Subaru Users Meeting 2025
25 October 2025 @Mitaka, NAOJ

MAHALO Deep Survey: Environmental effects on star-forming galaxies in protoclusters at cosmic noon

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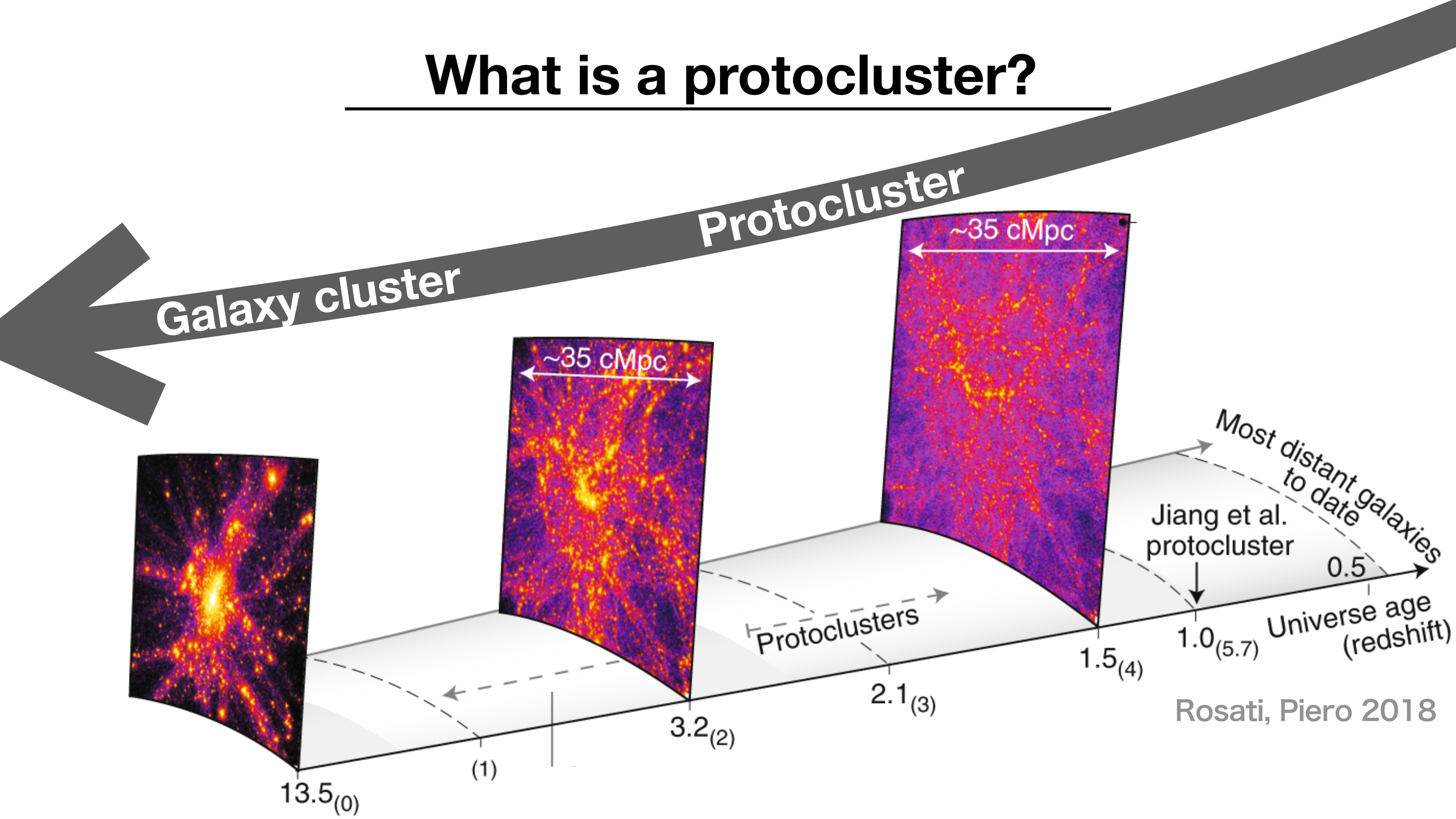
D. Erb (Univ. of Wisconsin-Milwaukee), P. Best (Univ. of Edinburgh), K. Fukushima (Seoul National Univ.)

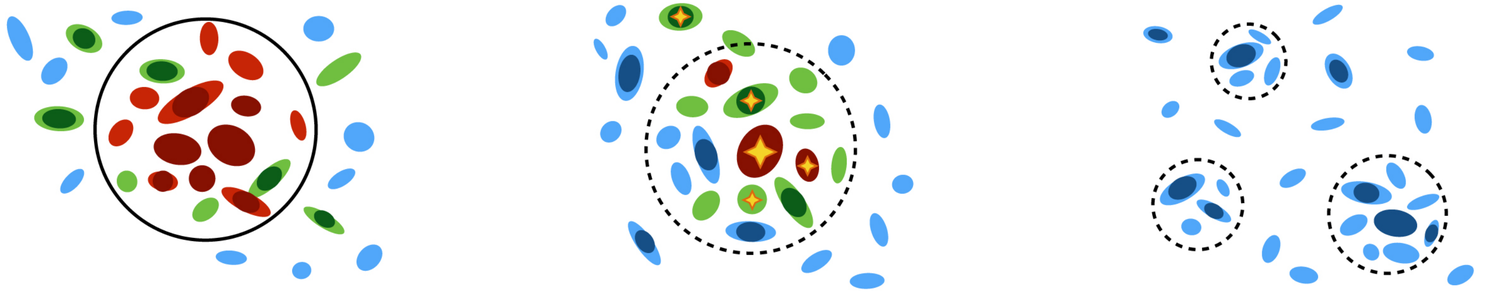
What is a protocluster?



Rosati, Piero 2018

Star formation and Gas accretion across cosmic time

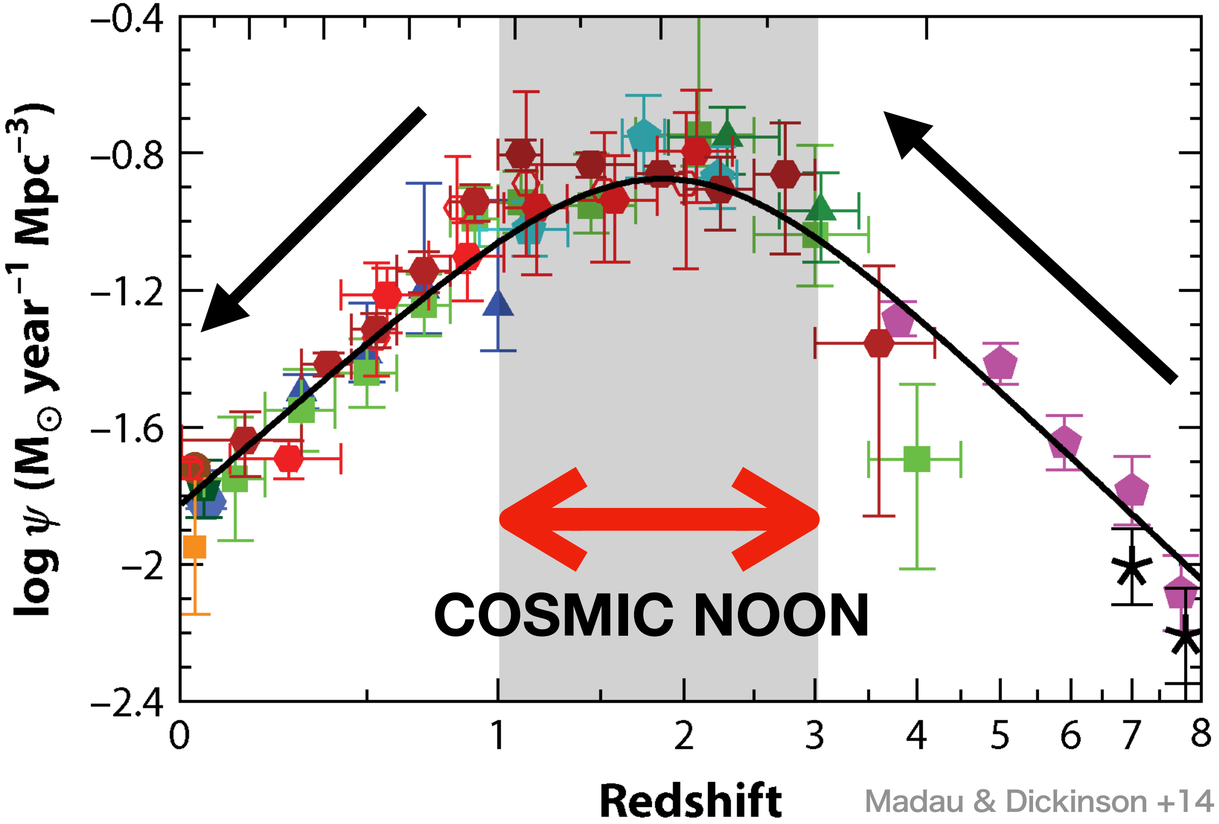
Declining Phase (z≤2) ⇦ Maturing Phase (2≤z≤3) ⇦ Growing Phase (3≤z)



Shimakawa+18b

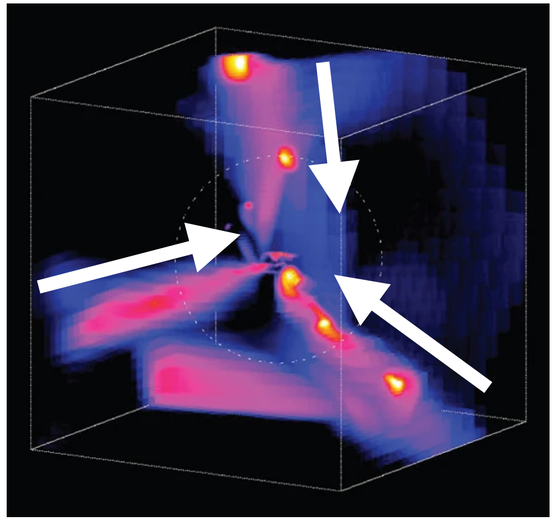
“Inefficient” Cold gas accretion phase

Credit: NASA/ESA/JPL-Caltech/Yale/CNRS



Madau & Dickinson +14

“Efficient” Cold gas accretion phase



Dekel+09

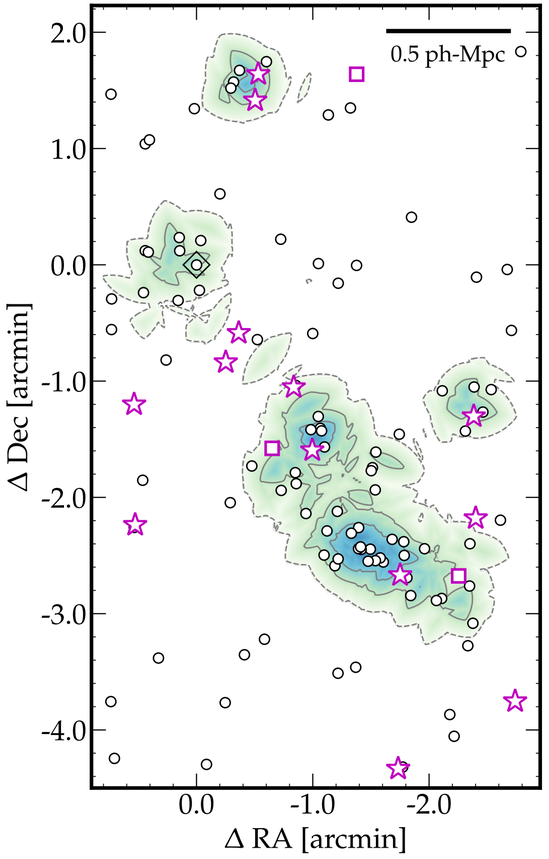
MAHALO DEEP Survey

MA*pping *HA*lpha and *L*ines of *O*xygen with *Subaru

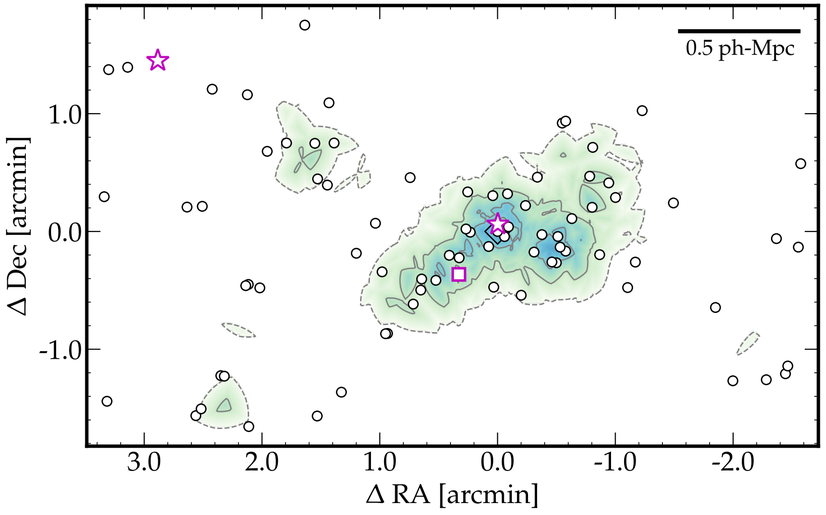
PI: T. Kodama

Proto-cluster Survey

USS1558-003 ($z = 2.53$)



Spiderweb (PKS1138-267, $z = 2.16$)



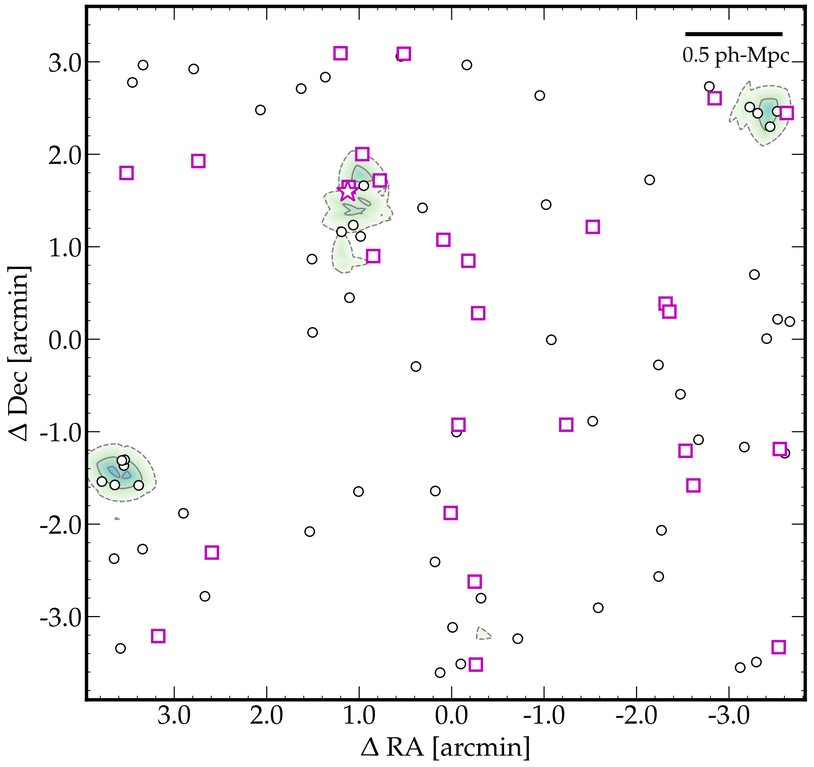
⬆ Proto-cluster at a relatively advanced stage of evolution

⬅ Young proto-clusters at an earlier evolutionary stage

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

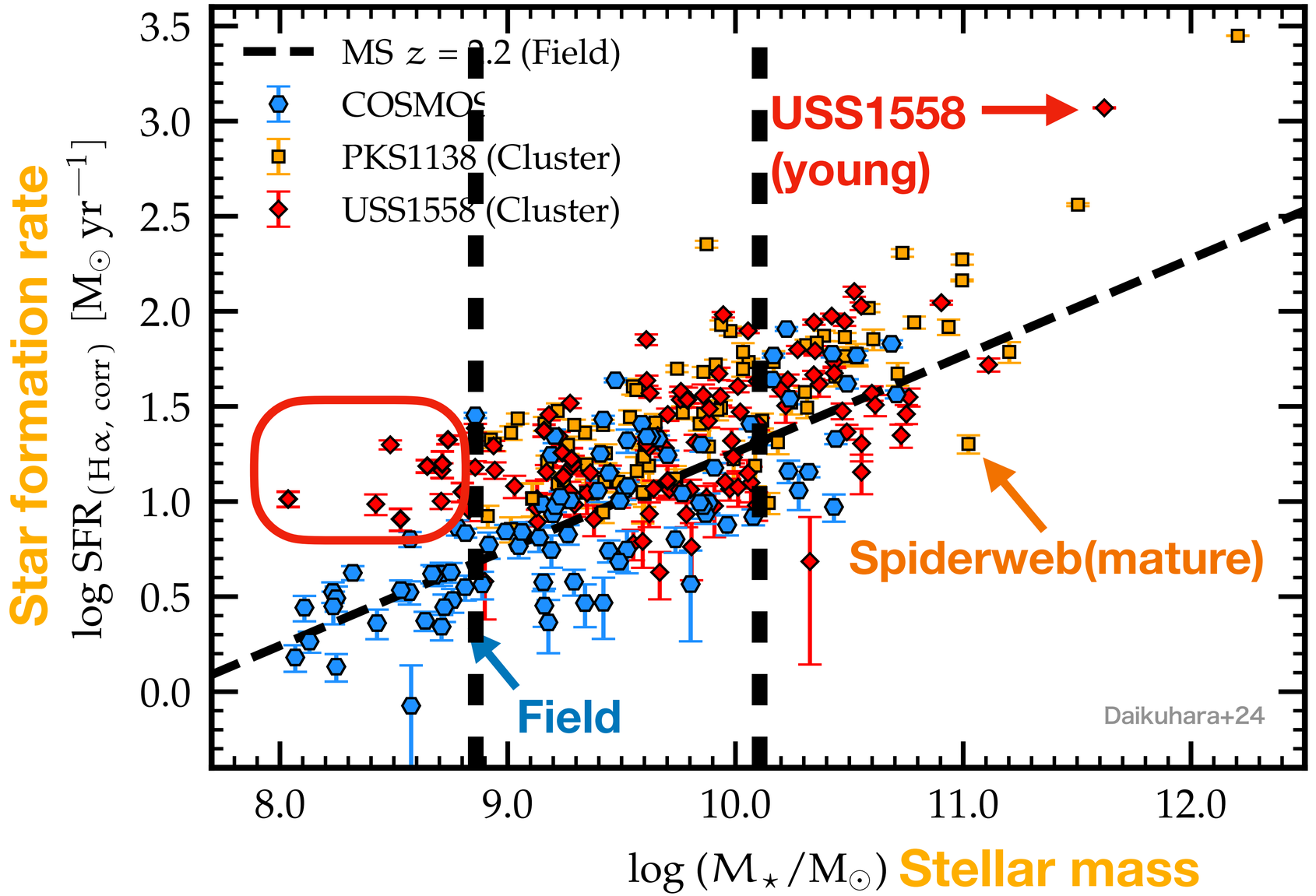
Field Survey

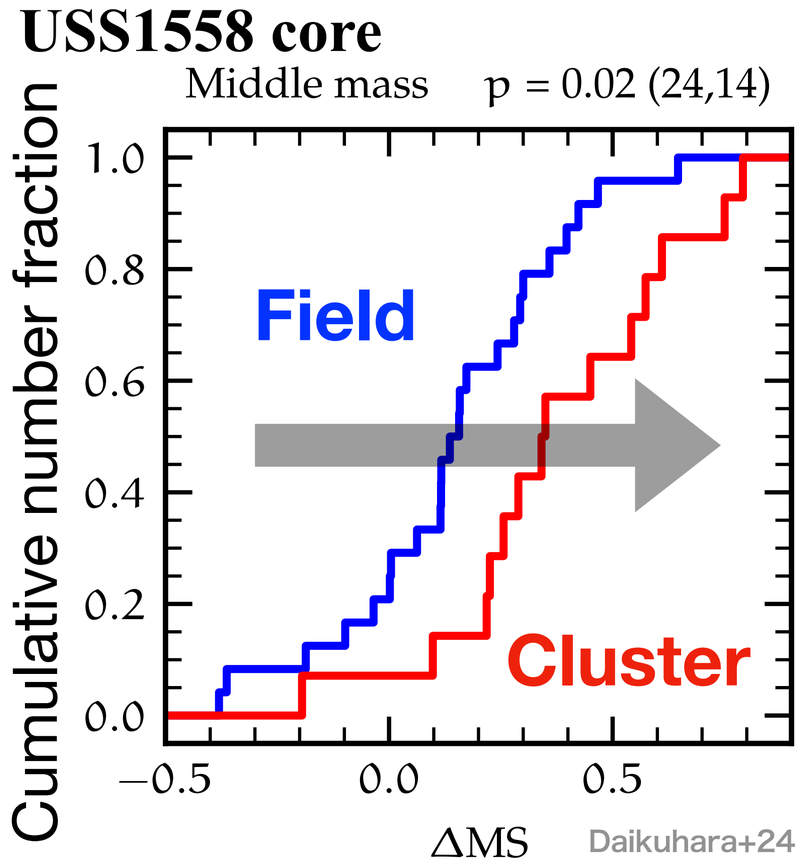
COSMOS ($z = 2.19$)



Daikuhara et al. 2024

Enhanced Star-forming activites





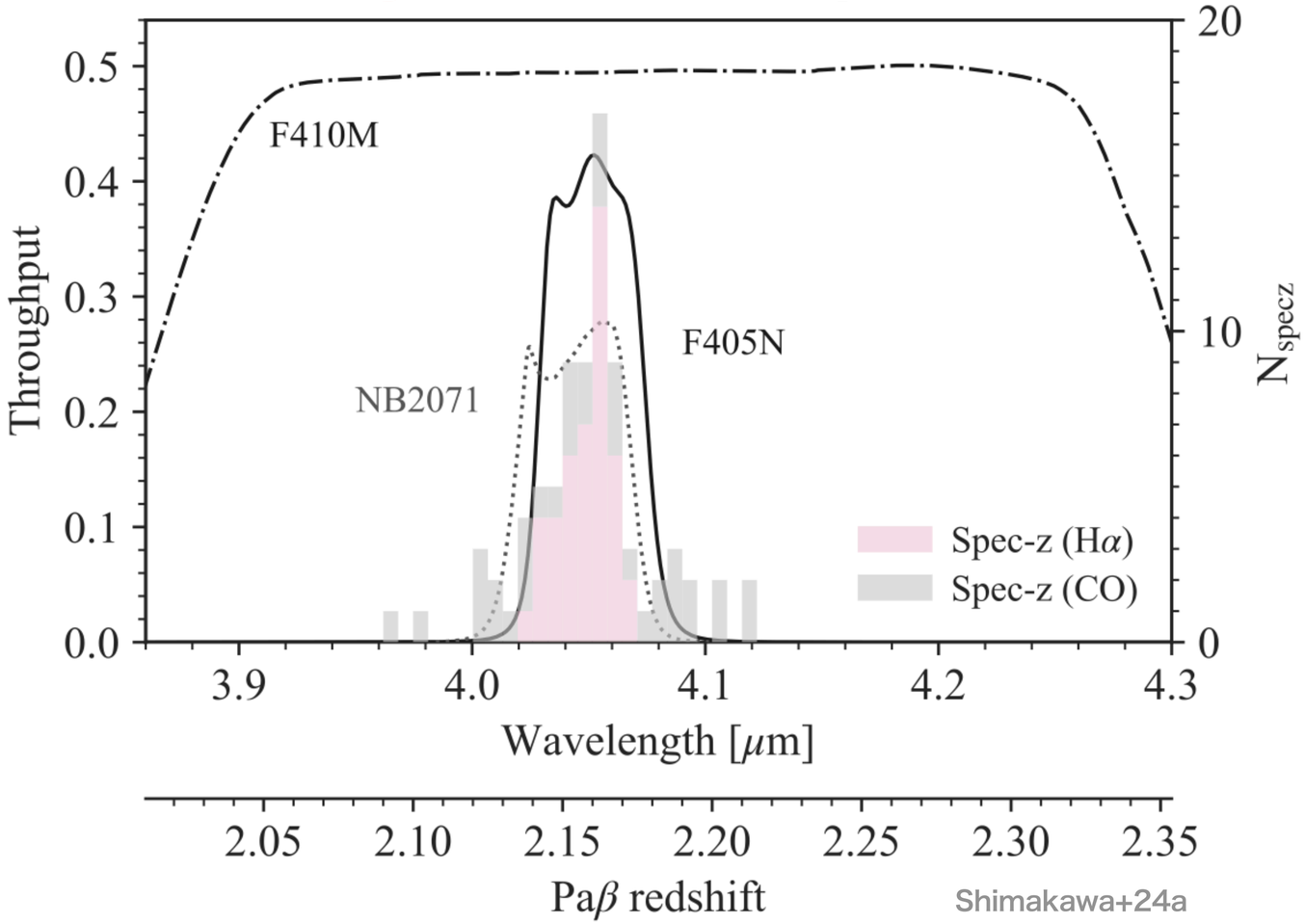
Enhanced star-forming activities in USS1558.

Spider-Webb project

JWST/NIRCam imaging for the Spiderweb in the JWST Cycle-1 GO program

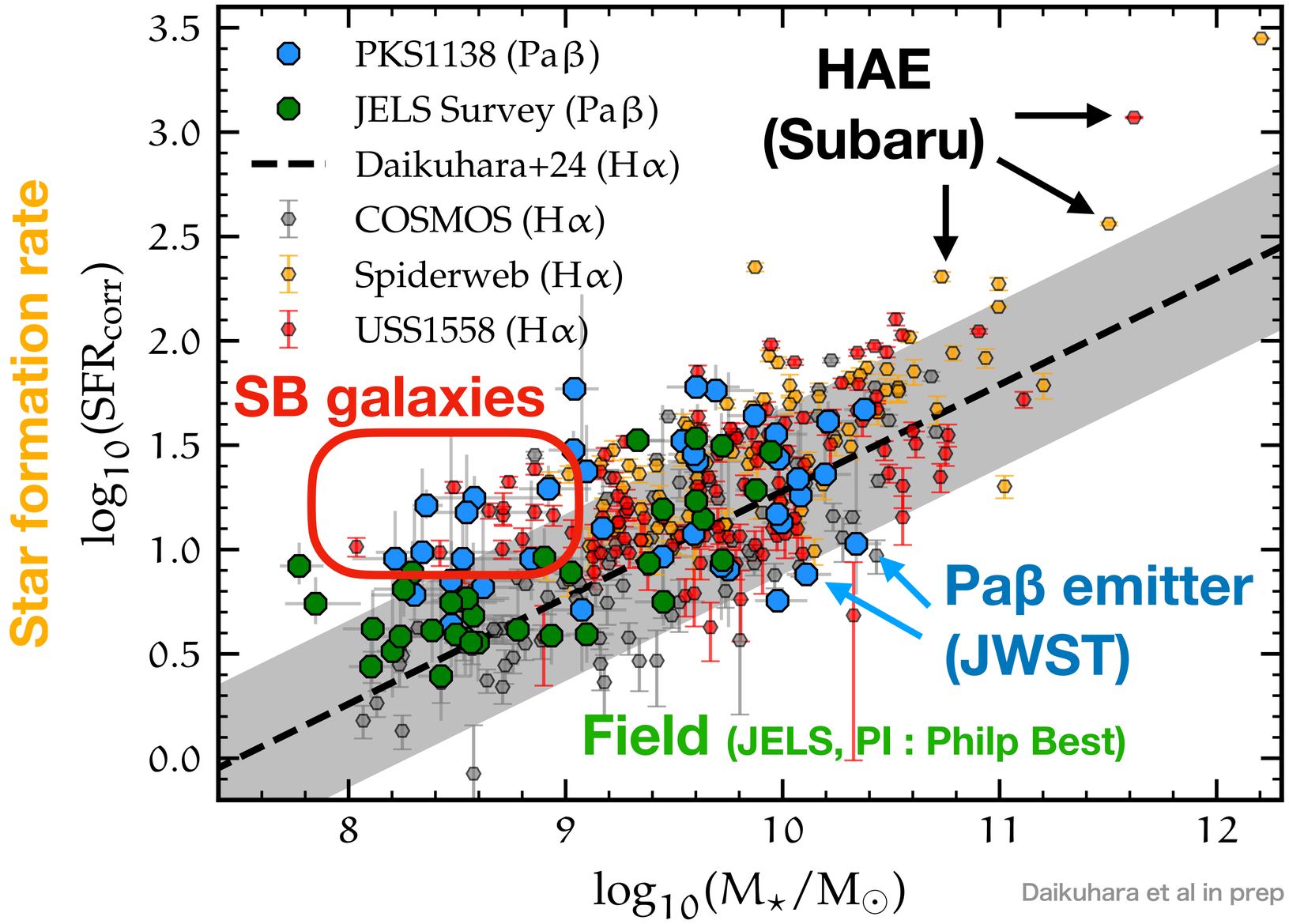
PIs: H. Dannerbauer and Y. Koyama

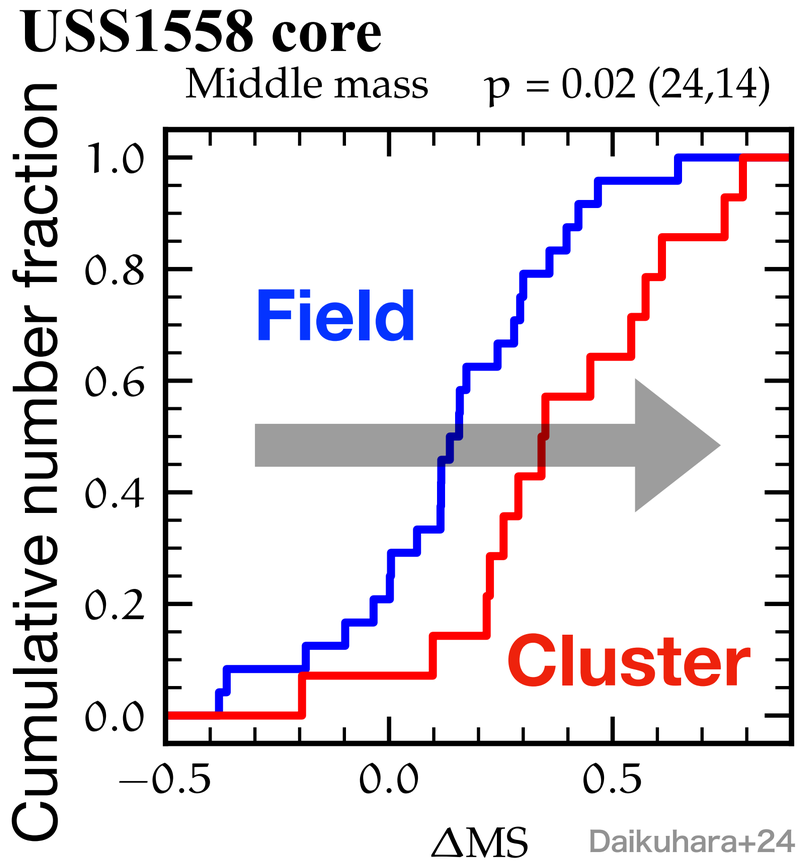
Perfectly-matched Paβ NB filter



@M. Yoda

Enhanced Star-forming activites on the low-mass end





Enhanced star-forming activities in USS1558.

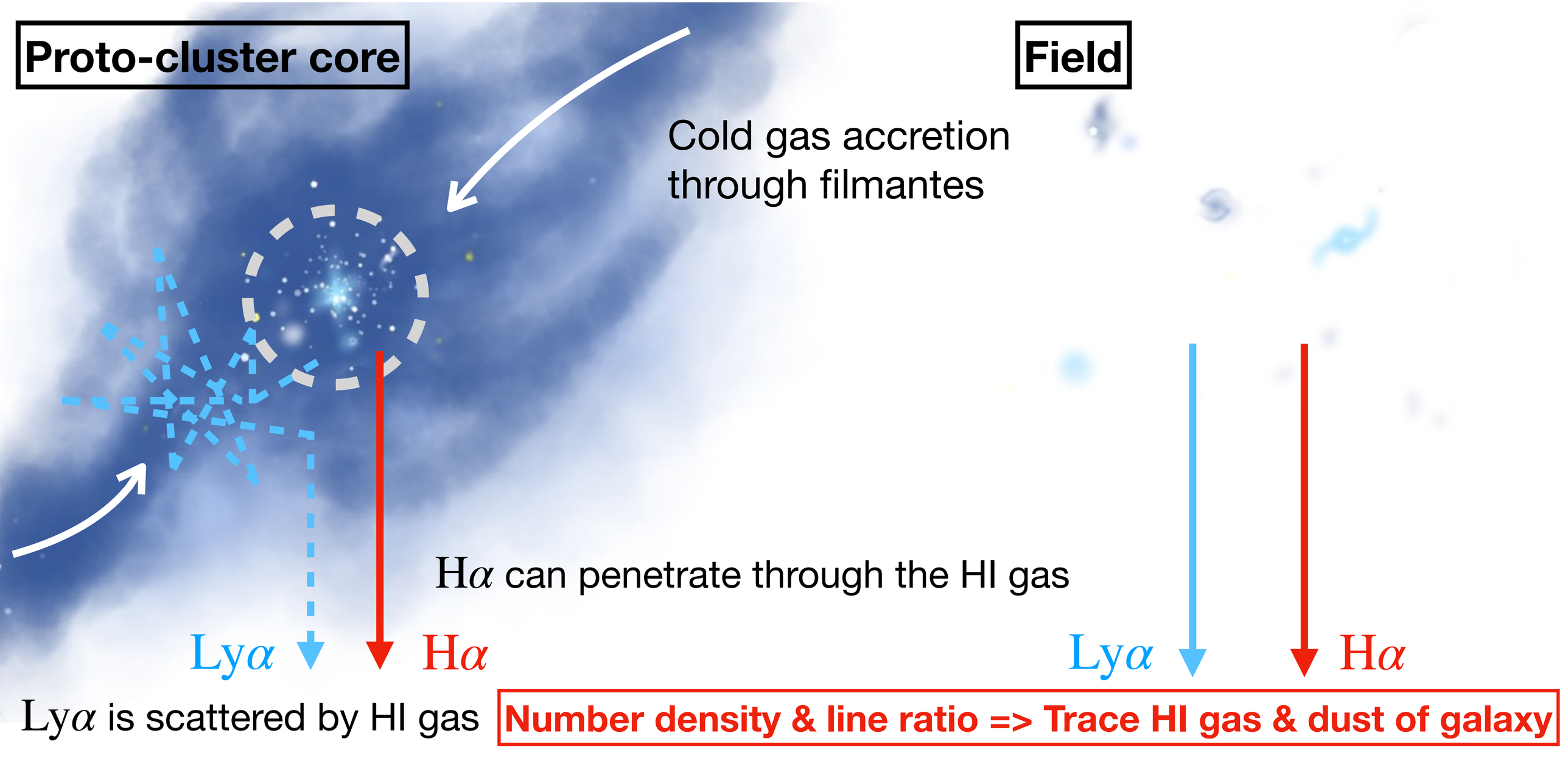
Summary of Enhanced star-forming activity

✔ In cosmic-noon, the environment acts to enhance SF activity

✔ **Mass** and **evolutional state** dependentnce of enviromental effects

ΔMS Star formation act.		High-mass	Intermediate-mass (Core)	Low-mass
Spiderweb	Mature	✕	✕	○
USS1558-003	Young (Clumpy)	✕	○	○

Dual NB imaging will trace HI gas



Lyα is scattered by HI gas

Number density & line ratio => Trace HI gas & dust of galaxy

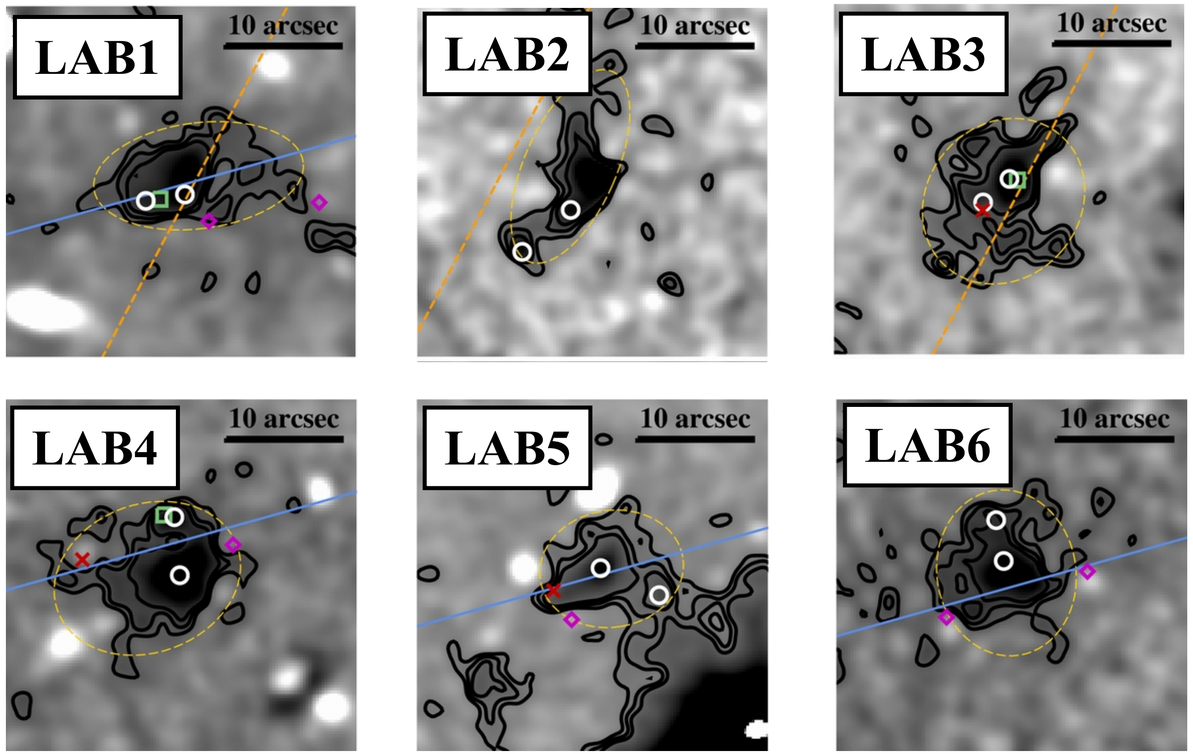
Filamentary protocluster HS1700 at z=2.3

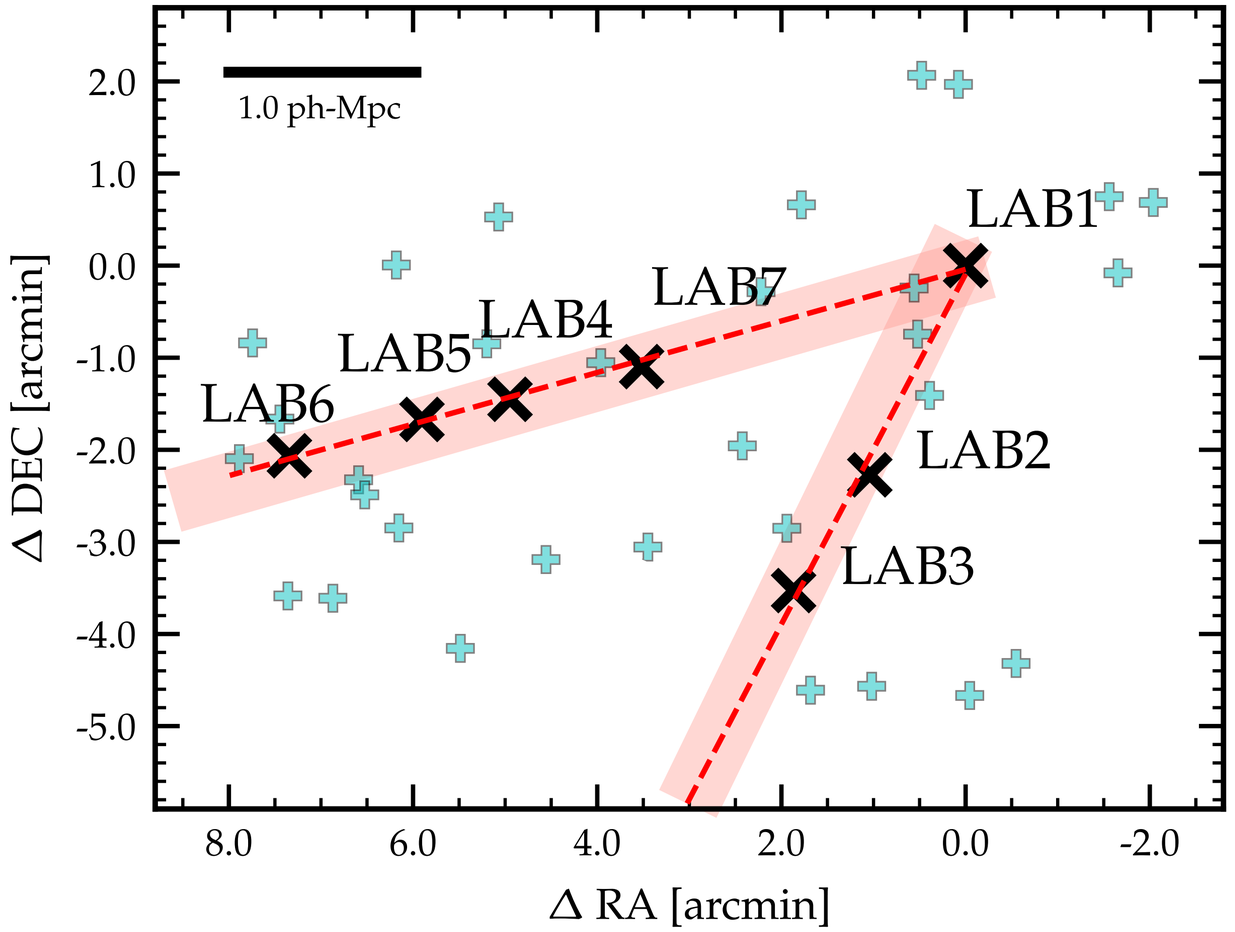
Proto-cluster HS1700+64

$z = 2.30$

a rich cluster today with a halo mass

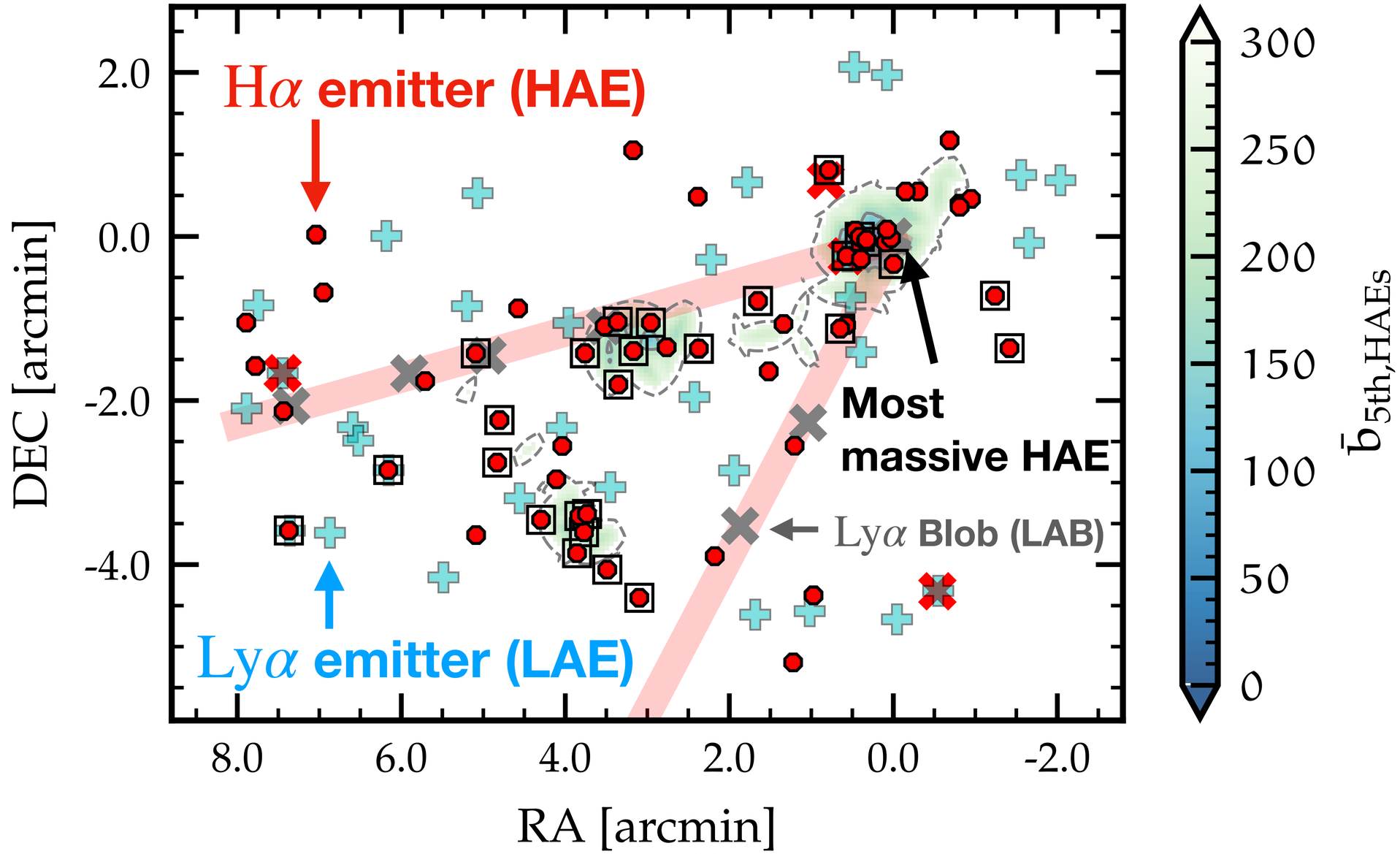
$M_h \sim 10^{15}\,\mathrm{M}_\odot$ at $z = 0$ (Steidel et al. 2005)



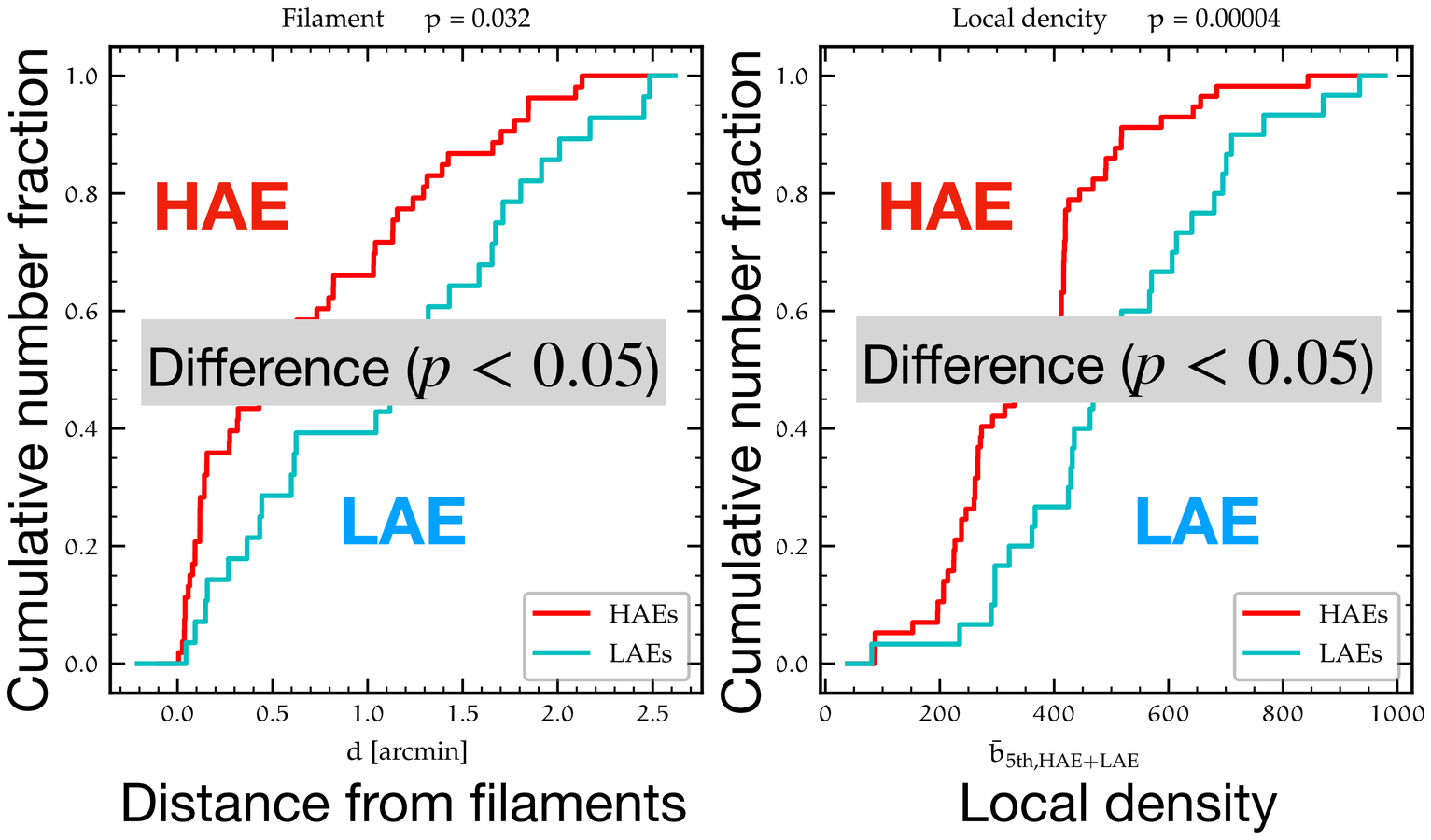


Erb et al. 2011

Filamentary protocluster HS1700 at z=2.3



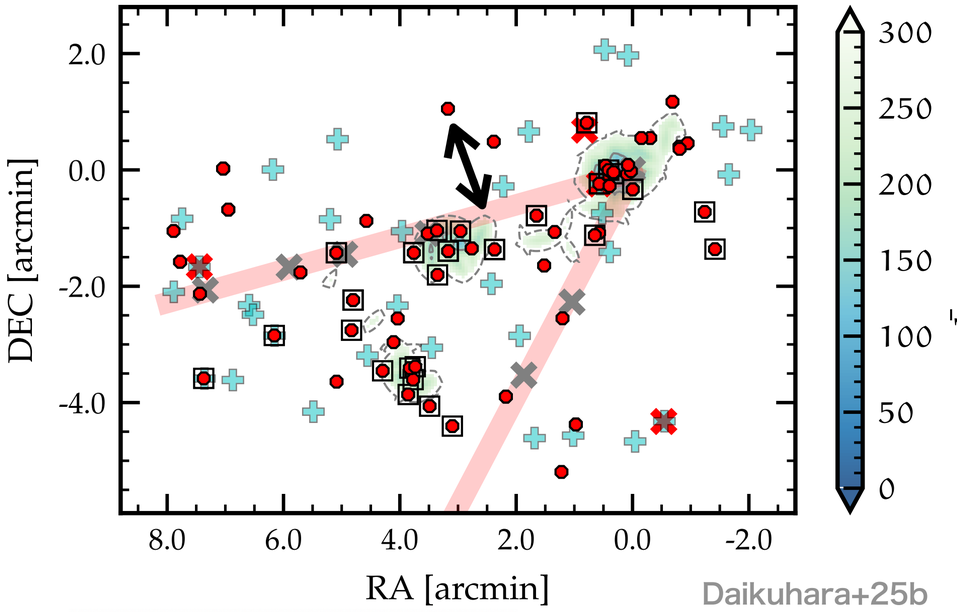
Filamentary protocluster HS1700 at z=2.3



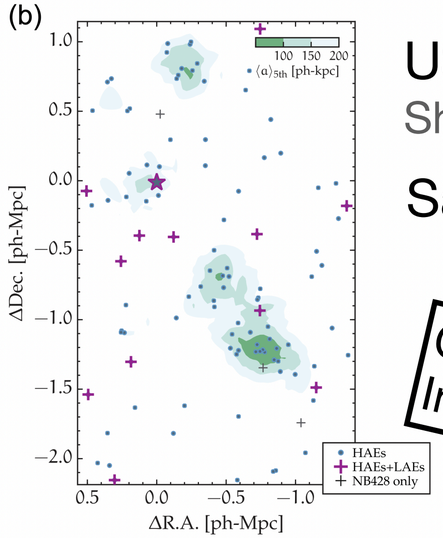
Distance from filaments

Local density

Daikuhara+25b



Daikuhara+25b



USS1558 (z=2.5)
Shimakawa+17

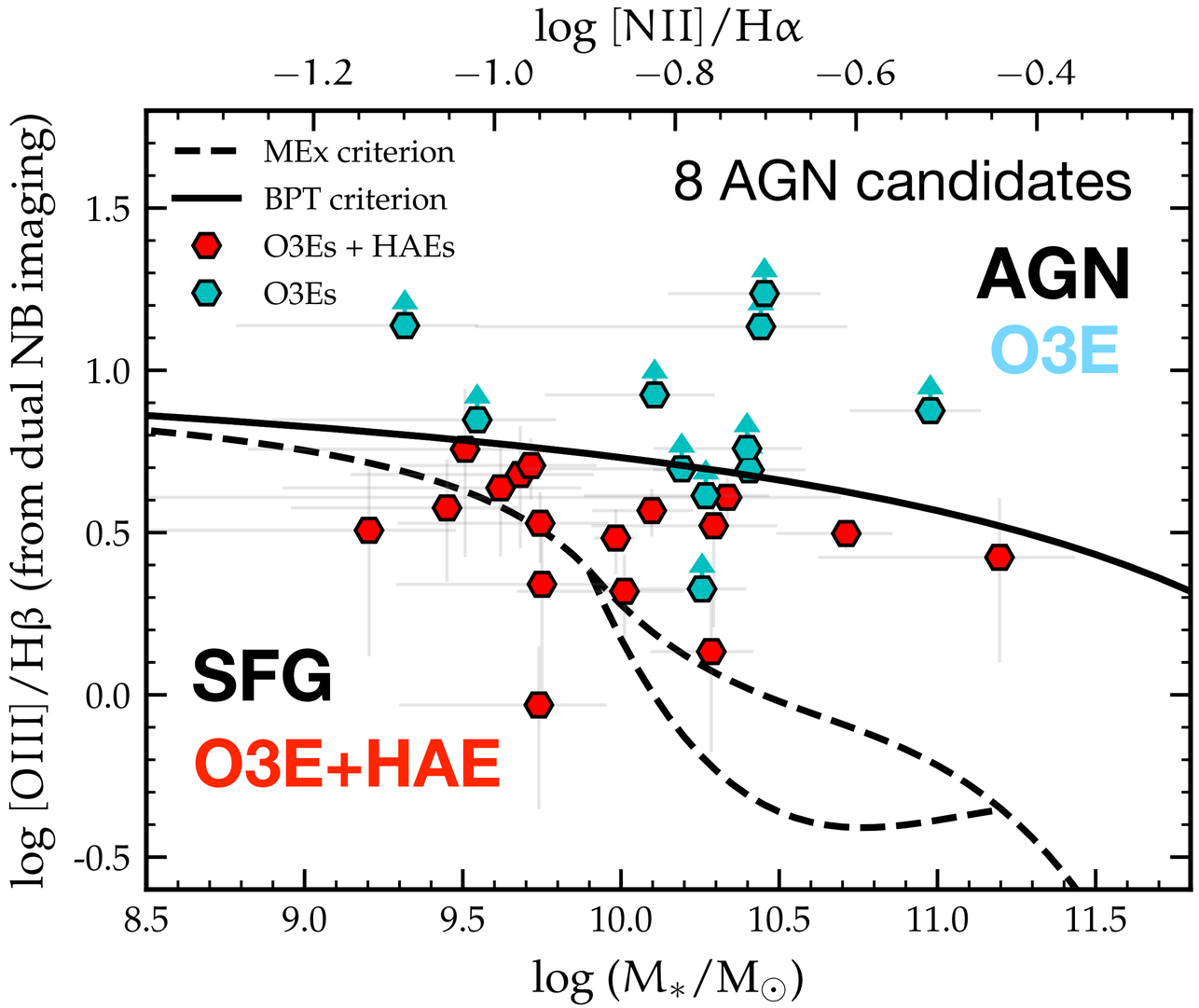
Same trend!

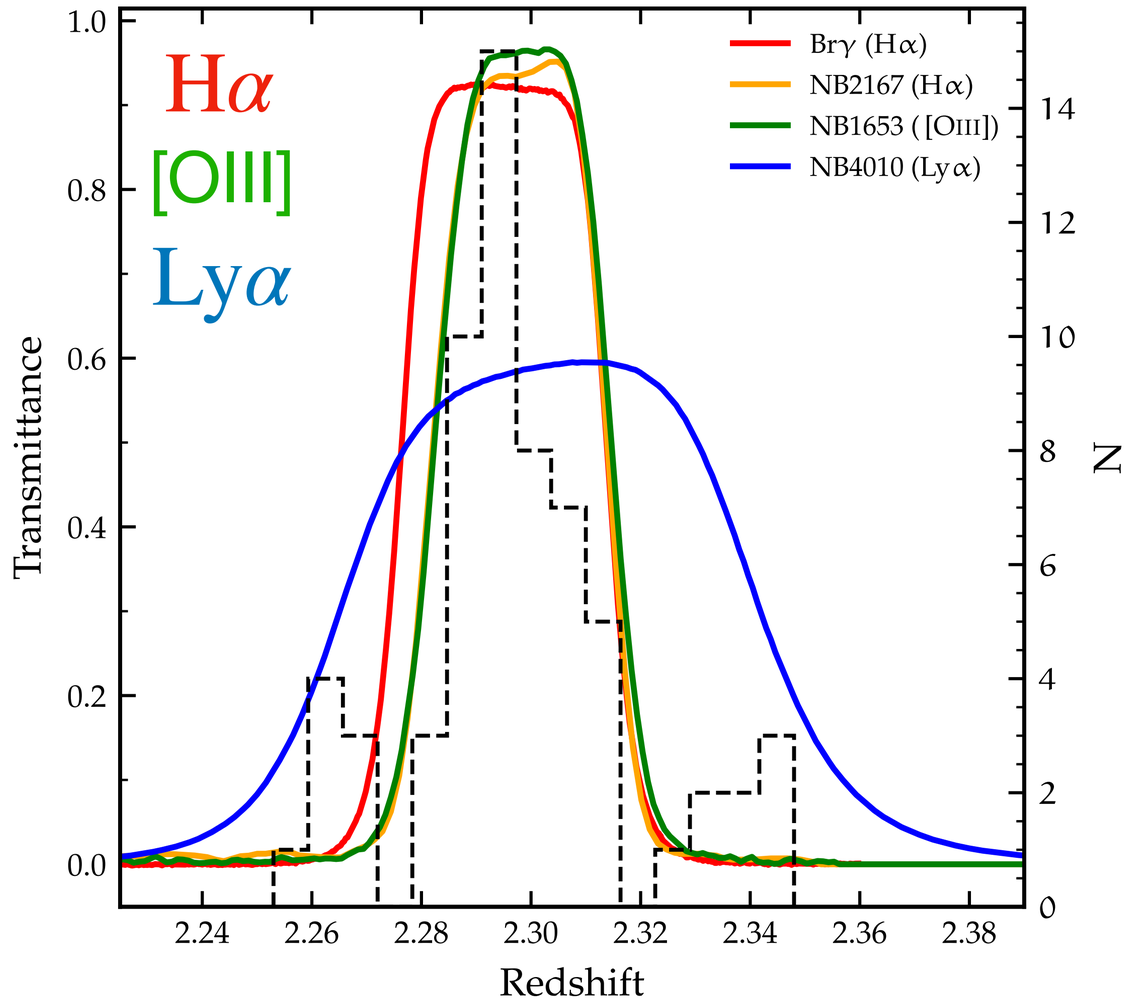
Common trend
In young protocluster?

LAEs tend to avoid **filaments and dense region**.

=> HI gas? Dust attenuation?

Dual NB trace AGN

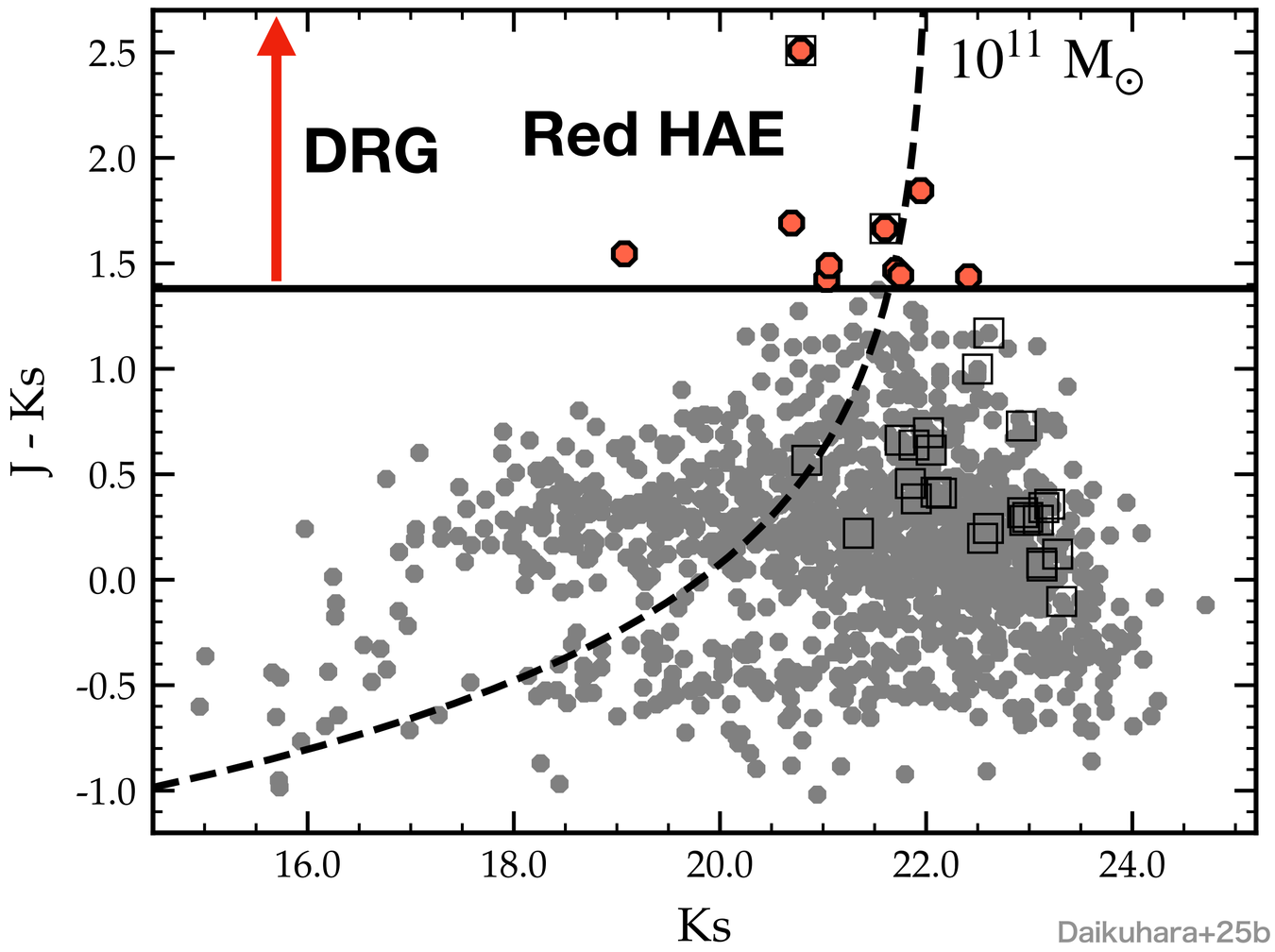




Daikuhara+25b

Distant red galaxies (DRGs)

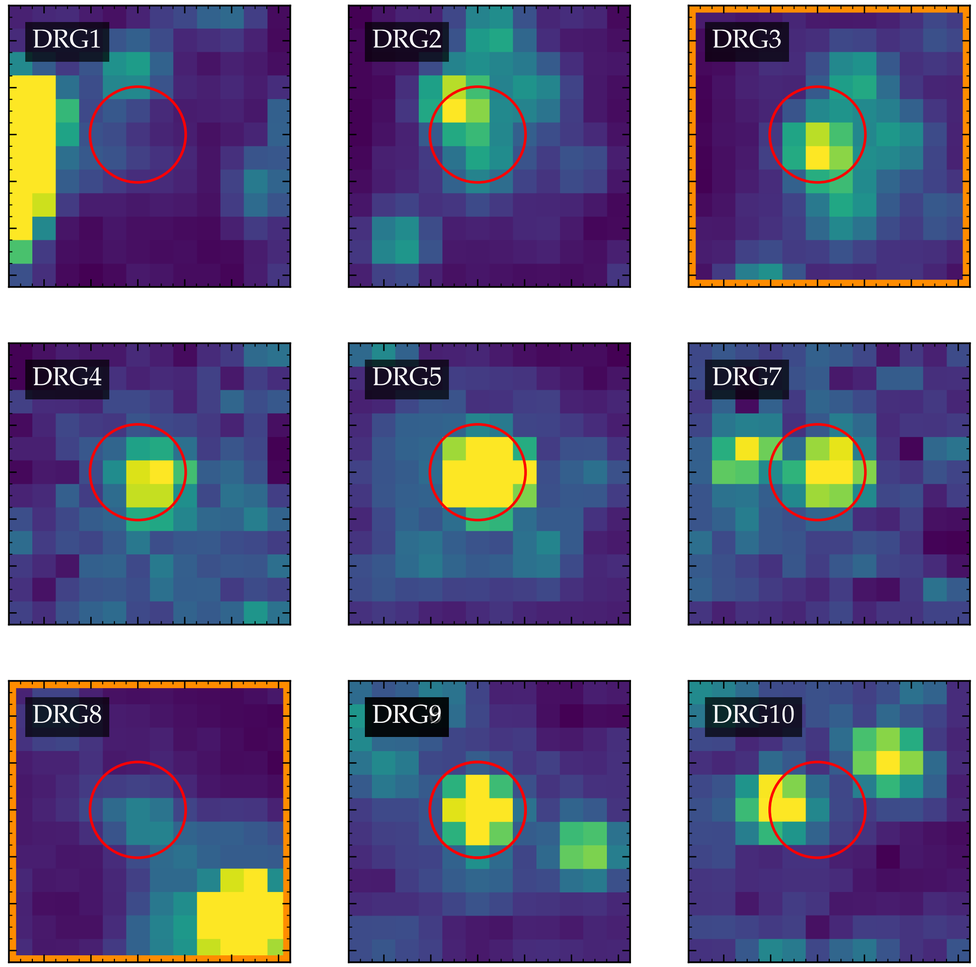
DRGs => Massive galaxies



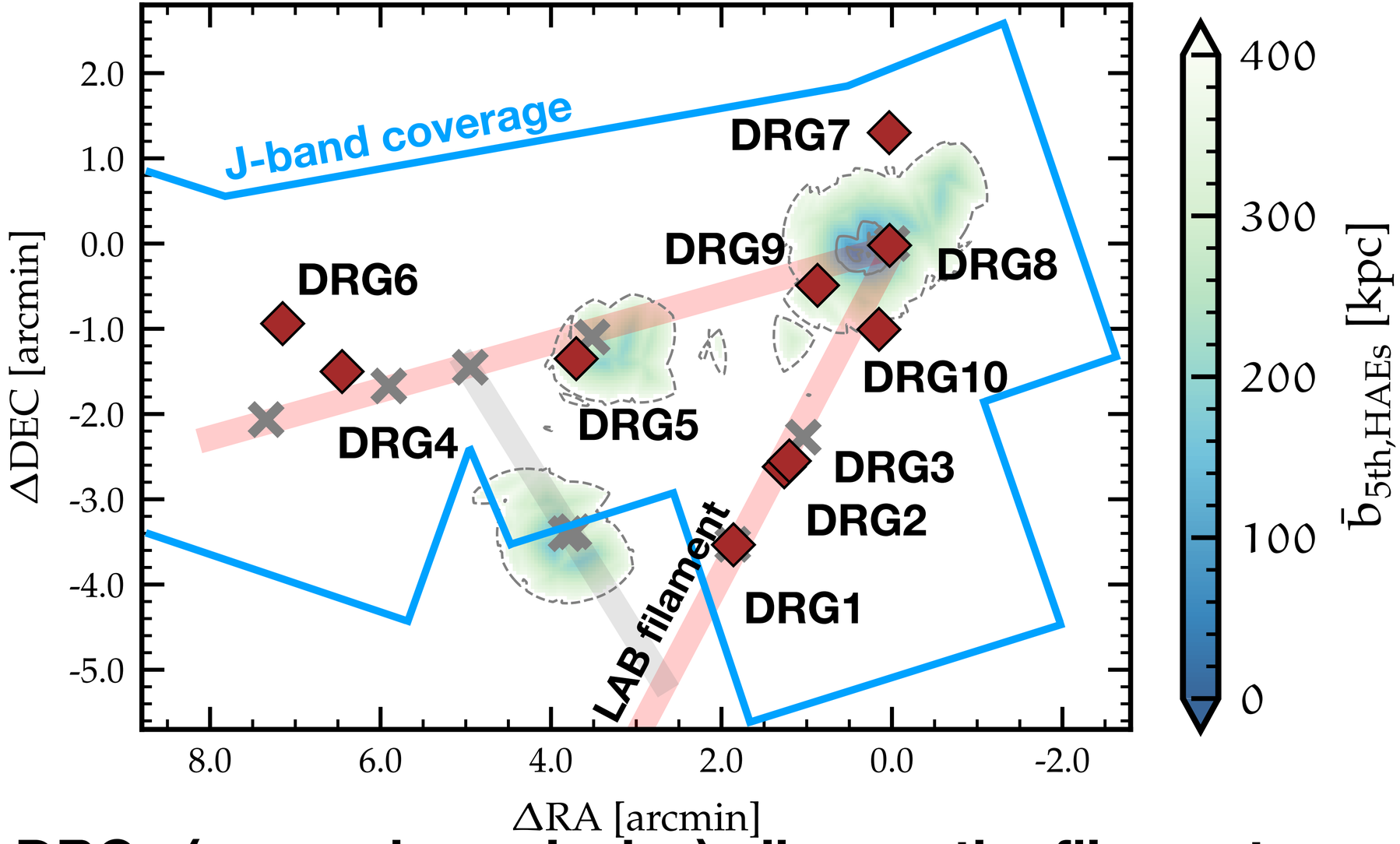
Daikuhara+25b

Spitzer MIPS (24 um)

PAH = tracer of dusty star-formation



Distant red galaxies (DRGs)



DRGs (= massive galaxies) align on the filaments.

Protocluster evolution

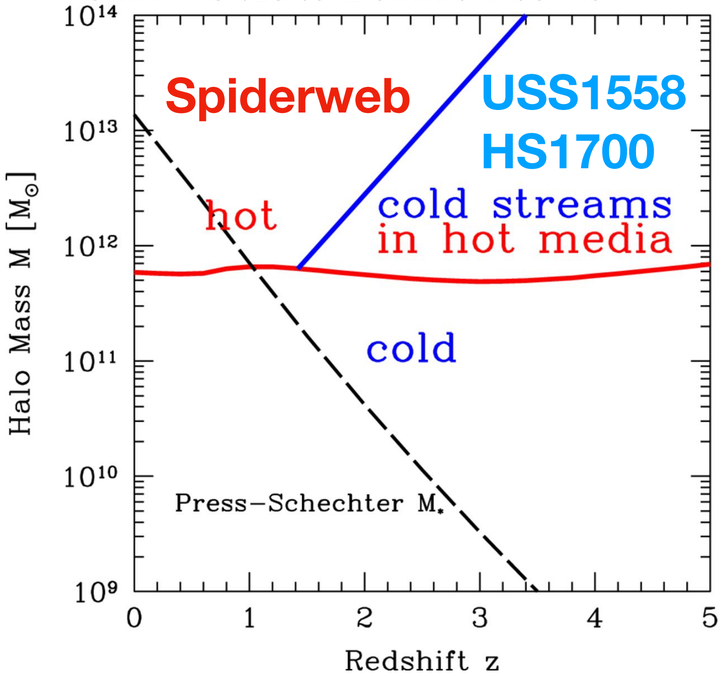
Suppressed SF activites

Maturing phase

Growing phase in the core and filament

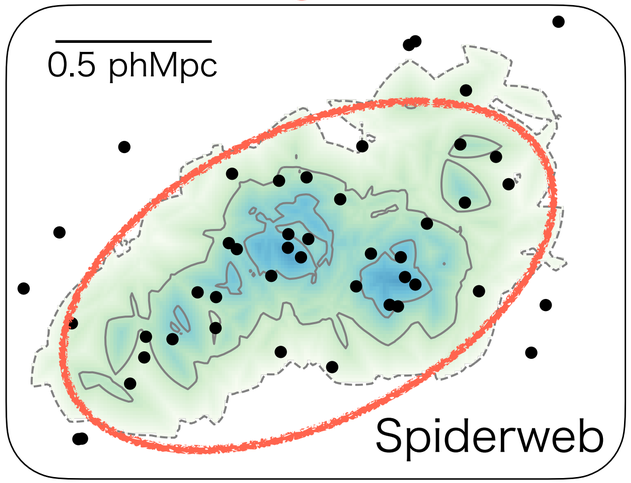
Enhanced SF activites

Credit: NASA/ESA/JPL-Caltech/Yale/CNRS



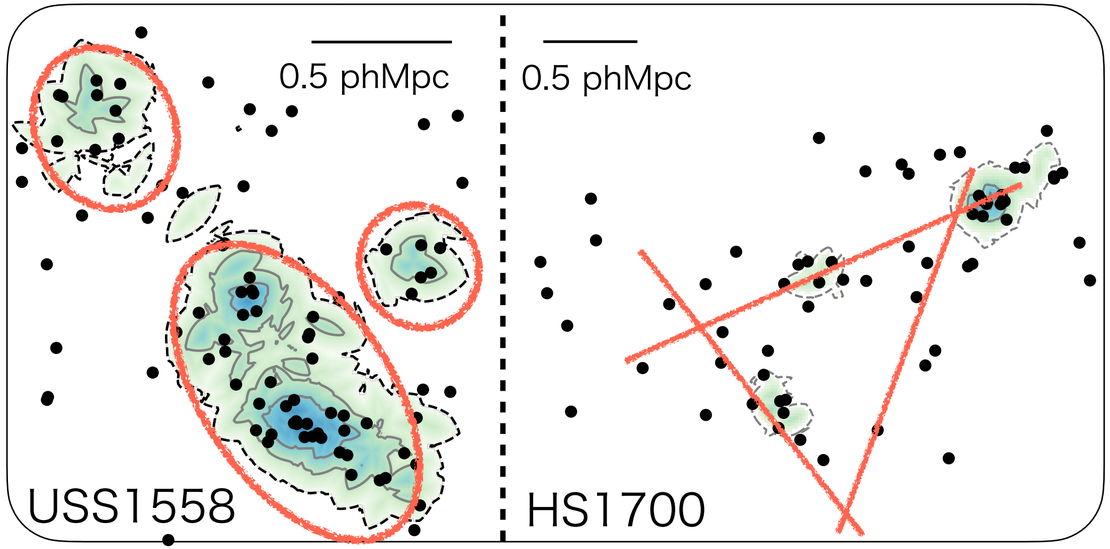
Dekel+13

“Inefficient gas accretion”



Hot gas formation
Metal enrichment

“Efficient gas accretion”



Massive galaxy formation
Enhanced SF, metal deficit