Environmental effects on massive galaxy formation in most distant clusters

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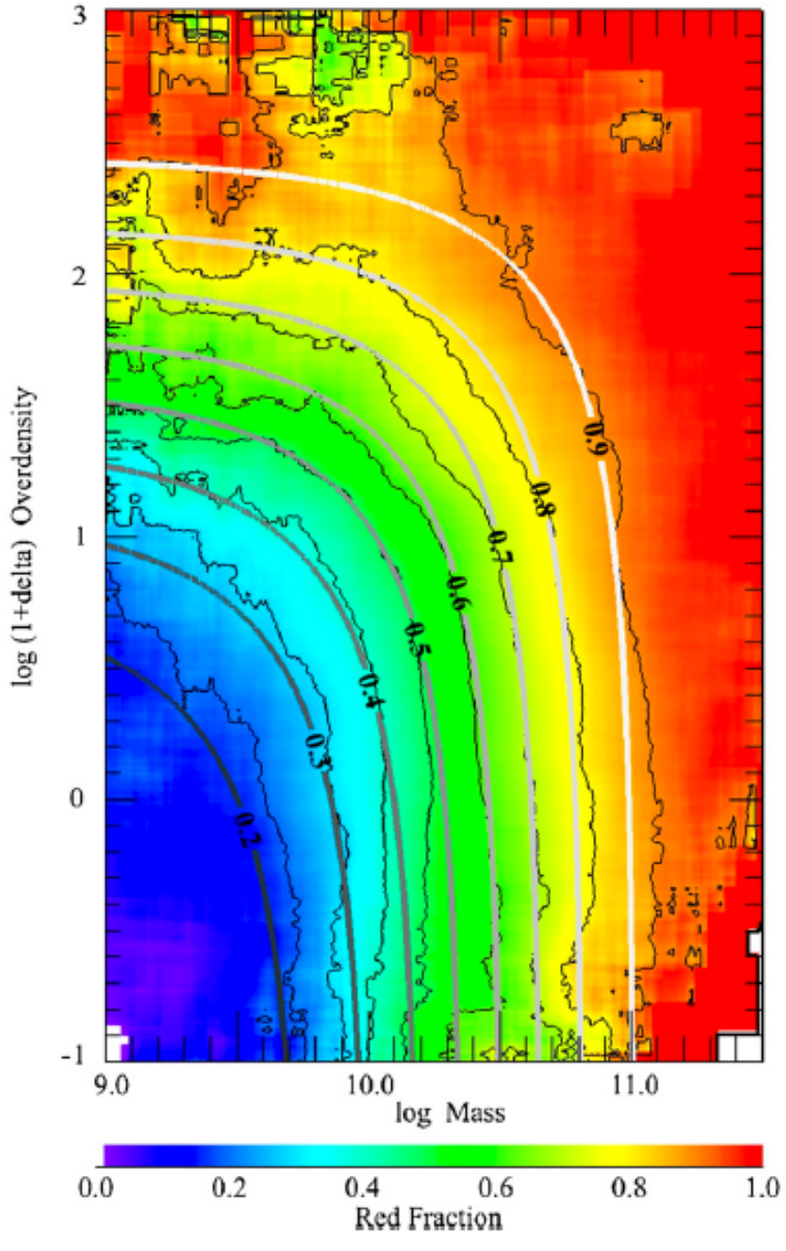
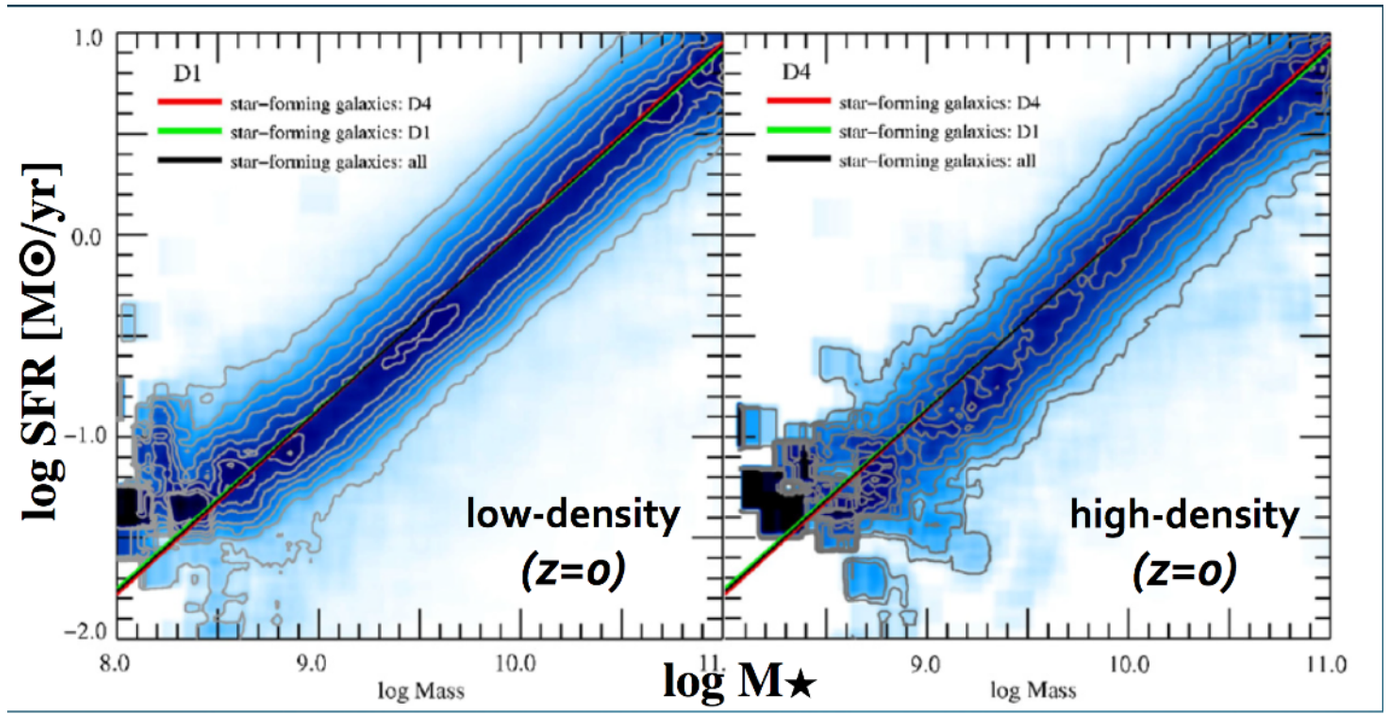
Subaru Telescope 20th anniversary, Hawaii, 2019/11

Environmental effects on massive galaxy formation



Peng+2010

Invariant star forming main-sequence

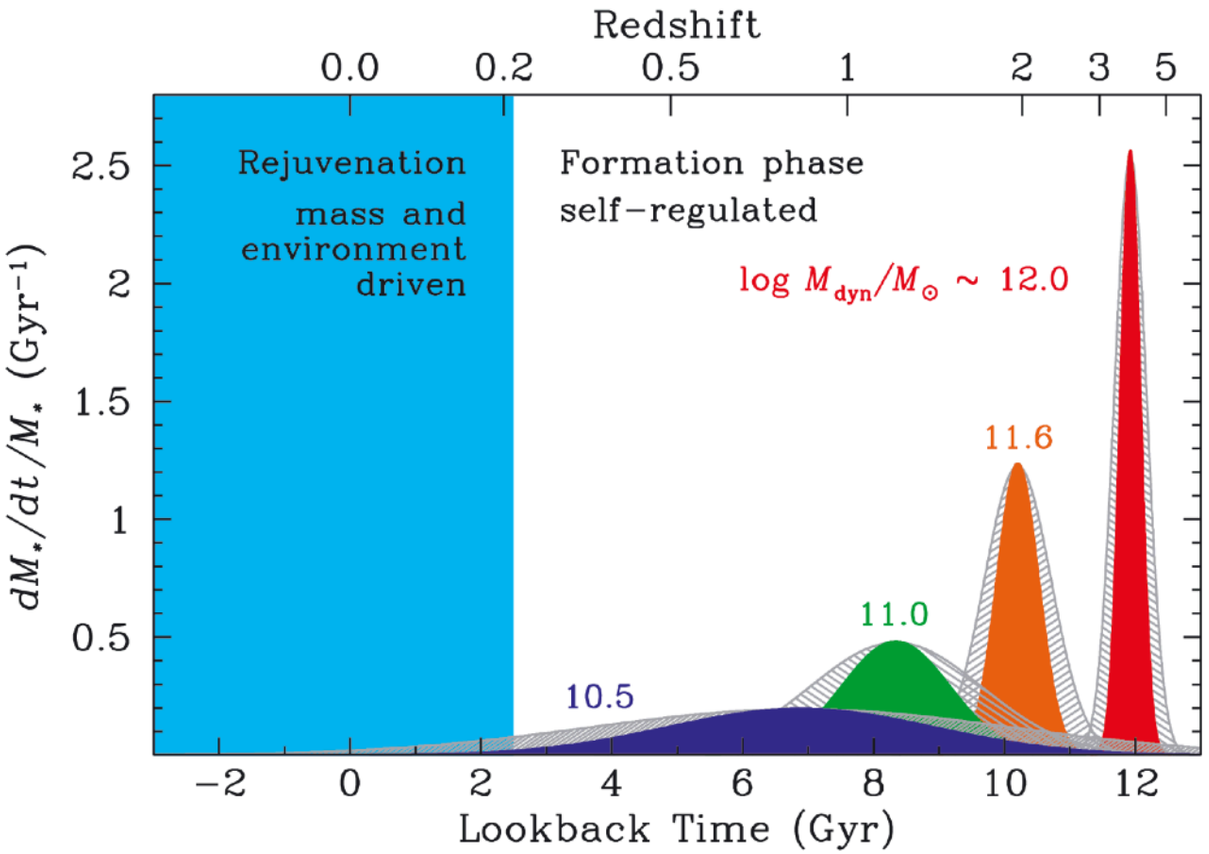


Baldry+2006

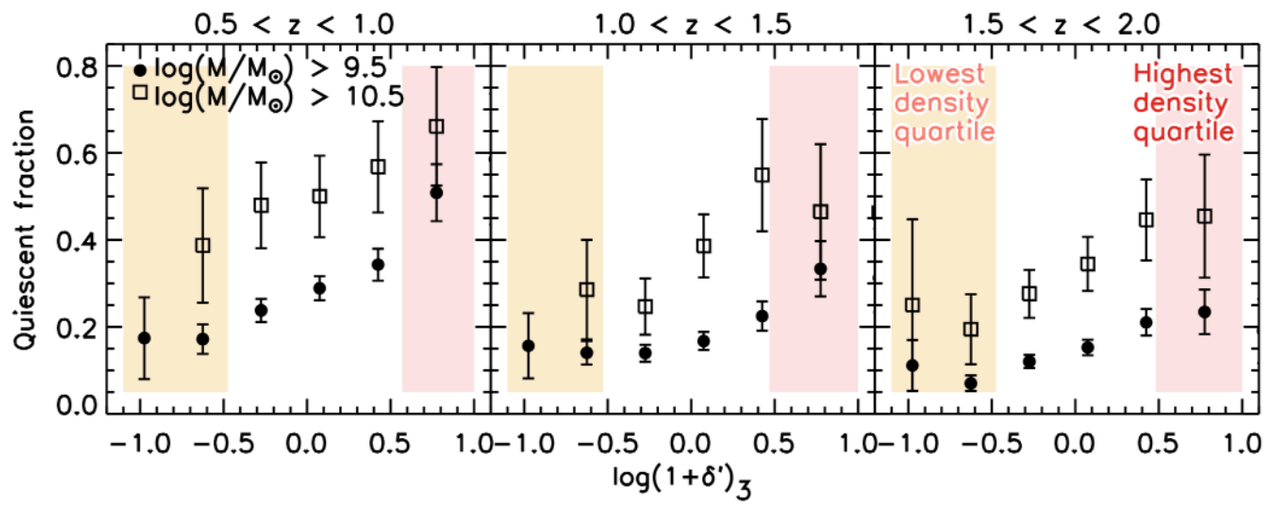
also see Koyama+2013 for high-z

The role of environment in massive galaxy formation/quenching remains unclear.

The early assembly of massive (cluster) galaxies



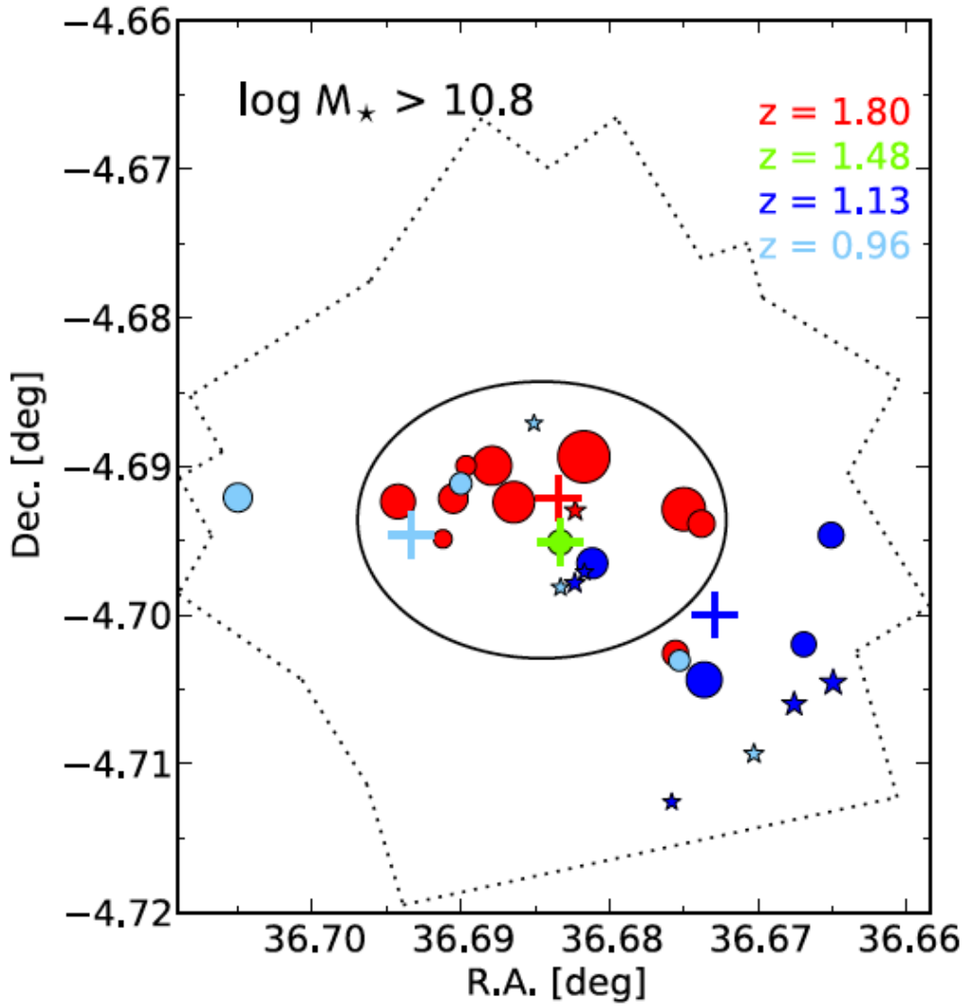
Thomas+2010



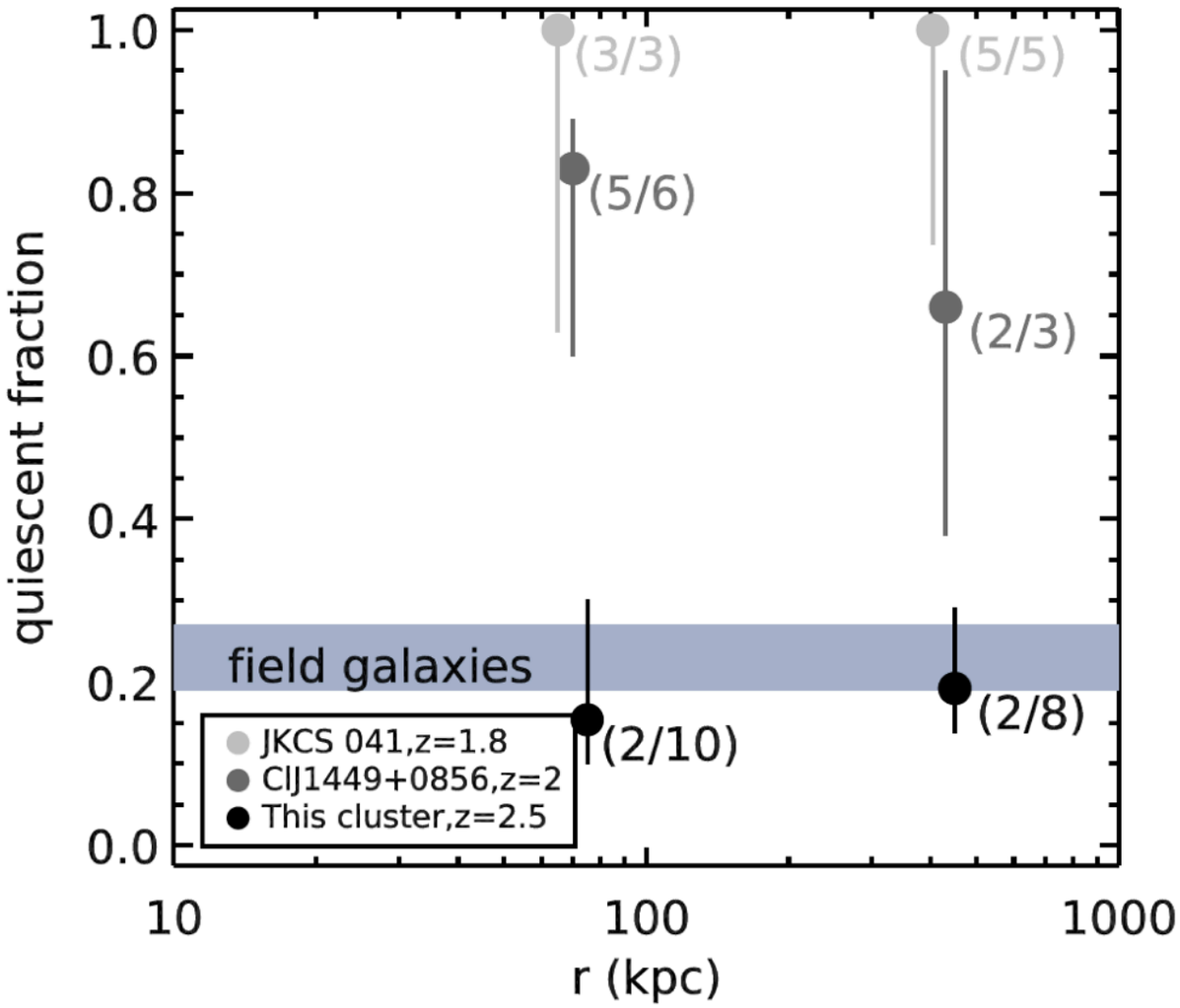
Kawinwanichakij+2017

The early assembly of massive cluster galaxies:

The core of the most massive clusters are already dominated by quiescent galaxies at z~2

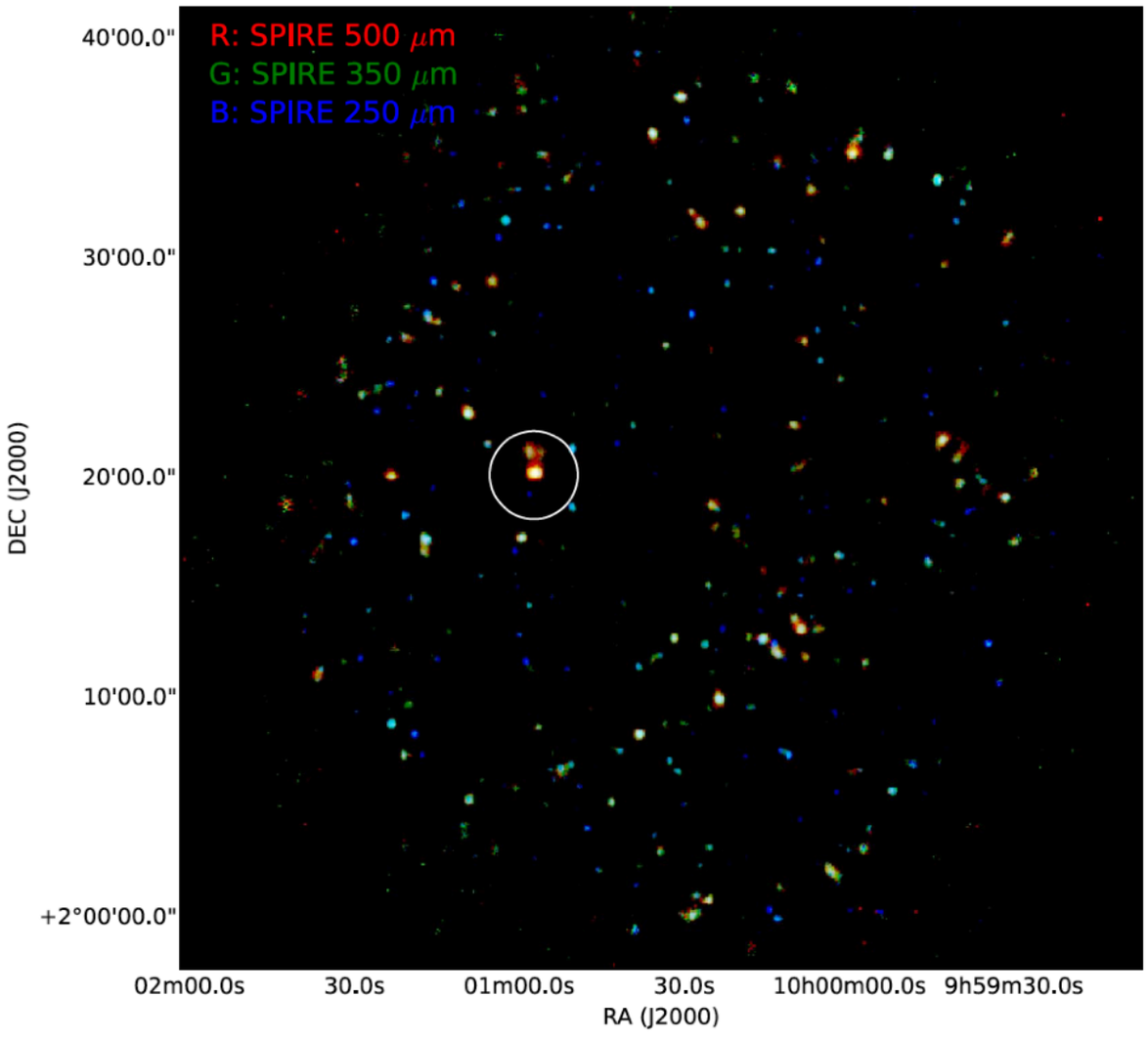


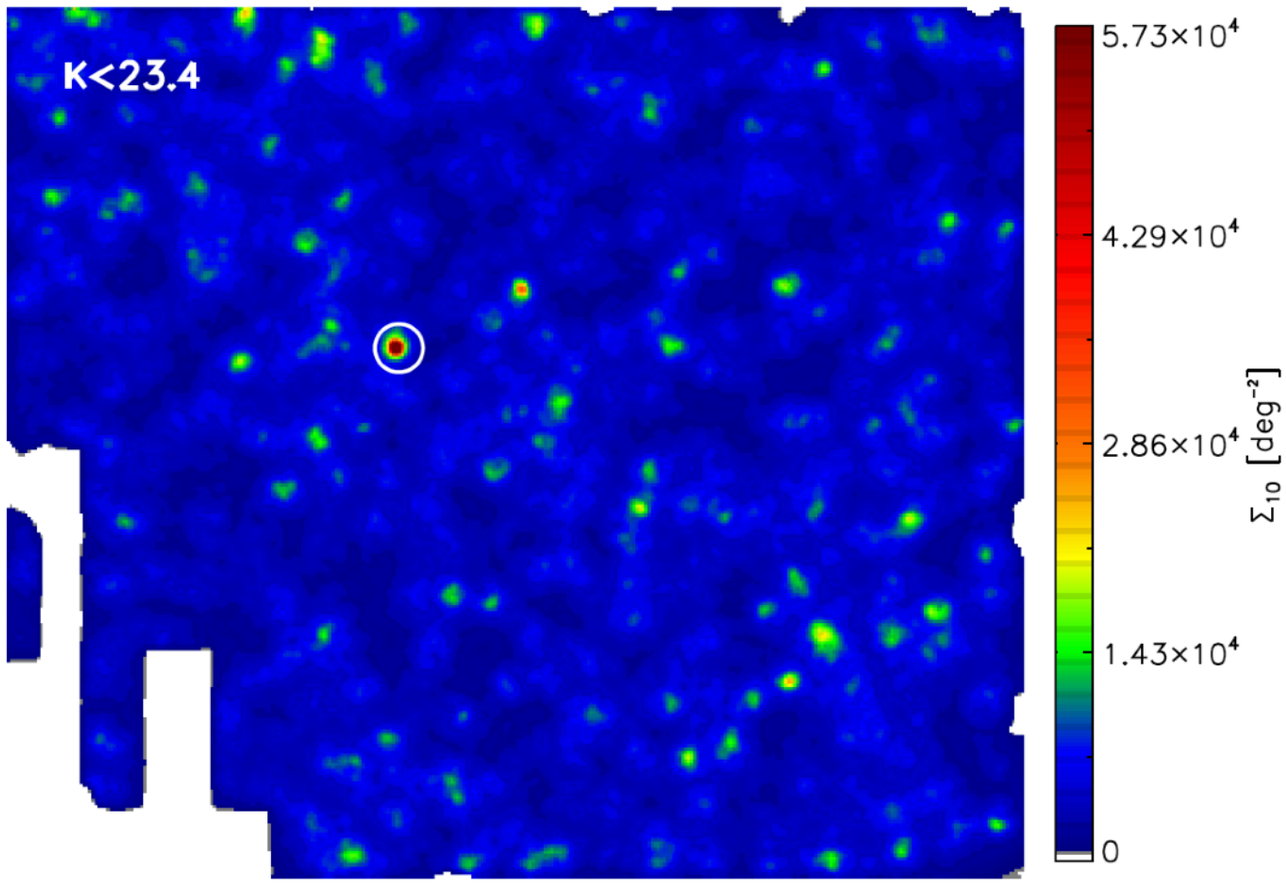
Newman+2014



Strazzullo+2013,Wang+2016

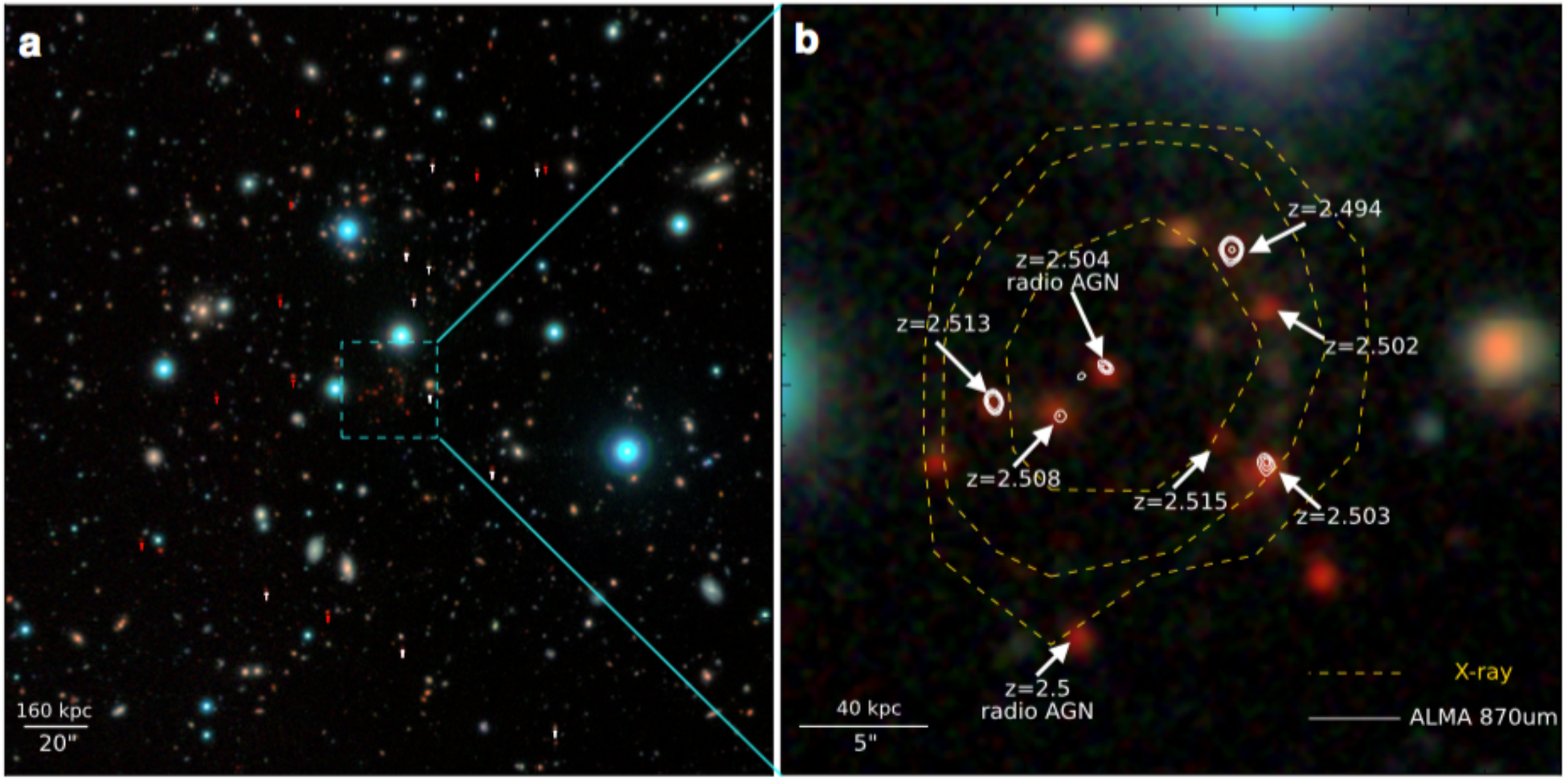
Hunting for massive galaxy clusters in formation (starbursting galaxy clusters)





Herschel/SPIRE-selected extremely luminous infrared sources

“Discovery of a Galaxy Cluster with a Violently Starbursting Core at z=2.506”

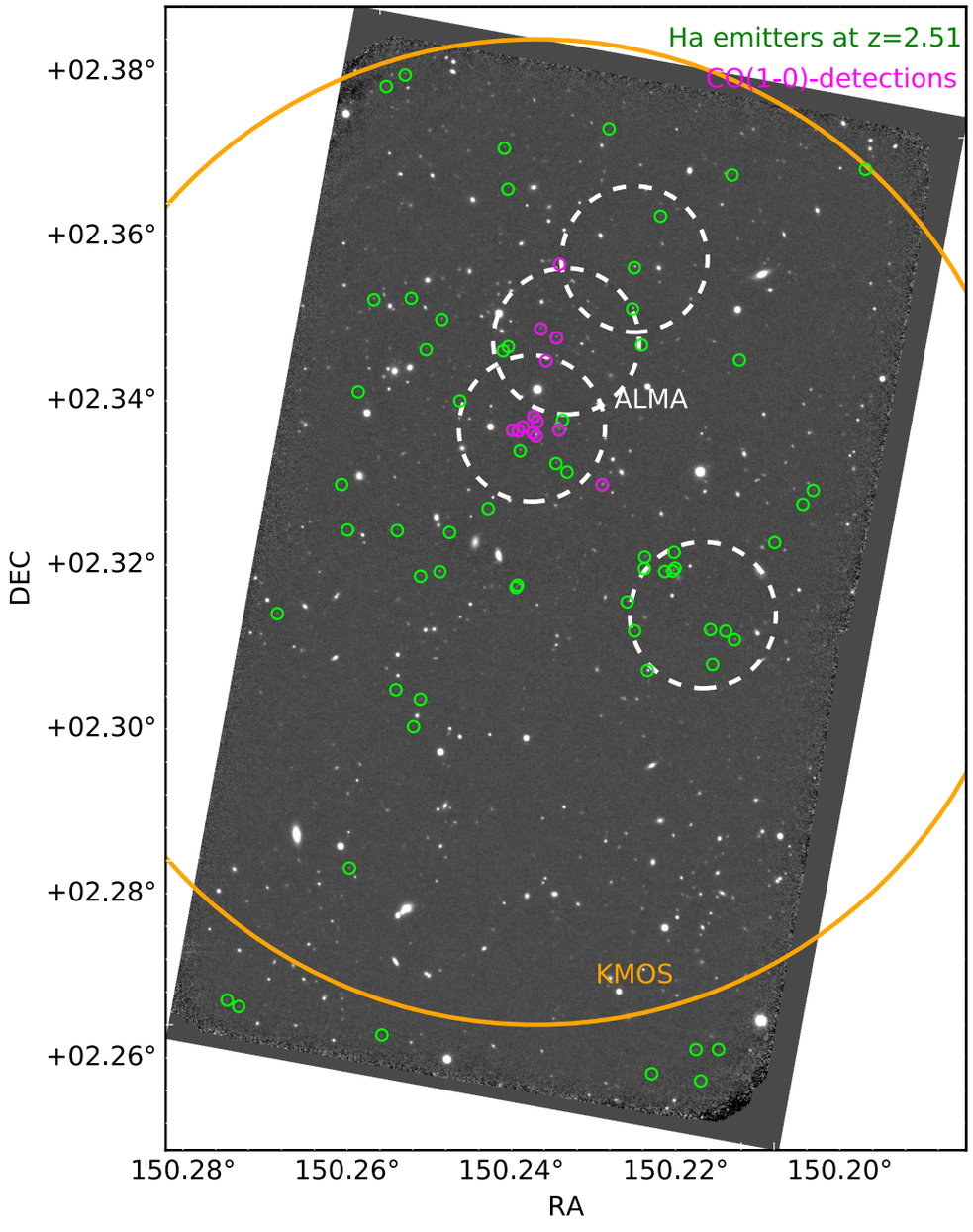


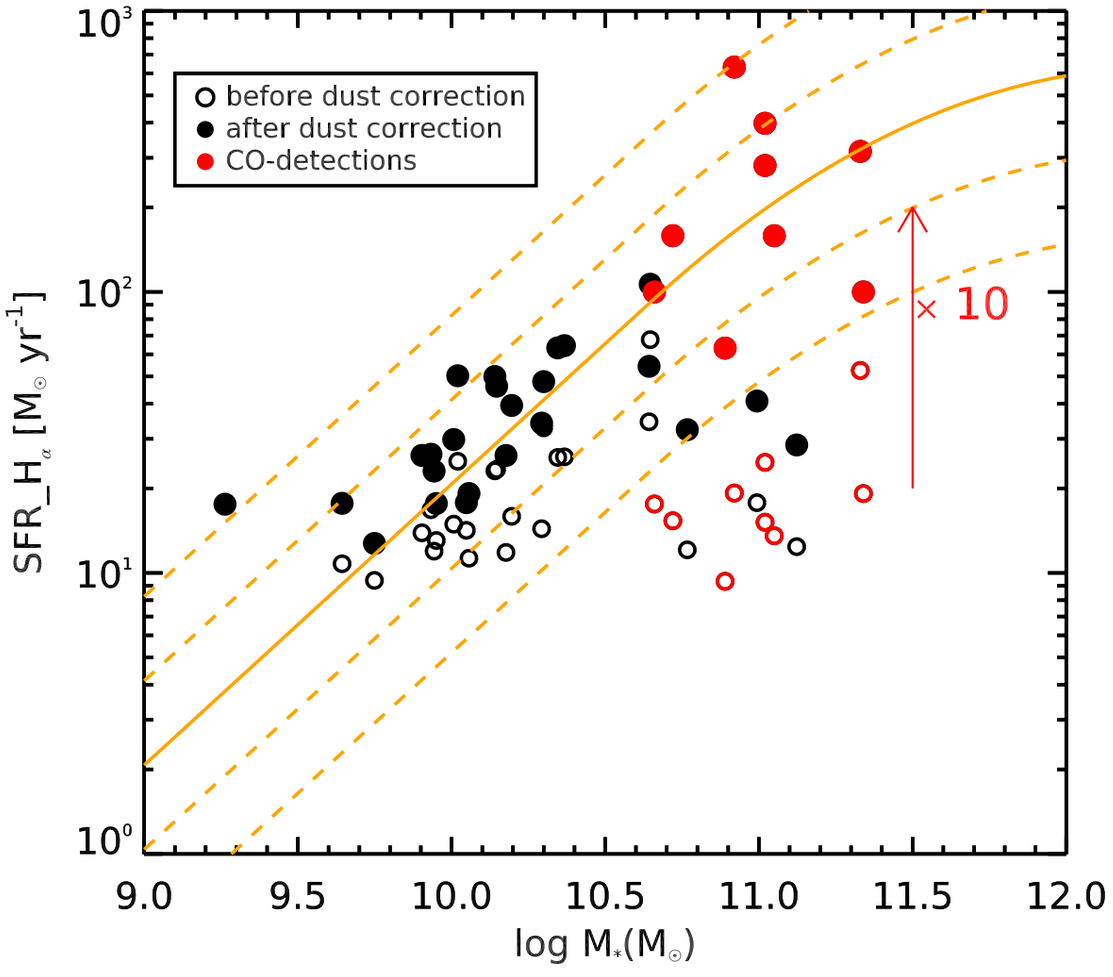
Presence of both **extended X-ray emission** and a **dominant population of massive SFGs**

Wang,T+2016, ApJ, 828,56

Narrow-band imaging of J1001 with Subaru/MOIRCS:

Towards a complete census of star-forming cluster members

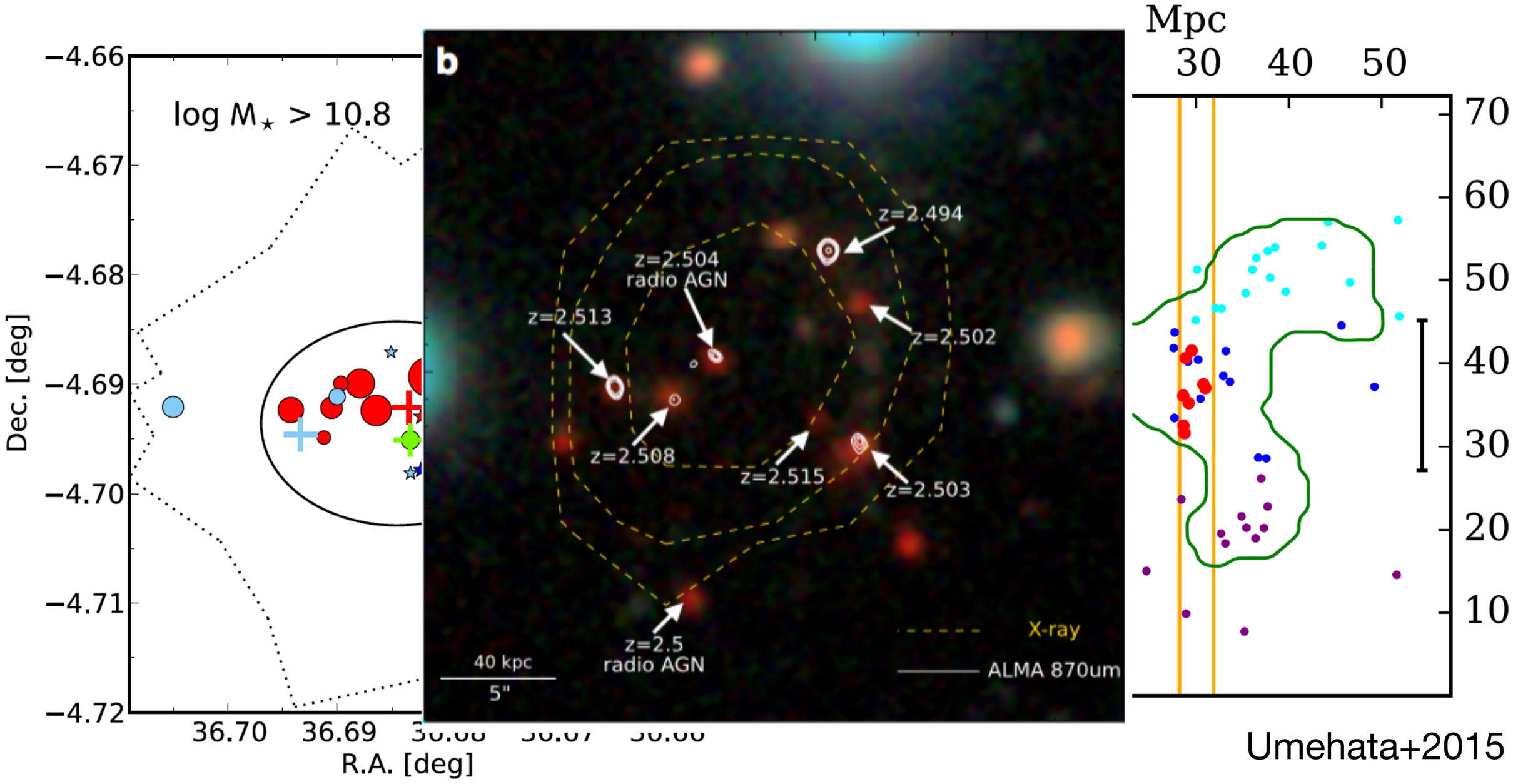




The massive cluster galaxies are heavily obscured.

Wang, **Kodama, Tanaka**, et al. in prep

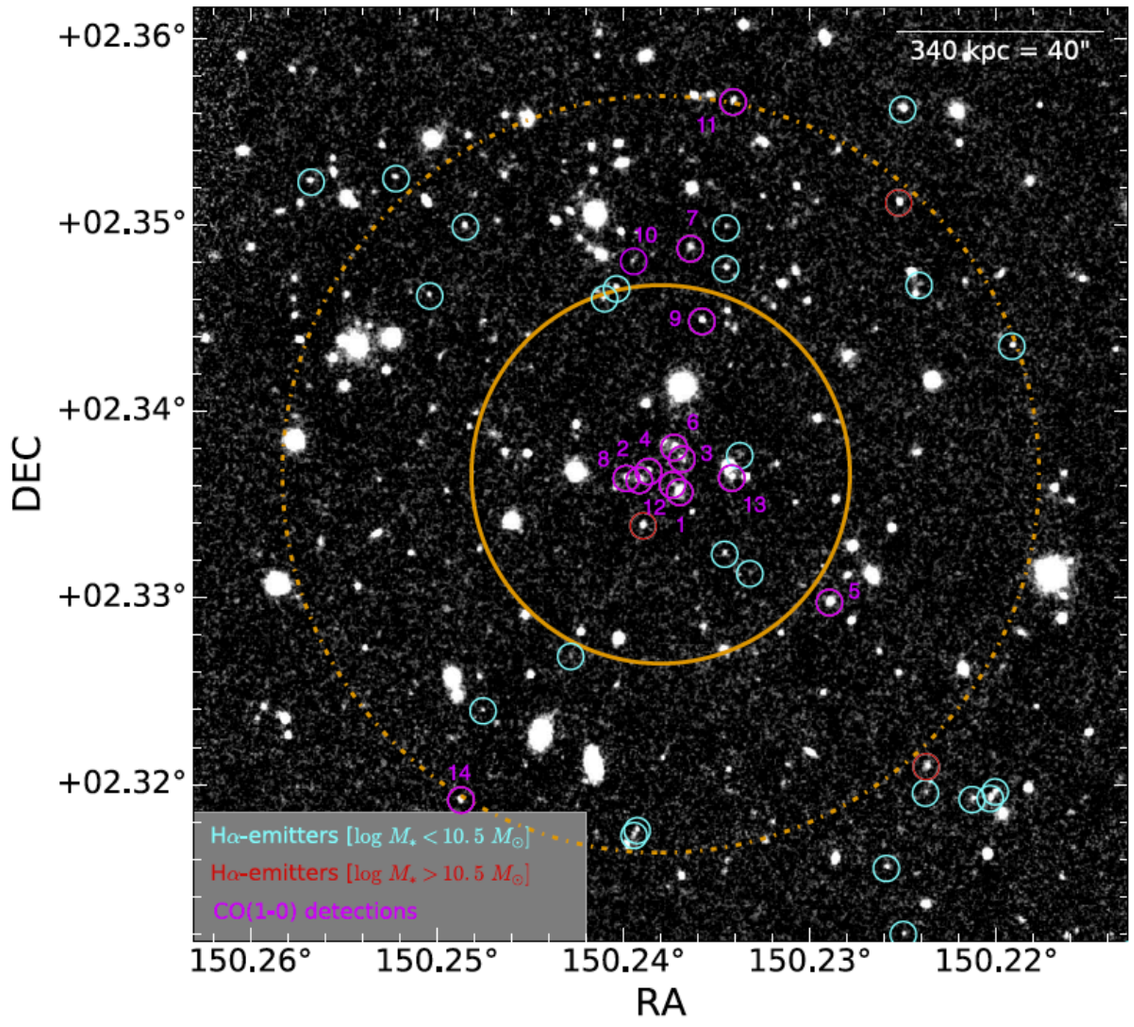
J1001 bridges the gap from protocluster to mature clusters

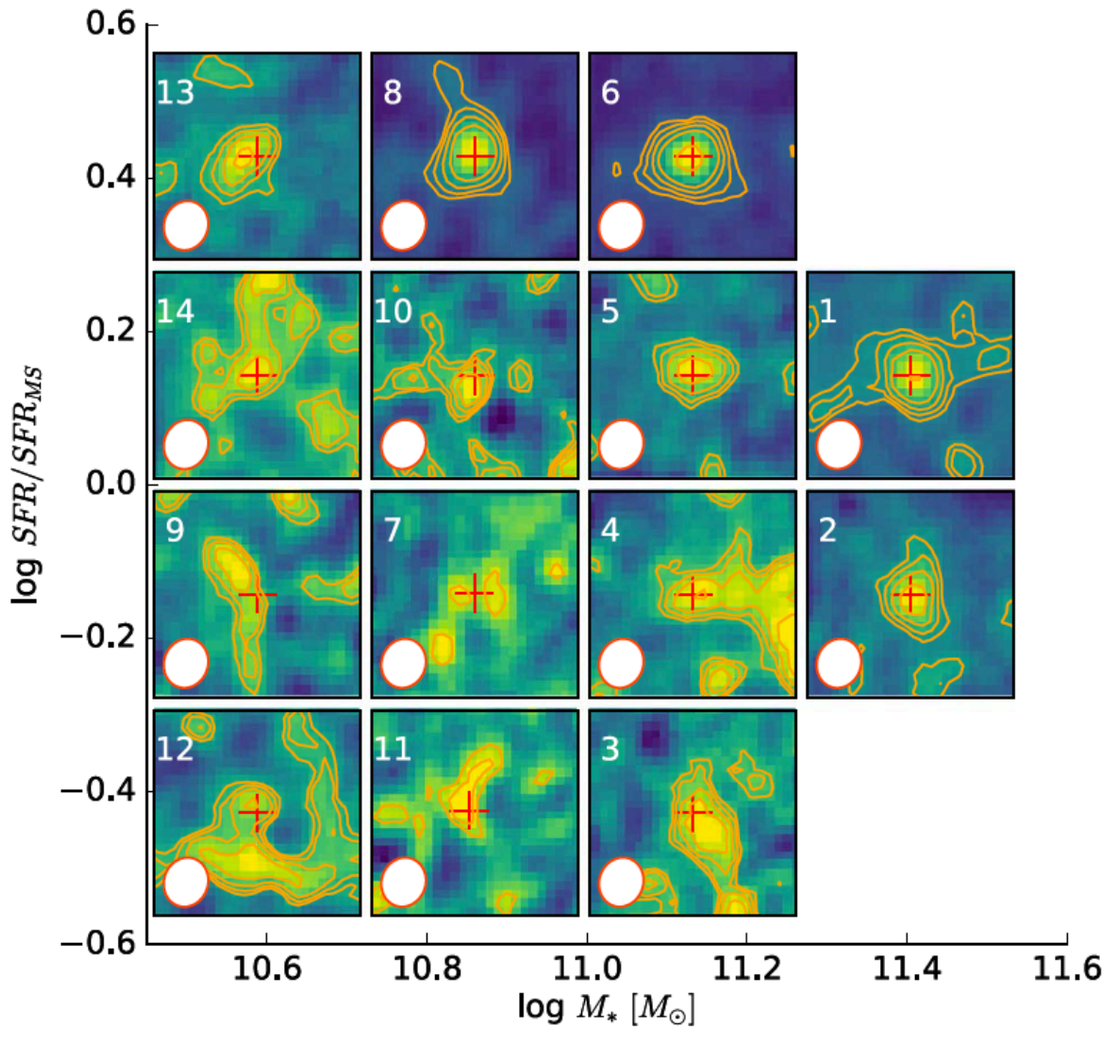


Umehata+2015

A cluster-size, virialized halo yet a dominant population of massive star-forming galaxies

Galaxy Properties in J1001: CO(1-0) observations with VLA



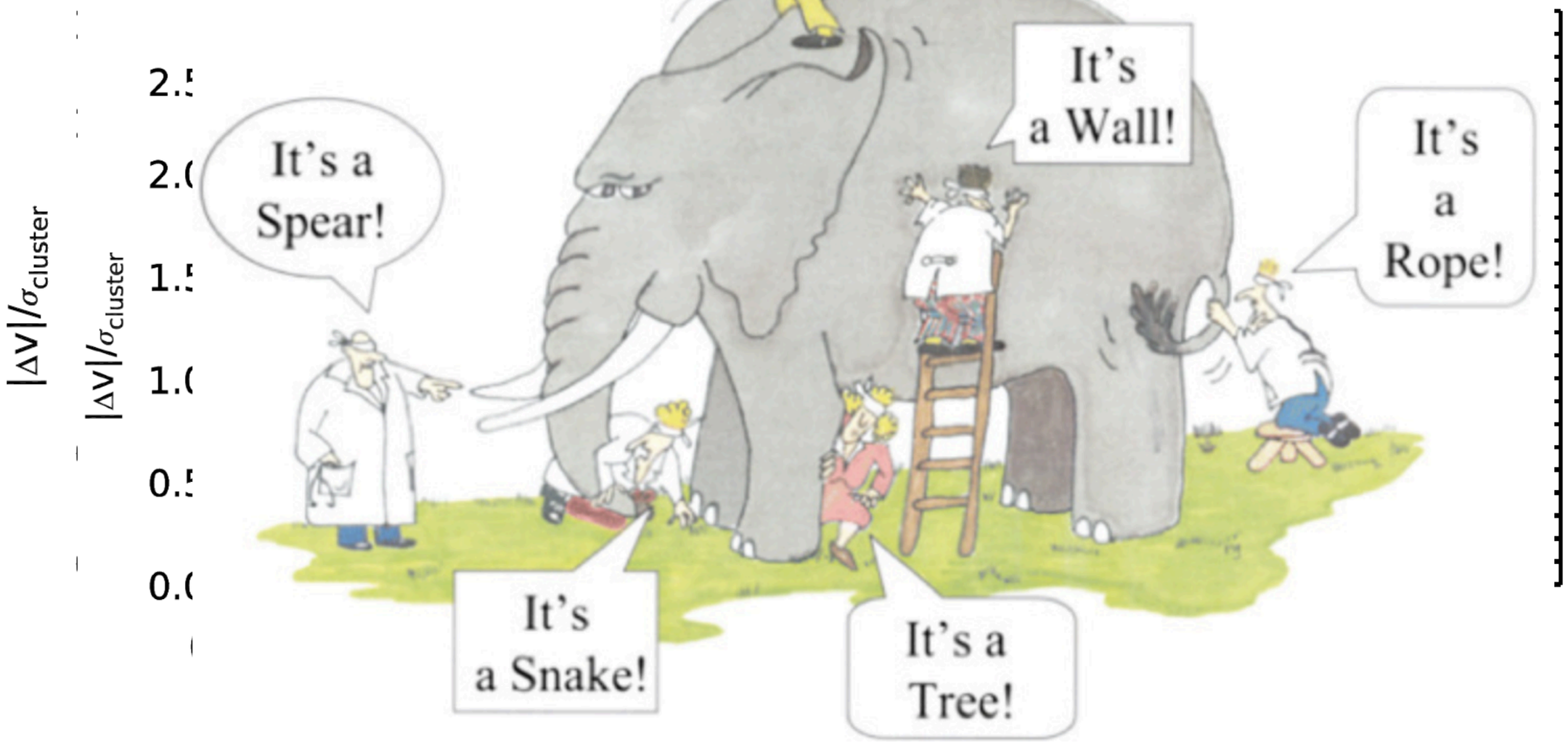


With a single pointing from VLA, we detected 11 cluster members in CO(1-0), which nearly doubles the total number of CO(1-0)-detected normal galaxies at z>2

Wang+2018, ApJL,867, 29

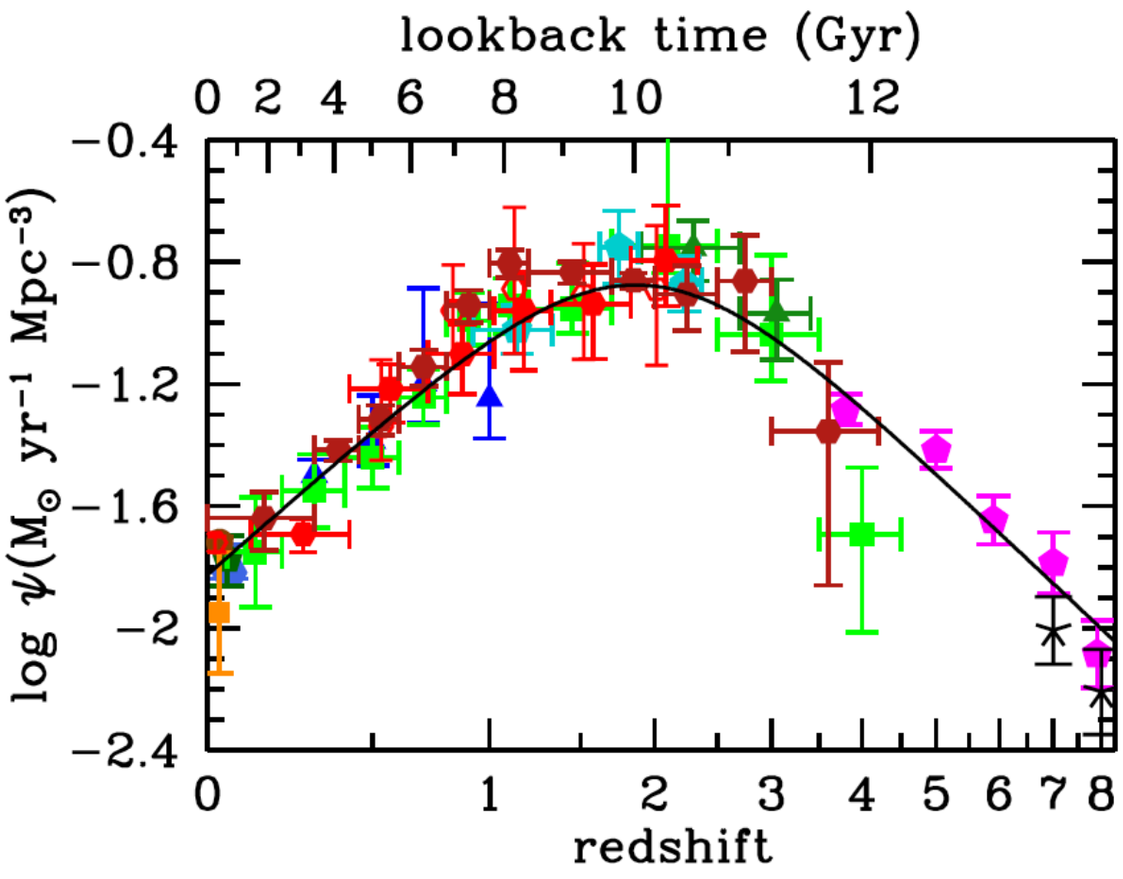
First evidence of environmental dependence of gas content at z>2:

De

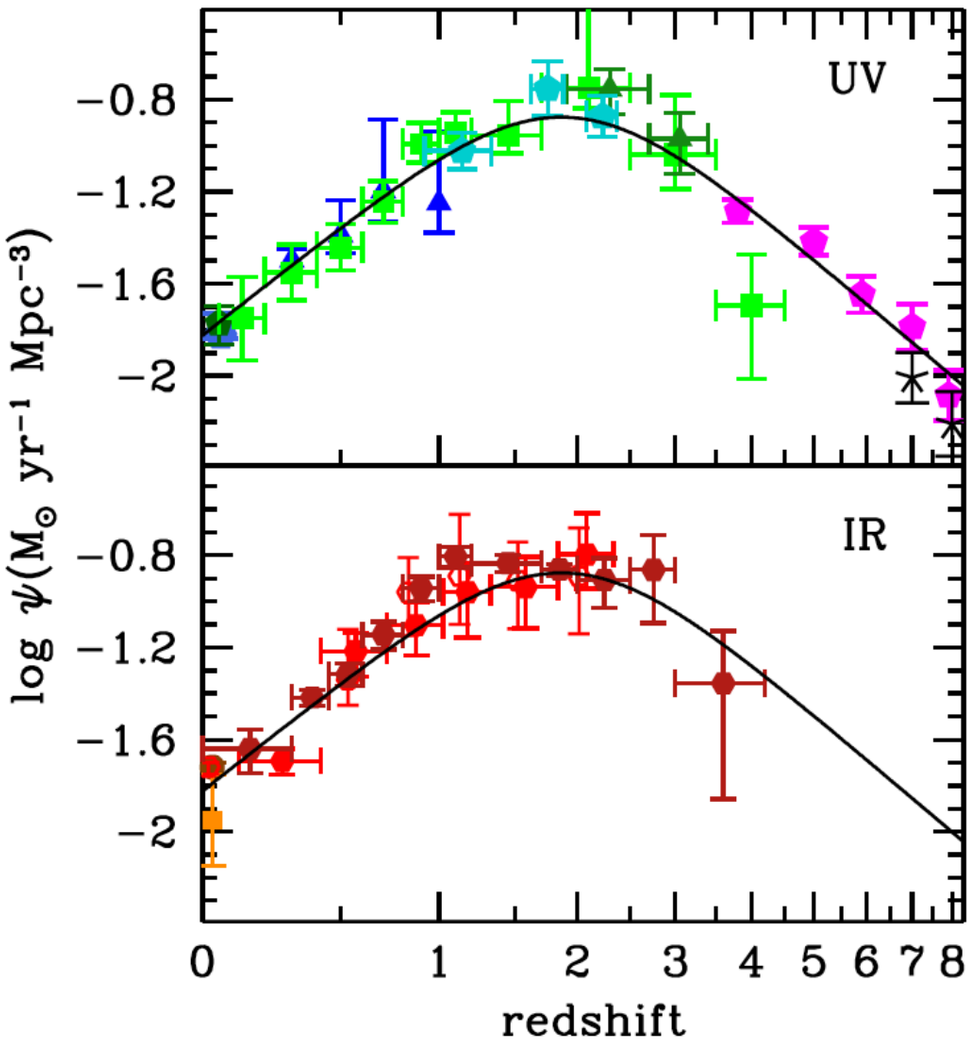


Key: CO(1-0) observations of mass-complete samples of cluster members across different local environment! also see Tadaki+2019

Dark galaxy clusters revealed by overdensities of HST-dark galaxies at z>3:



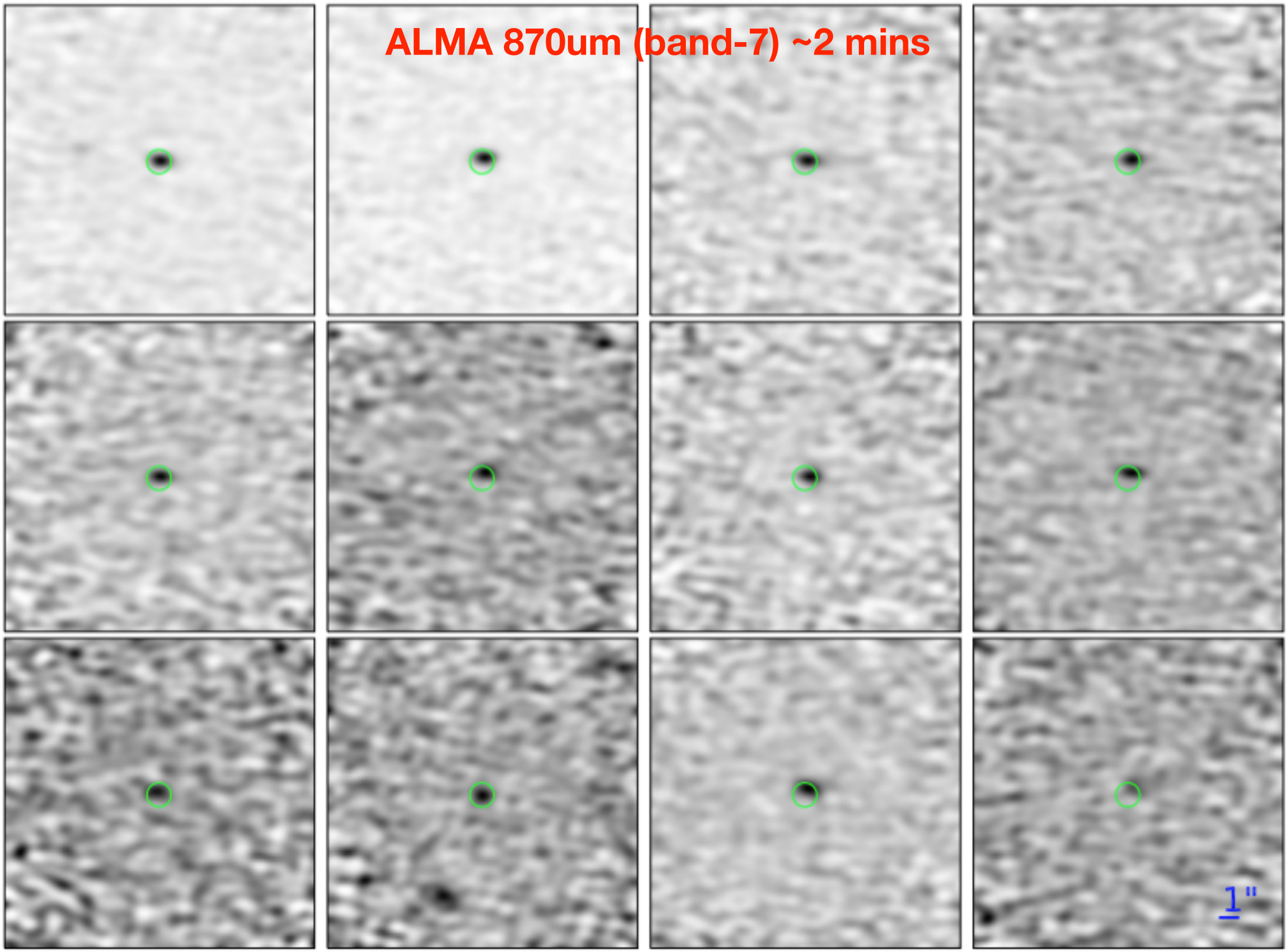
Madau & Dickinson, 2014



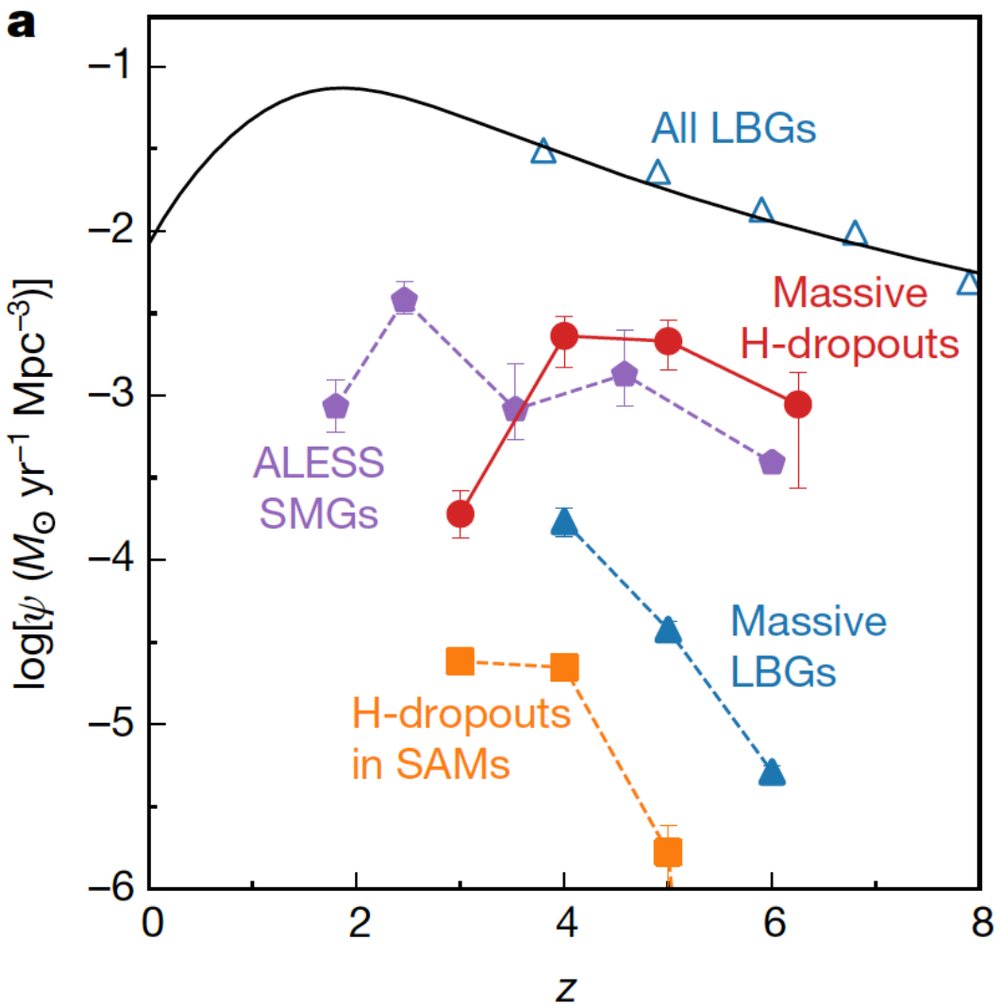
Current determination of the cosmic star formation rate density at z>3 is solely based on UV-bright galaxies.

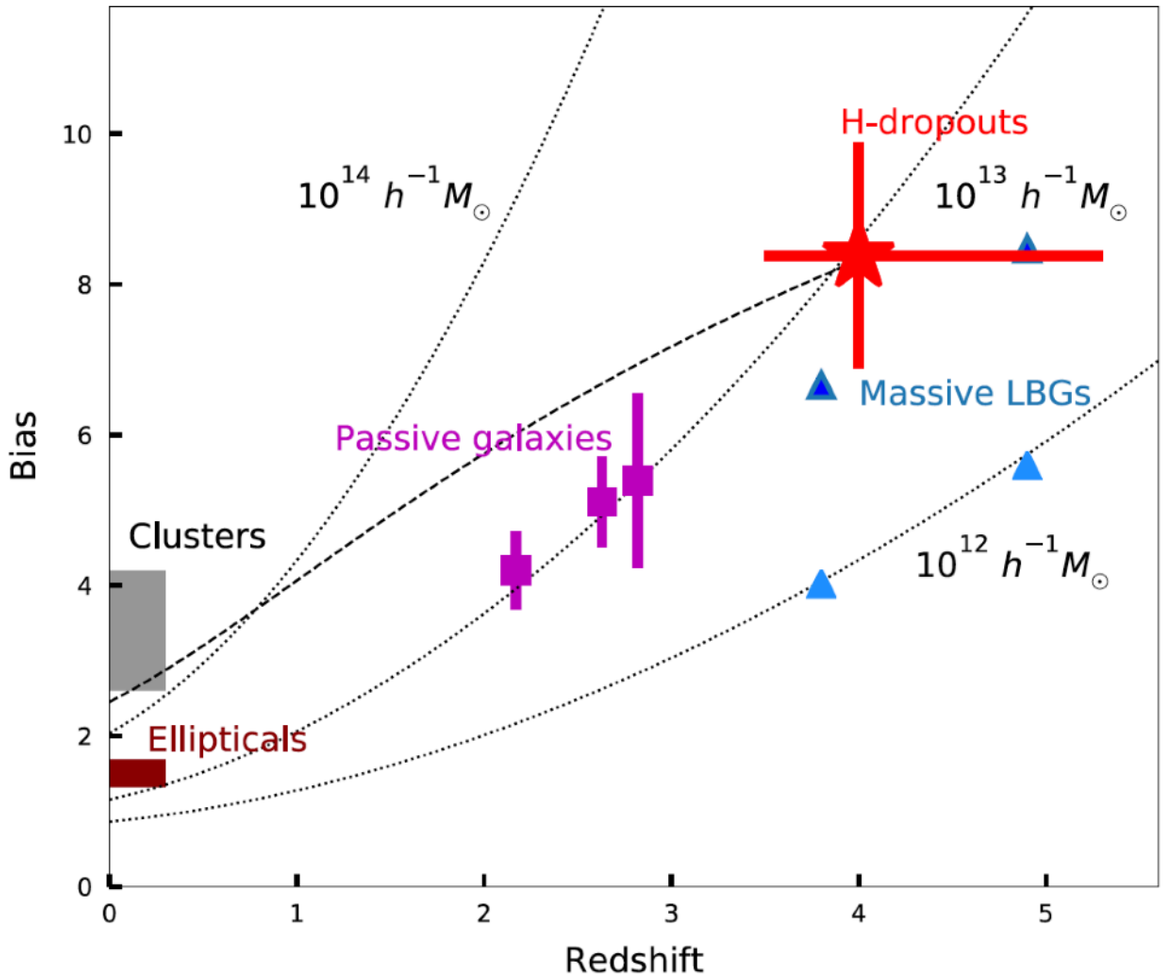
Are the most massive z>4 galaxies missed by HST?

(A complete H-dropout sample down to [4.5] < 24)



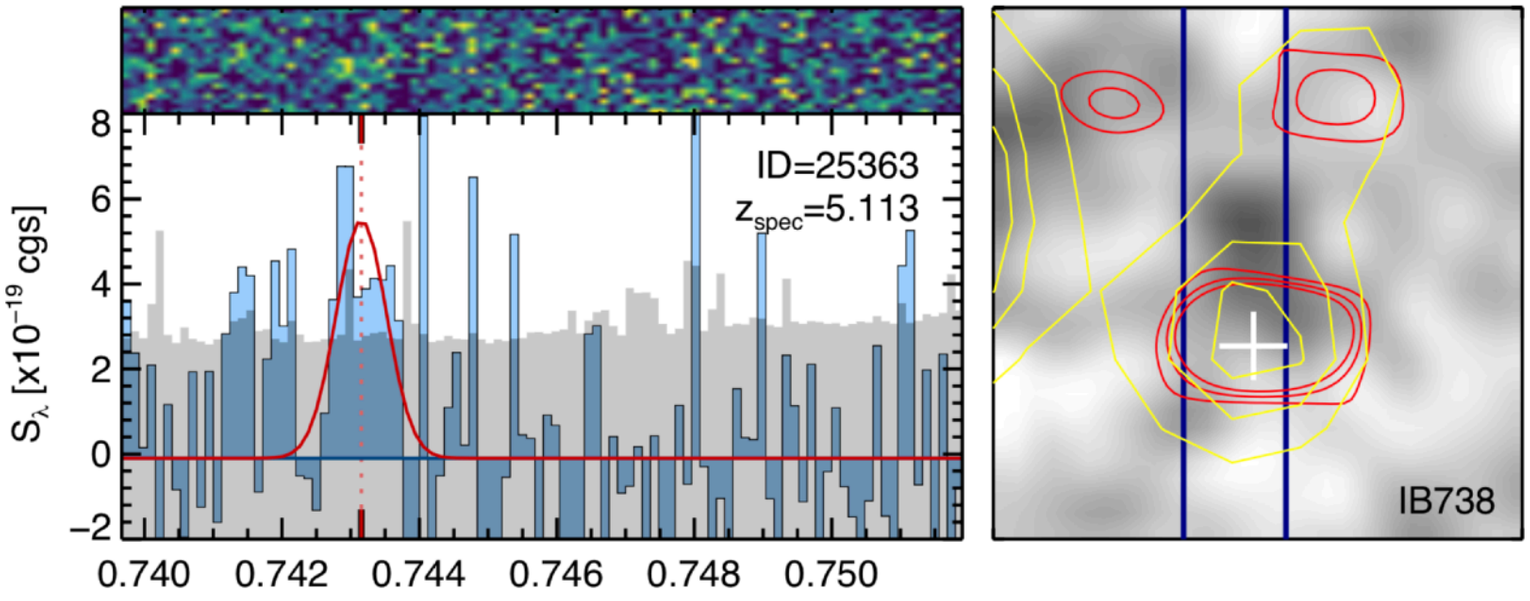
H-dropouts dominate the cosmic SFR density from massive galaxies, and are likely progenitors of today's most massive galaxies in clusters





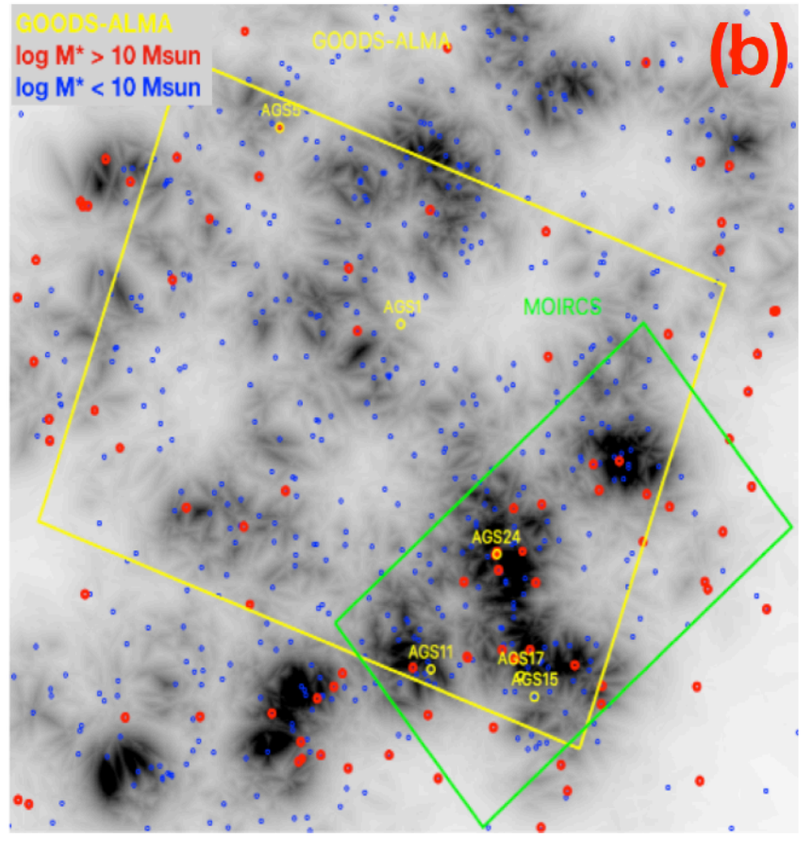
Wang,T+2019, Nature, 572, 211

Dark galaxy clusters revealed by overdensities of HST-dark galaxies at z>3:



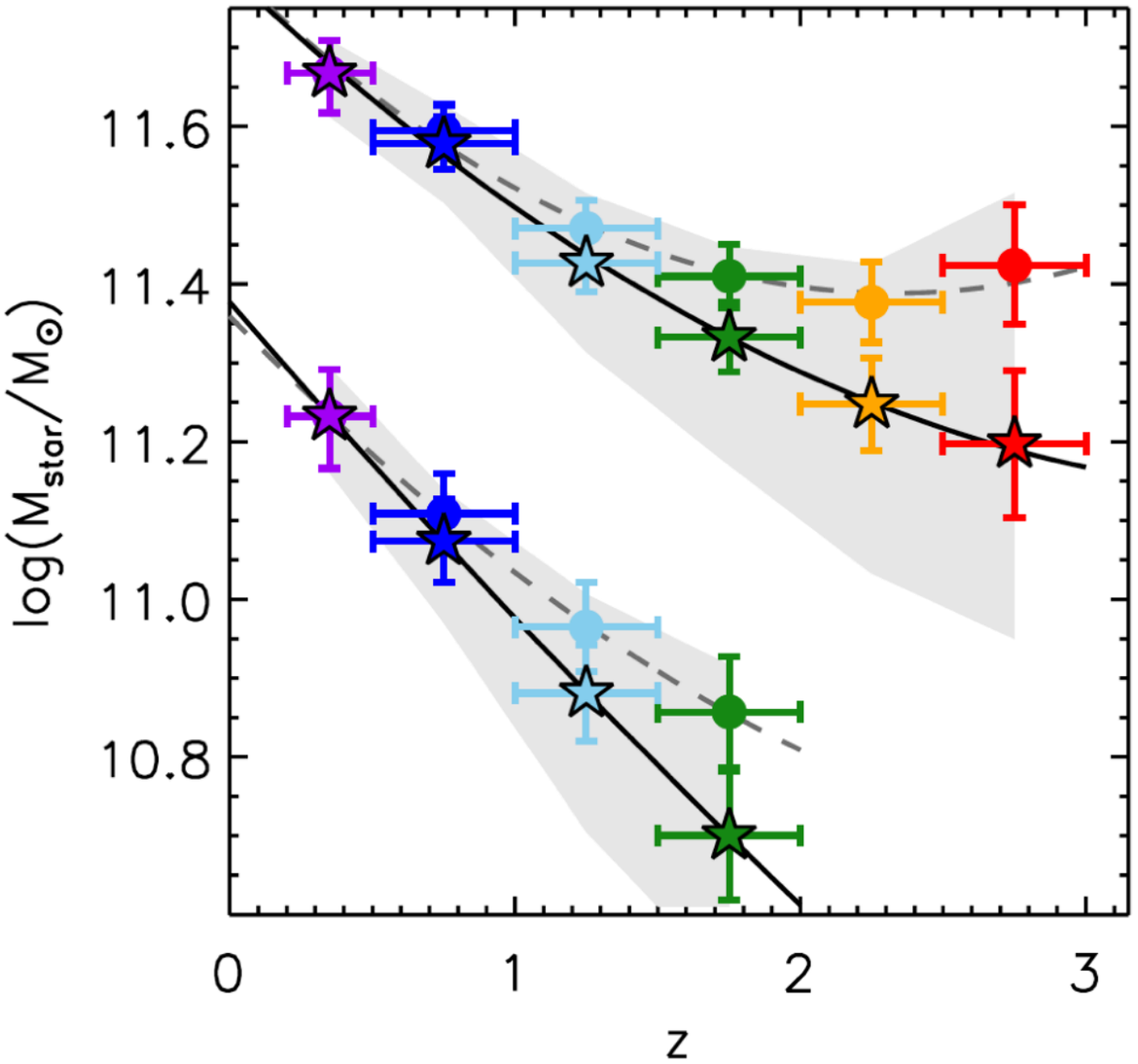
Subaru archival data!

Wang+2019, 2020 (in prep)



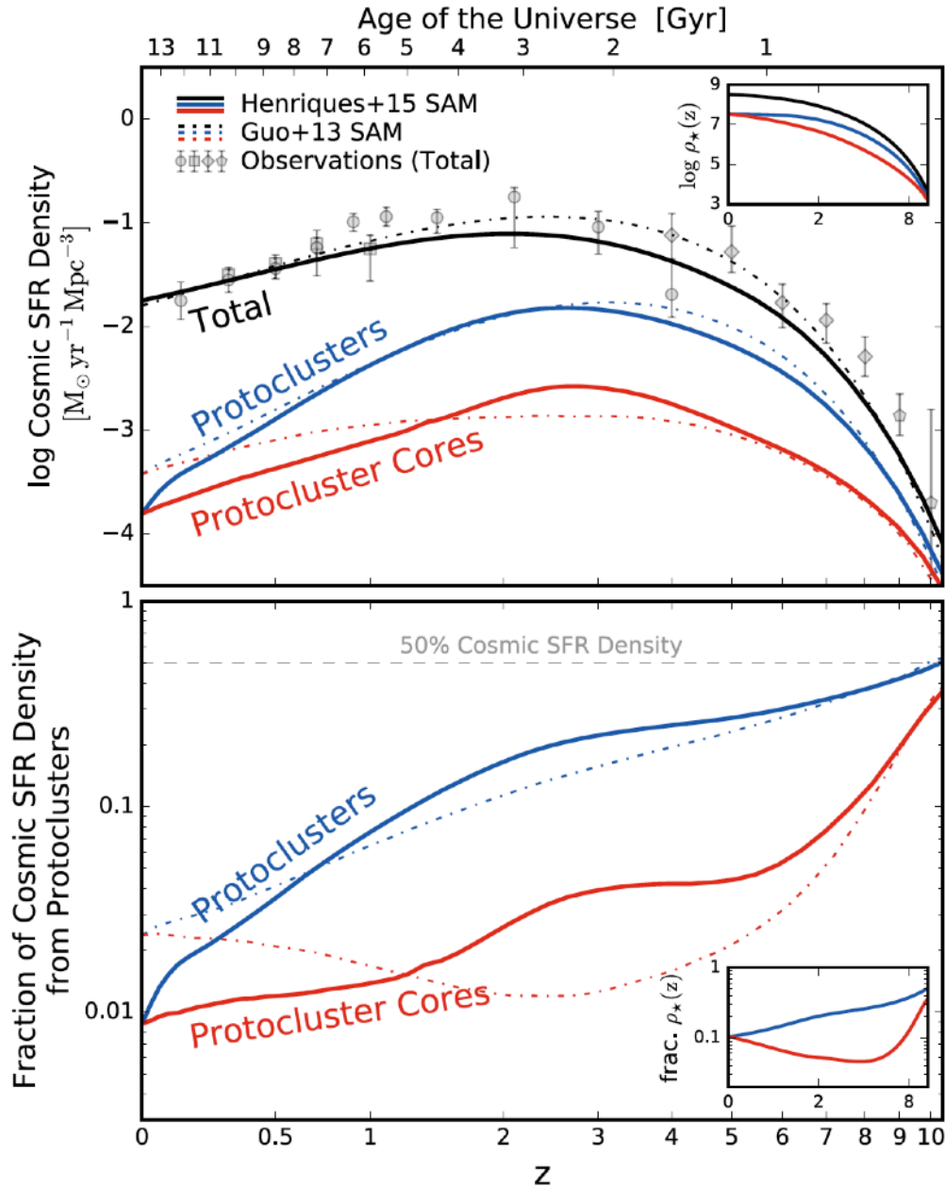
Zhou+2019 (to be submitted) and GOODS-ALMA

Massive galaxies at high-z are good tracers of galaxy (proto)clusters



Mass evolution of galaxies at constant number densities

Behroozi+2013



Increasing contribution from protoclusters to the cosmic SFR density at higher redshifts

Chiang+2015

Summary

- We reveal a novel population of young clusters with a dominate population of massive star-forming galaxies in the core, which bridges the gap between mature clusters and protoclusters.

- While most of the massive cluster galaxies locate on the main-sequence, strong cluster-centric radius dependence of molecular gas content (and SFE) is revealed in J1001, providing direct evidence on environmental dependence of massive galaxy formation at $z>2$.

- Subaru (MOIRCS, HSC) is critical to map the 3-D structures and obtain a complete census of member galaxies of young galaxy clusters in the early universe.