

# Environmental quenching and structural evolution in massive galaxy clusters at $z \sim 1.5$

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with M. Pannella, J. Mohr, A. Saro, M. Ashby & SPT-clusters

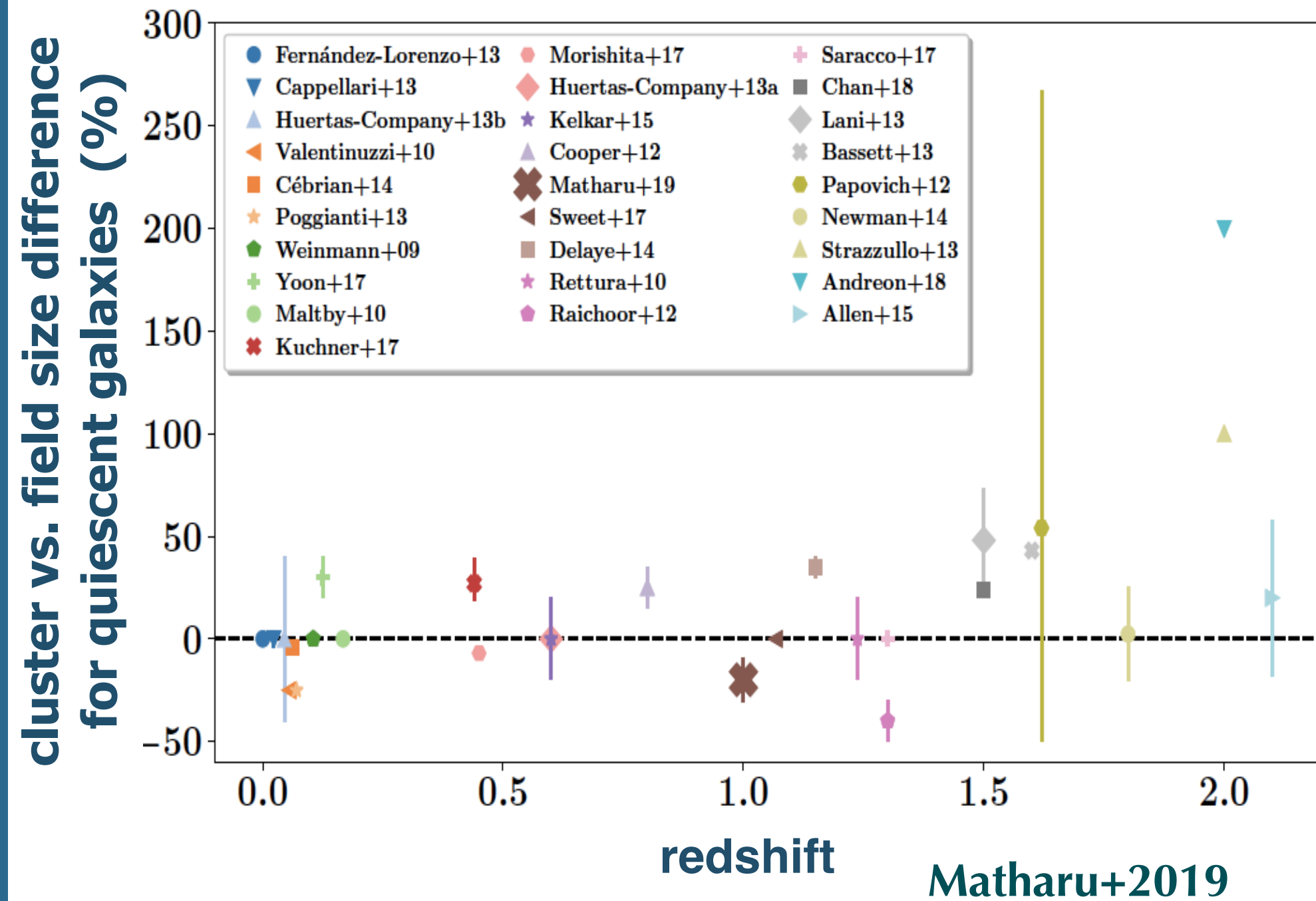
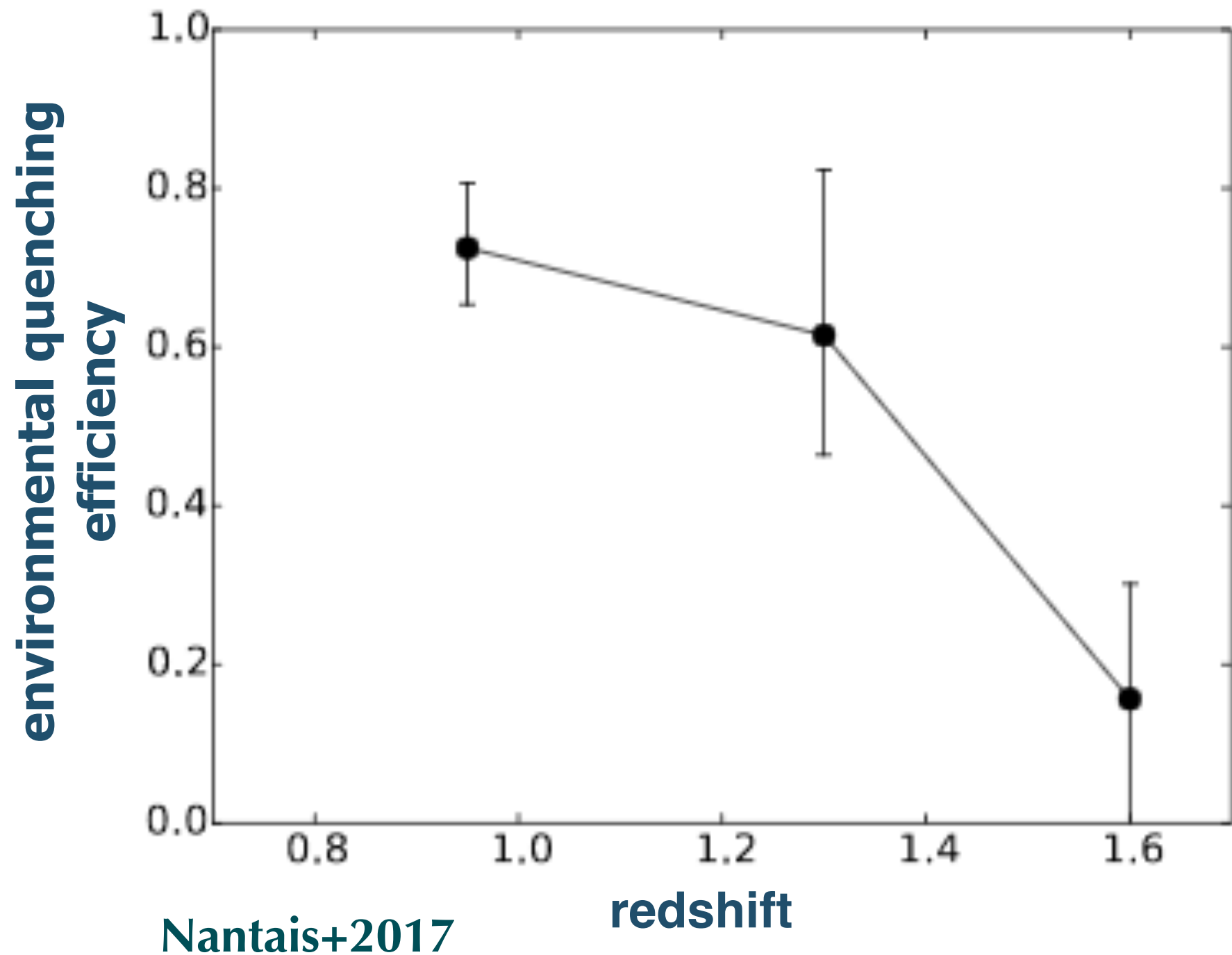


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Are cluster environments at  $z \sim 1.5$  already effective at suppressing star formation?

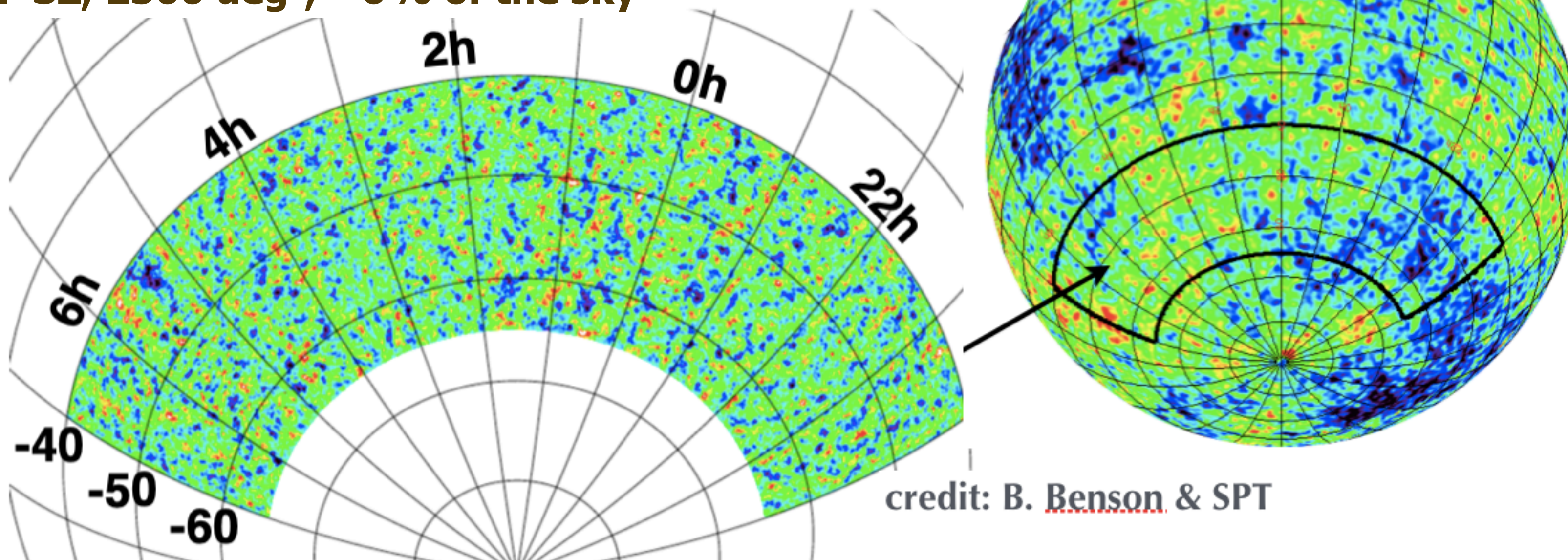
Are there environmental signatures on structural properties (of quiescent galaxies)?





# Massive distant clusters in the SPT-SZ survey

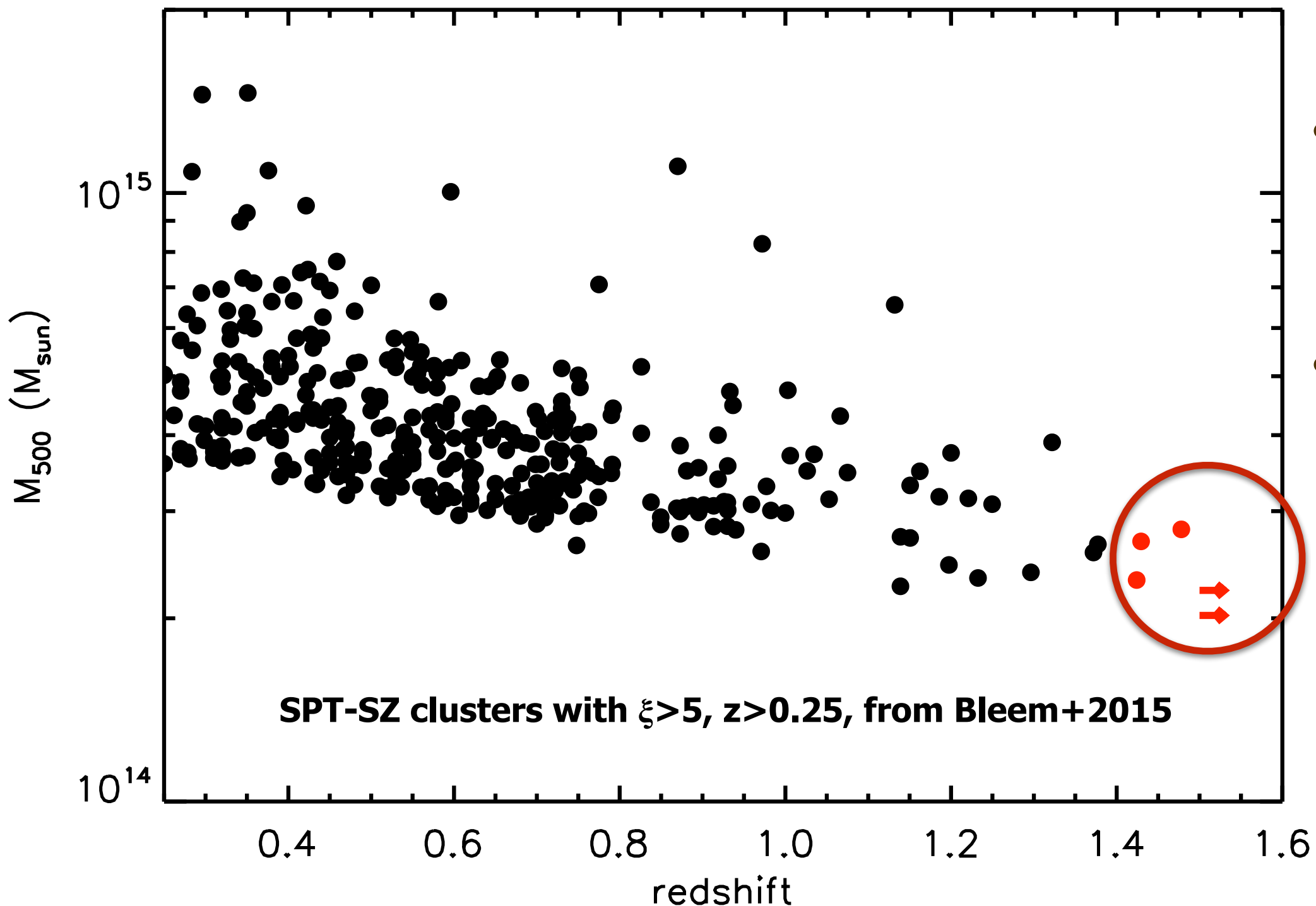
SPT-SZ, 2500 deg<sup>2</sup>, ~6% of the sky



credit: B. Benson & SPT

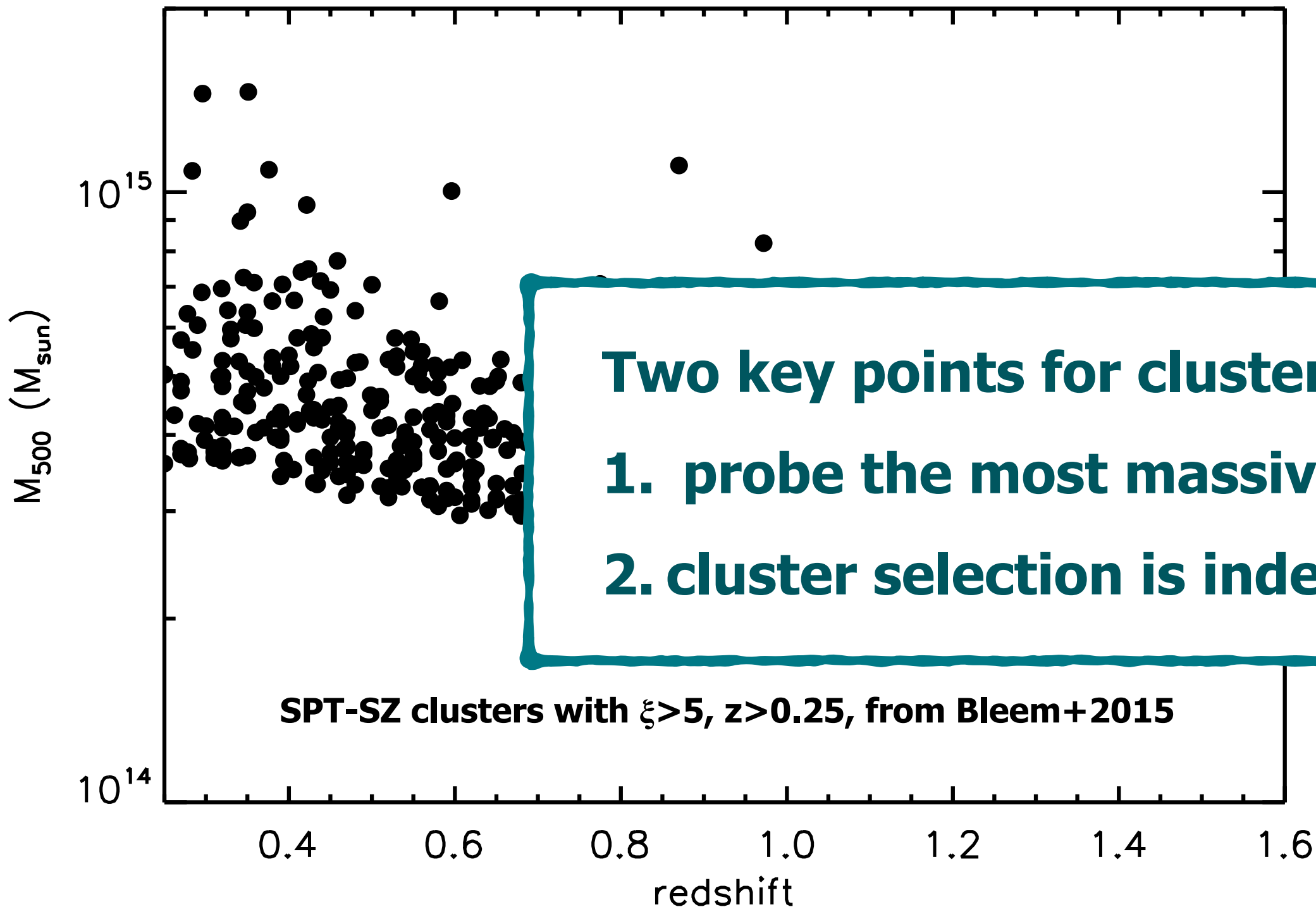


# A sample of most distant SPT-SZ clusters



- **>500 clusters over 2500 deg<sup>2</sup>, ~40 clusters at  $z > 1$ , 5  $\xi > 5$  clusters at  $z > 1.4$  in Bleem+2015**
- **clean sample with roughly redshift independent mass threshold  $M_{500} \gtrsim 3 \cdot 10^{14} M_{\odot}$  at  $z > 0.25$**

# A sample of most distant SPT-SZ clusters



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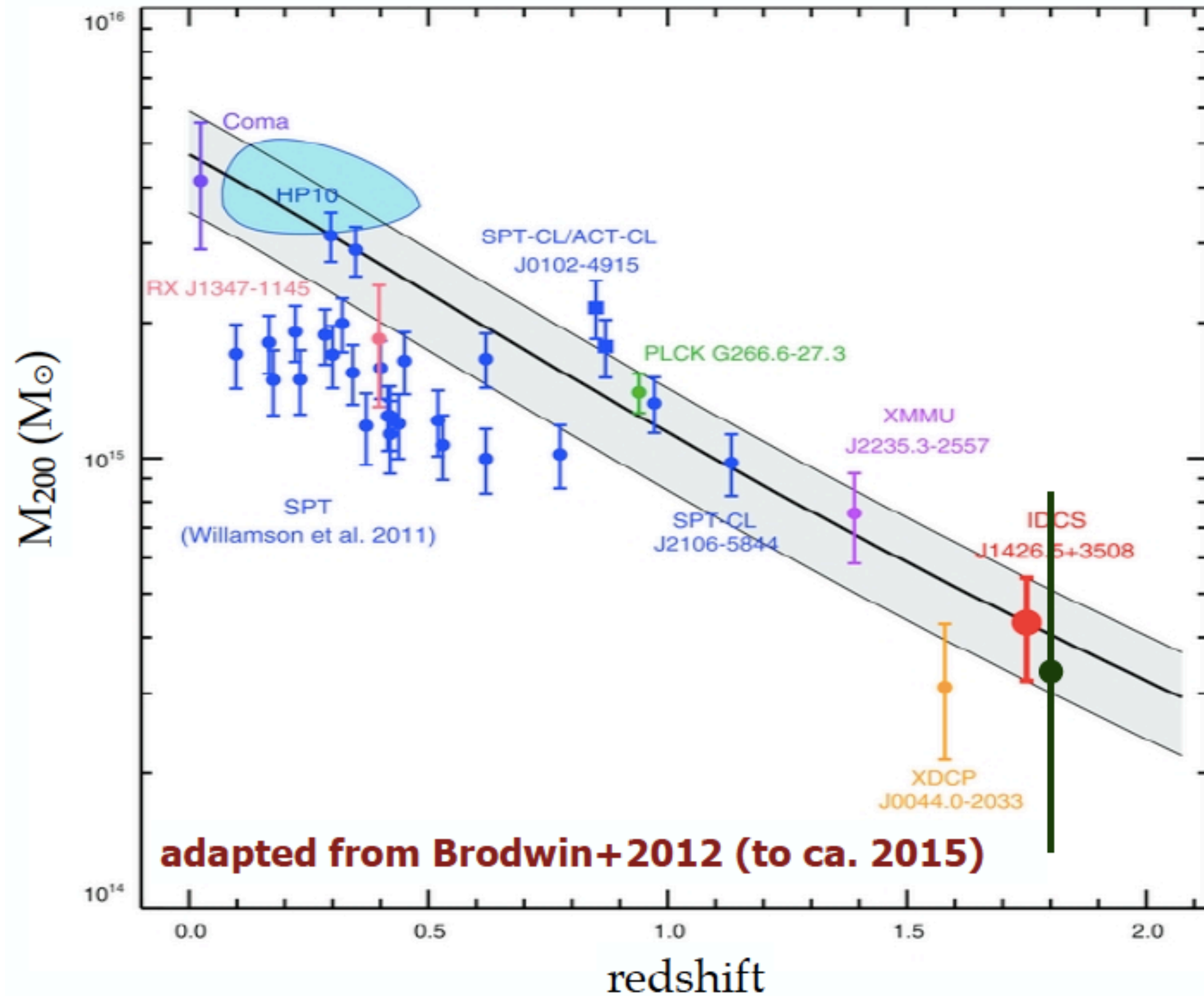
**Two key points for cluster galaxy evolution studies:**

- 1. probe the most massive clusters**
- 2. cluster selection is independent of cluster galaxies**

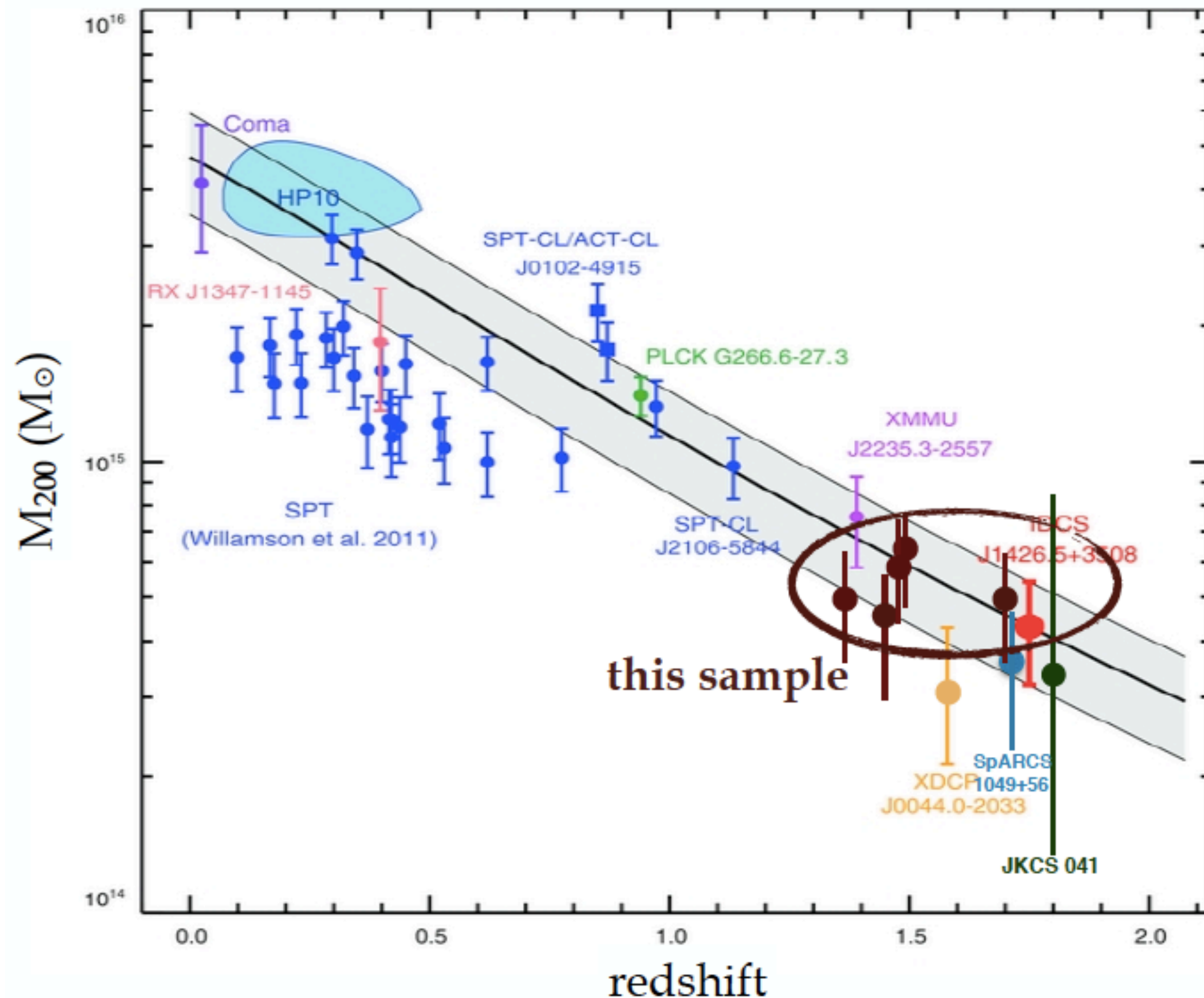
SPT-SZ clusters with  $\xi > 5$ ,  $z > 0.25$ , from Bleem+2015

dependent  
.25

# A sample of most distant SPT-SZ clusters



# A sample of most distant SPT-SZ clusters



**a clean sample probing the first very massive clusters**

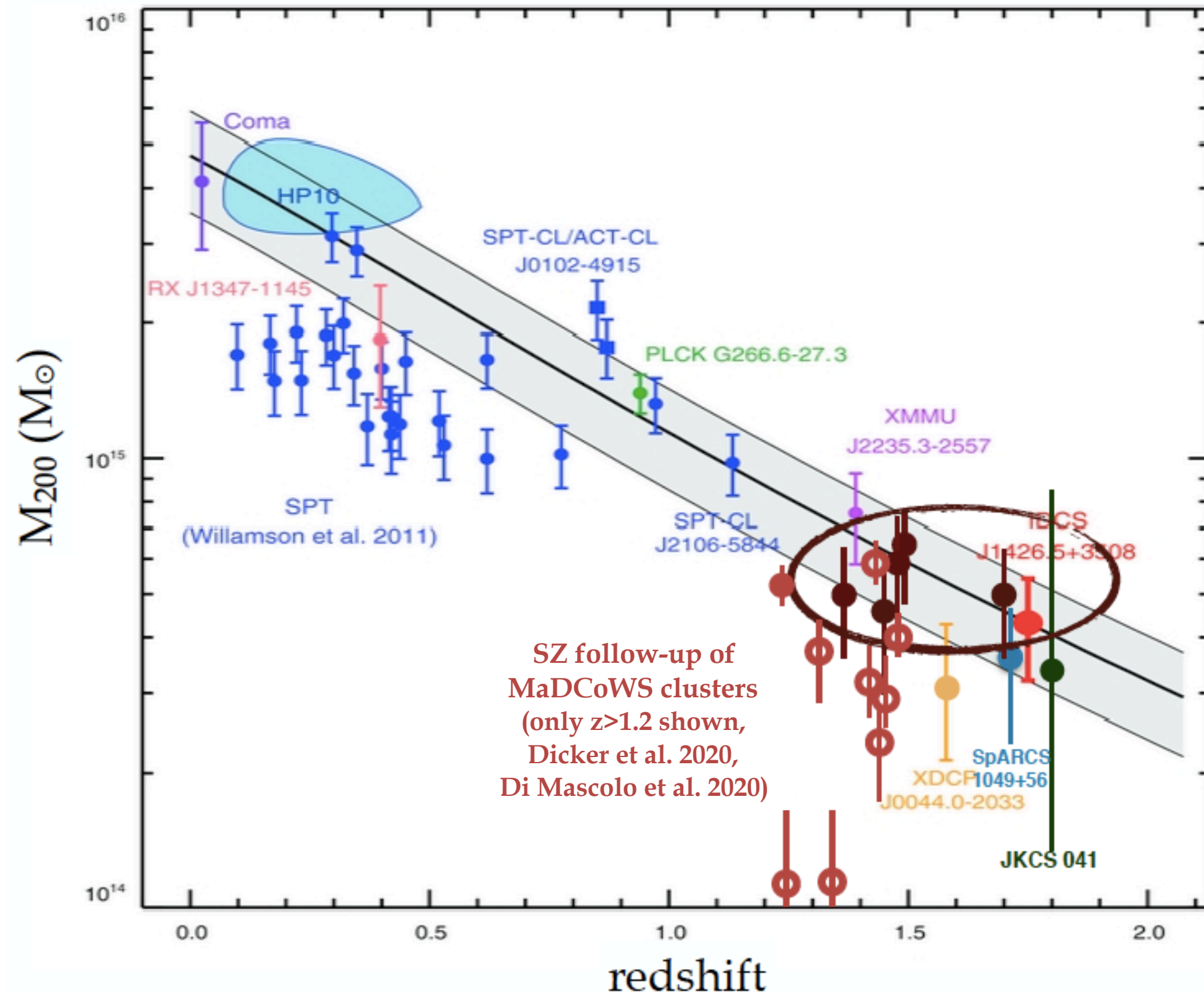
**with accurate SZE-based cluster mass determinations**

**among the rarest, most massive clusters known at these redshifts**

**homogeneously observed in a dedicated HST+Spitzer/IRAC „essential“ 4-band follow-up program**



# A sample of most distant SPT-SZ clusters



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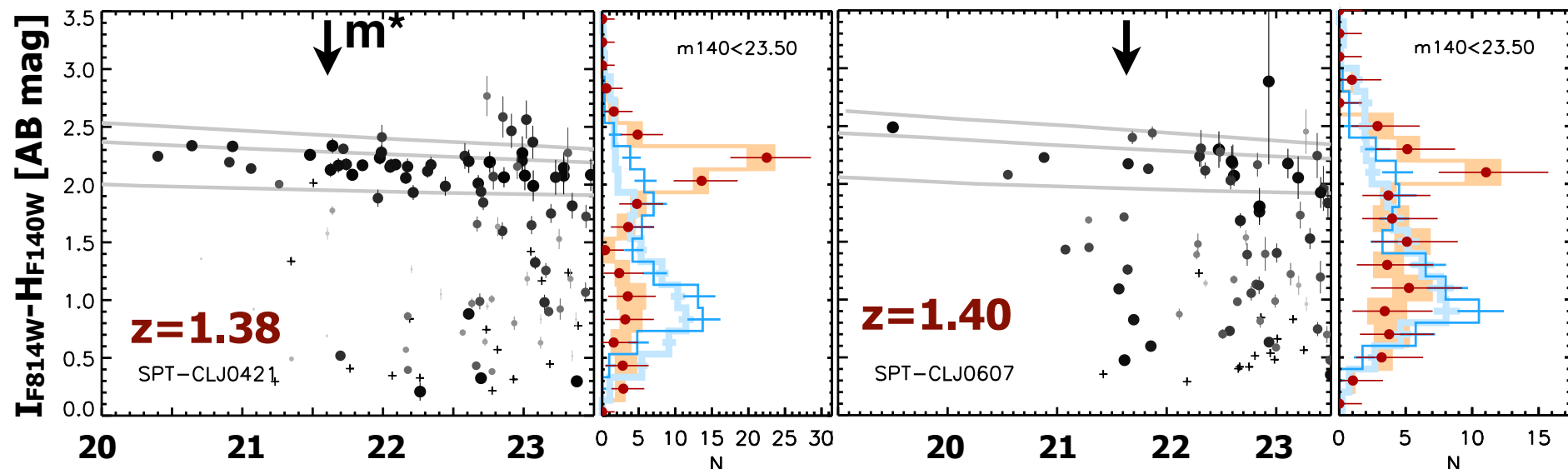
**homogeneously observed in a dedicated HST+Spitzer/IRAC „essential“ 4-band follow-up program**



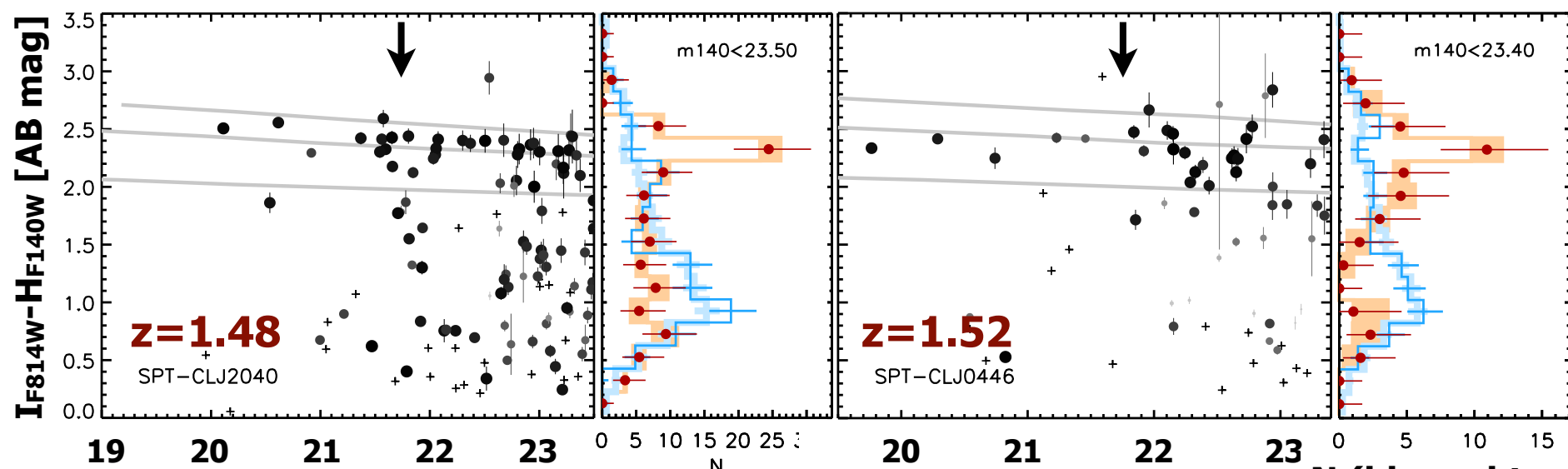
**(Spitzer/IRAC  $3.6\mu\text{m}$  &  $4.5\mu\text{m}$  , HST/ACS+WFC3 F814W & F140W)**

- 1. candidate member sample selection ( $3.6\mu\text{m}$ - $4.5\mu\text{m}$  + optical/NIR color)**
- 2. cluster redshift constraints ( $3.6\mu\text{m}$ - $4.5\mu\text{m}$  + red-sequence color)**
- 3. stellar mass estimates ( $3.6\mu\text{m}$  flux+ restframe U-V color)**
- 4. quiescent vs. star-forming classification (UVJ-like)**
- 5. morphologies / structural parameters (restframe optical WFC3 imaging)**

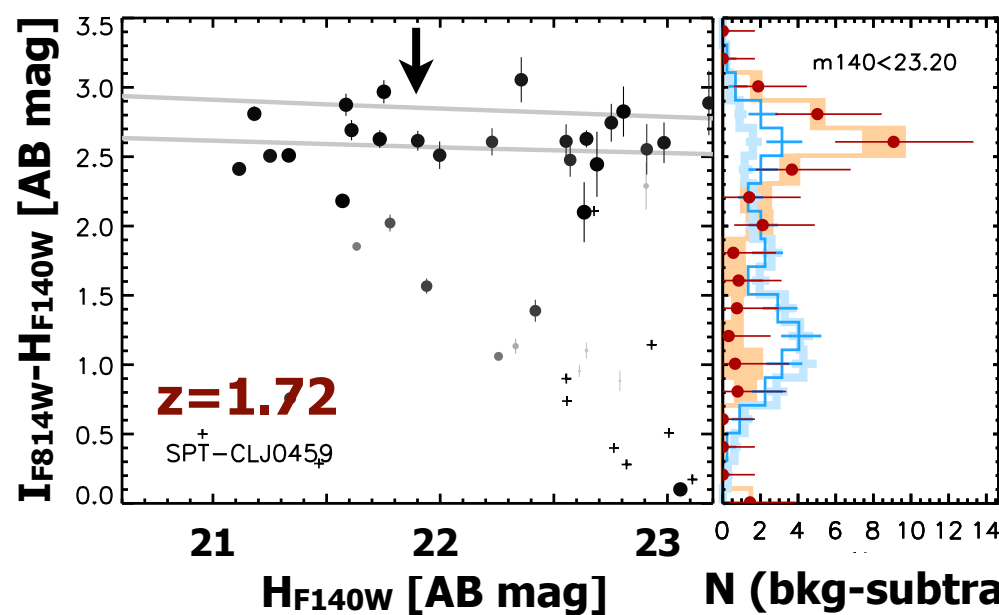
# Environmental quenching - I



$r < 0.7 r_{500}$

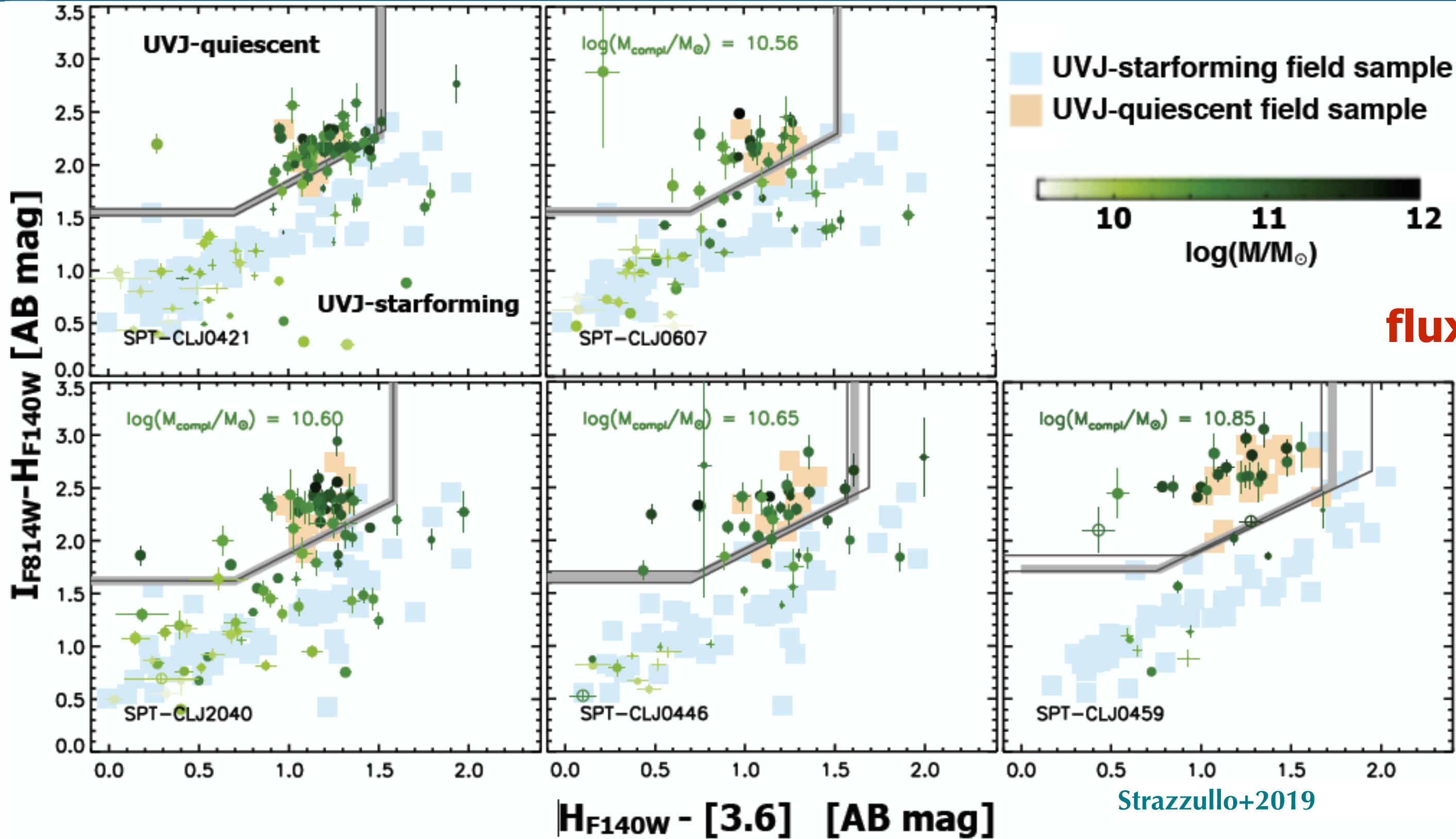


- a massive red sequence typically dominates the bright population
- a clear excess of red sources compared to the field color distribution at same redshift



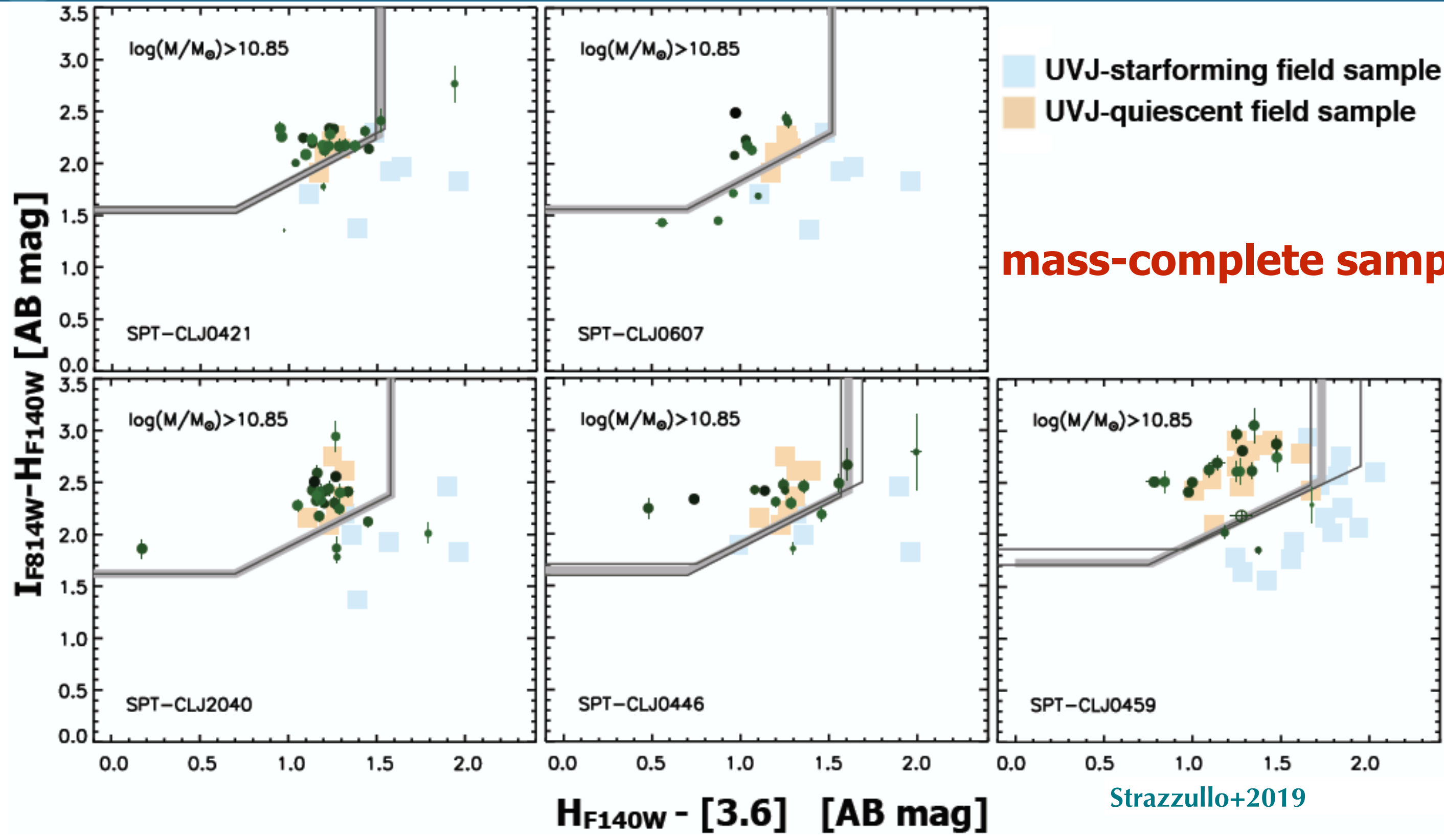
Strazzullo+2019

# Environmental quenching - II





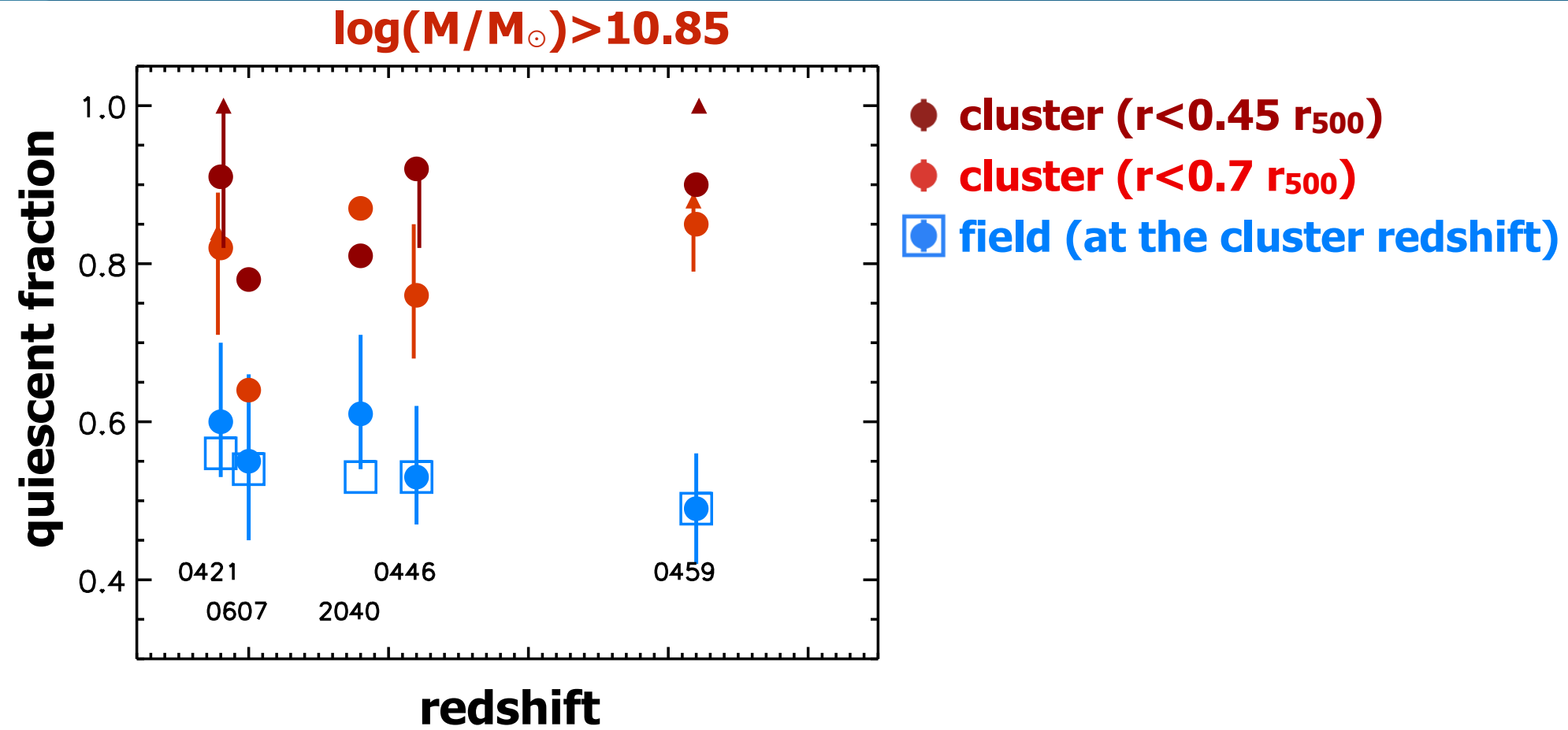
# Environmental quenching - II



mass-complete samples,  $\log(M/M_{\odot}) > 10.85$

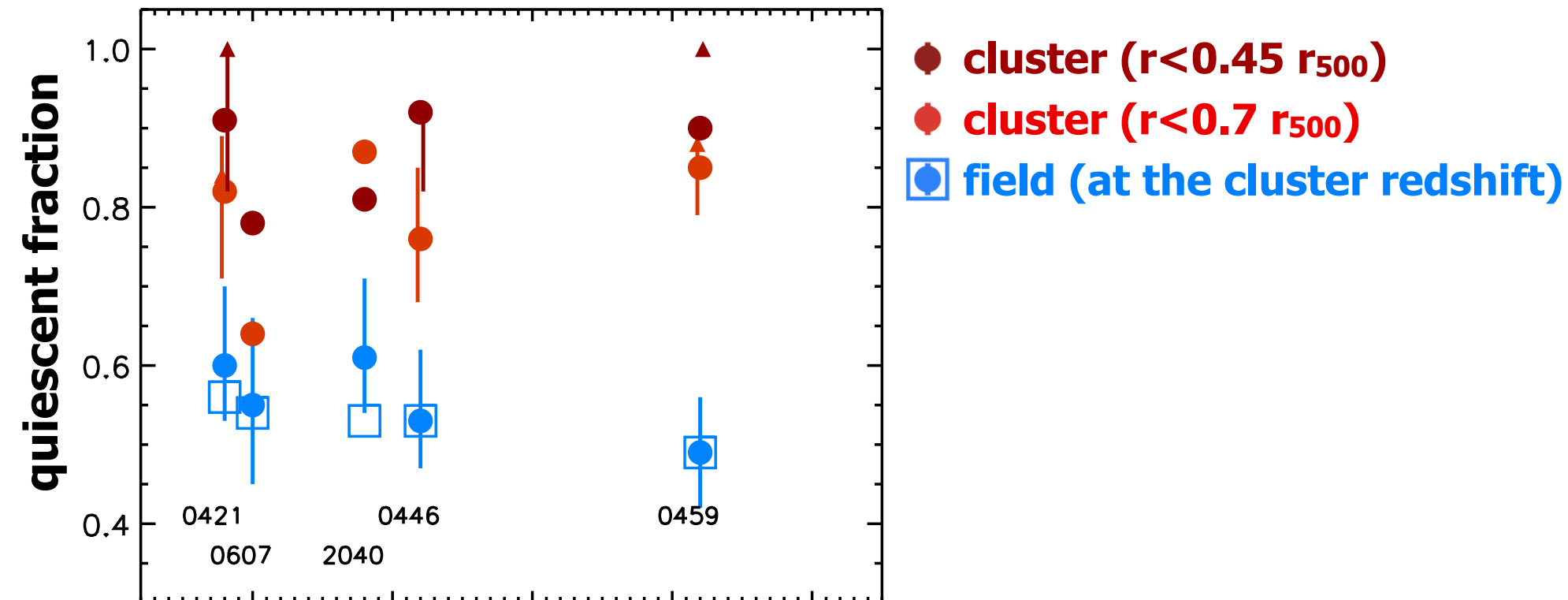
Strazzullo+2019

# Environmental quenching - III

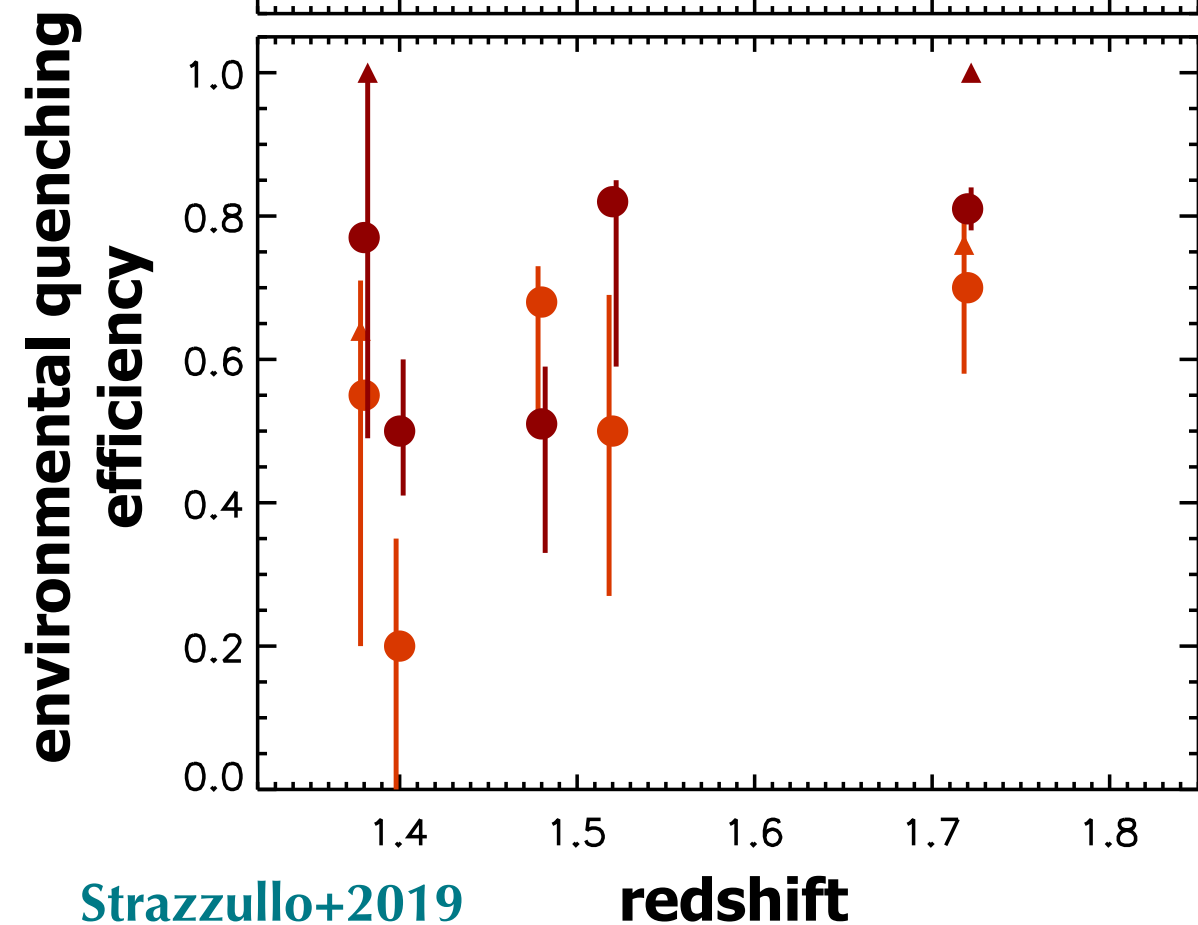


# Environmental quenching - III

$\log(M/M_{\odot}) > 10.85$



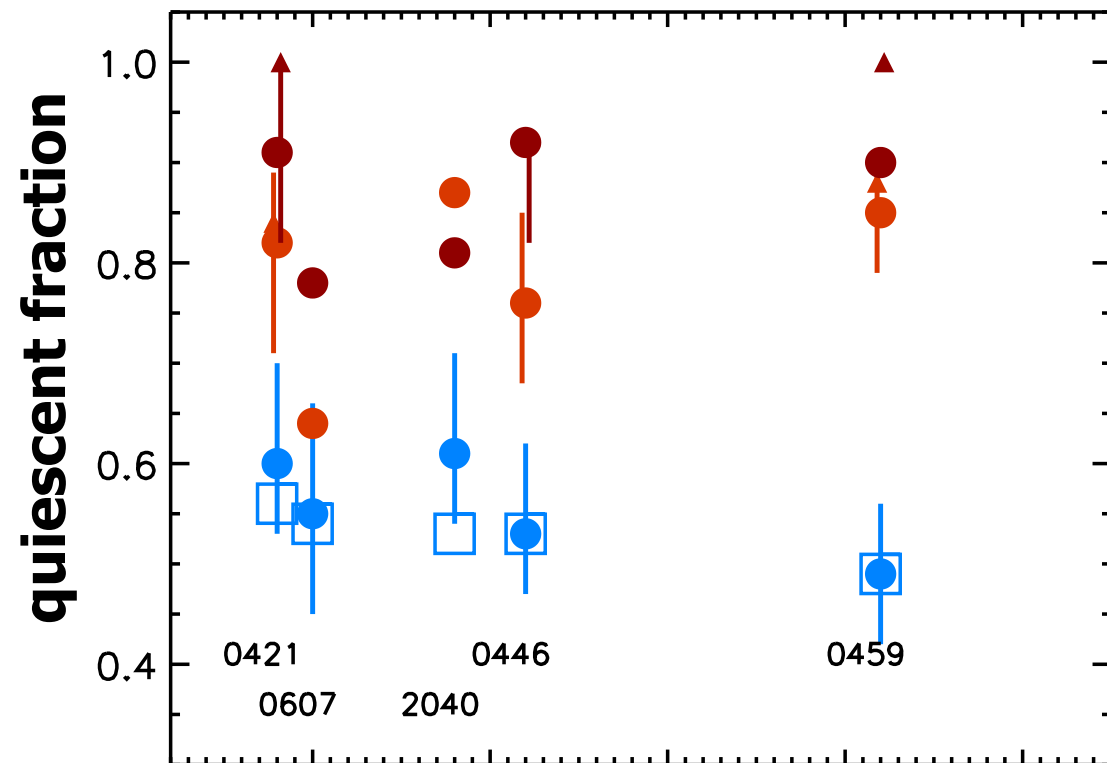
The environmental quenching efficiency at high stellar masses, in the central regions of these massive clusters, is typically  $\geq 50\%$  over the probed redshift range.





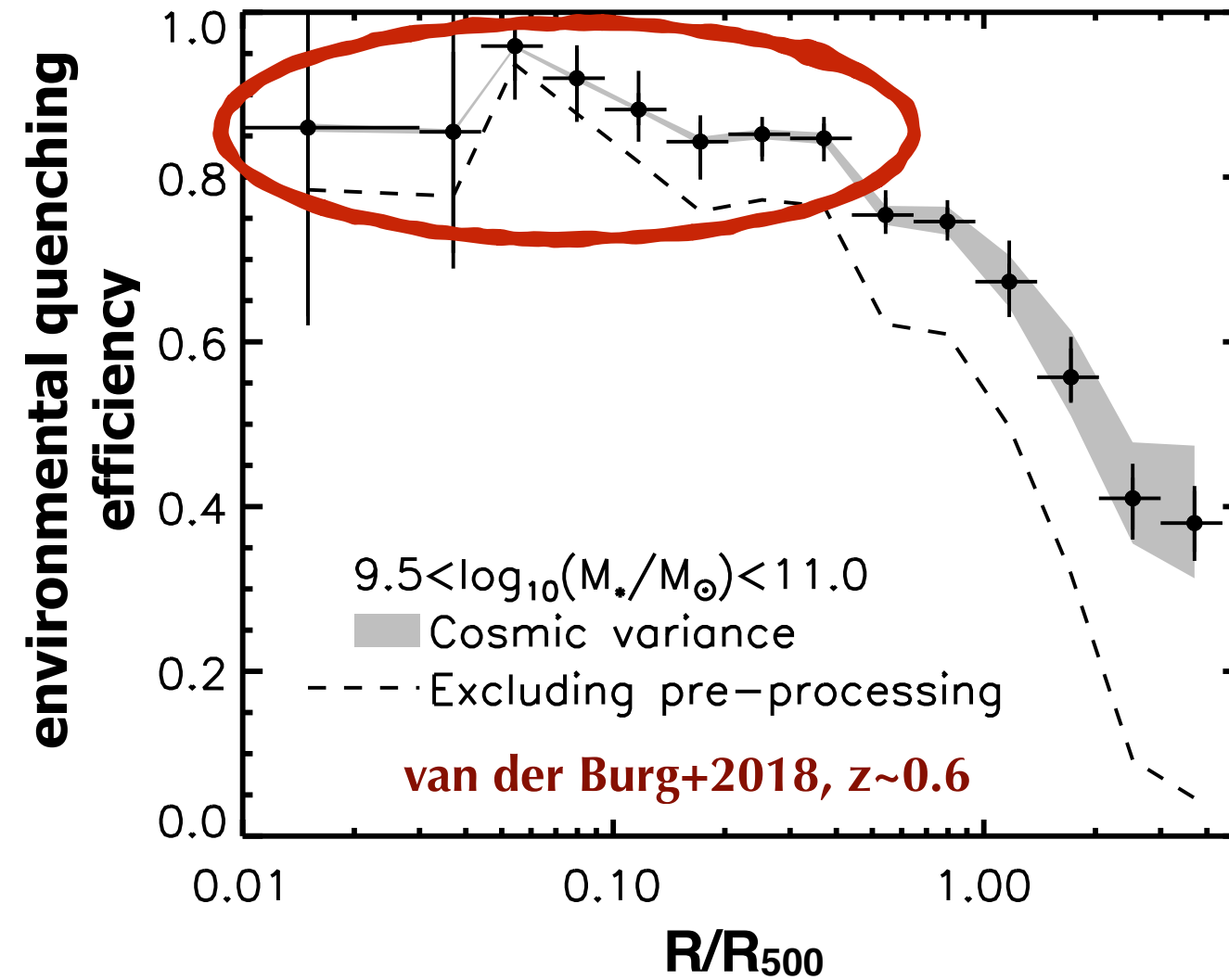
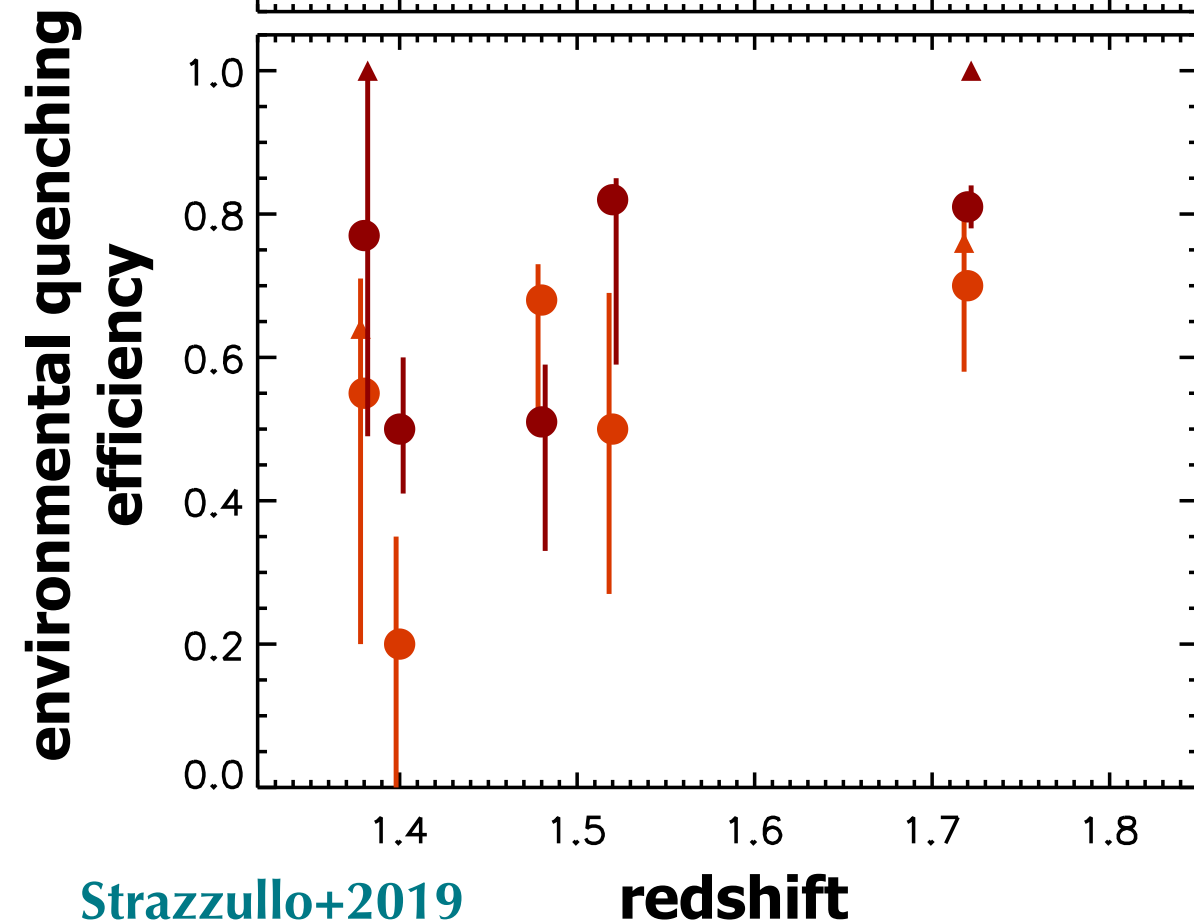
# Environmental quenching - III

$\log(M/M_{\odot}) > 10.85$



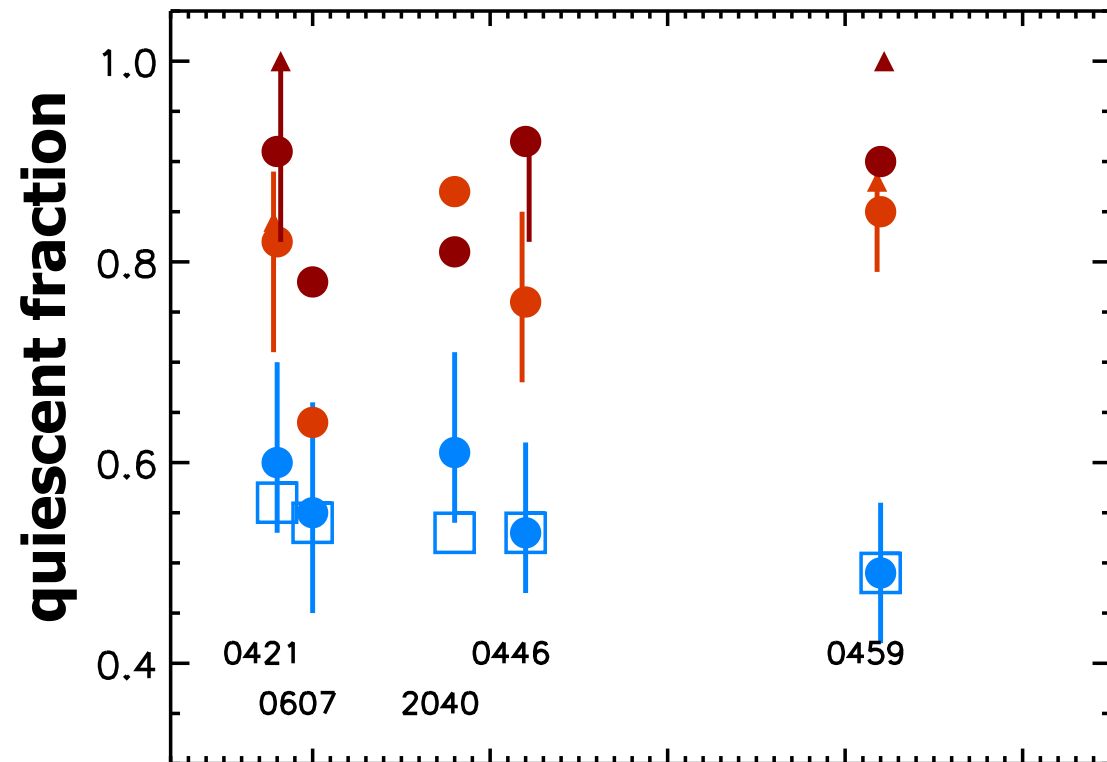
- cluster ( $r < 0.45 r_{500}$ )
- cluster ( $r < 0.7 r_{500}$ )
- field (at the cluster redshift)

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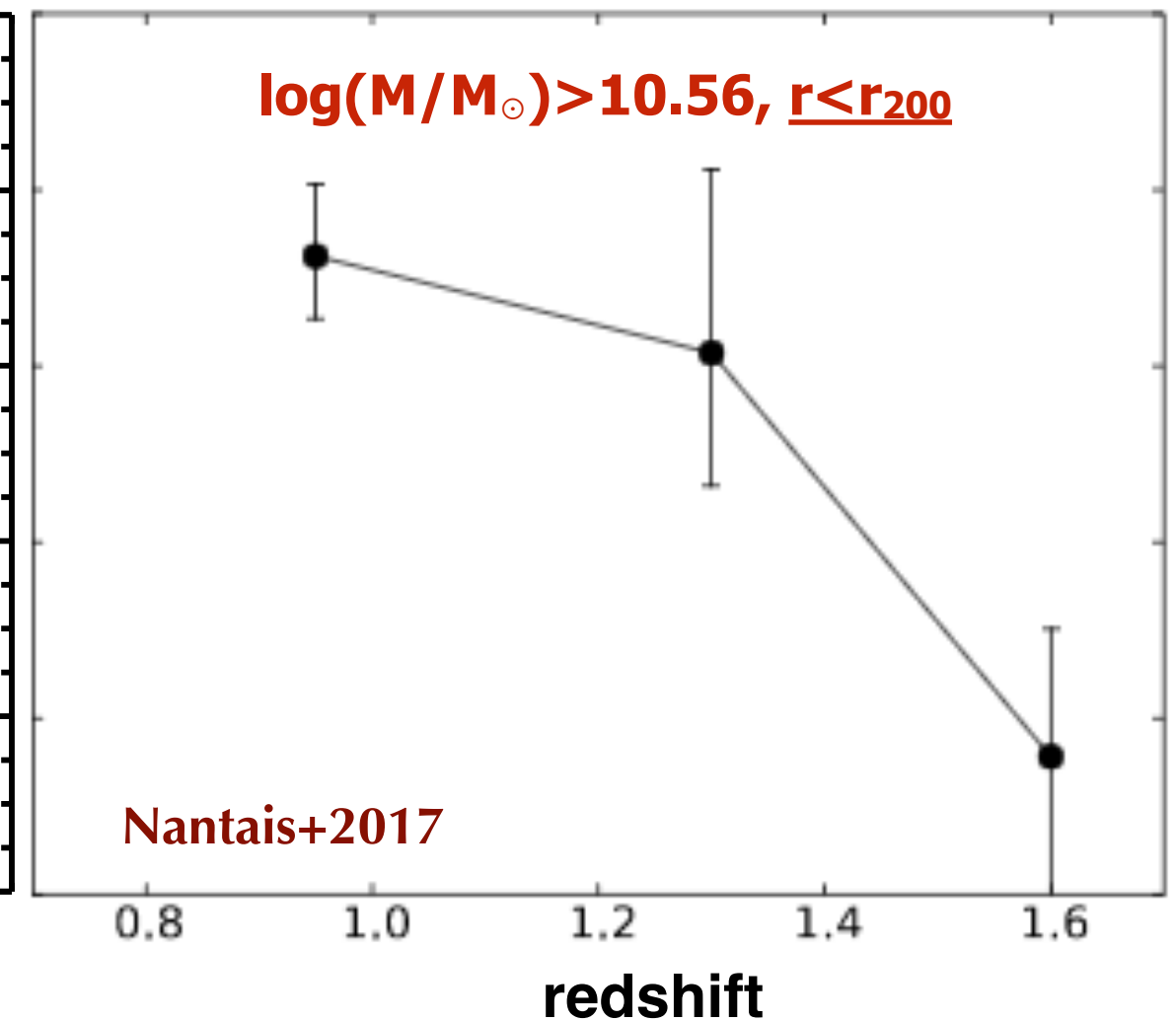
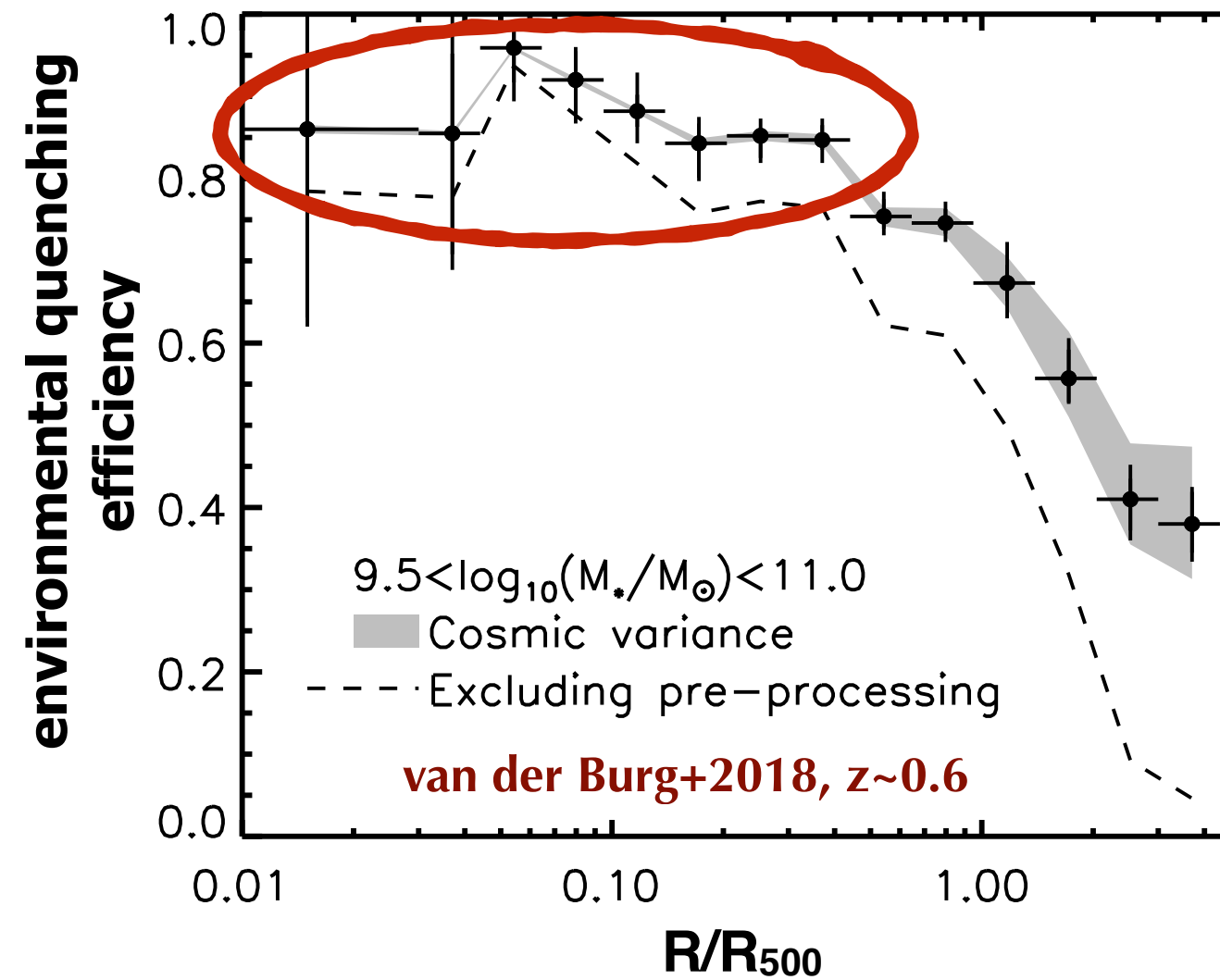
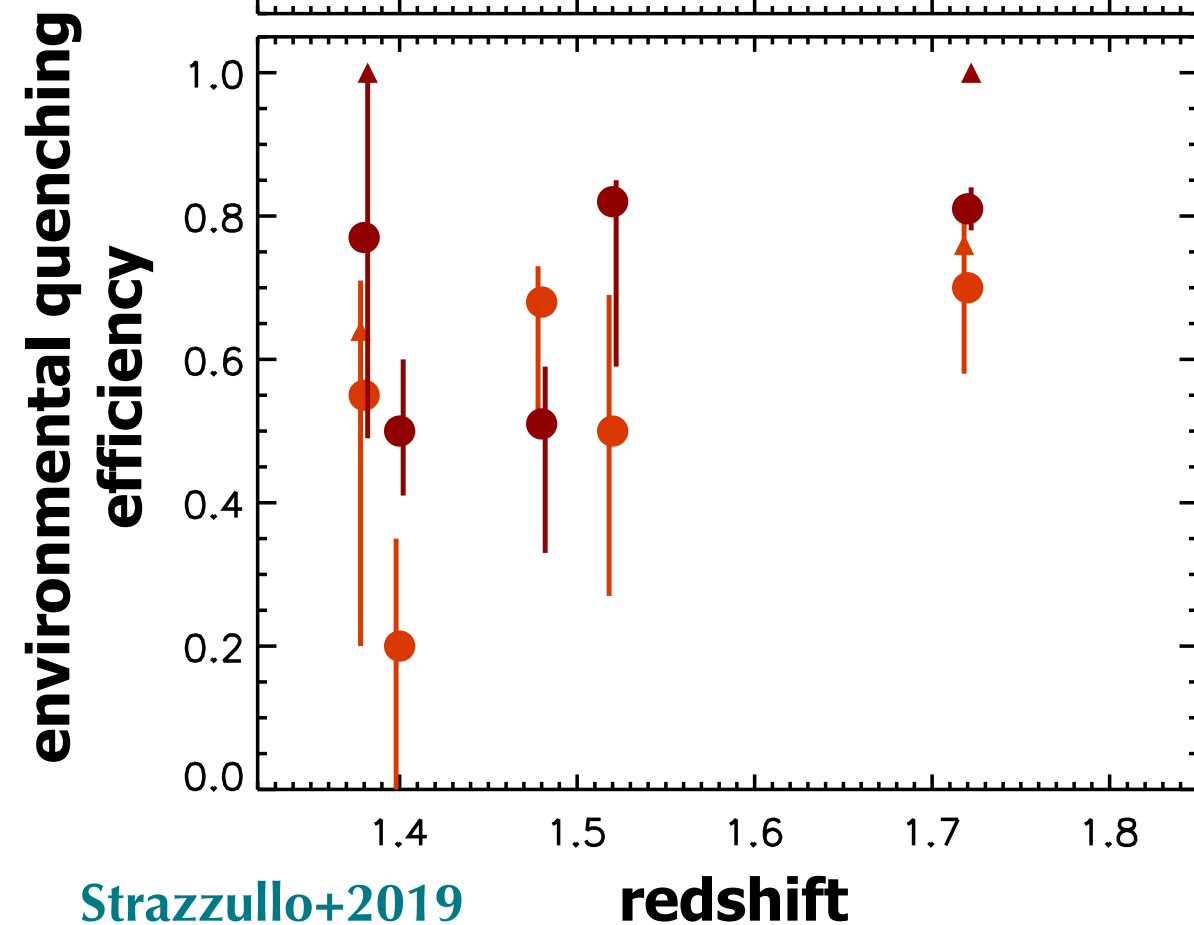
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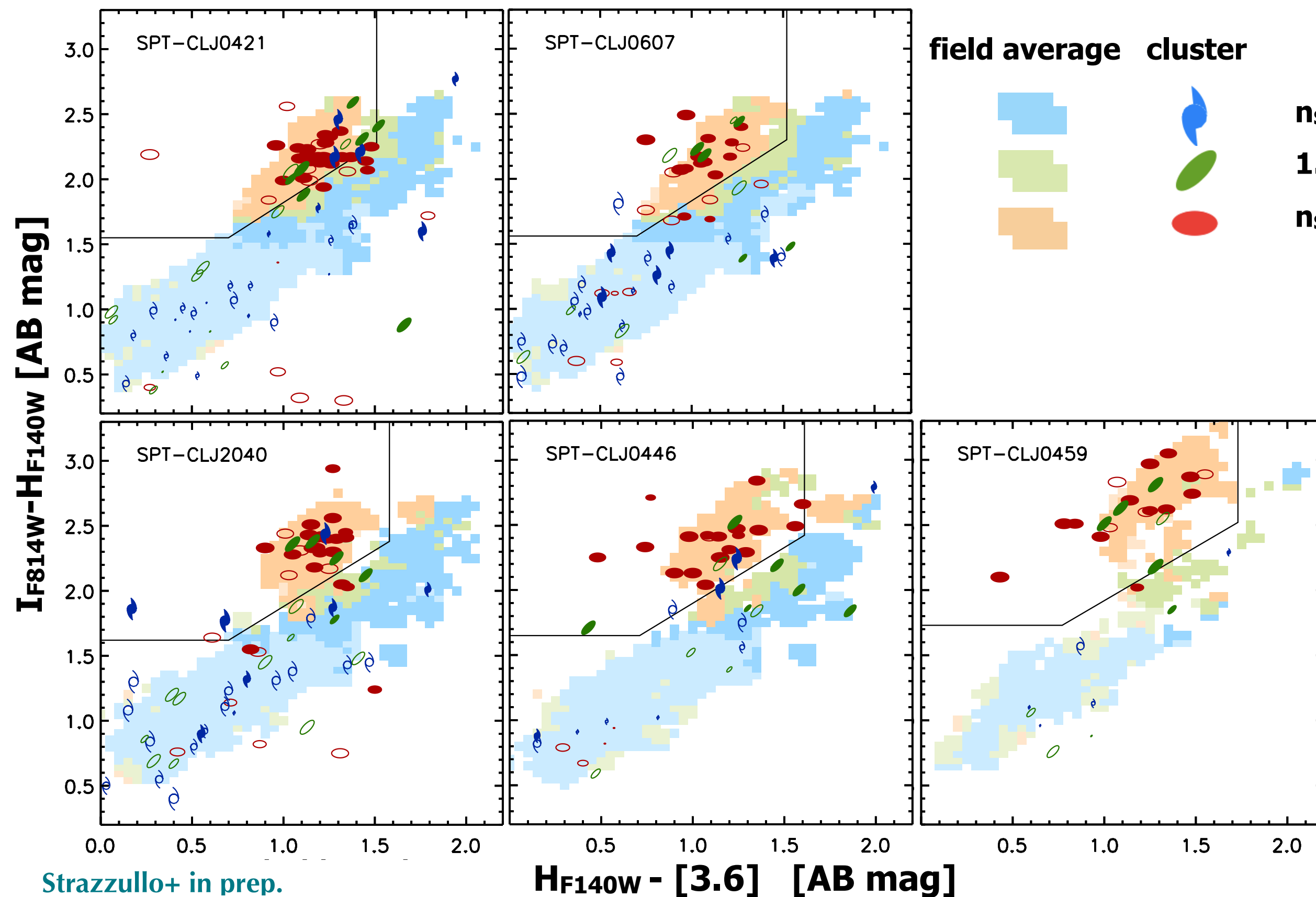


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# Structural properties of quiescent and star-forming cluster galaxies

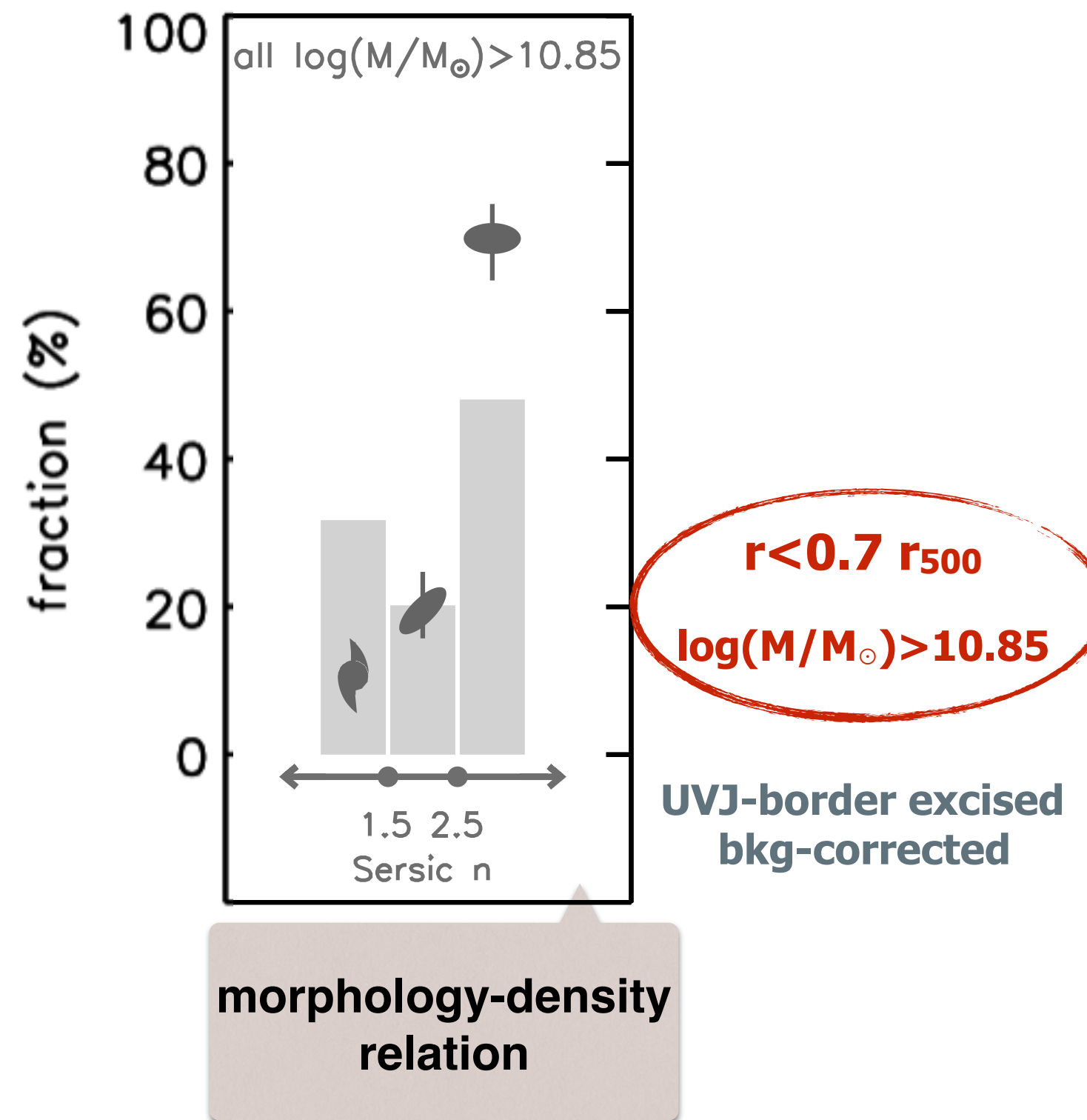


**Morphological and stellar population properties tightly related (as in the field)**

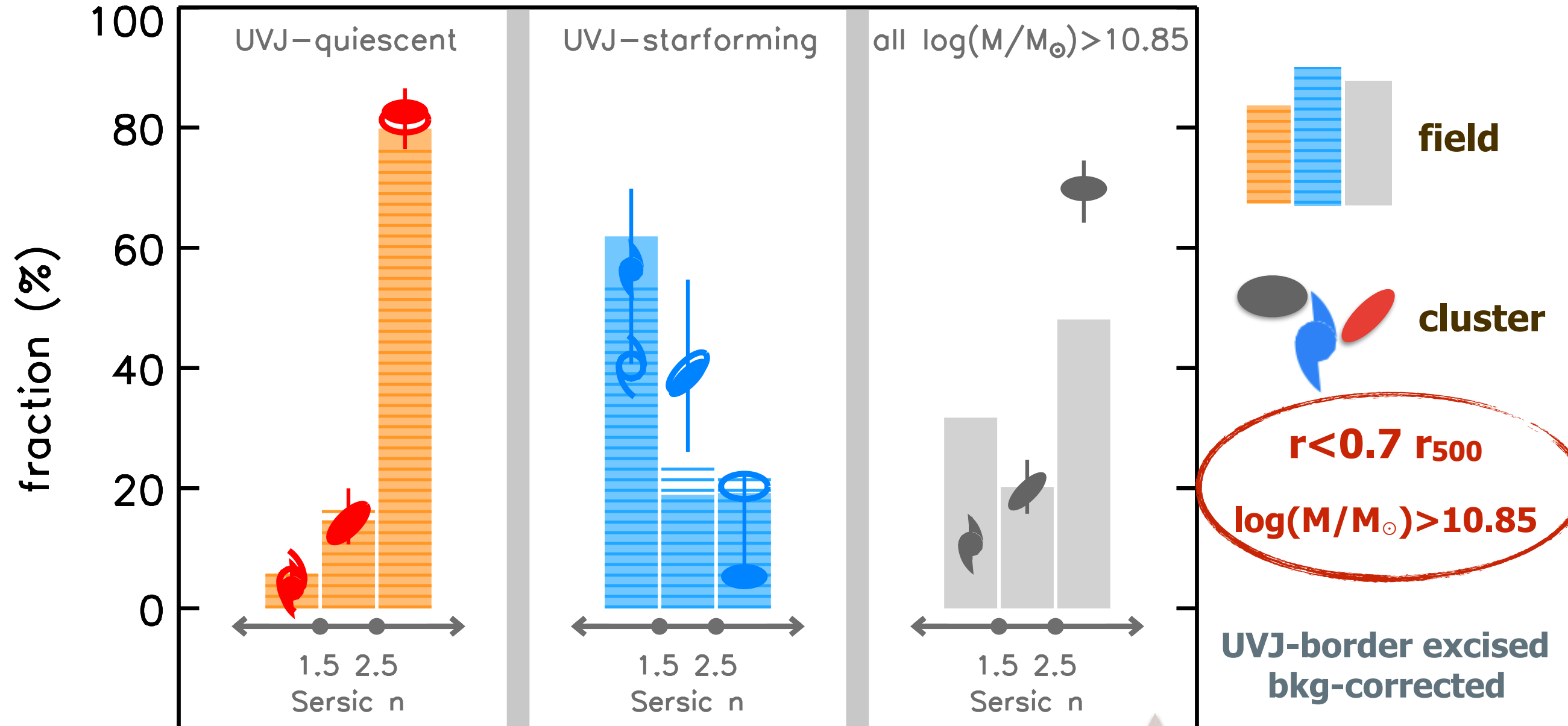
**The red sequence is mostly made of quiescent, largely bulge-dominated sources**



# Structural properties of quiescent and star-forming cluster galaxies



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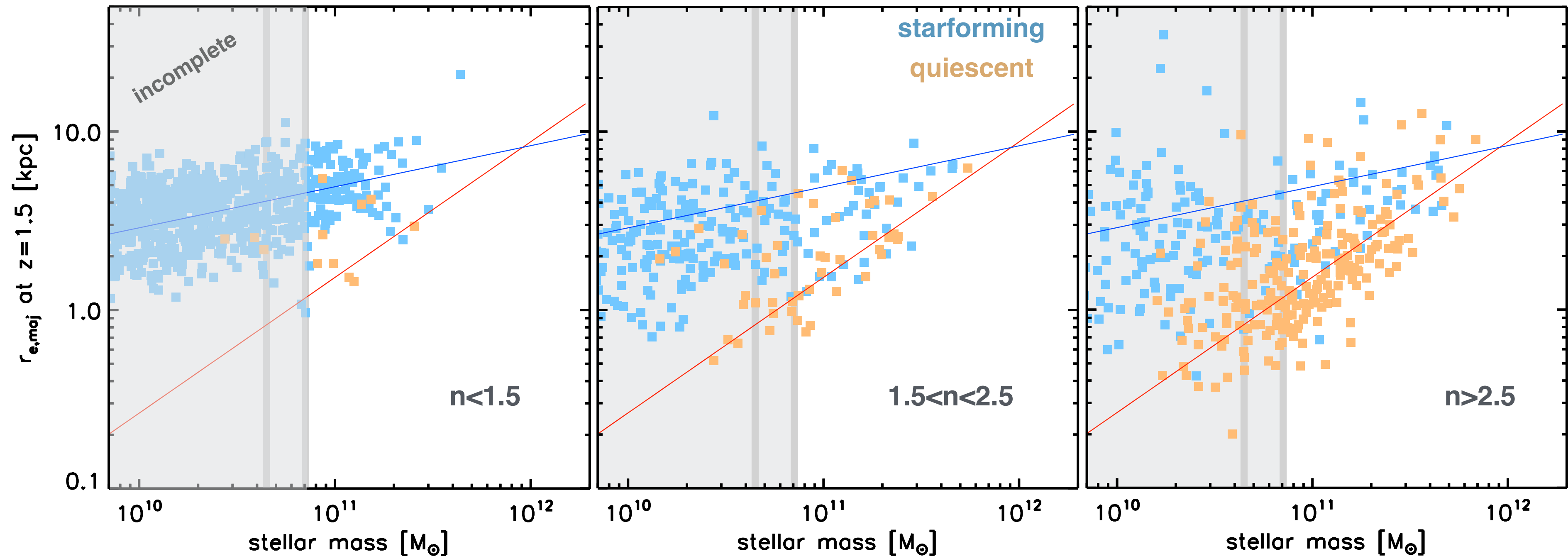


Strazzullo+ in prep.

largely driven by high quiescent fraction

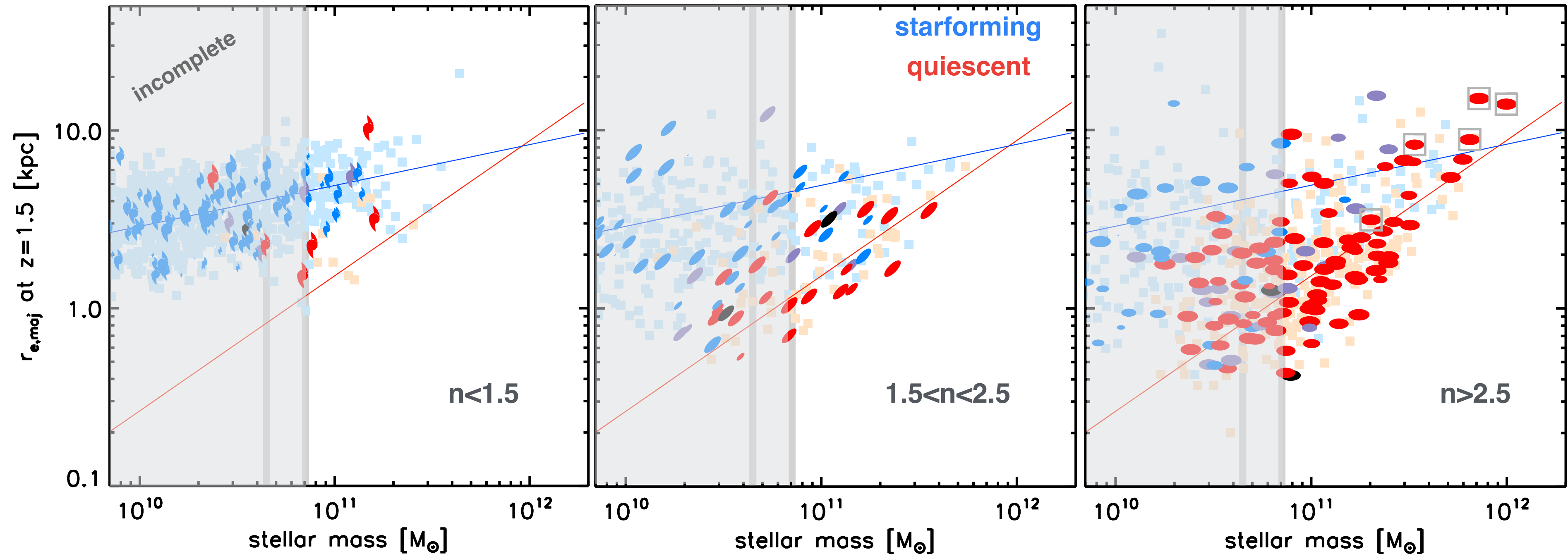
morphology-density relation

# Mass-size relation of cluster galaxy populations



**field**  
(van der Wel+14)

# Mass-size relation of cluster galaxy populations

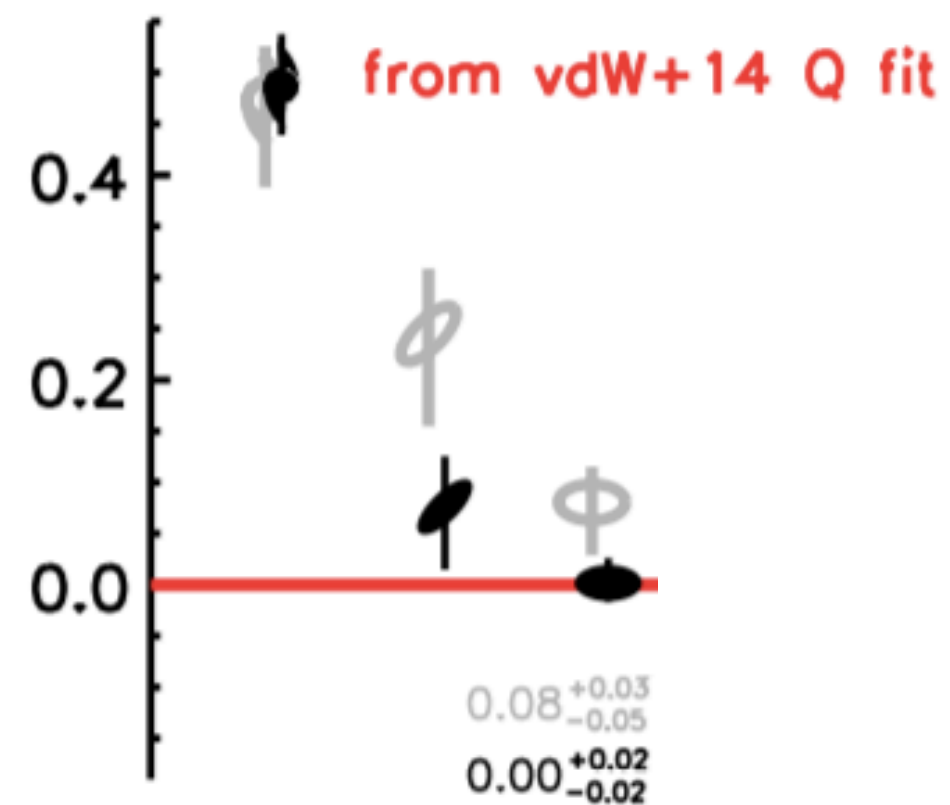
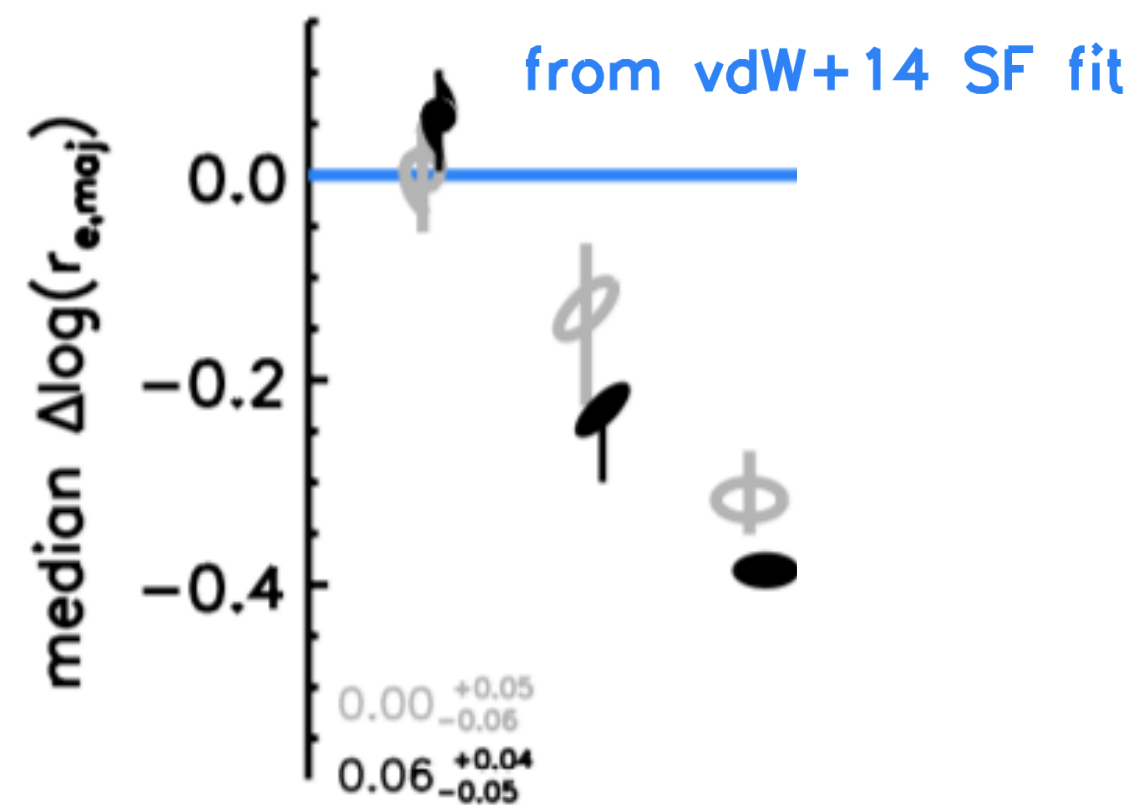
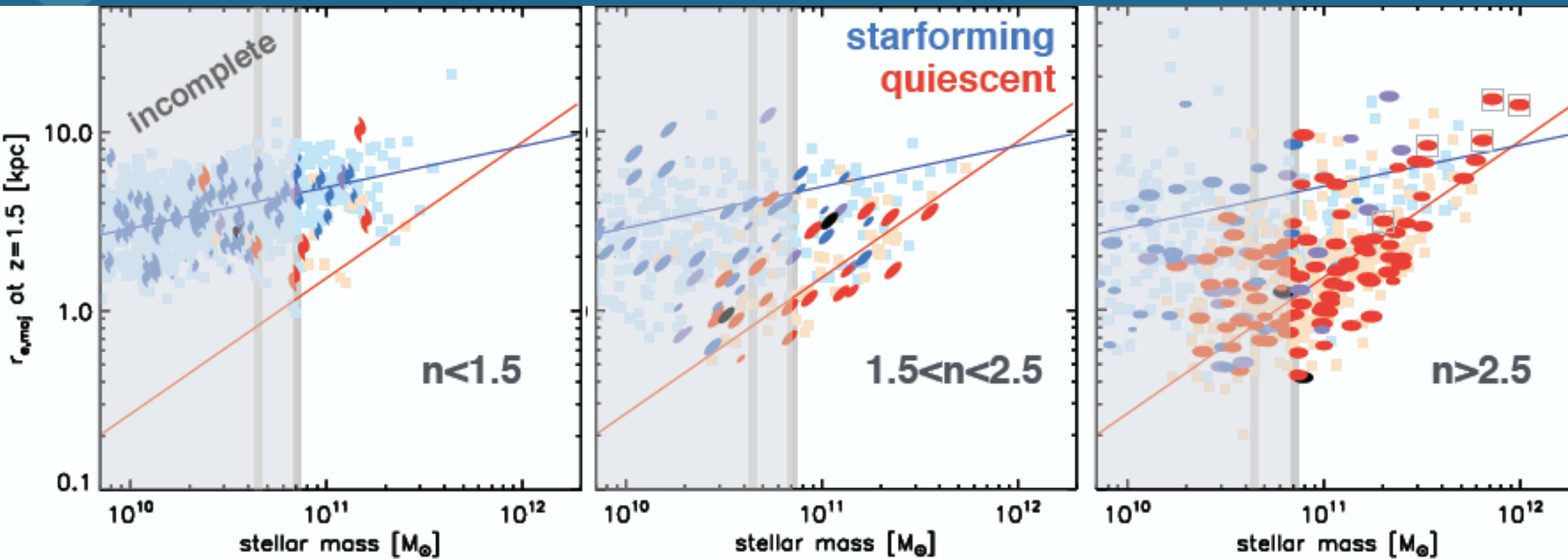


**all clusters  
(scaled to  $z=1.5$ )**

Strazzullo+ in prep.



# Mass-size relation of cluster galaxy populations

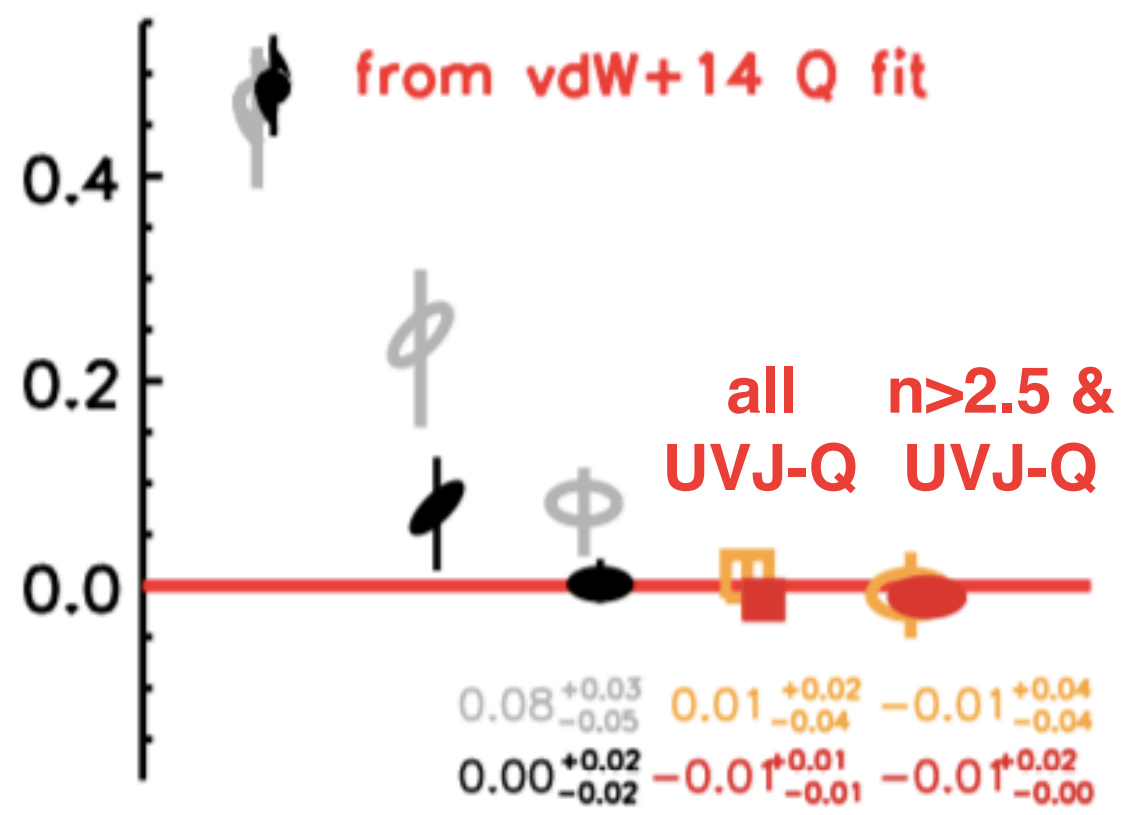
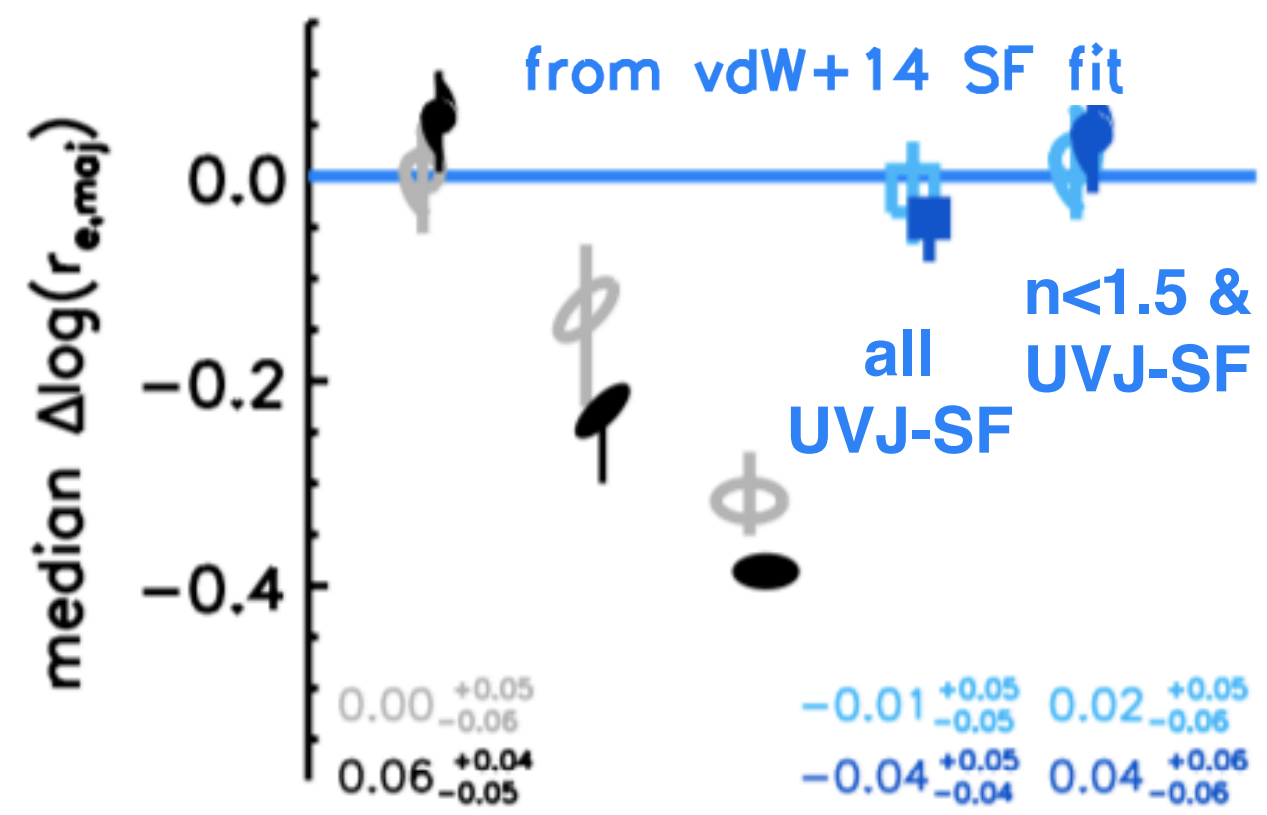
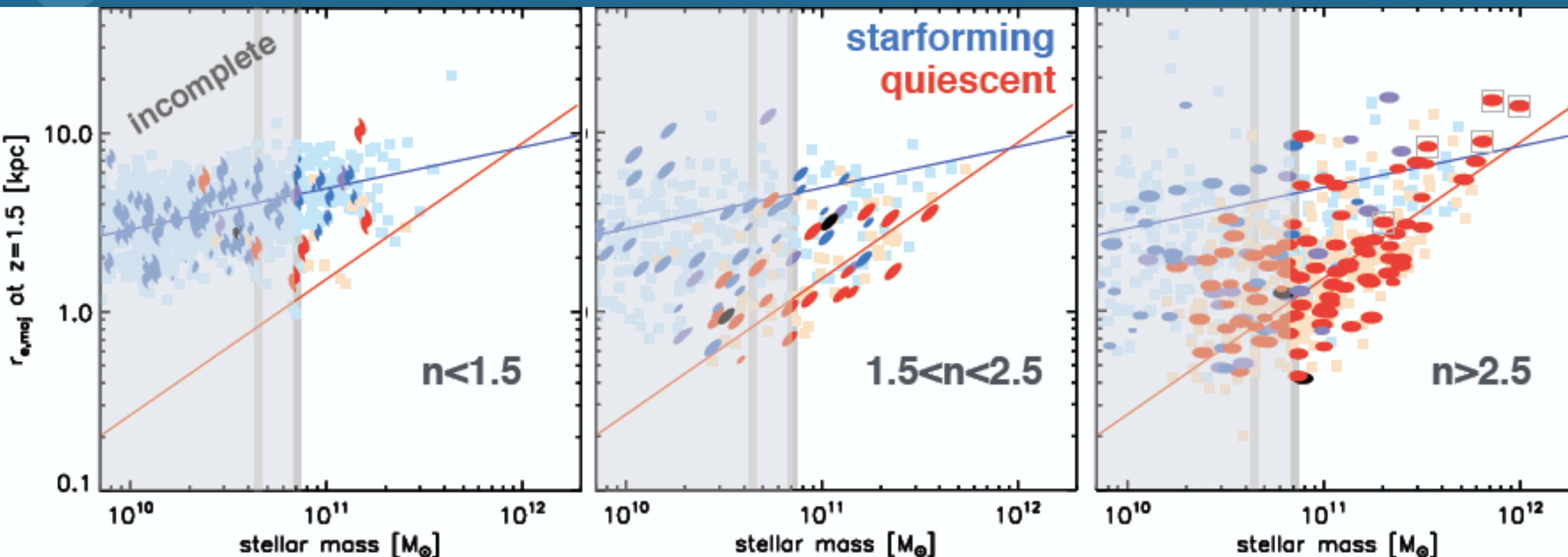


field  
 cluster

$\log(M/M_{\odot}) > 10.85$

Strazzullo+ in prep.

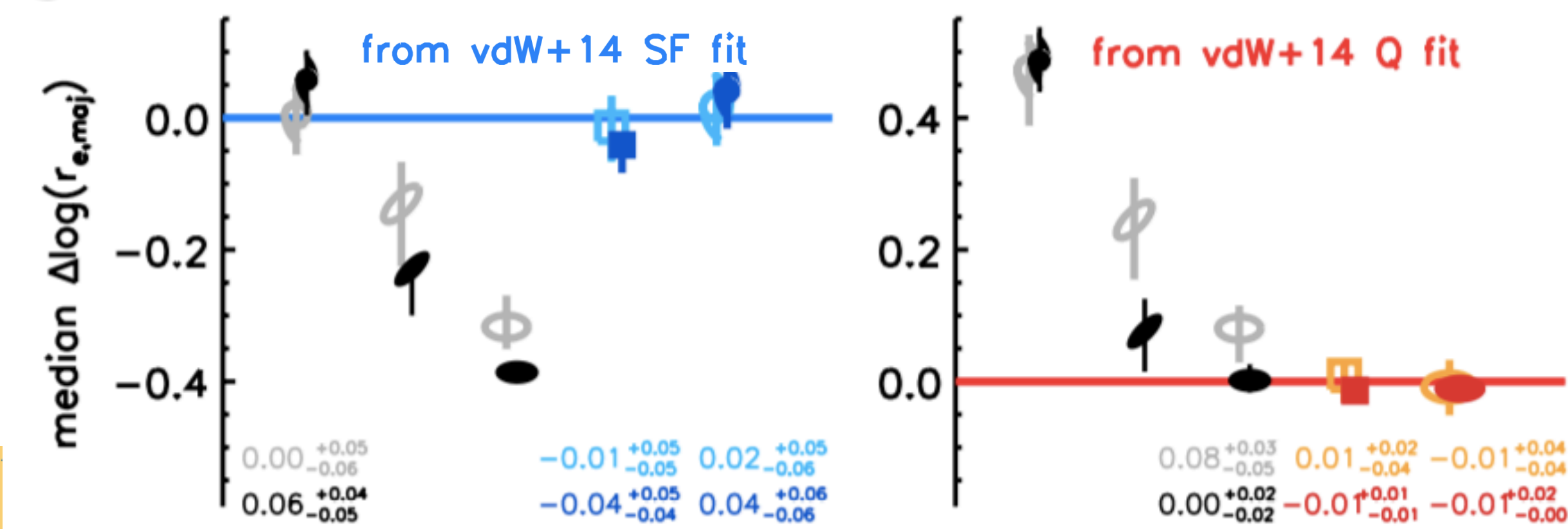
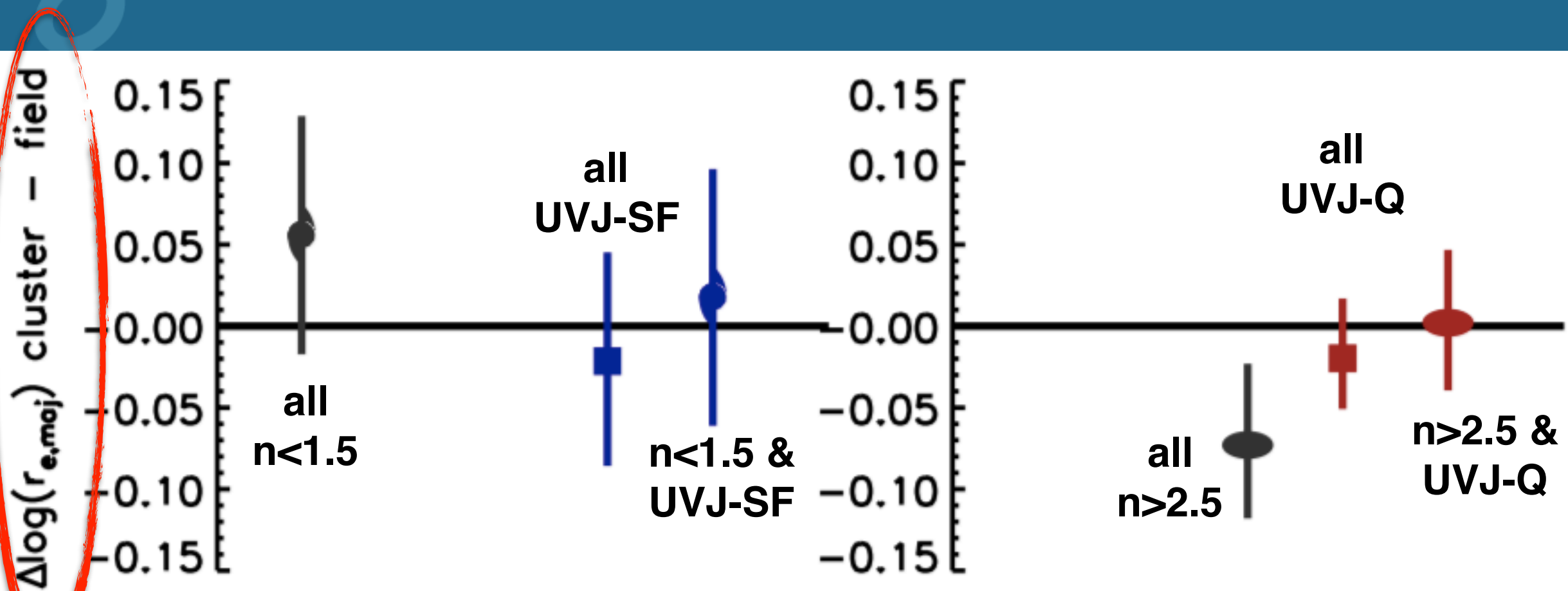
# Mass-size relation of cluster galaxy populations



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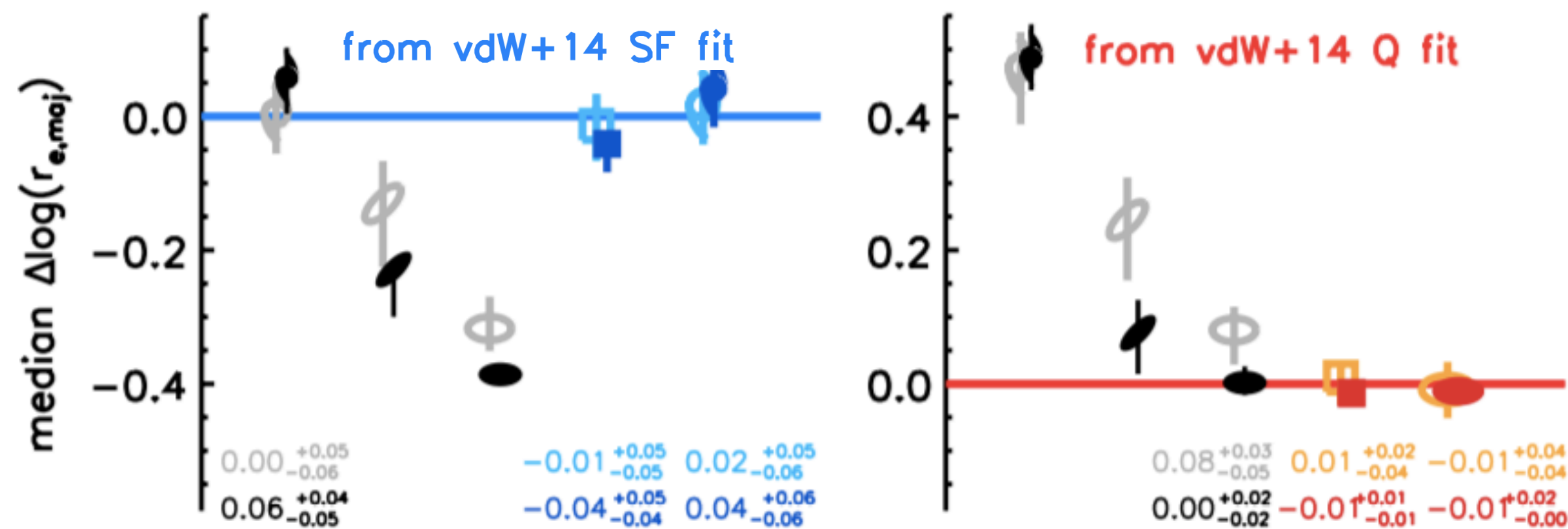
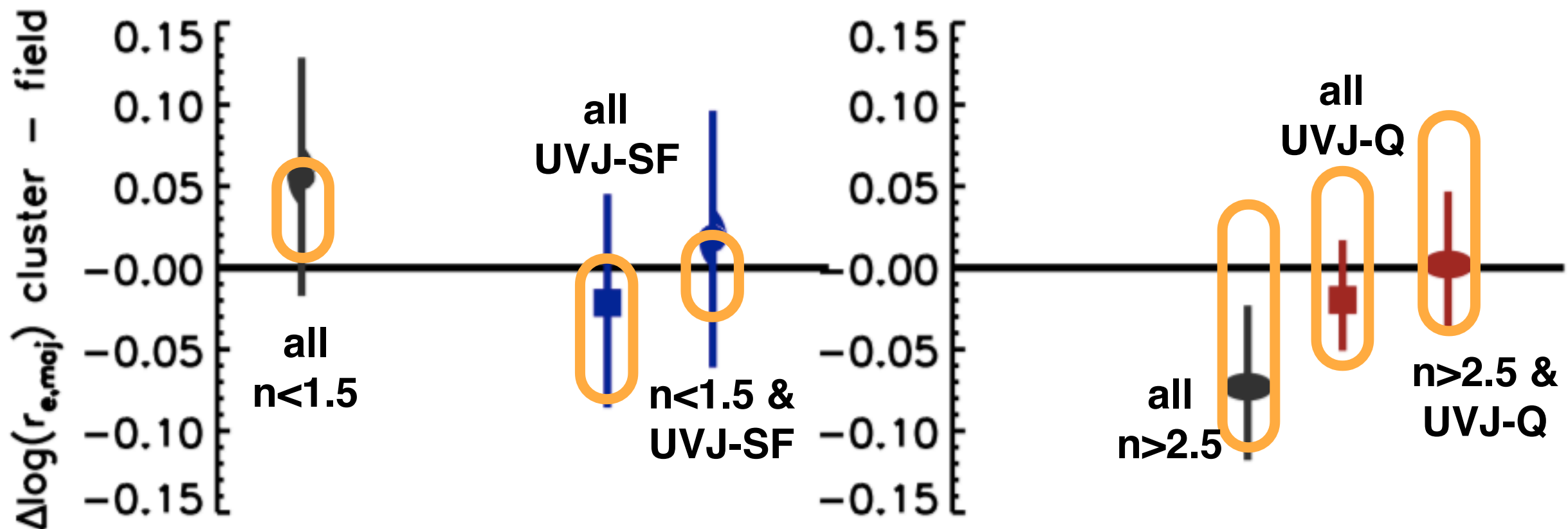
Strazzullo+ in prep.

# Mass-size relation of cluster galaxy populations



Strazzullo+ in prep.

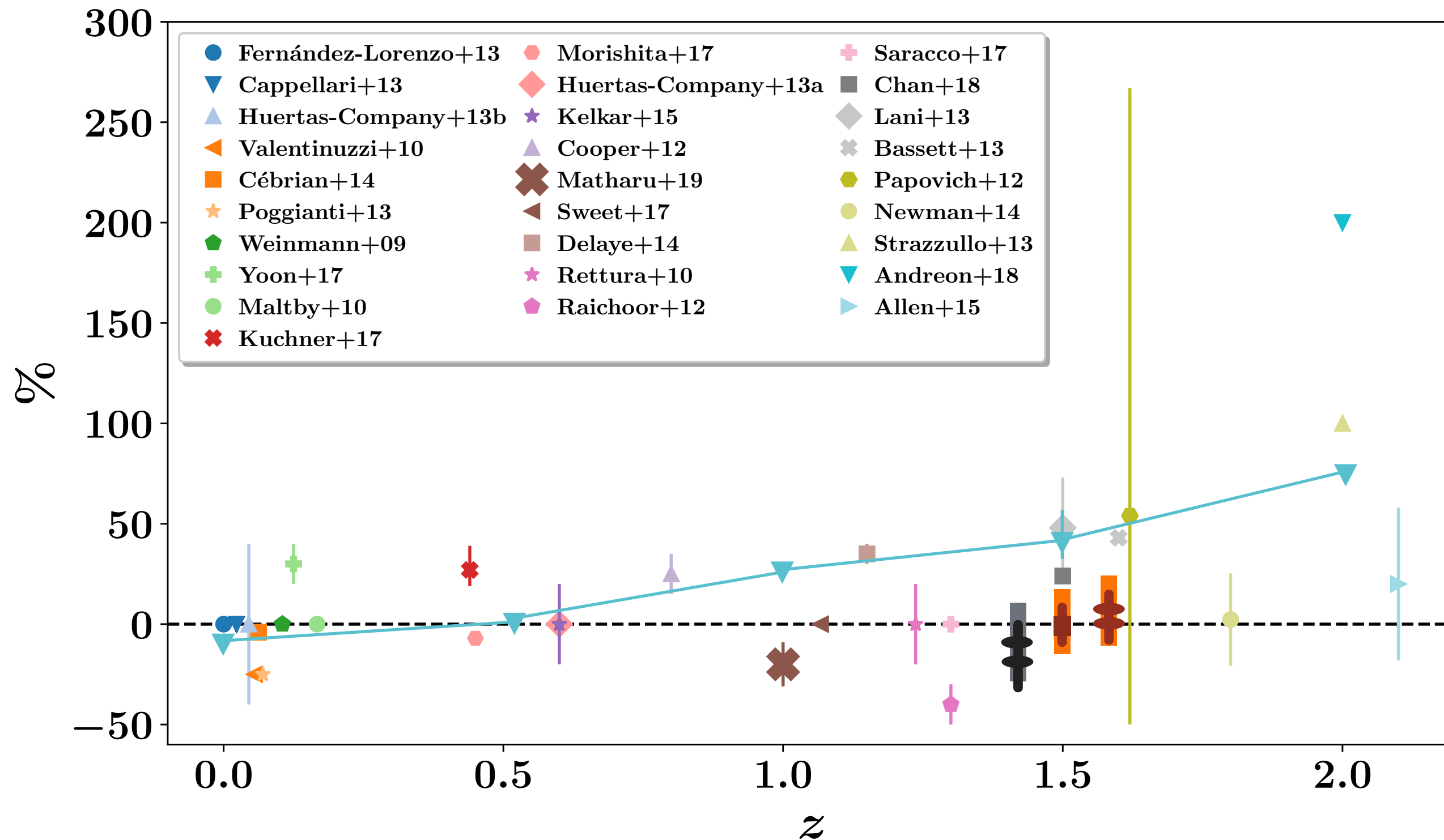
# Mass-size relation of cluster galaxy populations



Strazzullo+ in prep.



## Environmental dependence of (early-type) galaxy sizes ?

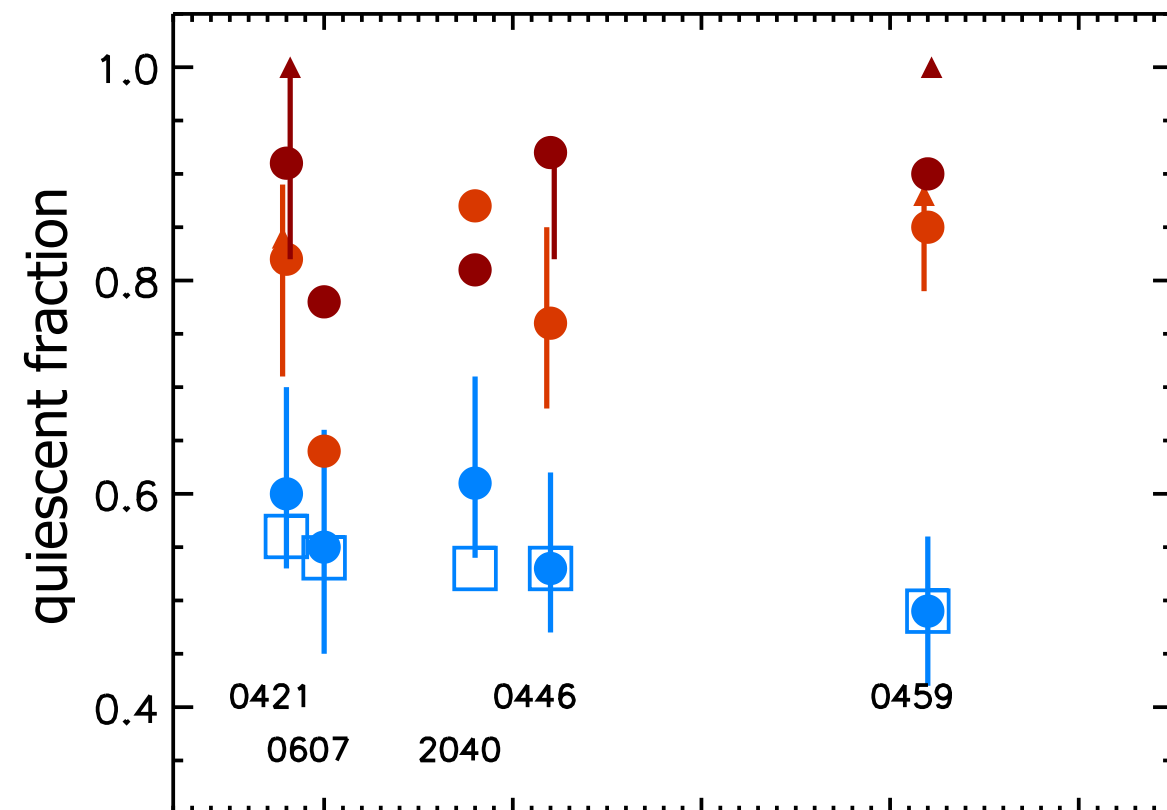


adapted from  
Matharu+2019

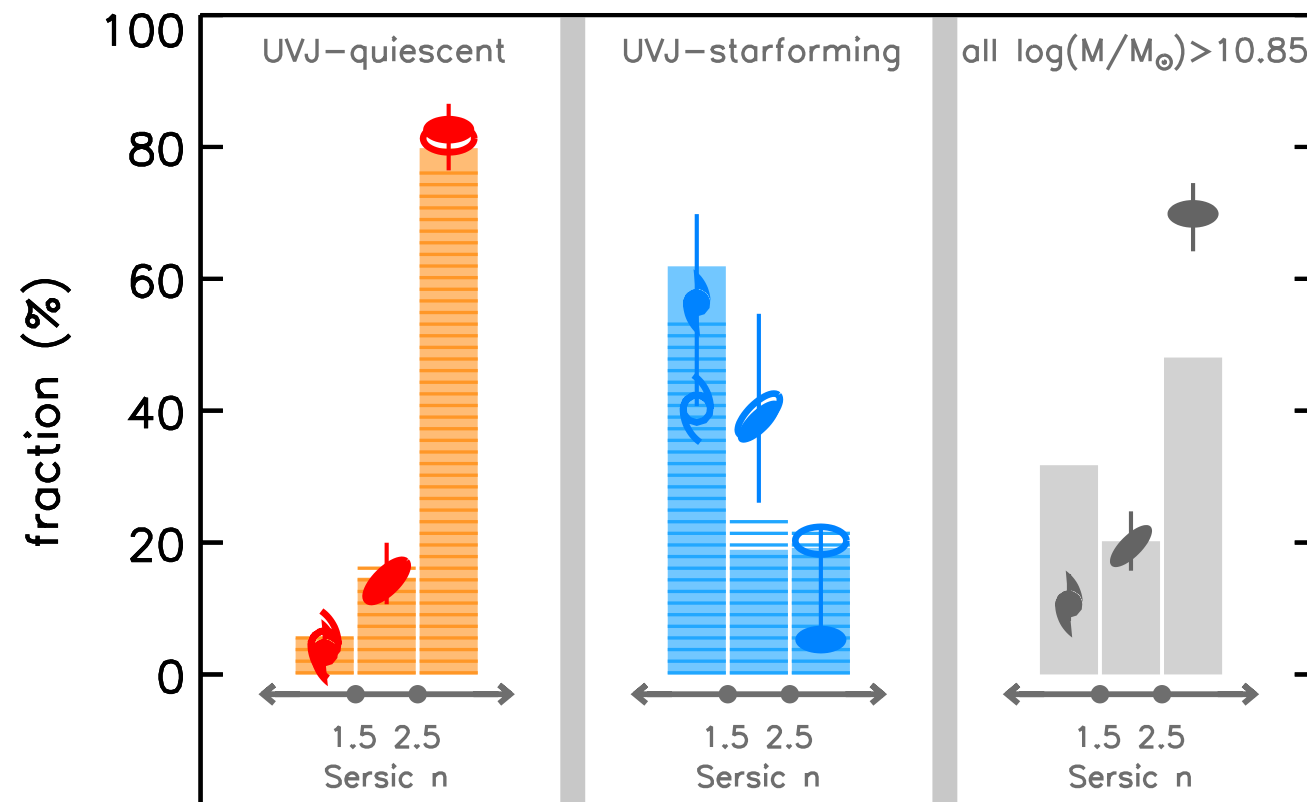
# Summary

In the central regions of the most massive clusters at  $z \sim 1.5$ :

Environmental quenching is active



Morphological evolution follows along



Size differences wrt field (?)

