Star forming activities and cold gas accretion in z~2 protoclusters with various evolutionary stages

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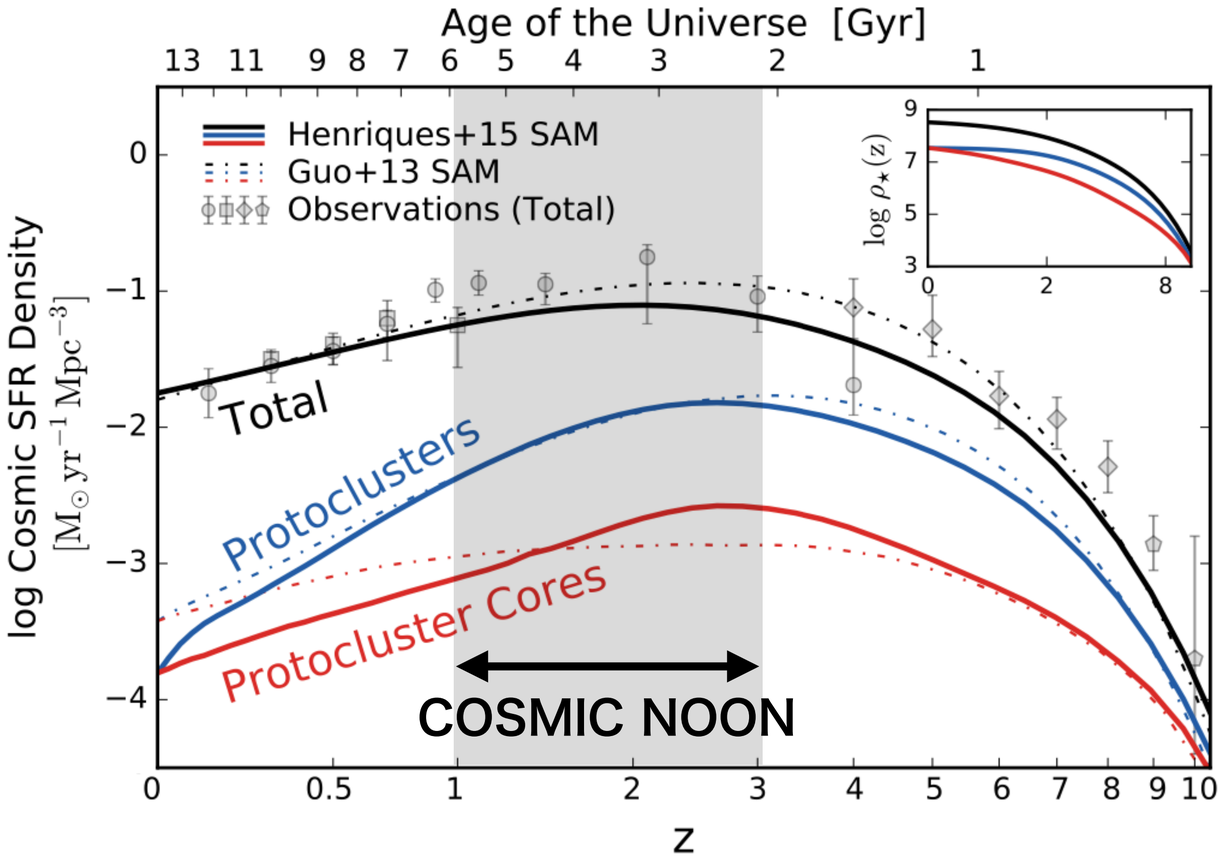
Introduction

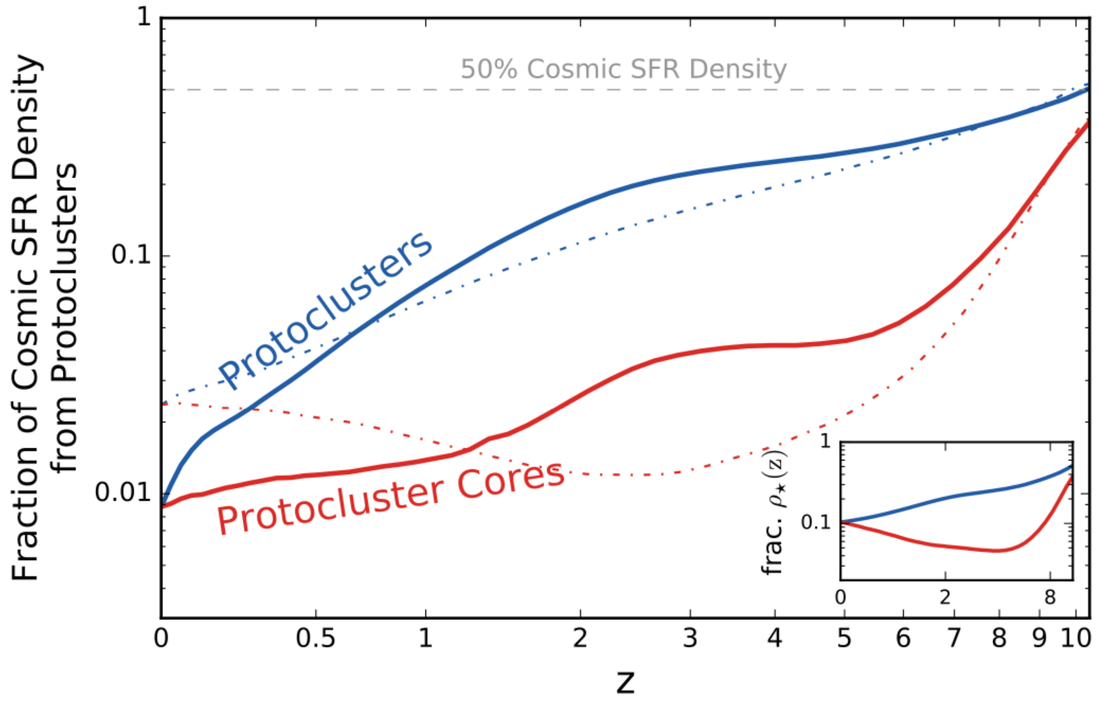
— Structure evolution of galaxy clusters

— The Role of Environment in Galaxy Formation and Evolution

— The Relationship Between Gas Accretion/Feedback, star formation, and environment

☑ **Protoclusters are an important population at high redshifts.**





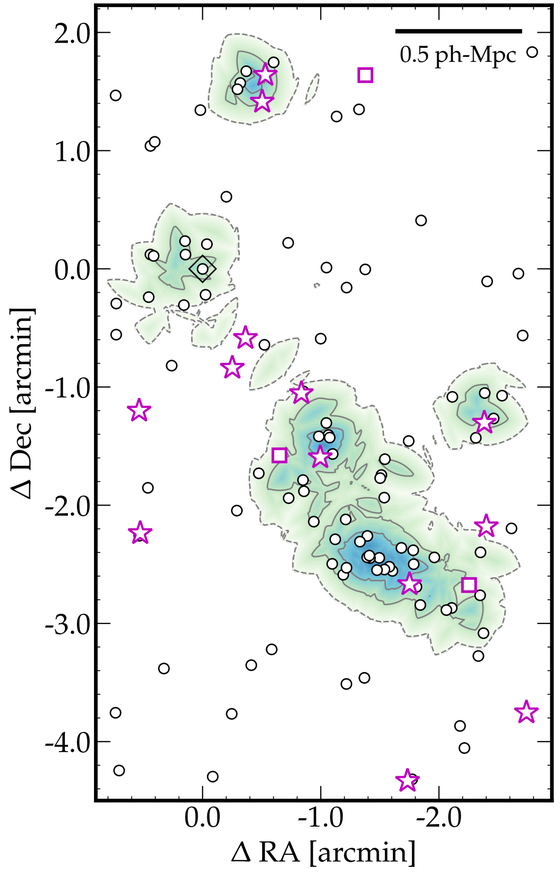
Chiang et al. 2017

MAHALO - DEEP Survey

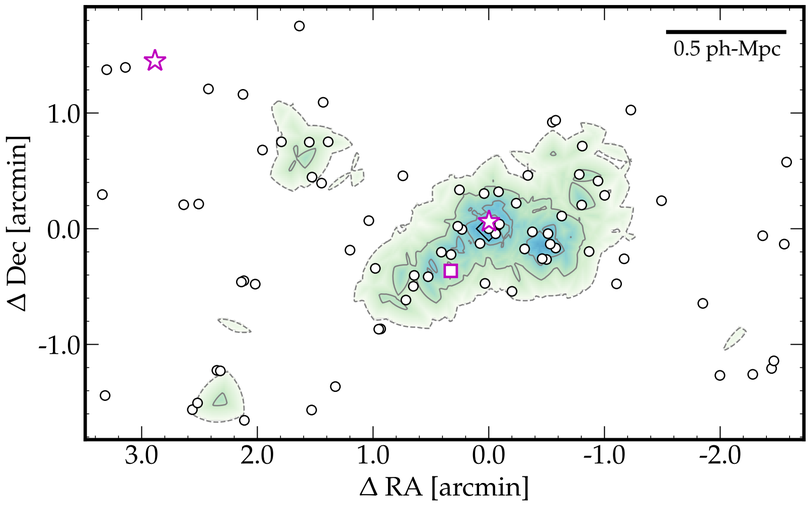
M*apping *HA*lpha and *L*ines of *O*xygen with *Subaru PI: T. Kodama

Proto-cluster Survey

USS1558-003 ($z = 2.53$)



PKS1138-267 ($z = 2.16$)



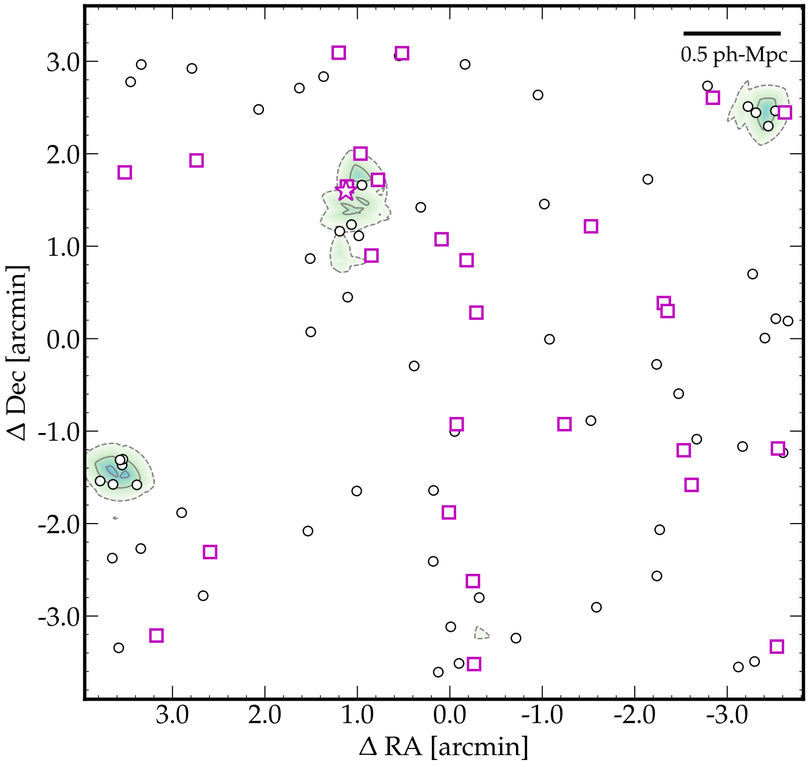
⬆ Proto-cluster at a relatively advanced stage of evolution

⬅ Young proto-clusters at an earlier evolutionary stage

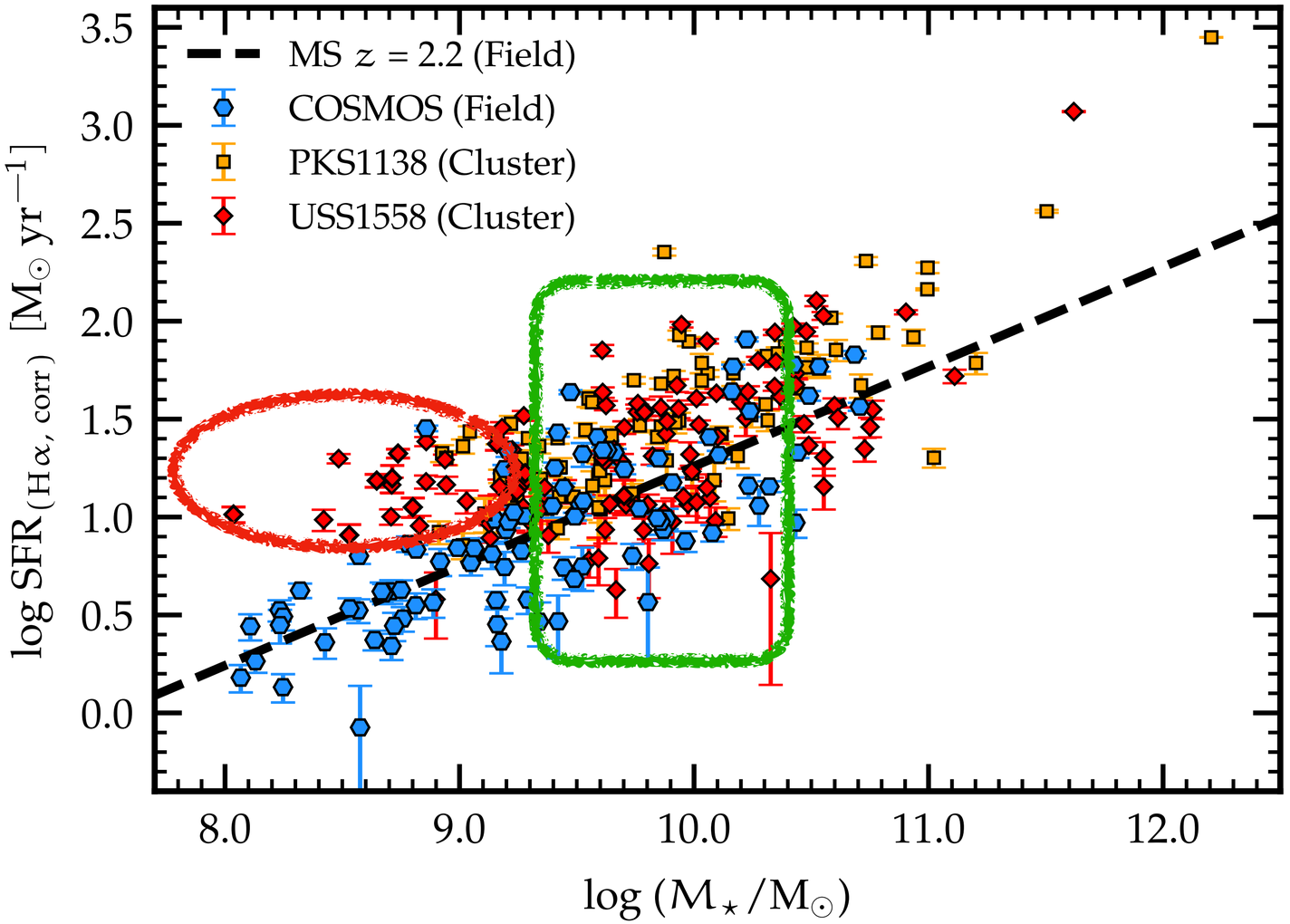
See also Hayashi et al. 2016, Shimakawa et al. 2018a,b

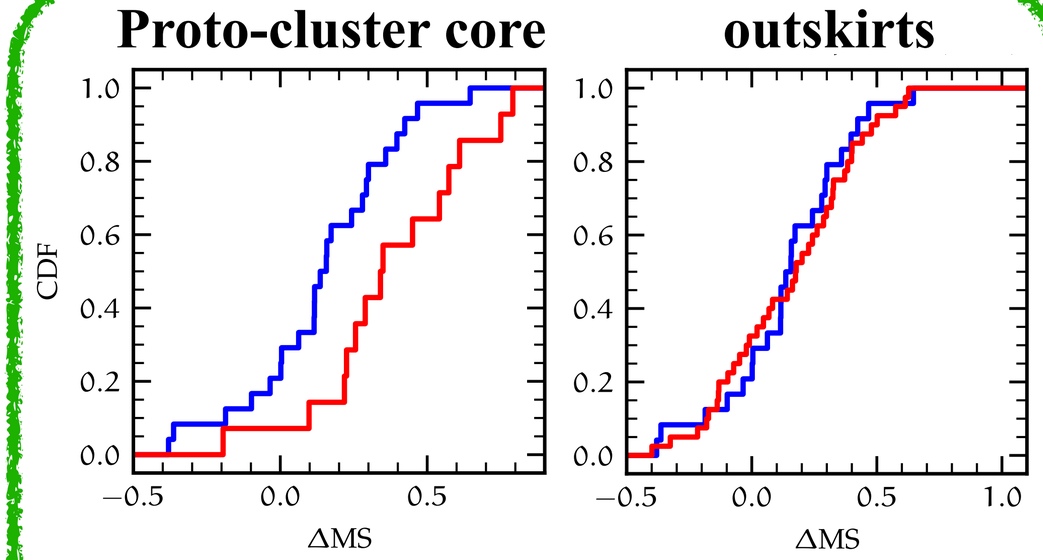
Field Survey (This work)

COSMOS ($z = 2.19$)



Enhanced star-formation activities in USS1558-003





ΔMS = log(SFR) - log(SFR_field)

Enhanced star-formation activities in USS1558 core.

Daikuhara et al. in prep

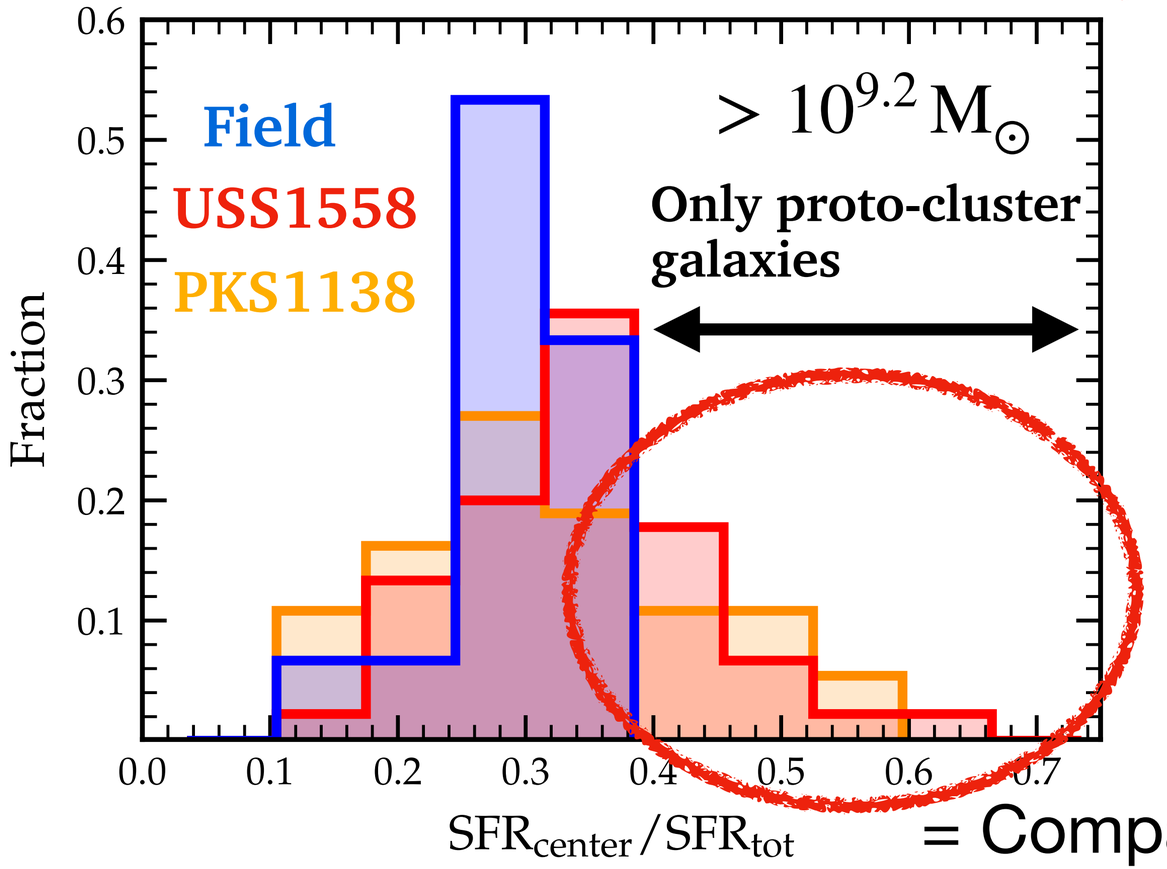
There are lots of starbursts at the low-mass end in USS1558, which is almost absent in COSMOS even with the deeper data!

Enhanced star-formation activities in USS1558-003

(1) **Higher gas accretion rates in the young protocluster core**

(2) **Galaxy mergers/interactions**

Compact



Protocluster galaxies tend to have more concentrated star formation.

Driven by mergers/interactions?

= Compactness of Star-forming activities

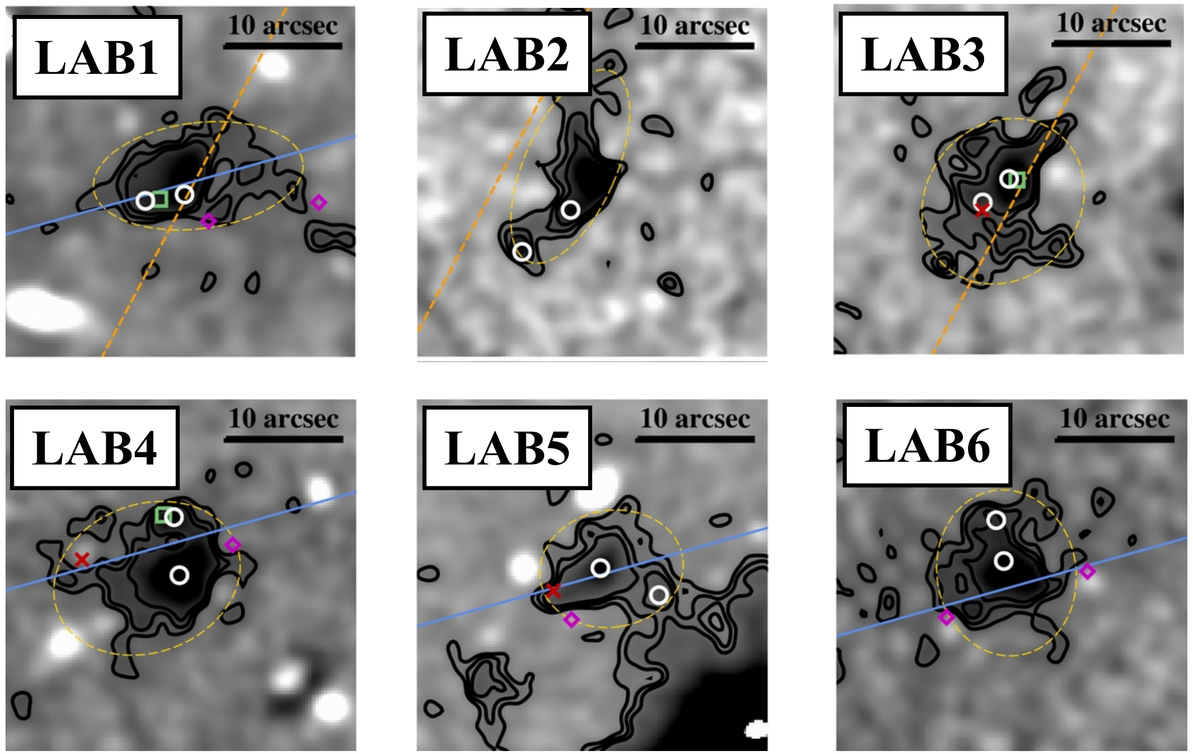
Filamentary protocluster HS1700 at z=2.3

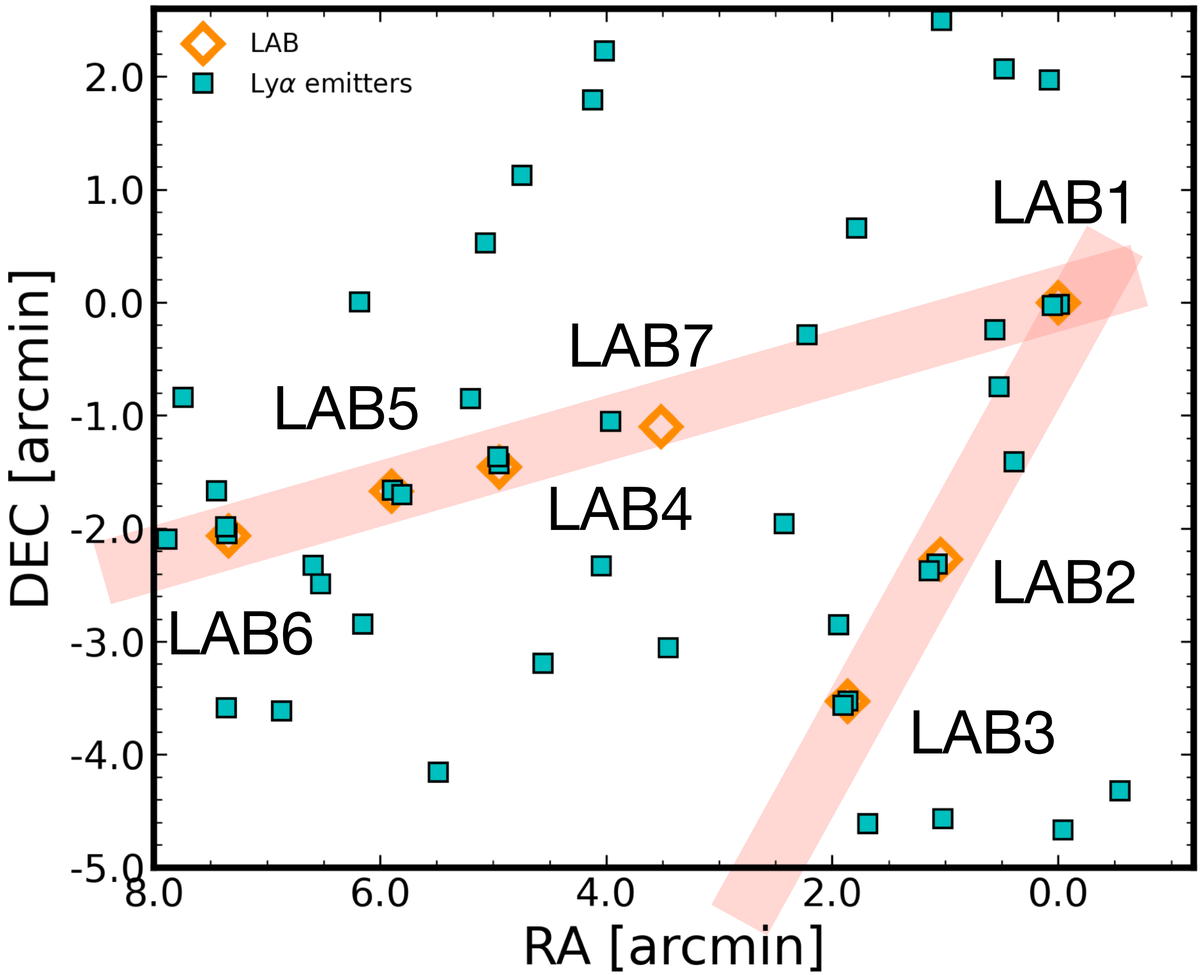
Proto-cluster HS1700+64

$z = 2.30$

a rich cluster today with a halo mass

$M_h \sim 10^{15}\,\mathrm{M}_\odot$ at $z = 0$ (Steidel et al. 2005)





Erb et al. 2011

Summary

- **Enhanced low-mass star-forming galaxies in USS1558.**
- **In the protocluster core, there are many middle-mass galaxies with enhanced star forming activities in USS1558.**

Low-mass galaxies	Middle-mass galaxies	High-mass galaxies
$M_*/M_\odot < 10^{9.2}$	$10^{9.2} < M_*/M_\odot < 10^{10.2}$	$M_*/M_\odot > 10^{10.2}$
◎	○	
Only USS1558	Only USS1558 core	

- **In protoclusters, galaxies tend to have more centrally concentrated star formation than in the field.**
- Star formation activity may be enhanced by environmental effects such as galaxy mergers/interactions, and gas accretion.
- **In young proto-clustes, LAEs tend to avoid the dense region of HAEs. => HI gas & dust**