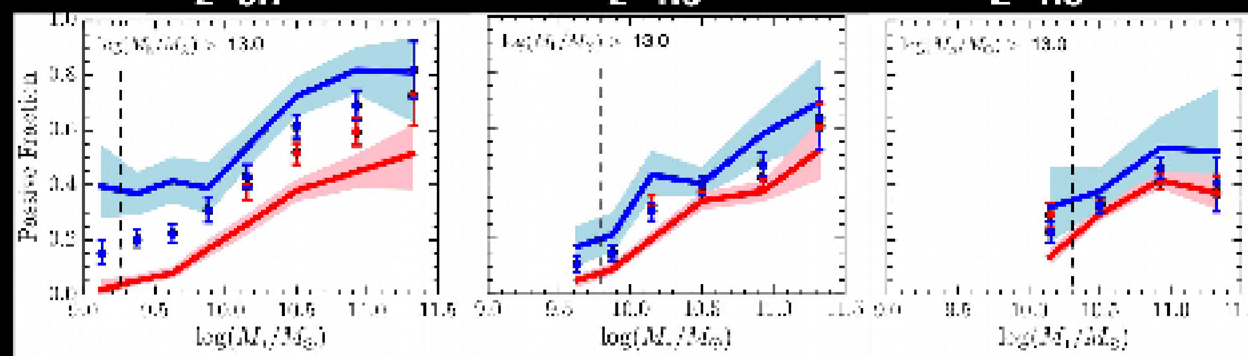


UKIDS-UDS (photo-z)
Local density as tracer of environment

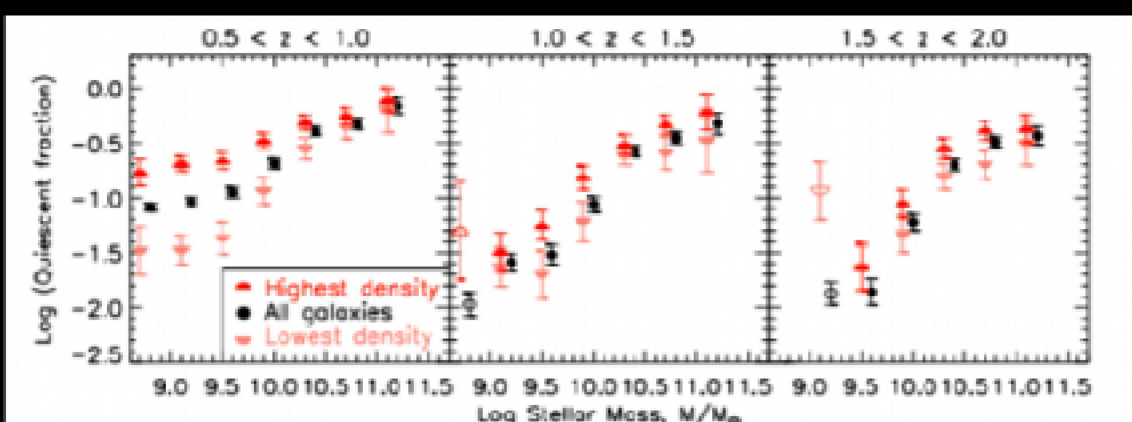
Quadri+2012

3DHST data + SAM calibrations
Group scale environments

z~0.7 z~1.0 z~1.5



Fossati+2017

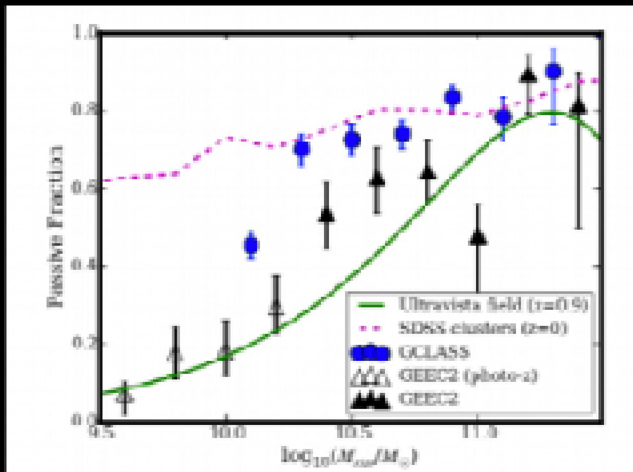


ZFOURGE data
Local density as tracer of environment

Kawinwanichakij+2017

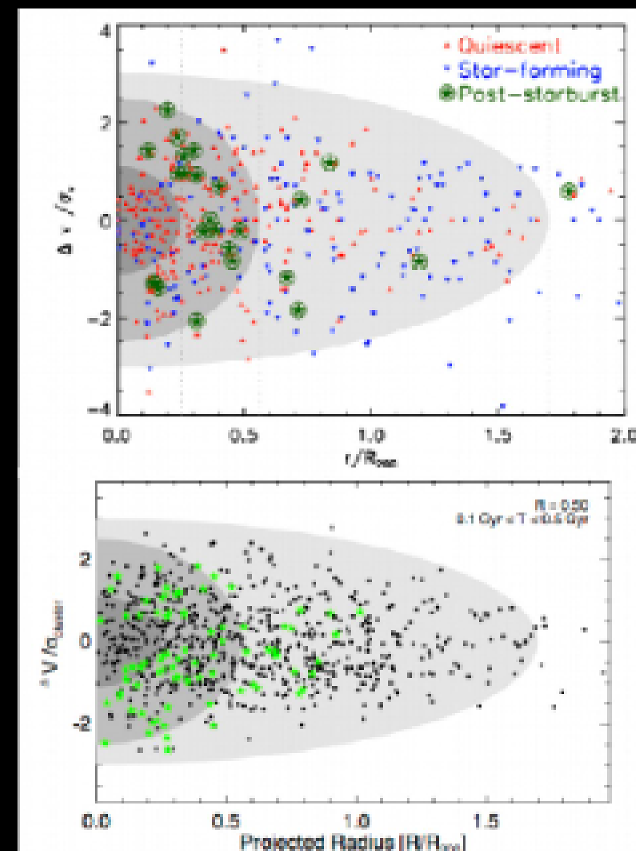
Passive fraction as a function of cosmic time II

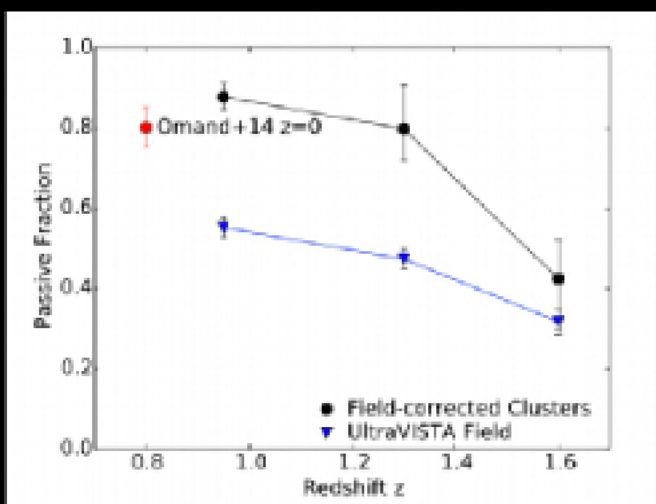
GEEC2 groups + GCLASS clusters z=1
Passive fraction has a dependence on halo mass



Balogh+2016

Muzzin+2014



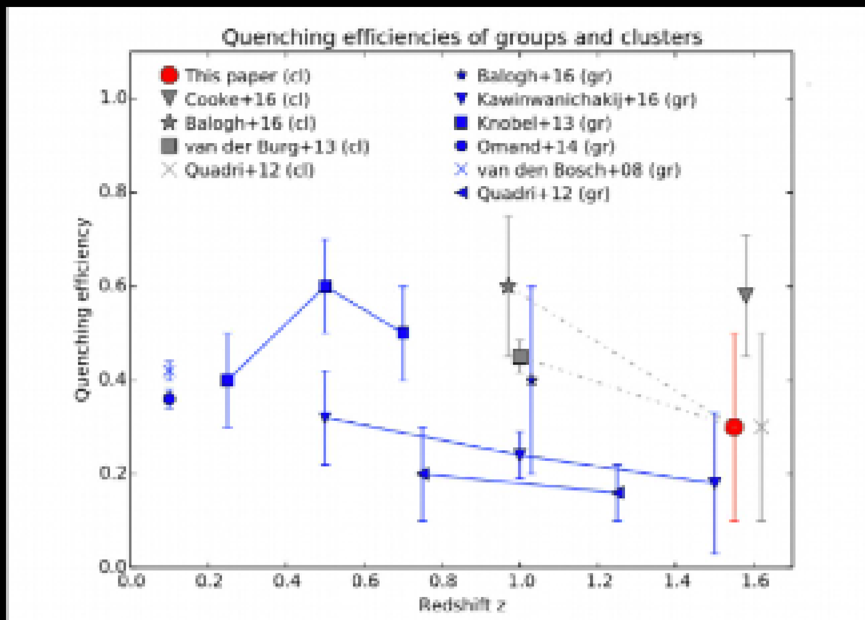


Nantais+2017

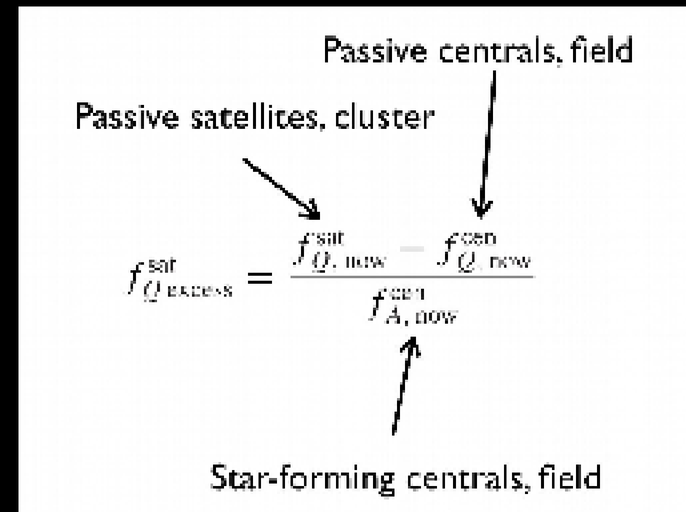
SpARCS clusters + field control sample
Passive fraction in clusters starts to differentially evolve from the field at z<1.5

GCLASS clusters
The location of recently quenched galaxies in phase-space suggests rapid quenching of at least some of the cluster galaxies

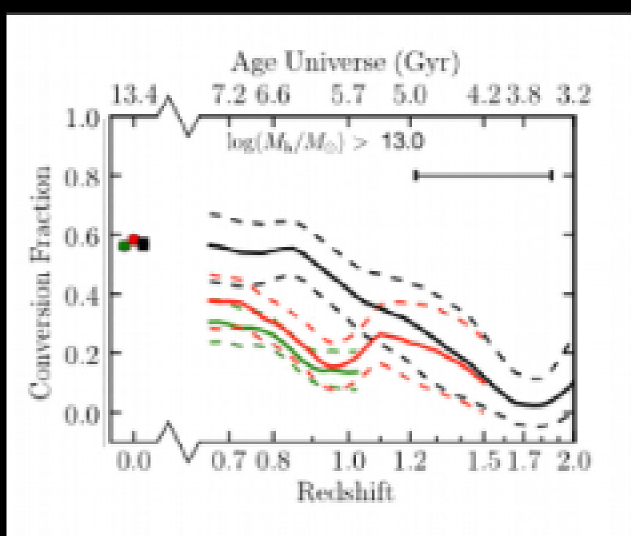
Environmental quenching efficiency and timescales



Nantais+2016



Van den Bosch+2008,
see also Wetzel+2013



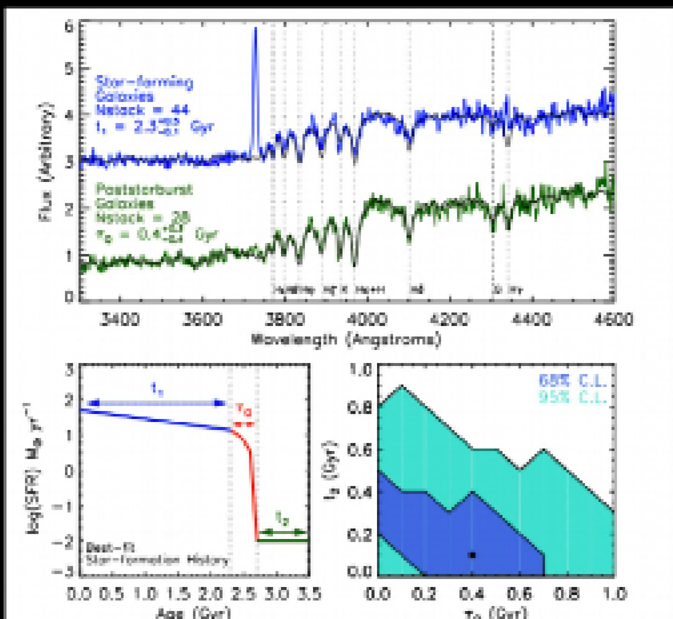
Fossati+2017

Environmental quenching is less significant at higher-z
At fixed redshift more massive haloes have
a stronger impact on galaxies

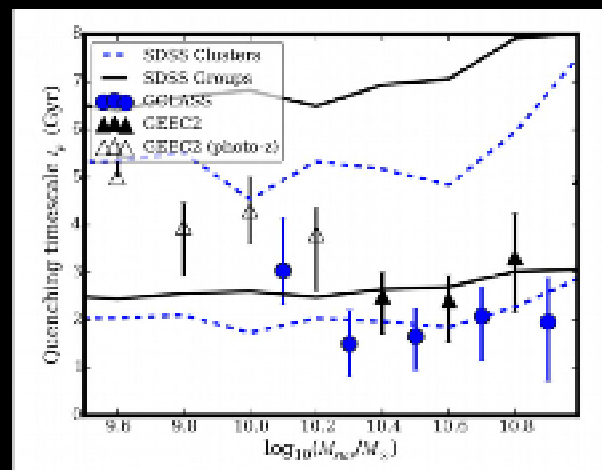
Quenching efficiencies can be turned into quenching times after making assumptions: e.g. there is no gas accretion on satellites. The distribution of times spent in the satellite phase can be derived for a given population of satellites.

Environmental quenching efficiency and timescales

Long quenching times in groups favor gas exhaustion in absence of accretion as a quenching mechanism.
Evidences for faster quenching in more massive haloes (clusters) ?



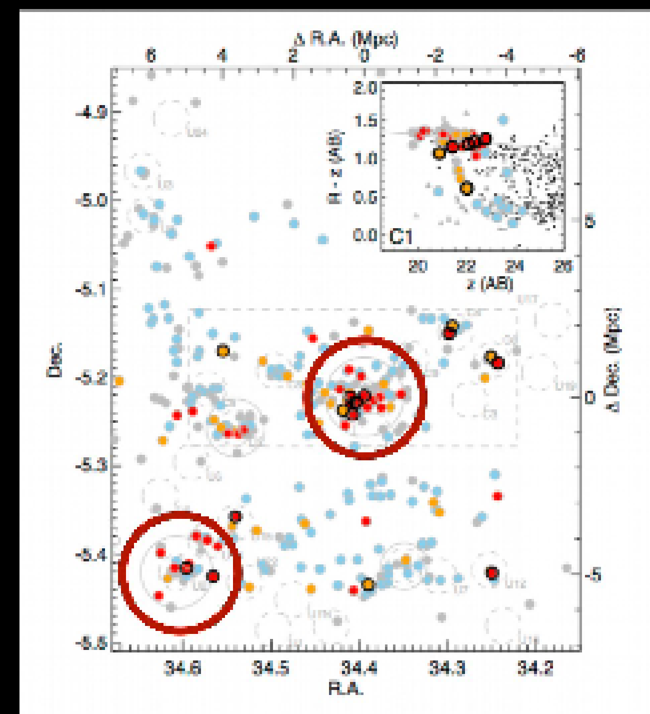
Muzzin+2014



Balogh+2016

Shorter quenching times
in clusters than in groups?

Stellar populations of stacked galaxies in clusters
Fast quenching of the post-starburst population
Is there another population undergoing slower quenching?



Galametz,A.+2017

Post-starburst galaxies are preferentially found in the most massive clusters in a z=0.65 supercluster in UDS

Take home messages

- Field surveys and pointed observations of groups/clusters offer highly complementary approaches
- Accurate, complete and unbiased redshifts are critical to obtain a 3D view of the local environment and to identify interlopers
- Special care should be taken to the identification of star-forming vs passive galaxies.
- Comparison of results from different teams/surveys usually made difficult by different definitions of "what is the environment", local density vs. halo mass

- Consensus about the decrease in strength of satellite quenching effects at $z>1-1.5$. Is it correct to call it a decrease in quenching "efficiency"? Or is it a timescale issue (no visible effects but the quenching mechanisms are already active) ?

- Fast or slow quenching? Or a mixture of the two channels? Which one dominates at each epoch?