# Galaxy population properties in high-redshift clusters:
a study of most distant cluster galaxies

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and the Cl J1449+0856 cluster team

Cl J1449+0856 (Gobat et al. 2011)

- Selected as an overdensity of IRAC-red galaxies
- a 20σ overdensity of optically red galaxies (Y-K>2)
- an a-posteriori 3.5σ detection of extended X-ray emission
- likely a sub-10^{14} system evolving into an "average" $\approx 6 \times 10^{14} M_\odot$ cluster by z=0

Gobat et al. 2011   YJK
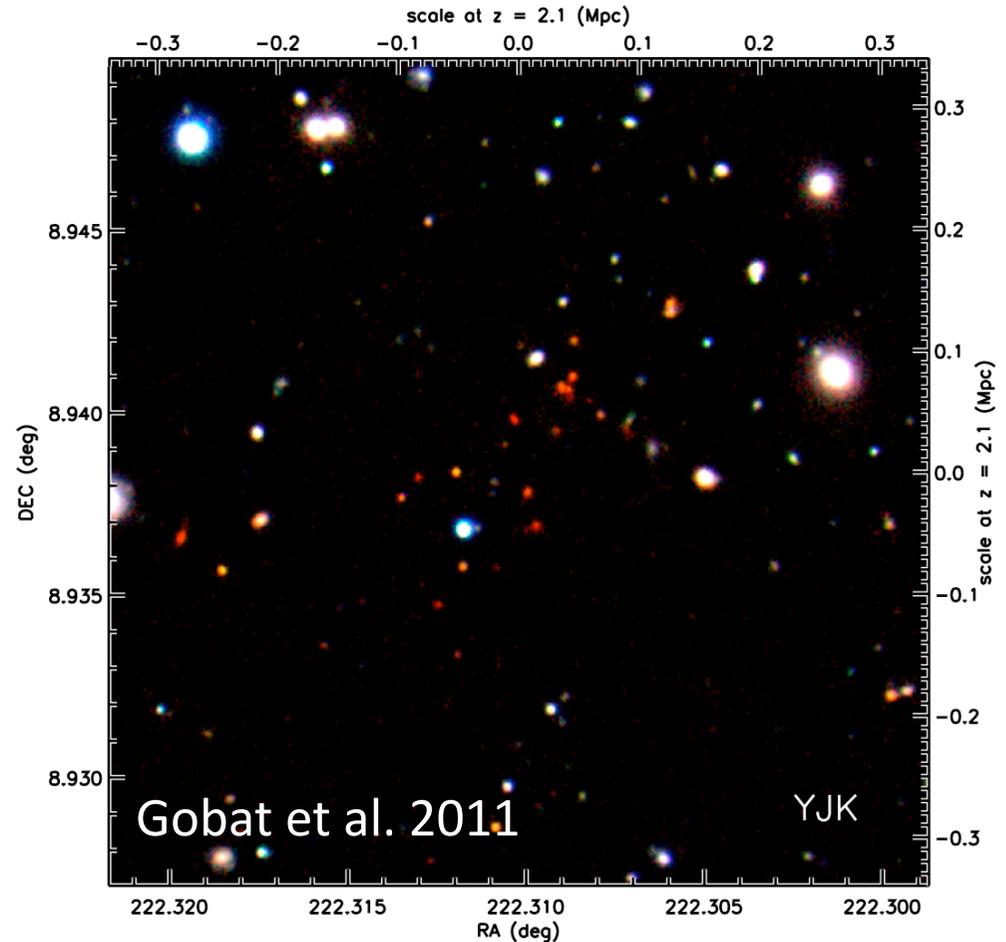
The following results are mainly based on 13-bands photometry from U band to 4.5μm, and HST/WFC3 imaging.

Cluster members – at redshift 2
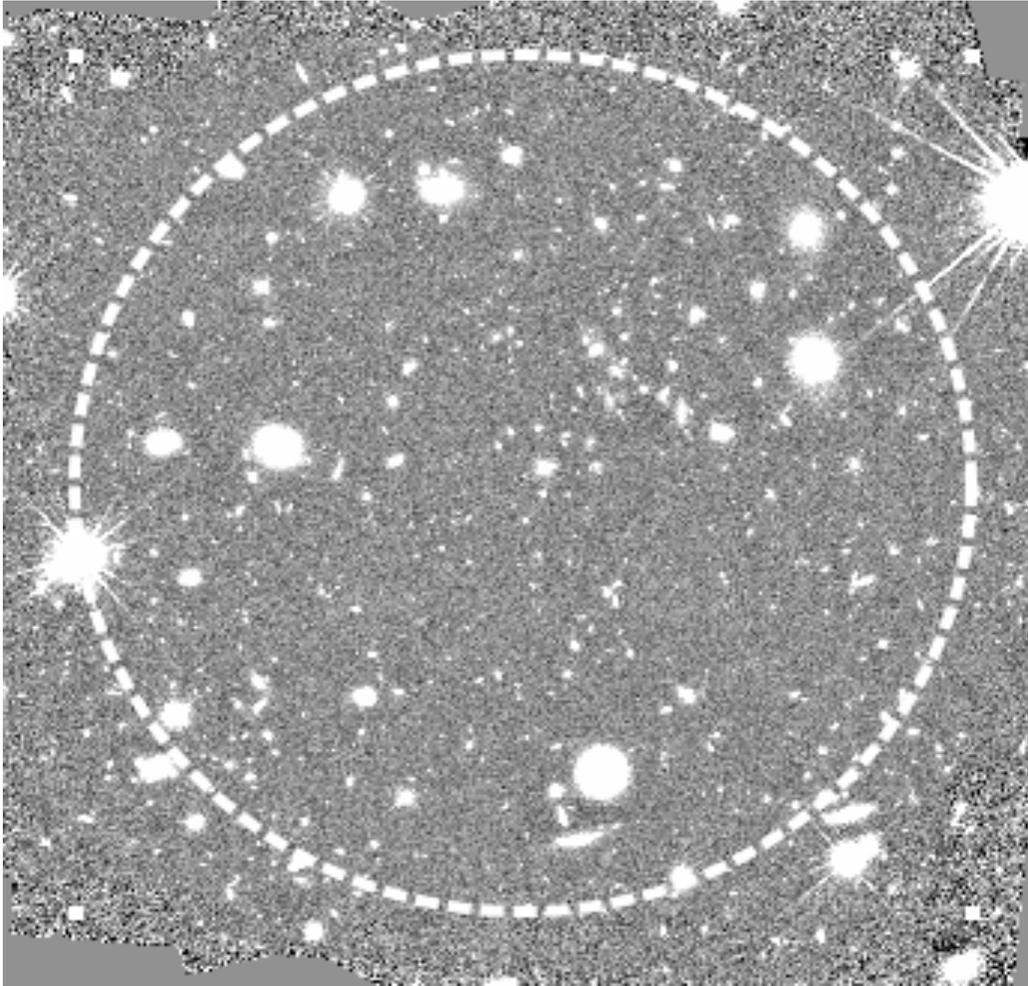
~2' or 965 kpc at z~2

At this redshift, even with HST/WFC3 spectroscopy, spectroscopic membership determination remains very difficult for most part of the massive cluster galaxy population.

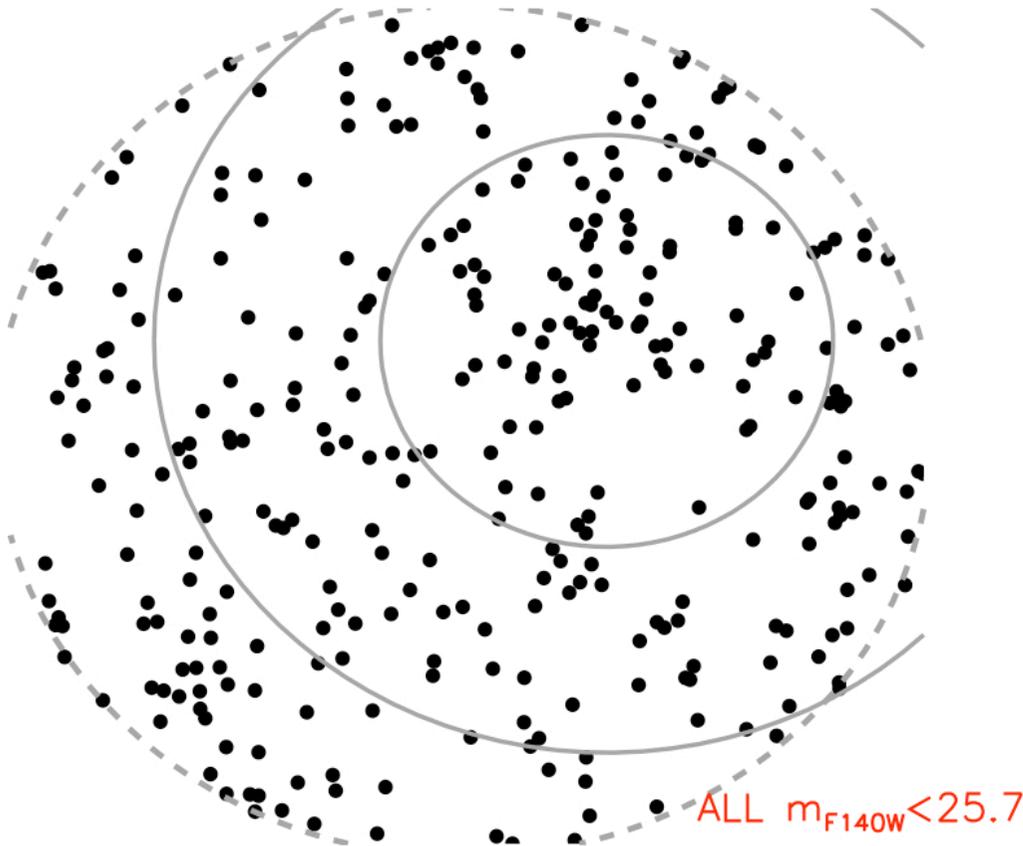A spectroscopic redshift is available for

- ≈20% of the $m_{140}<25.7$ sample
- ≈40% of the $m_{140}<24.5$ sample

This work is heavily based on photometric redshifts.

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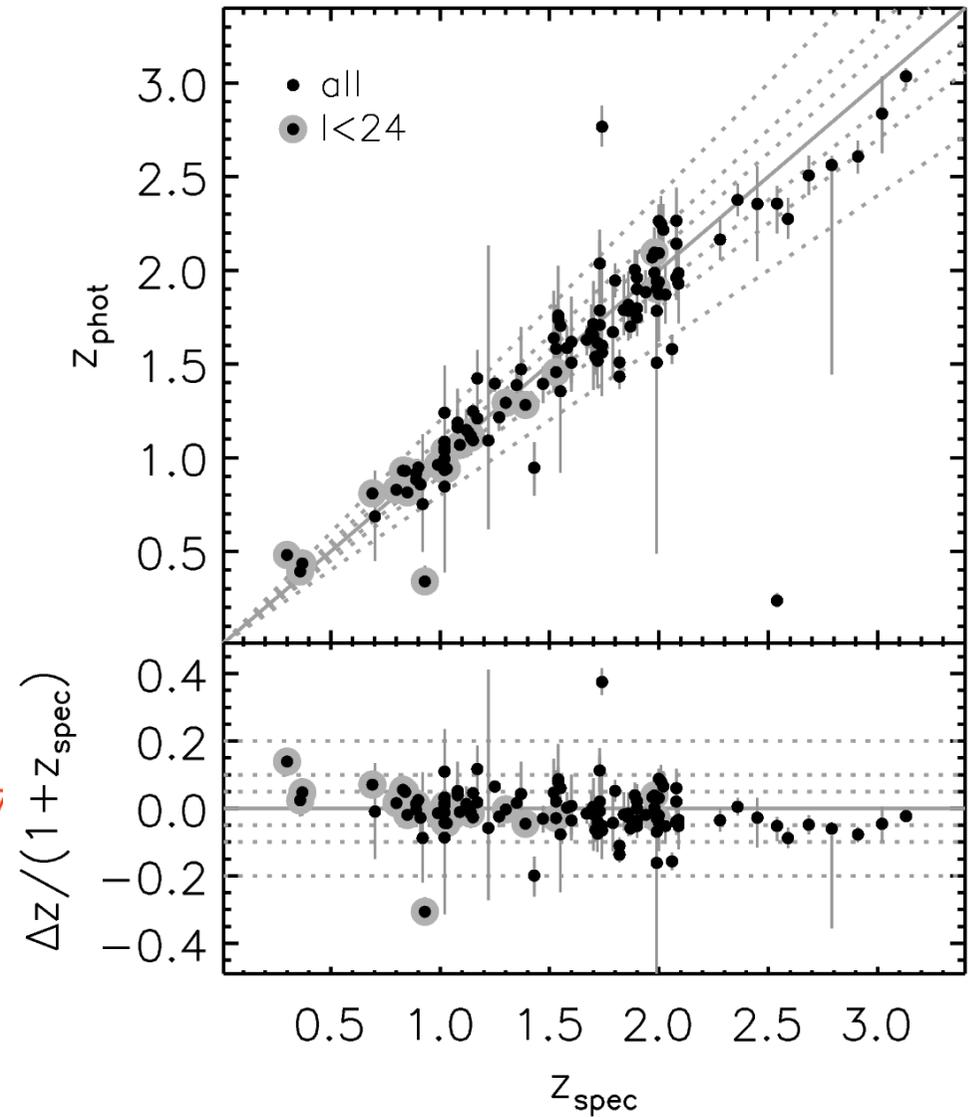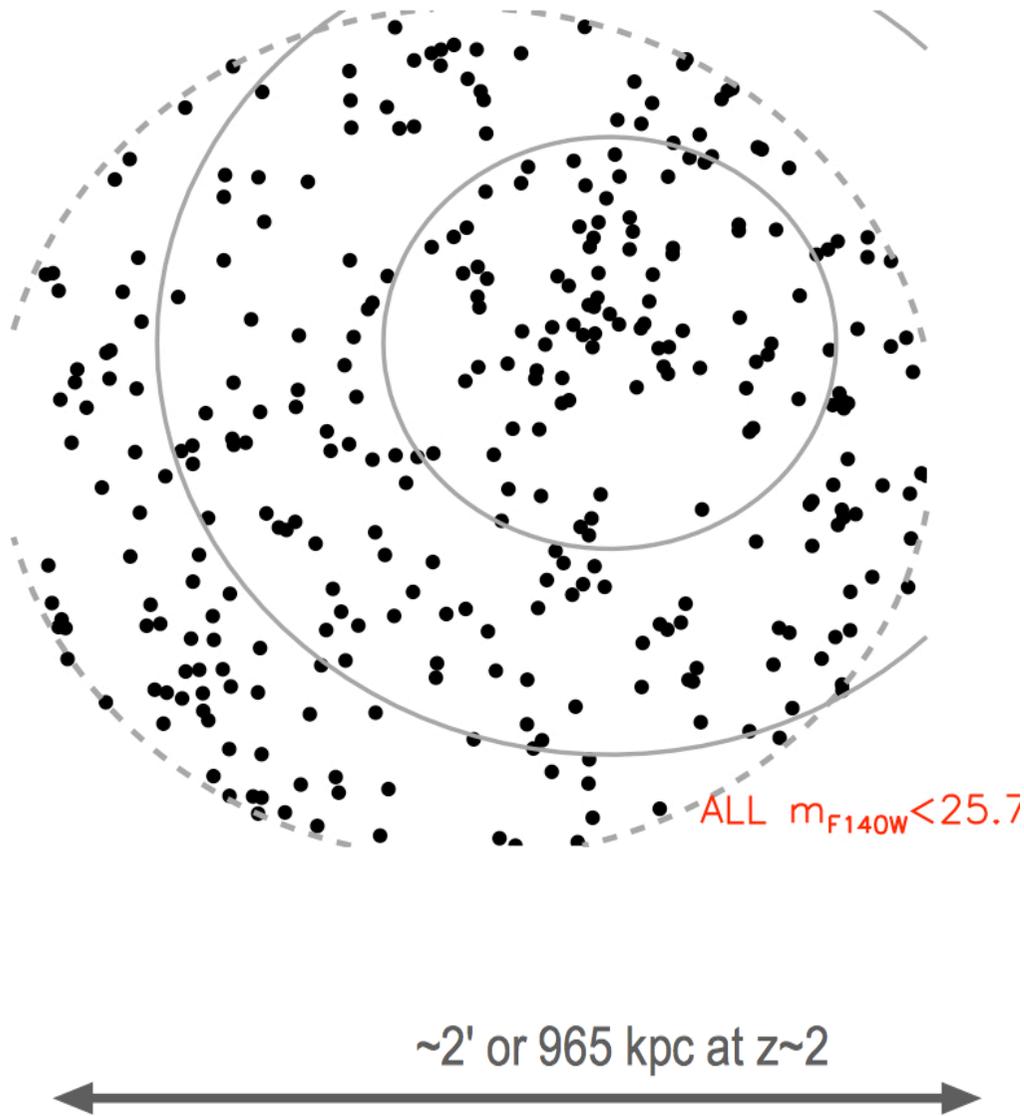A spectroscopic redshift is available for

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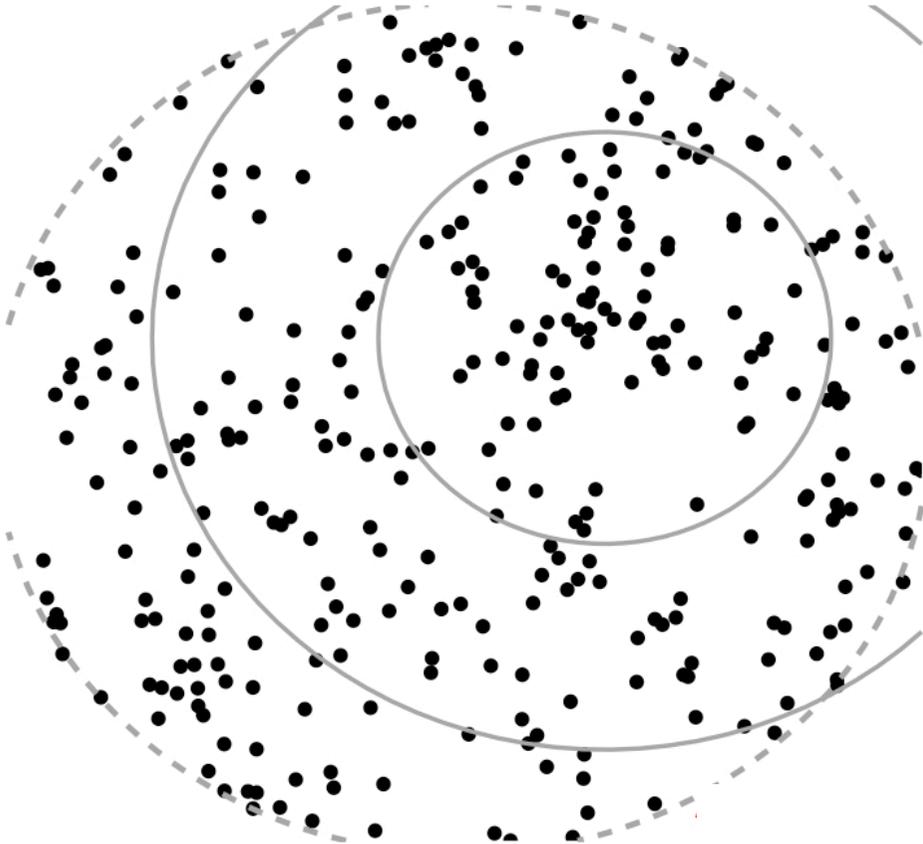

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Cluster members – at redshift 2

A z≈2 peak in the redshift distribution in the cluster field appears even with photo-z dominated redshifts, but it is not possible to separate cluster members from interlopers at similar redshift.
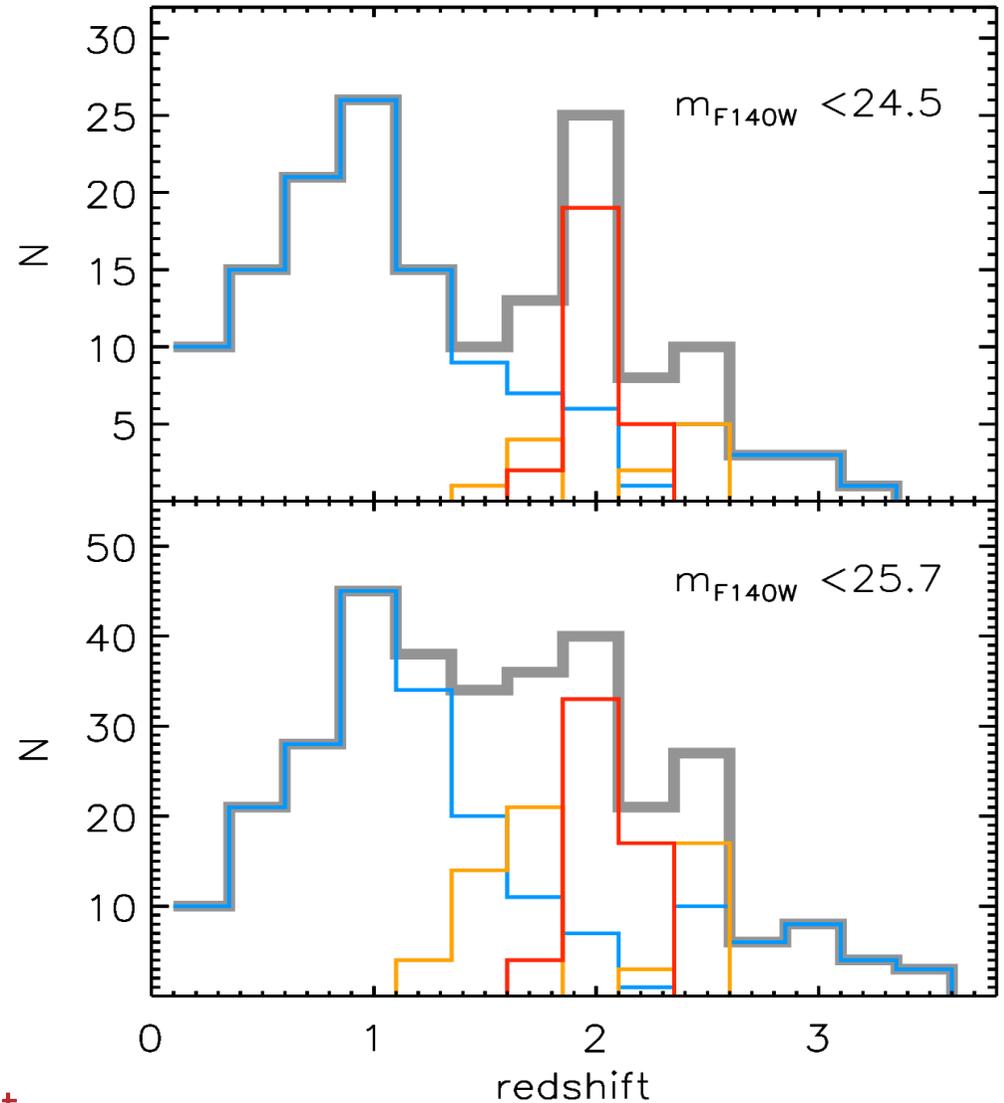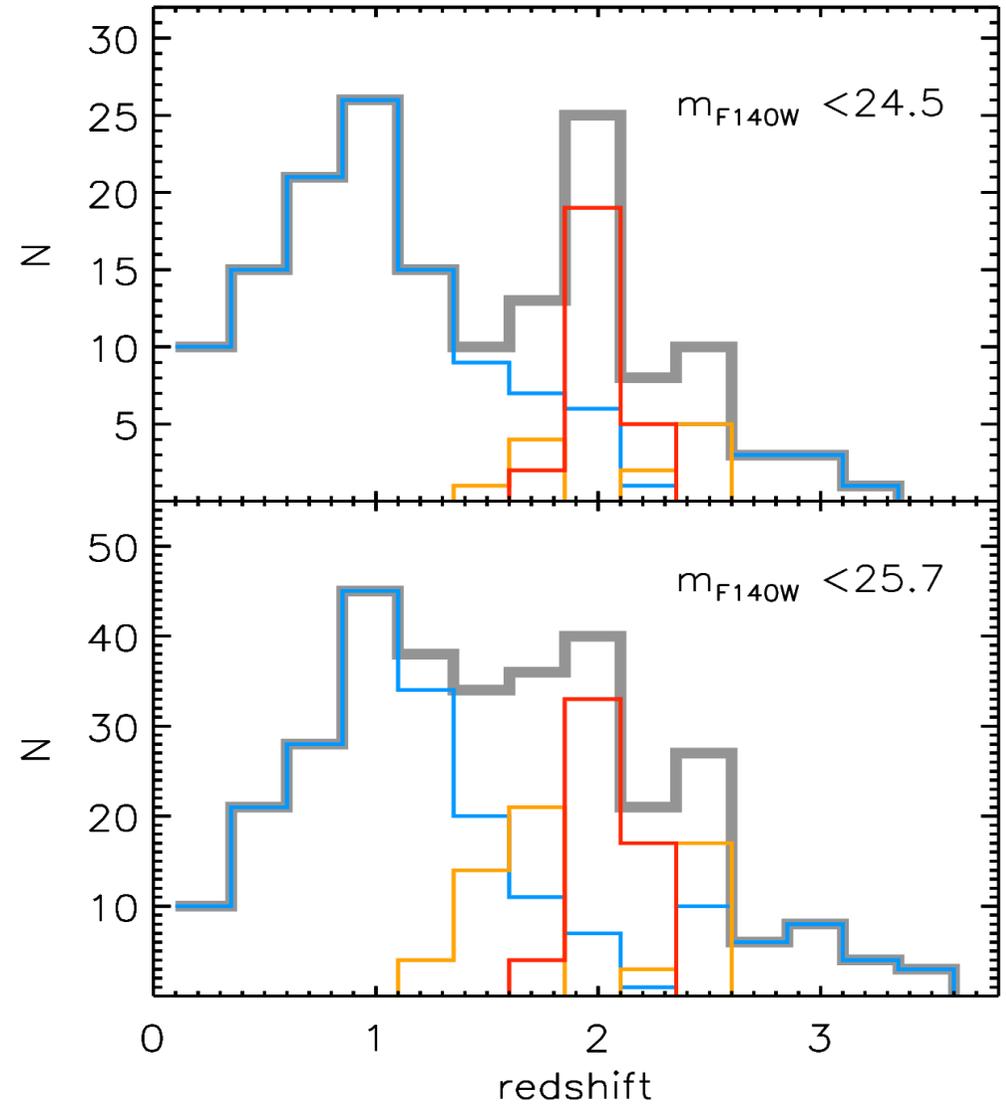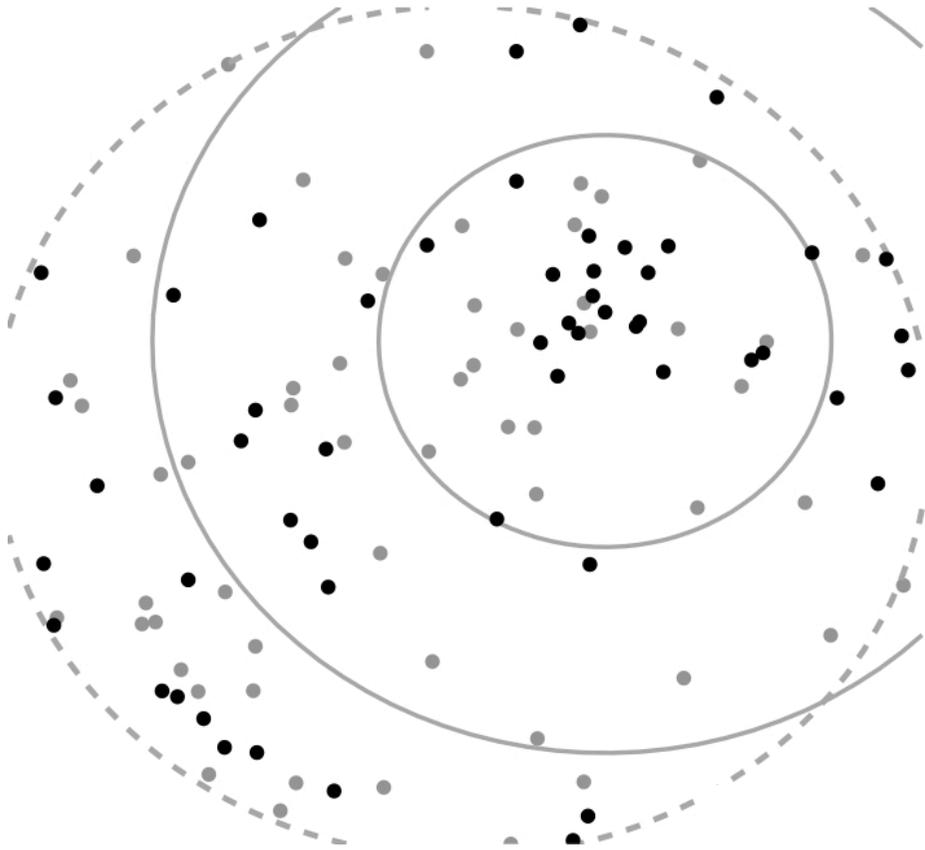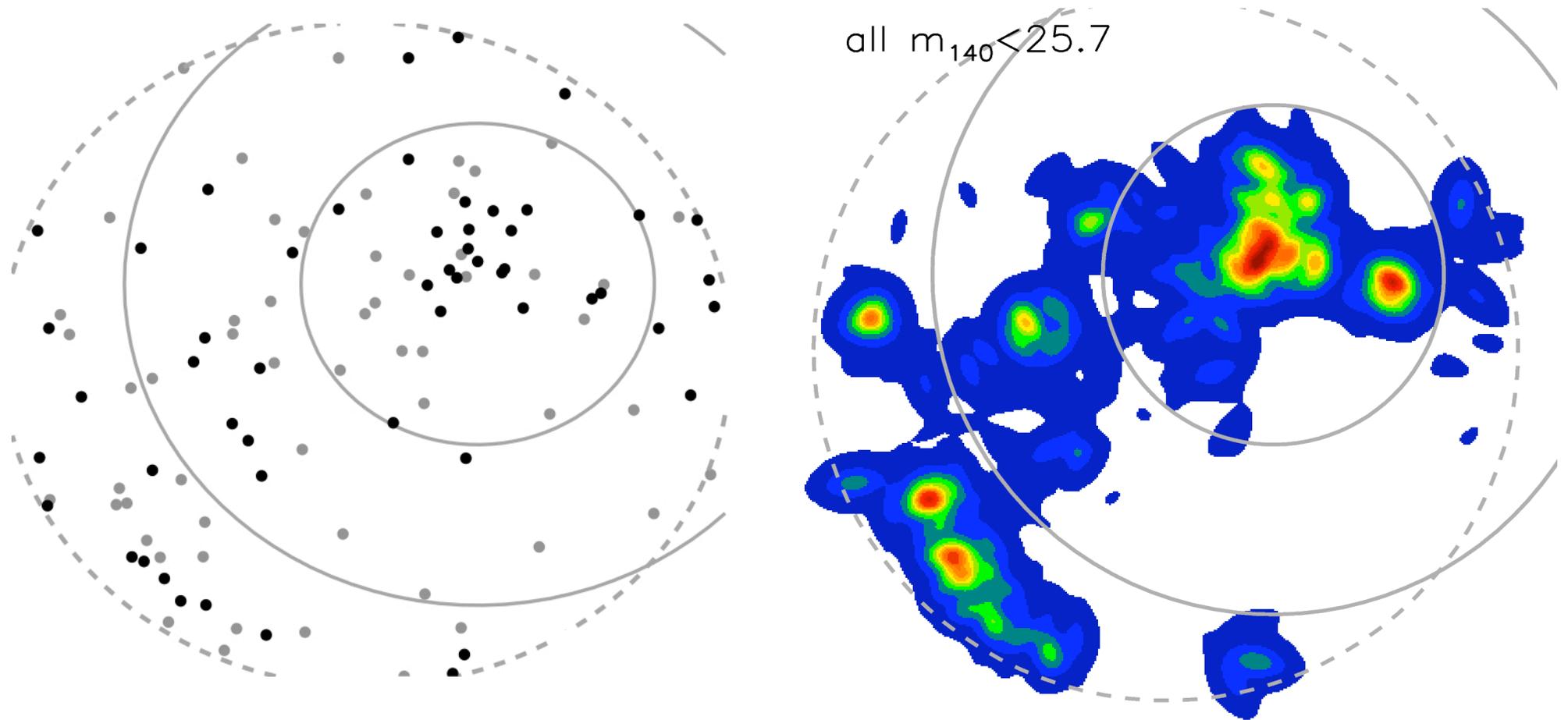
Cluster members – at redshift 2

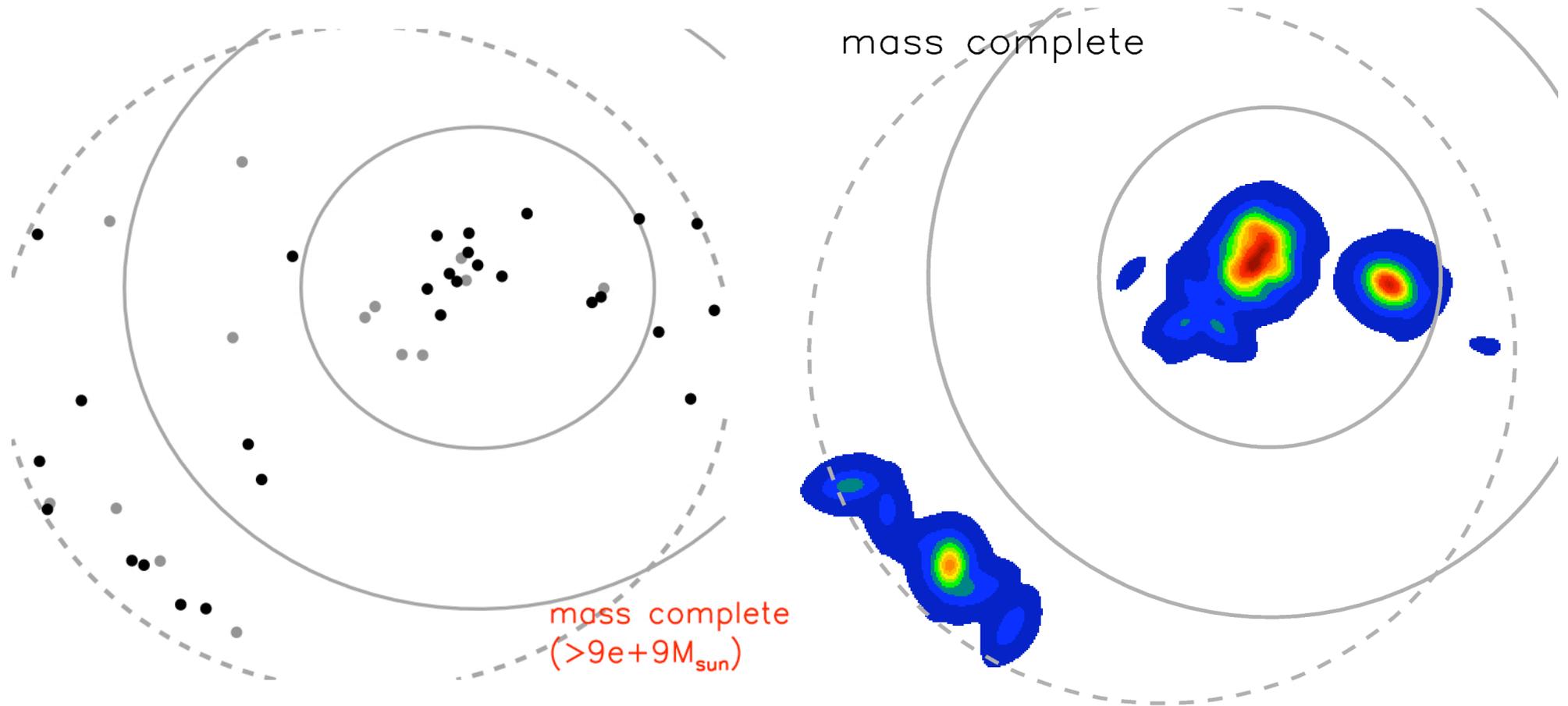# Cluster members – at redshift 2

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The projected distribution of candidate cluster members shows a clear concentration close to the center of X-ray emission, surrounded by lower-density structure.

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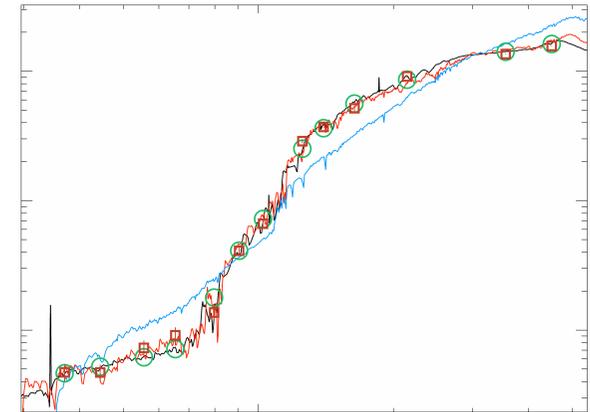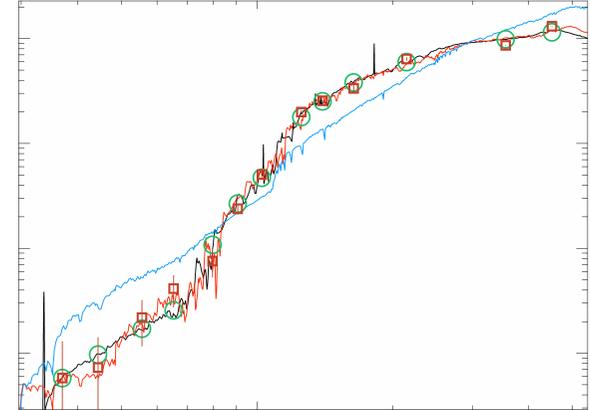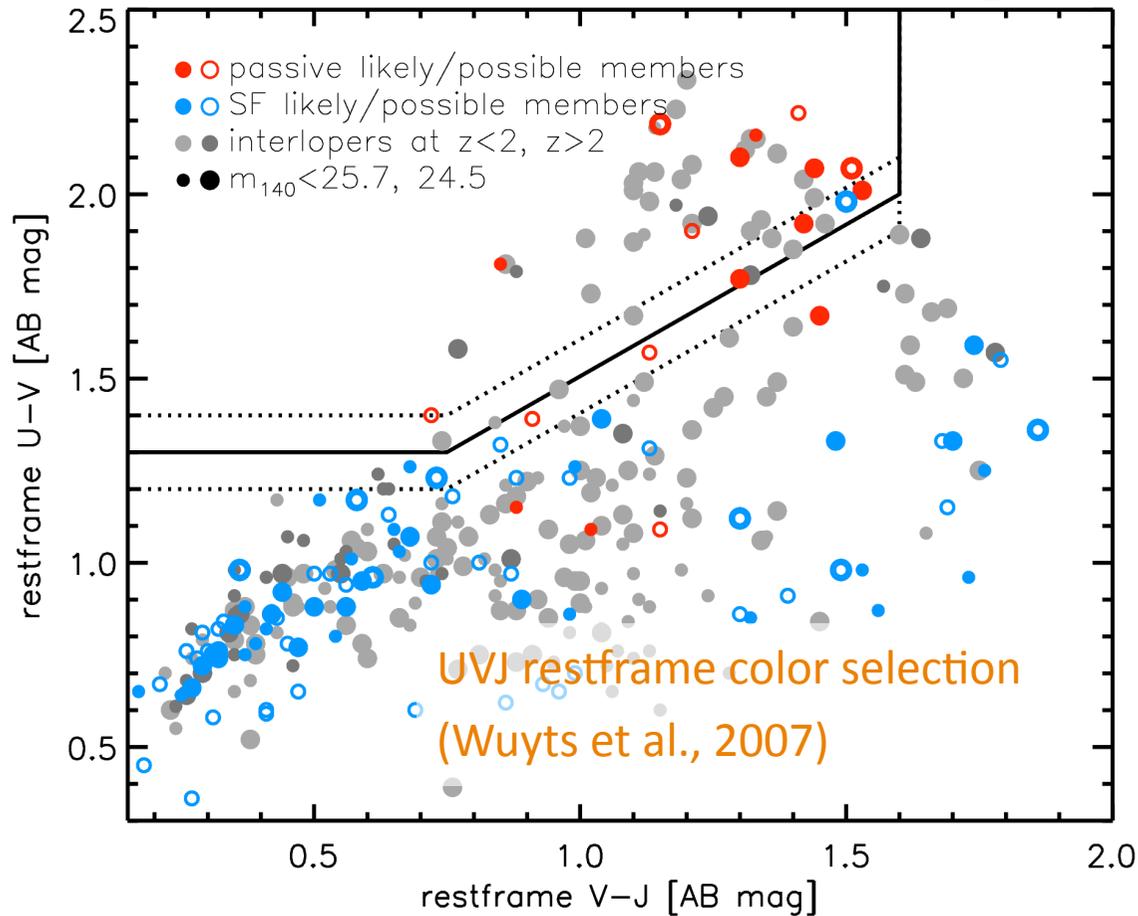

mass complete

mass complete
(>9e+9M$_{sun}$)

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Stellar population properties of cluster galaxies

The candidate member sample (≈110 sources down to $m_{140} < 25.7$) is divided in star-forming and quiescent galaxies based on the observed colors / SEDs.

<20% of the sample is classified as quiescent. Some optically-red (U-V) candidate members are classified as dust-reddened, star-forming sources.

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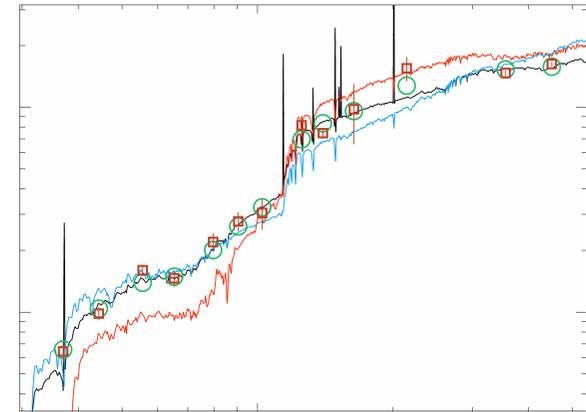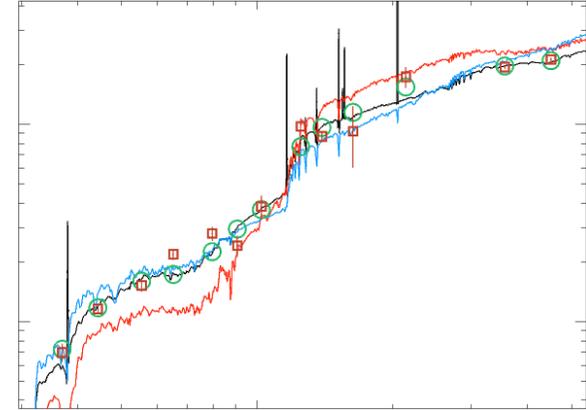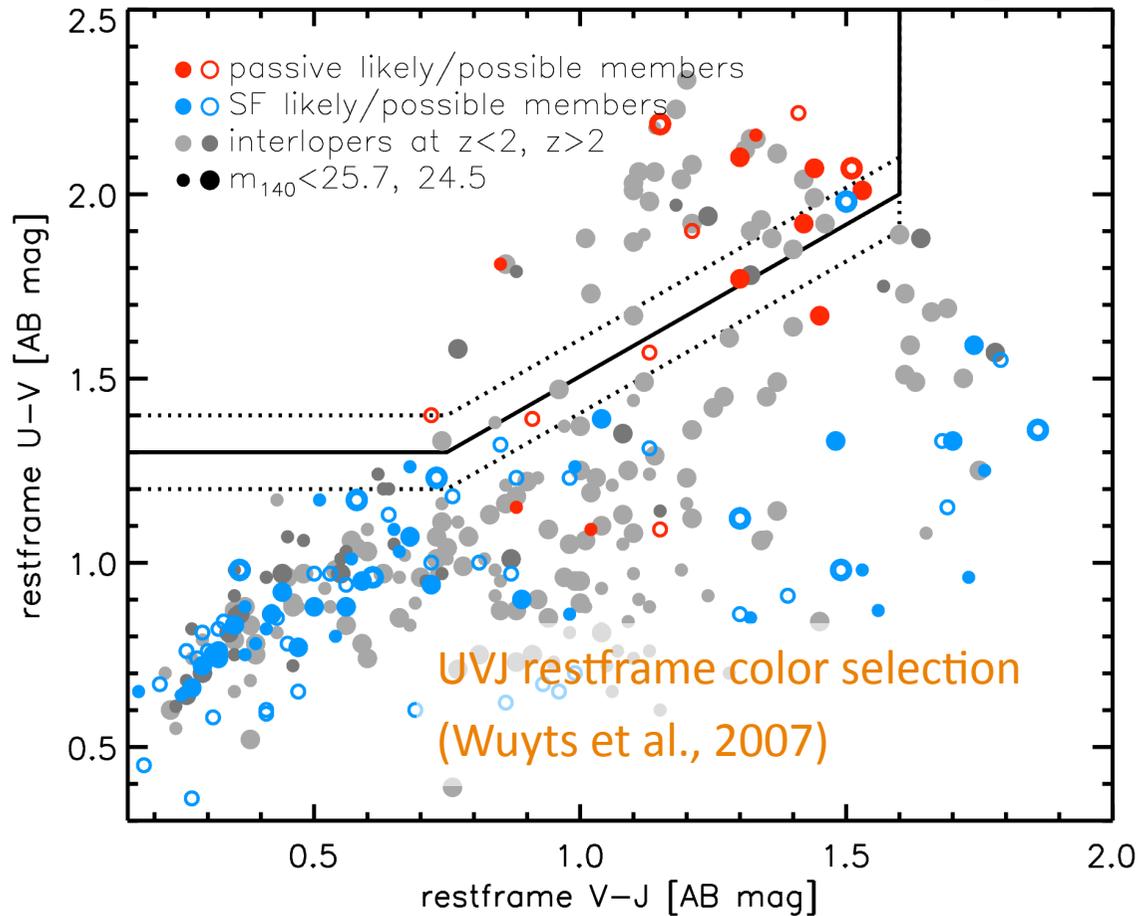
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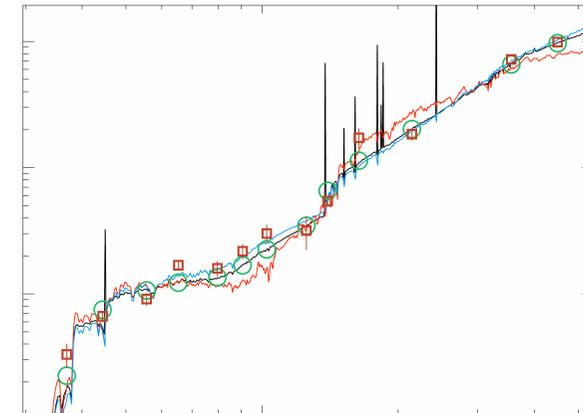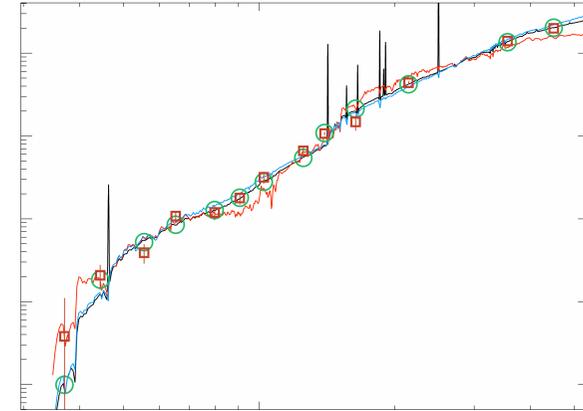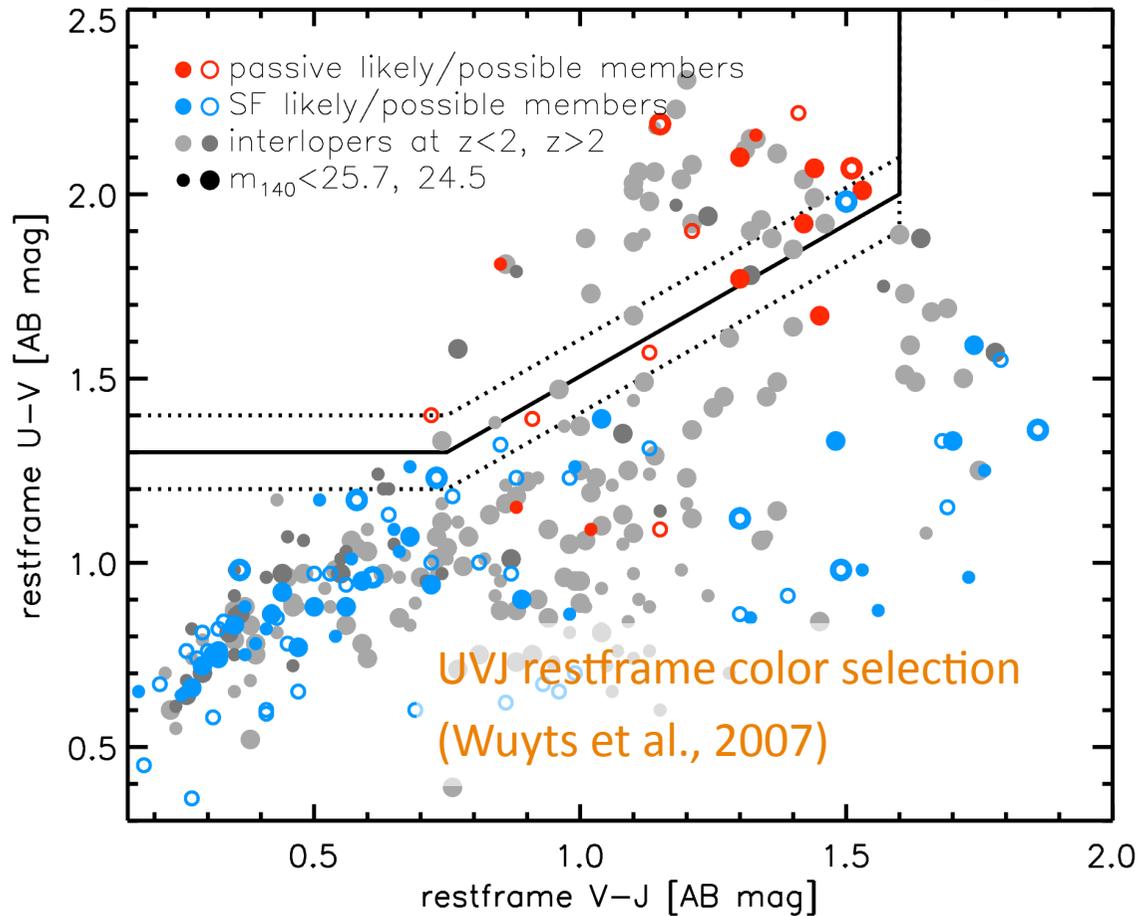
Cluster galaxy populations
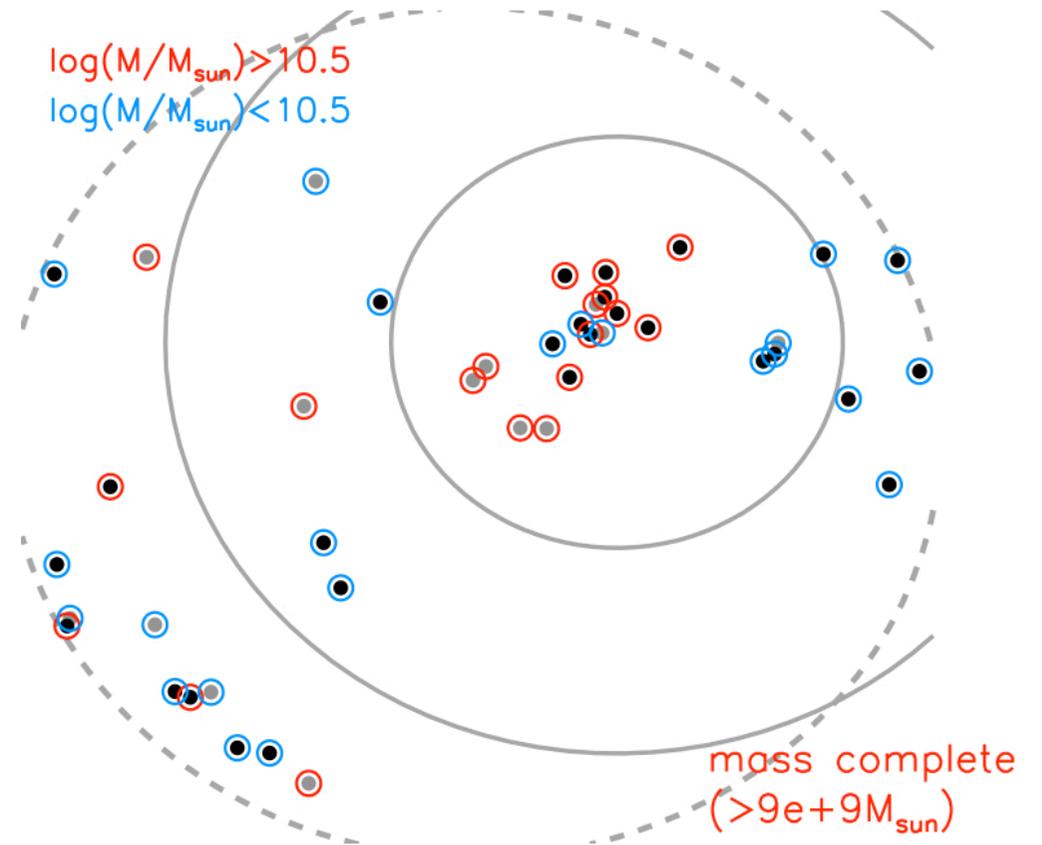
log(M/M$_{sun}$)>10.5
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mass complete
(>9e+9M$_{sun}$)

Most massive galaxies are preferentially located close to the cluster center.

Cluster galaxy populations

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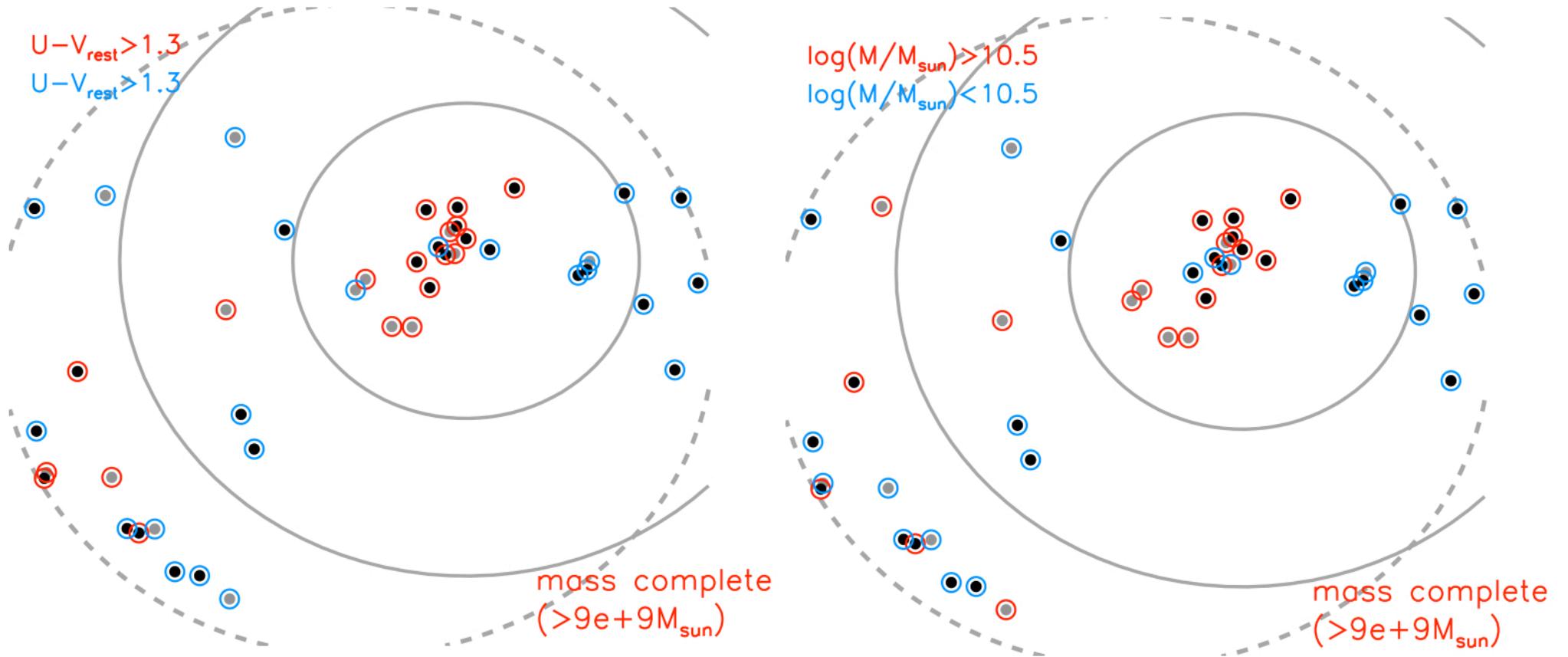
Most massive galaxies are preferentially located close to the cluster center.

Optically red galaxies are segregated close to the cluster center…

Cluster galaxy populations
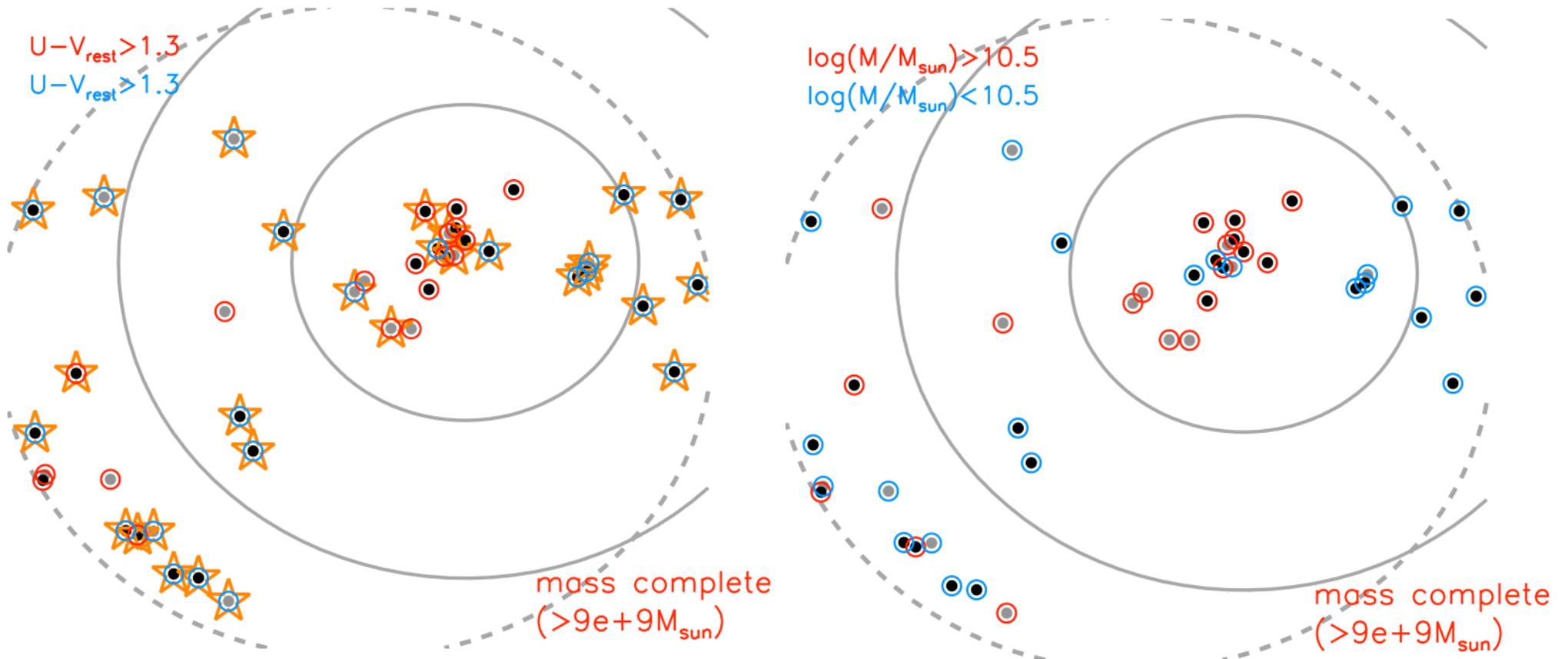
… although a fraction of the red sources is classified as reddened star-forming galaxies.

Galaxies classified as quiescent are typically segregated within ≈200kpc from the cluster center, likely together with a population of massive star-forming systems.

Most quiescent galaxies have masses exceeding $2\text{-}3\times10^{10}M_{sun}$

Cluster galaxy populations

$U-V_{rest}>1.3$
$U-V_{rest}>1.3$

mass complete
($>5\times10^{9}M_{sun}$)

- Star-forming fraction within 200kpc is ≈40-50% for mass complete sample.
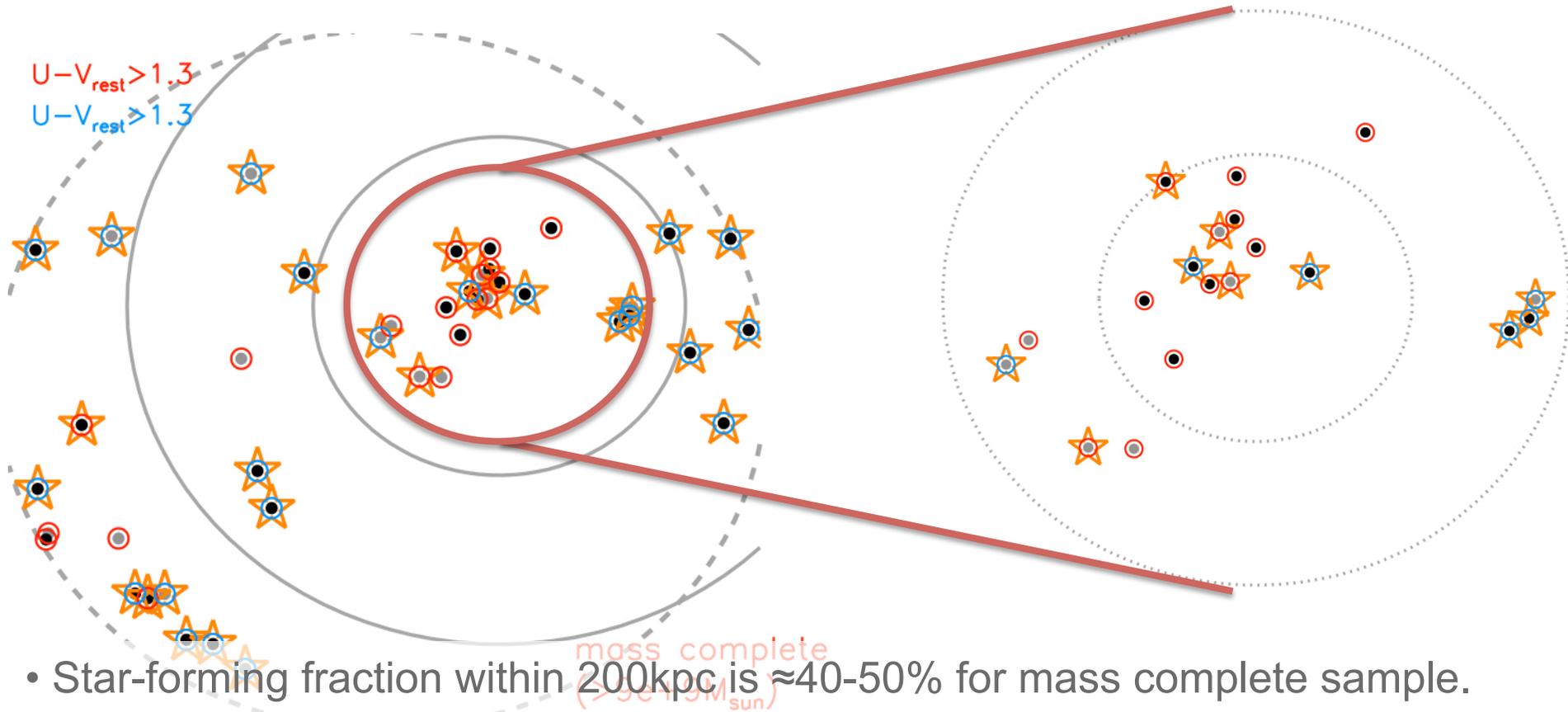
- Star-forming fraction tends to decrease at higher masses, reaching 20-40% for $M>2\times10^{10}M_{sun}$, - for the same mass limit, SF fraction beyond 200kpc is 70-80% (but beware of likely higher field contamination!) , and ≈60% for interlopers at similar redshift

- Most massive populations ($>10^{11}M_{sun}$) within 200 kpc reach SF fraction <20% (≈50% in the field)

Morphological properties of massive cluster galaxies
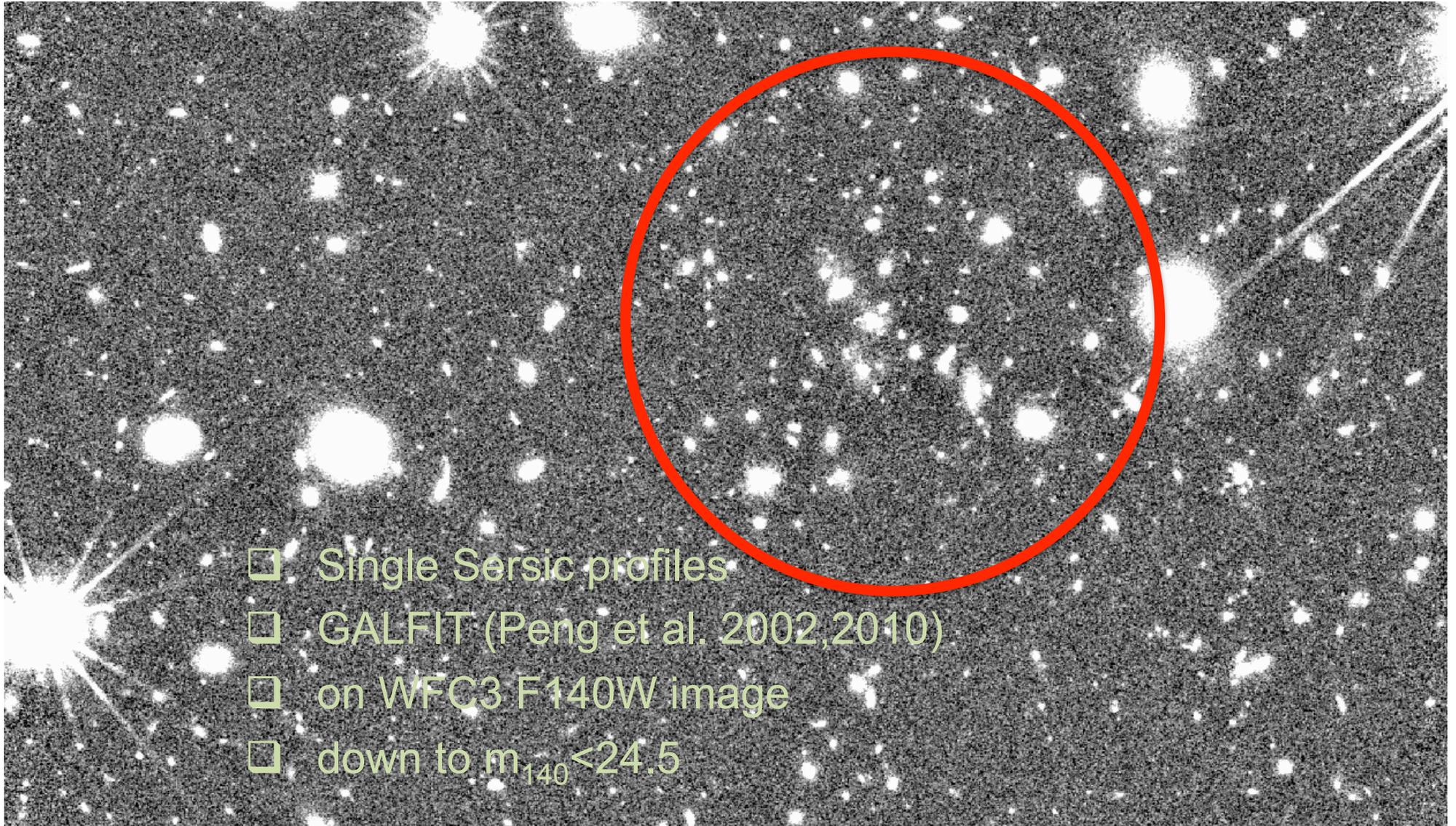
- Single Sersic profiles
- GALFIT (Peng et al. 2002,2010)
- on WFC3 F140W image
- down to $m_{140} < 24.5$

Morphological properties of massive cluster galaxies
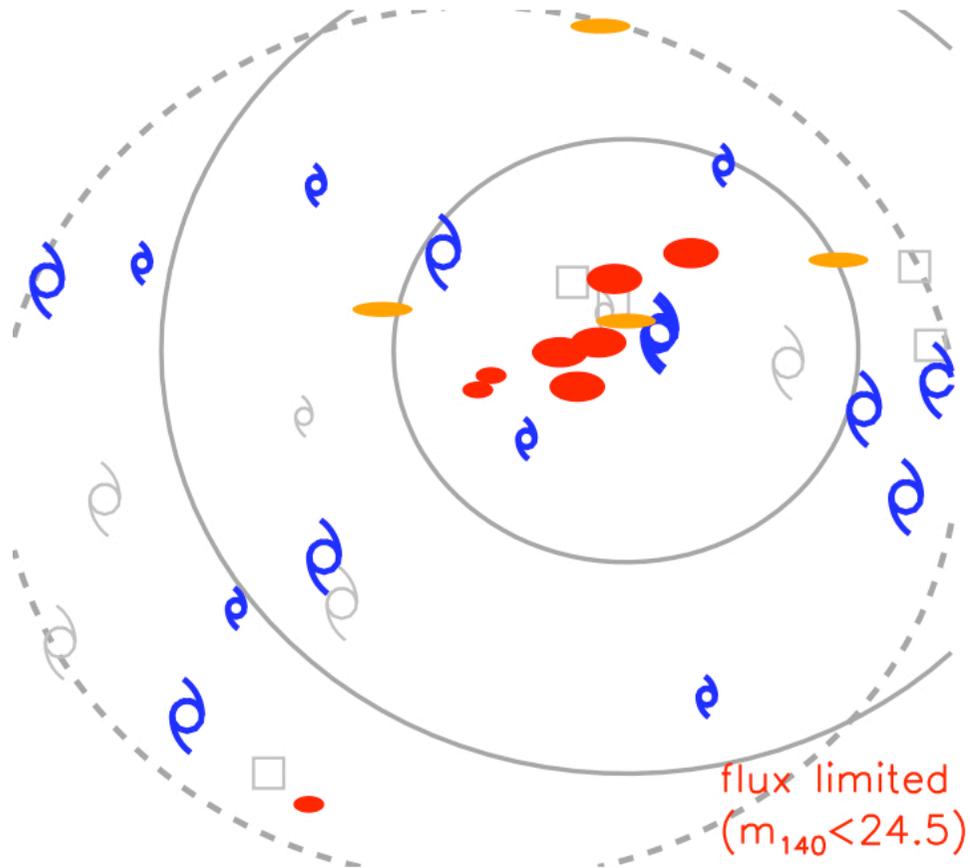
Galaxies with high Sersic index profiles are concentrated in the cluster core.

flux limited
($m_{140}<24.5$)

Morphological properties of massive cluster galaxies
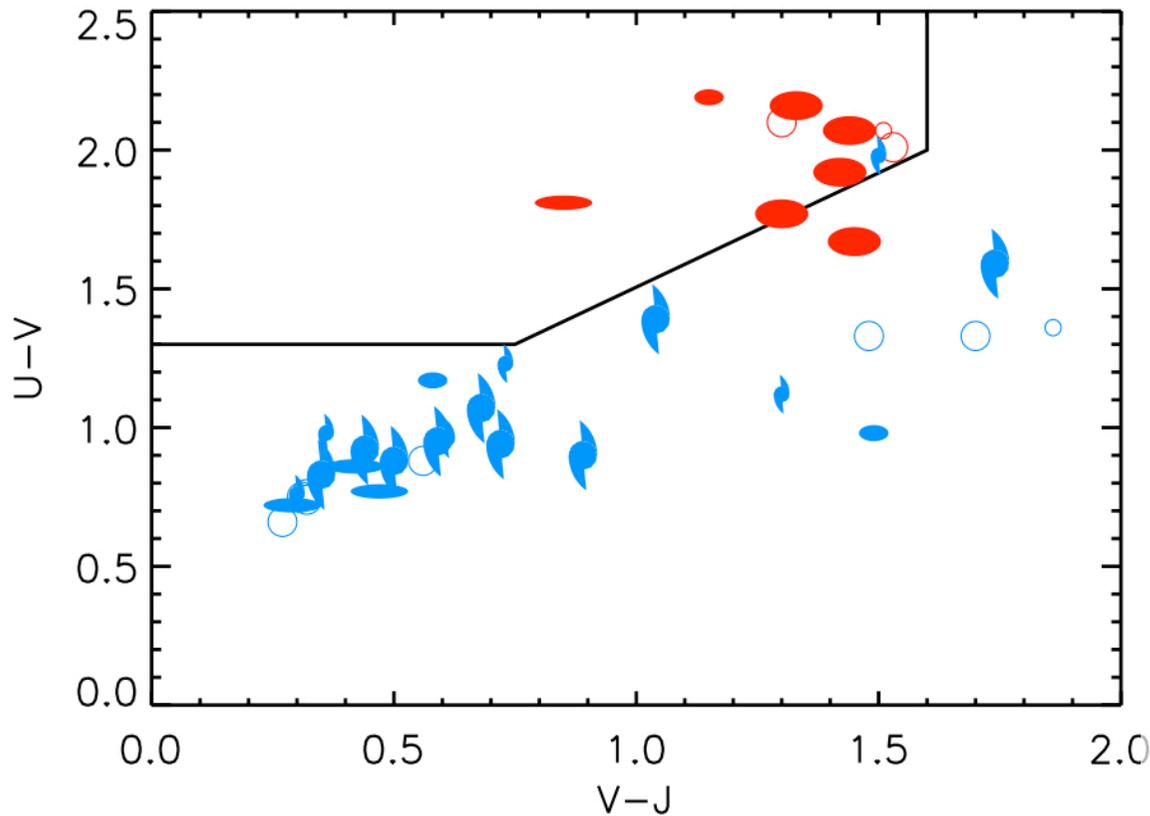
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Already at this redshift, galaxy structure correlates with stellar population properties (see also e.g. Bell+2012, Papovich+2012, Patel+2012, …)

The quiescent population
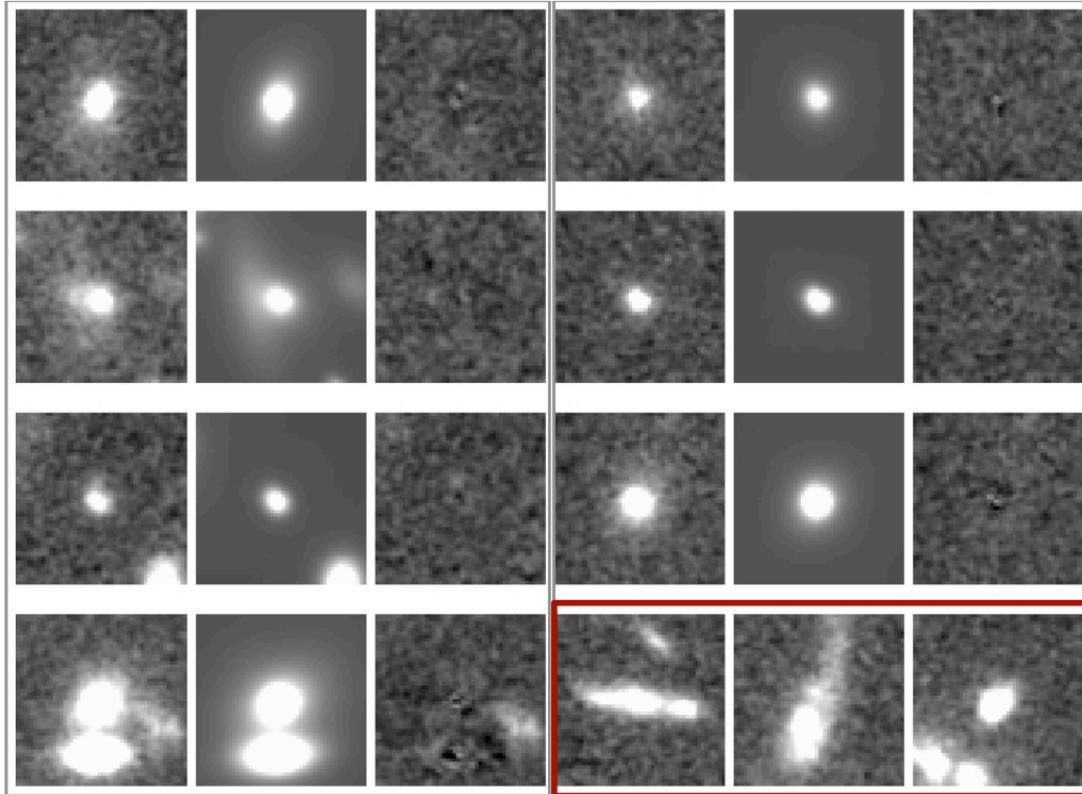
At the mass completeness limit for morphological analysis ($m_{140} \approx 24.5$ ➔ $M_* \geq 2.5 \cdot 10^{10} M_\odot$):

- ■ 10 quiescent candidate members
- ■ 7 have a $n_{Sersic} > 2$
- ■ 3 have non-ETG or unconstrained morphology

Cluster early-types at redshift 2

At the mass completeness limit for morphological analysis ($m_{140} \approx 24.5$ → $M_* \geq 2.5 \cdot 10^{10} M_\odot$):
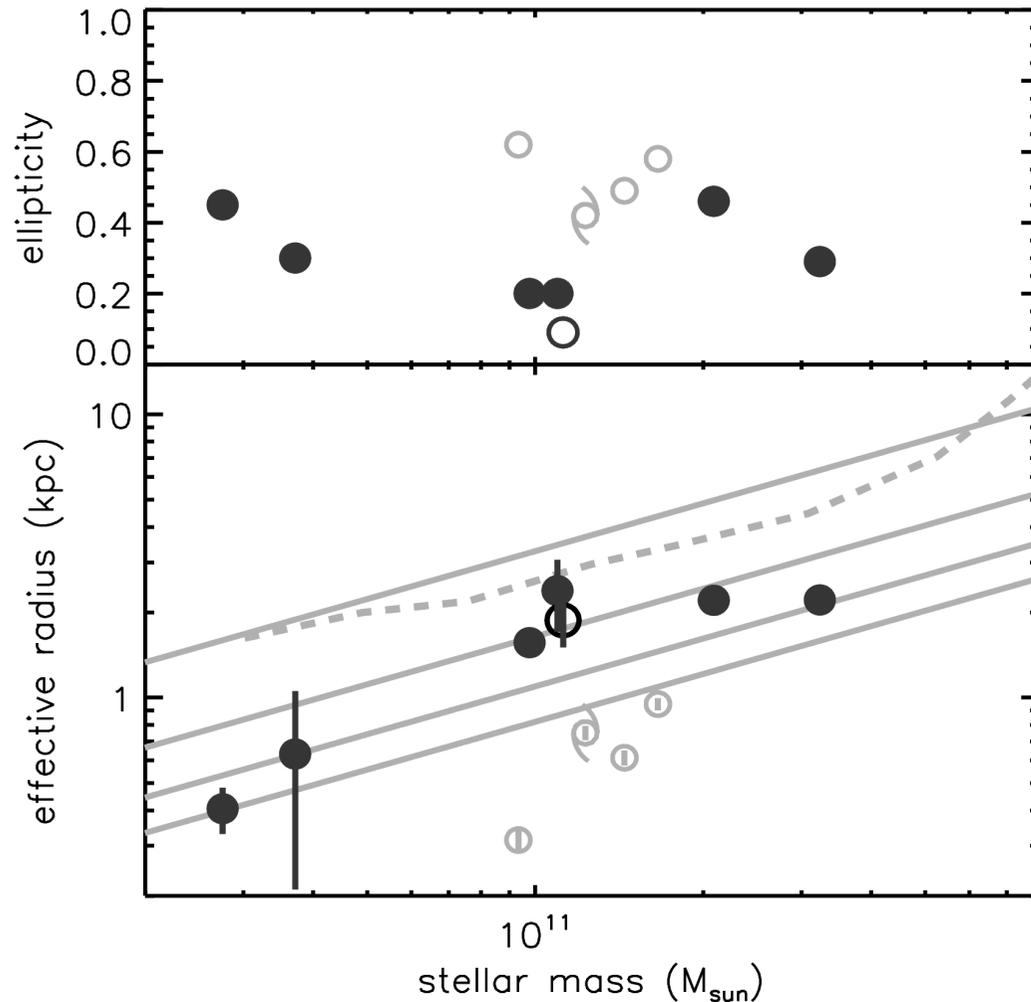
■ 10 quiescent candidate members (7 have a $n_{Sersic} > 2$)

■ 4 quiescent spectroscopic interlopers at similar redshift (3 have $n_{Sersic} > 2$)

Interlopers are systematically more compact than candidate members (e.g. Cooper+, Papovich+, Zirm+ 2012 ?), and have higher ellipticity. In spite of membership-related caveats, these observations exclude the presence of extremely compact passive ETGs in the cluster.

ellipticity

effective radius (kpc)

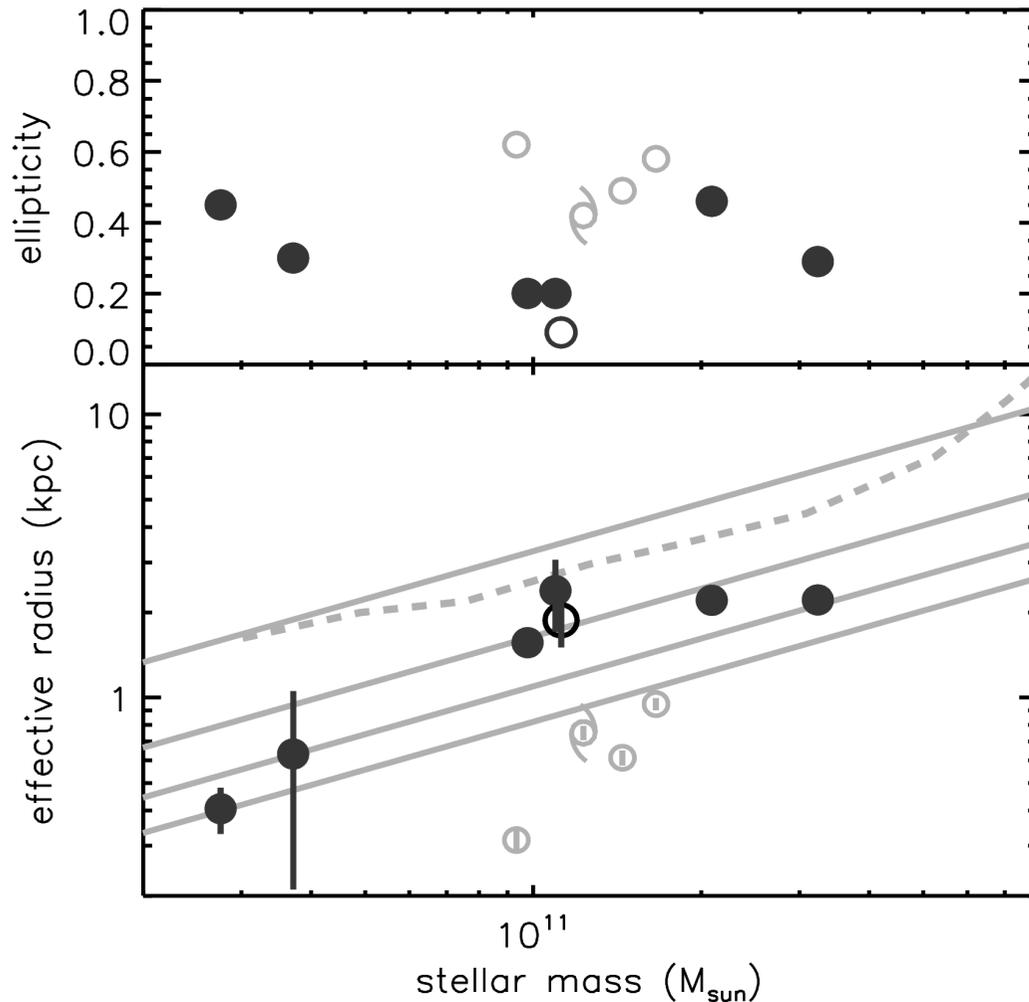stellar mass (M_{sun})

10^{11}

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Candidate passive cluster ETGs are 2-3 times smaller than their z=0 counterparts (consistent with expectations from previous measurements at lower redshifts).

Summary

■ a clear overdensity of (candidate) members, with massive, red, quiescent, early-type galaxies concentrated in the cluster core, likely together with a population of still actively star-forming sources

■ massive quiescent candidate members mostly have early-type morphology, and a factor 2-3 smaller size than their local counterparts

■ most compact galaxies in this field at z≈2 are spectroscopic interlopers - in spite of residual field contamination, the presence of very compact passive early-types in the cluster core is excluded.

Observational issues, including in particular uncertainties in the membership determination, still prevent sensible conclusions on:

■ the actual relevance (and details) of star-formation within the cluster core (and especially for the most massive populations)

■ a detailed comparison of structural and stellar population properties of cluster vs field galaxies at z≈2

■ ... much more! more data coming to the rescue...