中國科學院紫金山天文台

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# Galaxy Structure Evolution in protoclusters at z=2-3

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- Part I: What boost galaxy merger rates in two massive protoclusters at z=2.24 (2023, mnras, 523, 2422)
- Part II: Galaxy Structure evolution in protoclusters at z=2-3

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## What boost galaxy mergers in two massive galaxy protoclusters at $z = 2.24$?

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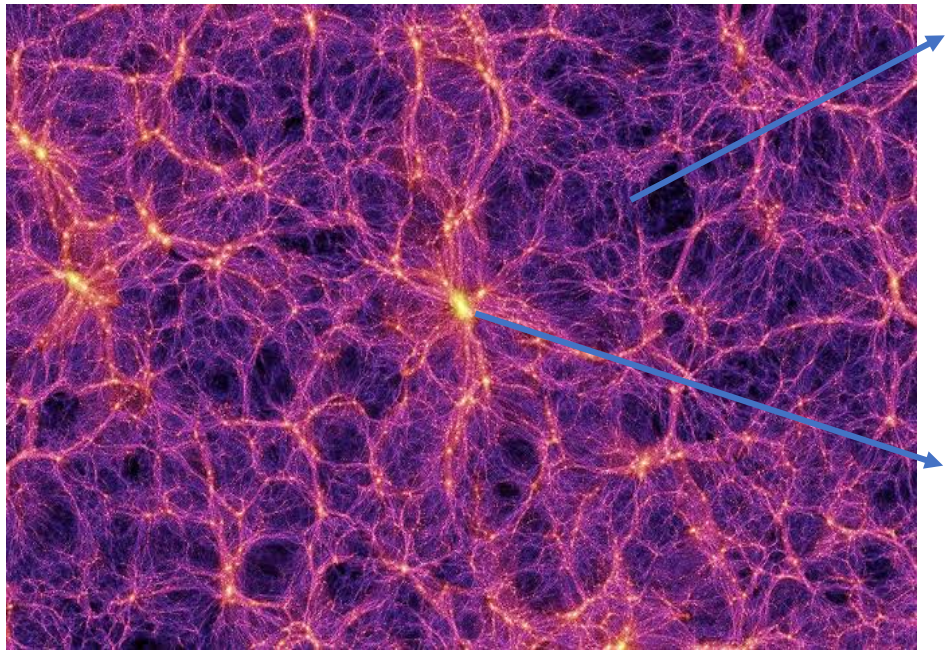
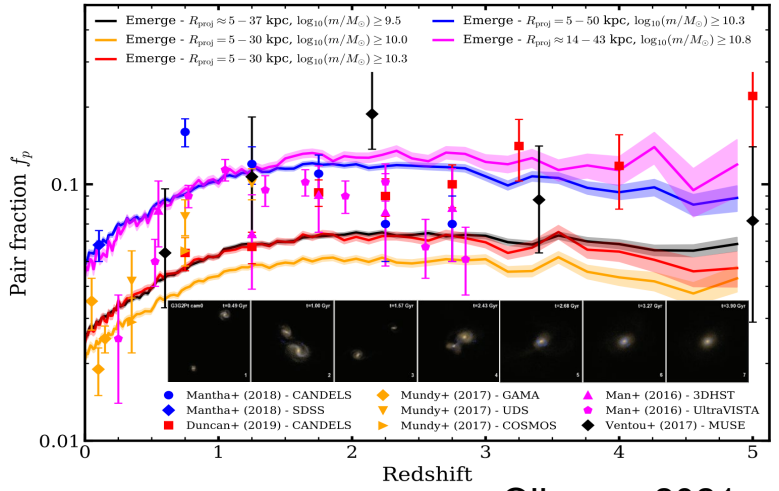
# Introduction

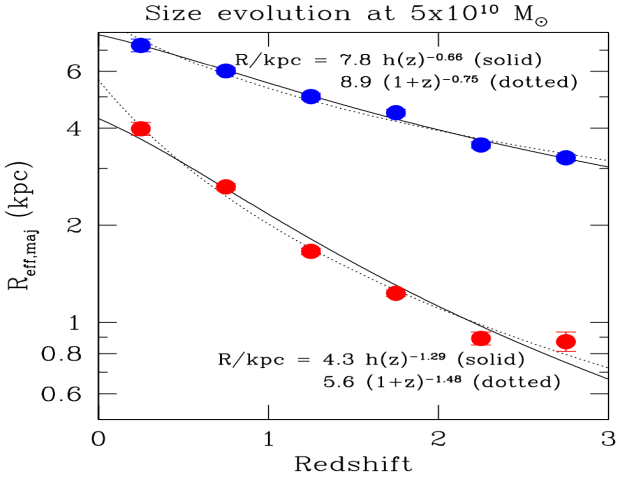
- Galaxy morphology evolution in general field and mature clusters

## Cosmic web

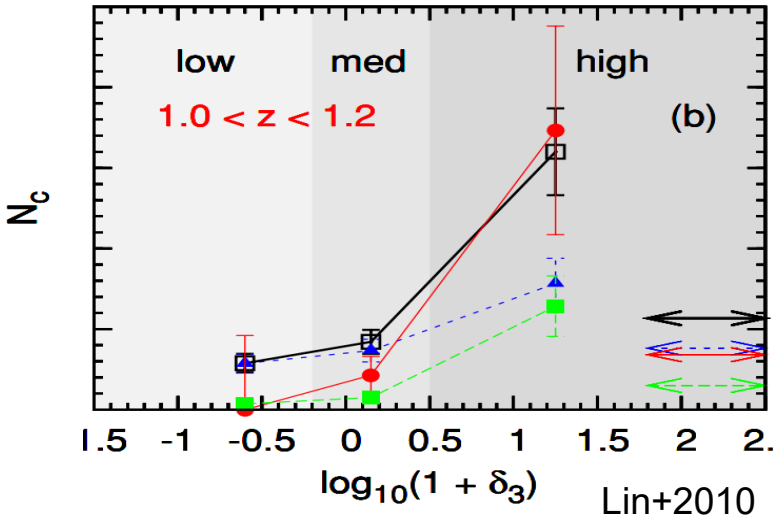




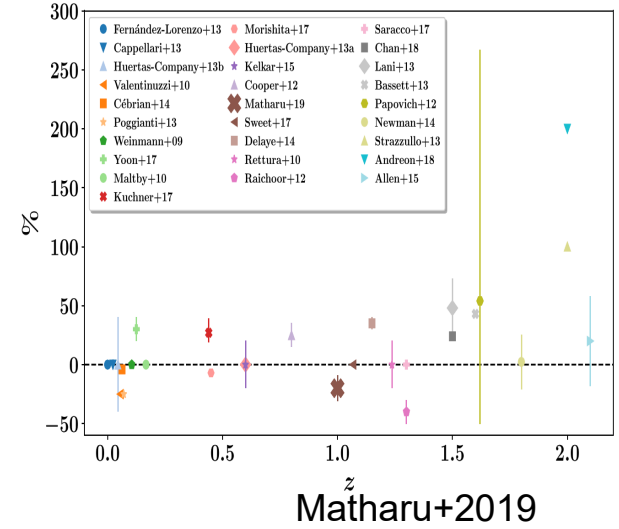

O'Leary+2021




Van der Wel+2014




Lin+2010

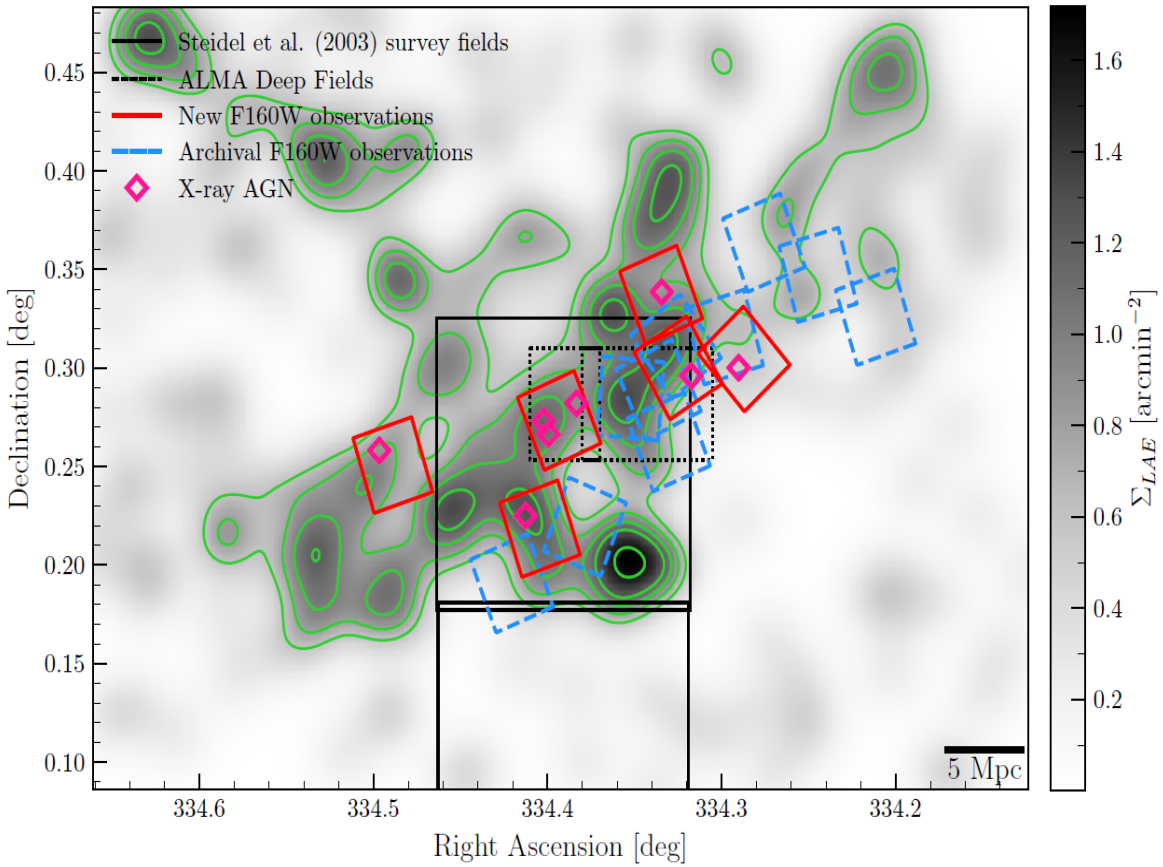



Matharu+2019

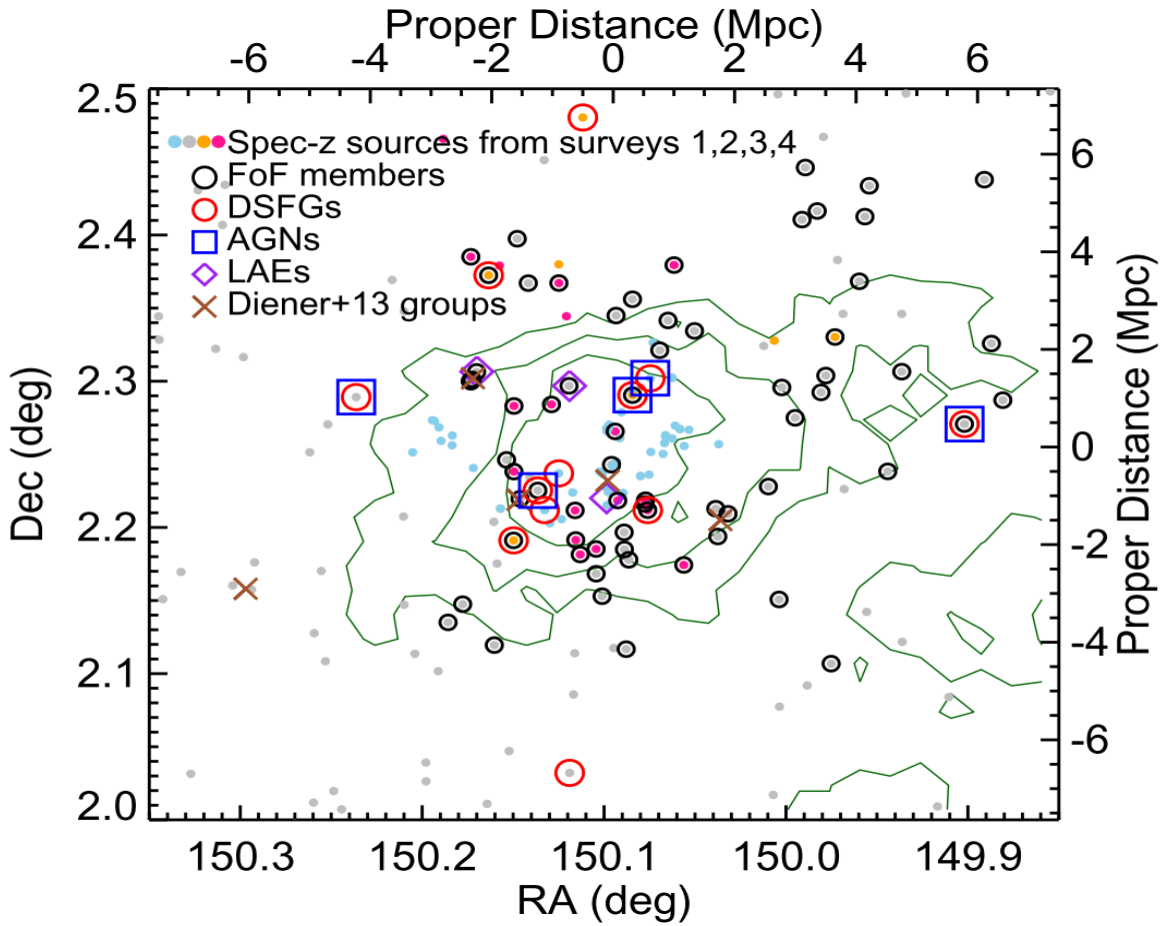
Less study on galaxy morphology in (proto)clusters at z=2-3

# Introduction

➢ Controversial results in high-z overdense environment




SSA22 at z=3.1 Monson+2022

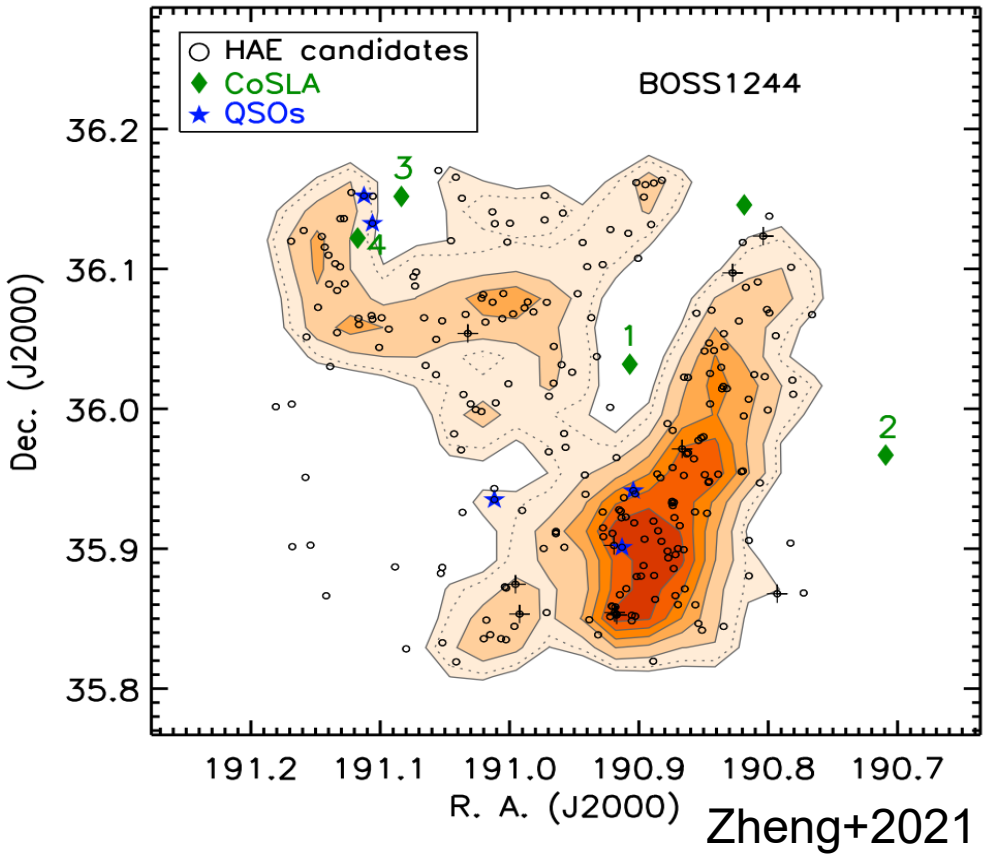



ZFIRE at z=2.1 Hung+2016

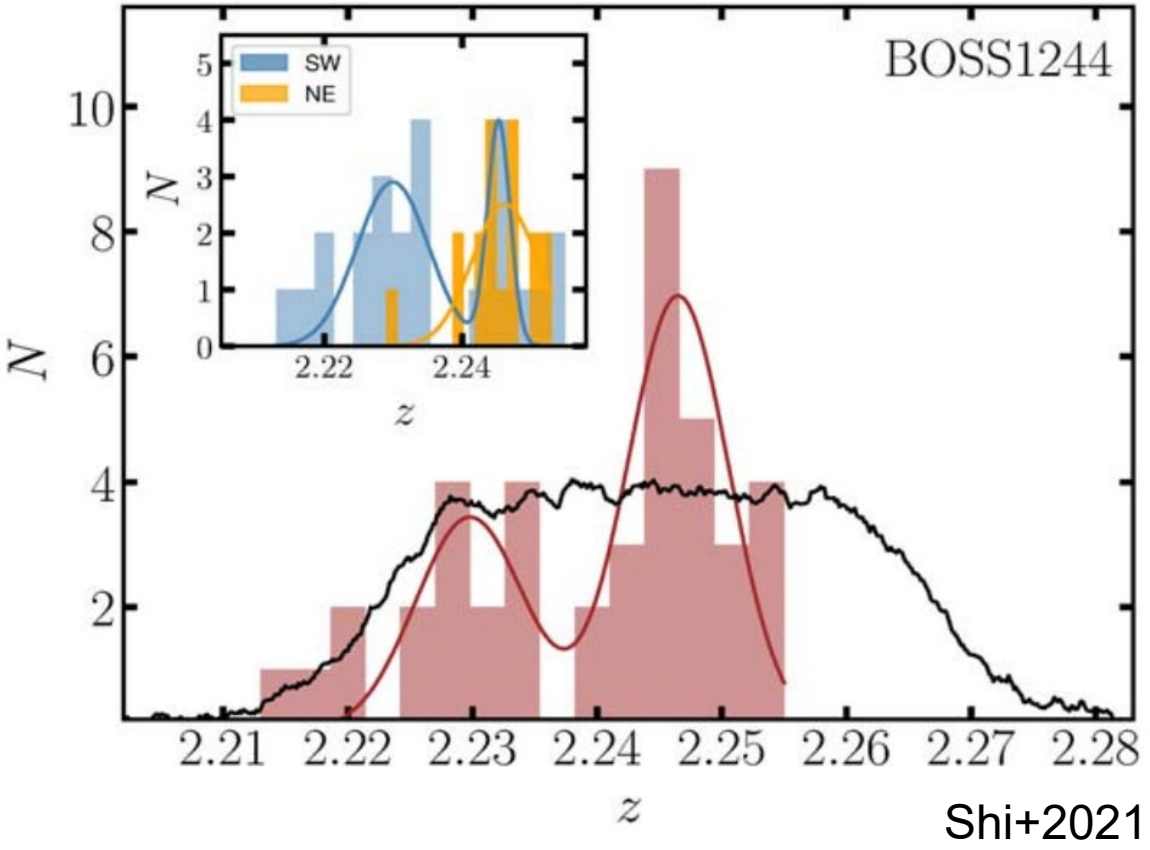
How different dynamical states of protocluters (overdensity factor, velocity dispersion) affect the galaxy size (gas accretion, disk instability) and galaxy merger rate?

# ◆ Sample and Observations

➢ Two massive protoclusters at z=2.24




Zheng+2021

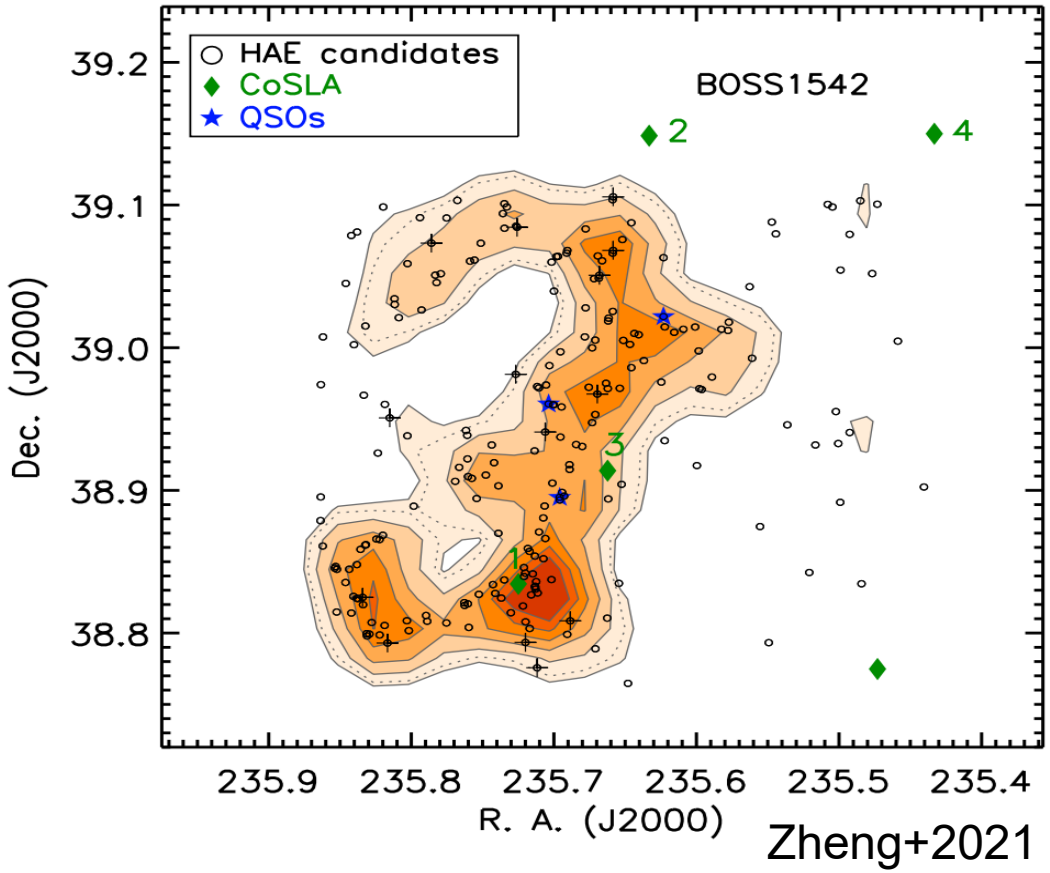



Shi+2021

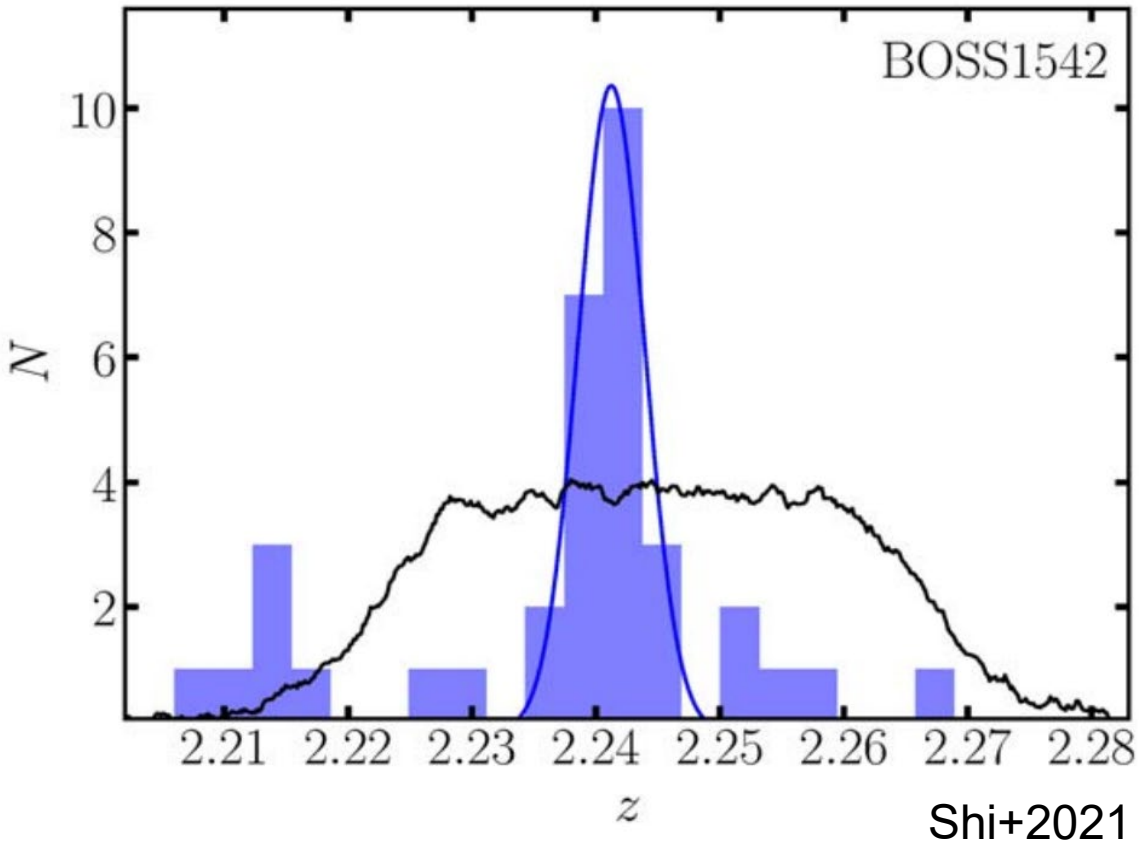
BOSS1244: two substructures with velocity dispersions of 304 km/s and 430 km/s.

# ◆ Sample and Observations

➢ Two massive protoclusters at z=2.24




Zheng+2021

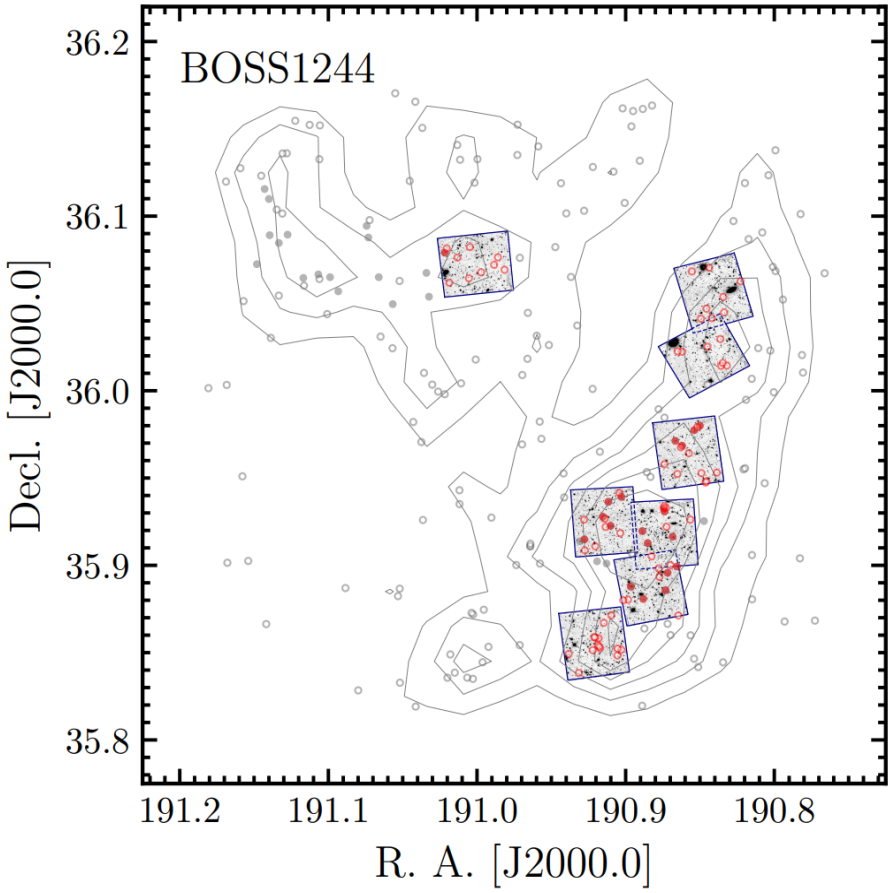


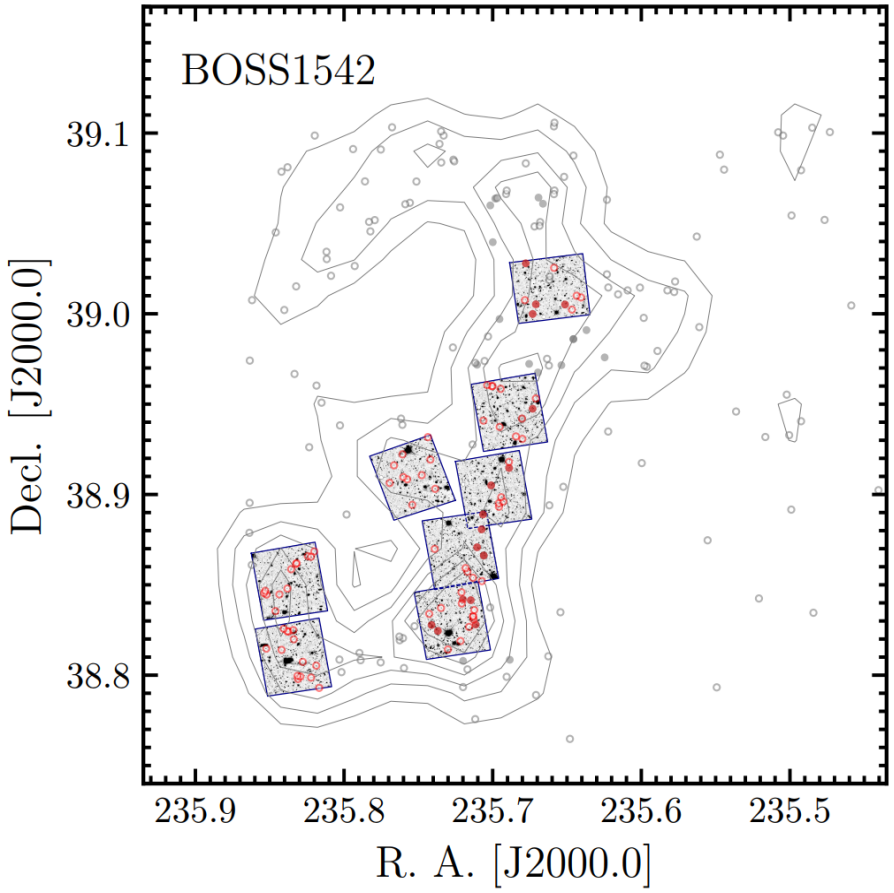

Shi+2021

BOSS1542: a giant filament structure with velocity dispersion of 255 km/s.

# ◆ Sample and Observations

➢ HST observation in two massive protoclusters

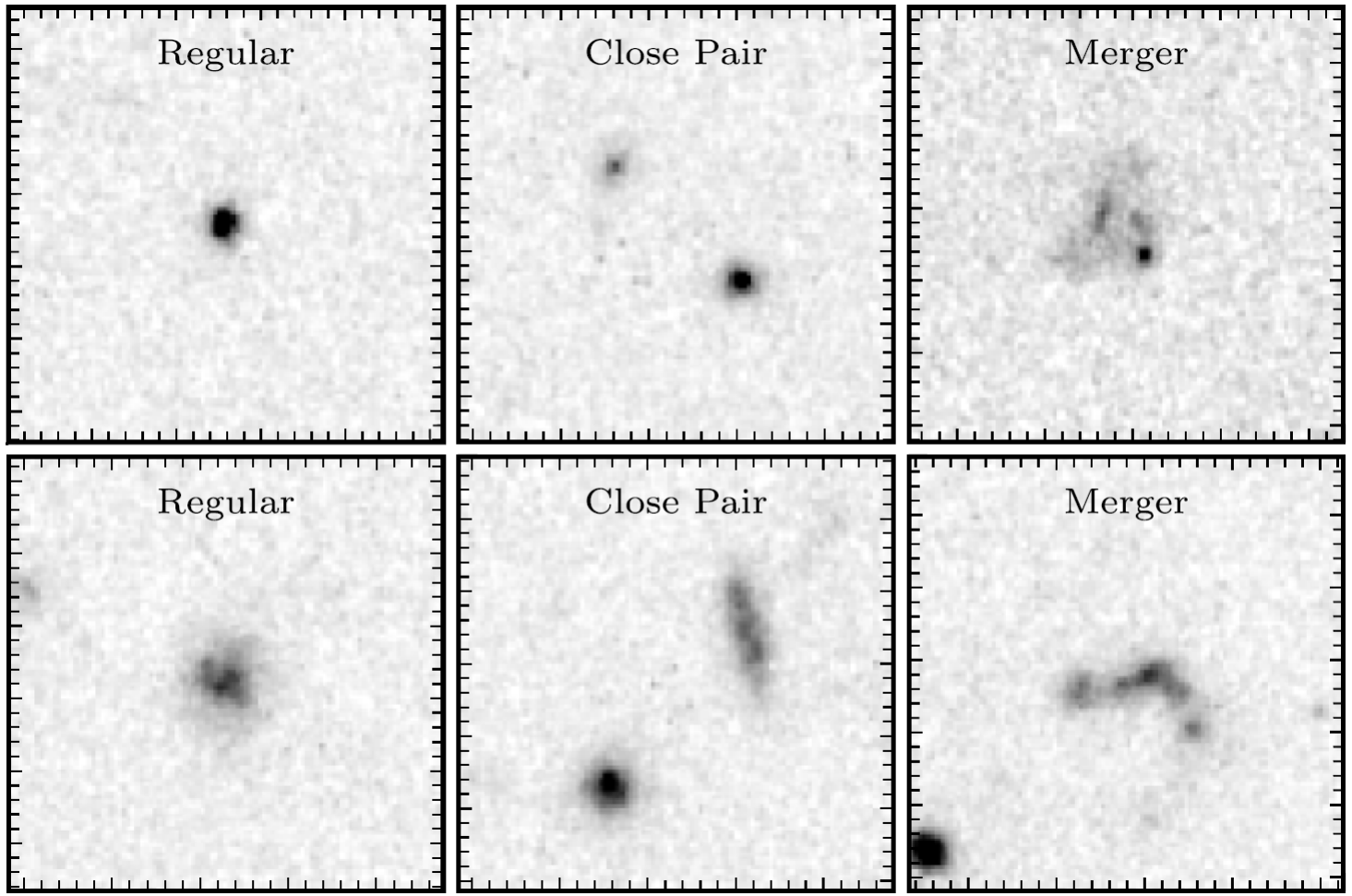



- HST WFC3 F160W Observation for BOSS1244 and BOSS1542 (GO-15266, PI: Z. Cai)
- GALAPAGOS (SExtractor+Galfit) performs 2D Sersic model fitting.
- Sample: 85/86 HAEs with HST observation in BOSS1244/1542

# ◆ Pair Fraction and Merger Rate

## ➢ Pair Fraction and Merger Rate




- Regular: isolated galaxies;
- Merger: disturbed morphologies;
- Close Pair: multi-objects within 5 < R < 30 kpc (3.64”), H-band flux ration < 1/4;

Cutout image: 6 arcsec X 6 arcsec (49.4 kpc at z=2.24)

# ◆ Pair Fraction and Merger Rate

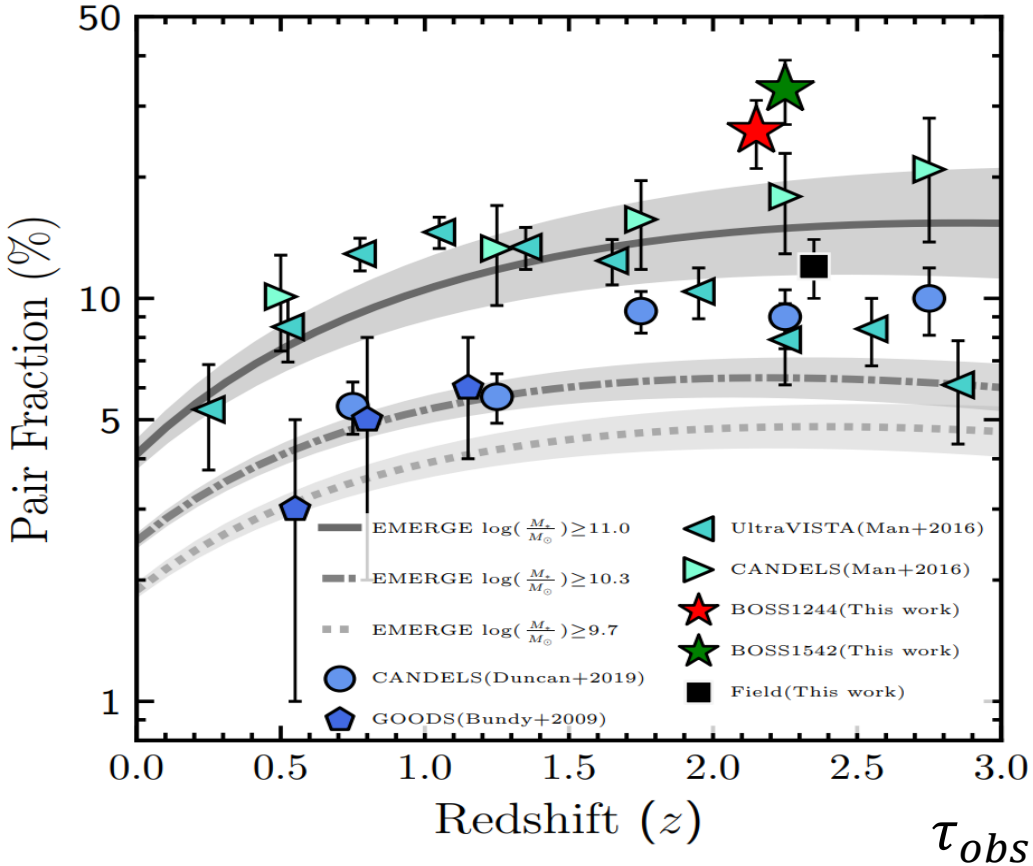
## ➢ Pair Fraction and Merger Rate

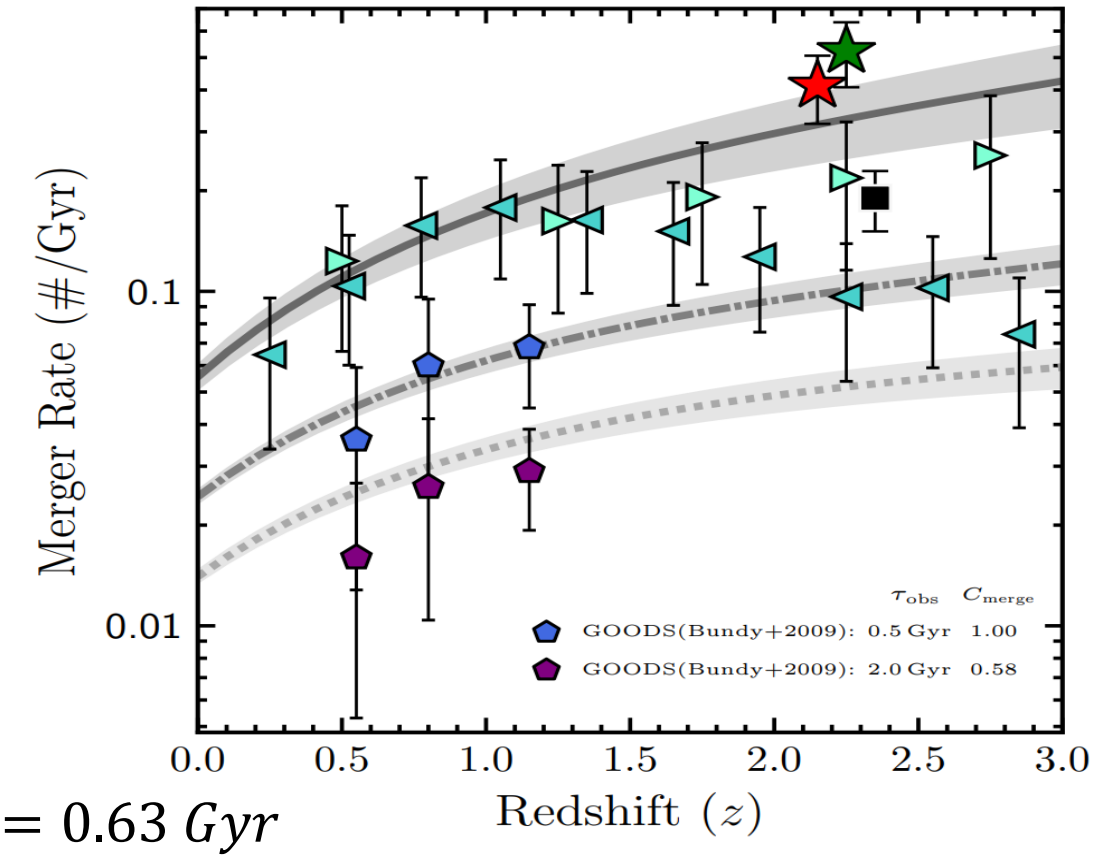
| Field | Sample | $N_{\rm tot}$ | $N_{\rm pair}$ | $N_{\rm merger}$ | $f_{\rm pair}$ (%) | $f_{\rm pair,corr}$ (%) | $f_{\rm merger}$ (%) |
|---|---|---|---|---|---|---|---|
| BOSS1244 | $z_{\rm spec}$ | 18 | 10 | 4 | 56±12 | 27±10 | 22±10 |
| | all | 61 | 31 | 16 | 51±6 | 22±5 | 26±6 |
| BOSS1542 | $z_{\rm spec}$ | 13 | 12 | 4 | 92±8 | 63±13 | 31±13 |
| | all | 61 | 38 | 19 | 62±6 | 33±6 | 39±6 |
| CANDELS | all | 455 | 55 | ··· | ··· | 12±2 | ··· |

- Control Sample: SFGs with stellar mass $\log\left(\frac{M_*}{M_\odot}\right) > 10.3$ , Ks<23.2 mag in 2.1<z<2.4 in CANDELS field.
- MCMC simulation: Randomly pick up 244/233 SFGs corresponding to the distribution of Ks, spec-z, and stellar mass for HAEs, and reconstruct the density map of BOSS1244/BOSS1542, leading to ~30% contamination from fore/background galaxies.

# ◆ Pair Fraction and Merger Rate

➢ Pair Fraction and Merger Rate



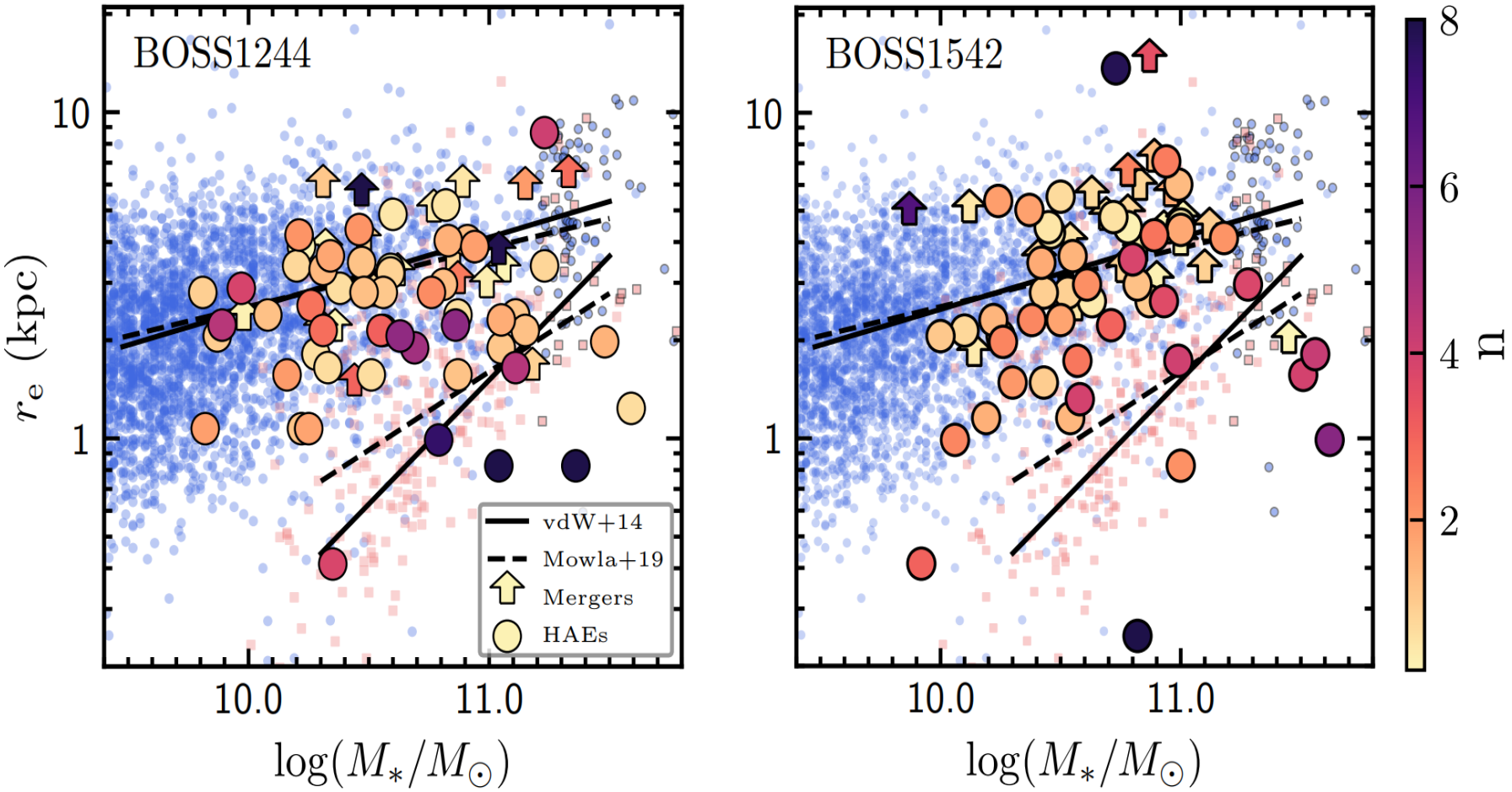




$$\tau_{obs} = 0.63\ Gyr$$

The merger rates and pair fraction in BOSS1244 (BOSS1542) is 1.8 (2.8) times that of the general fields with merger rate at the same epoch.

# ◆ Stellar-Mass-Size Relation

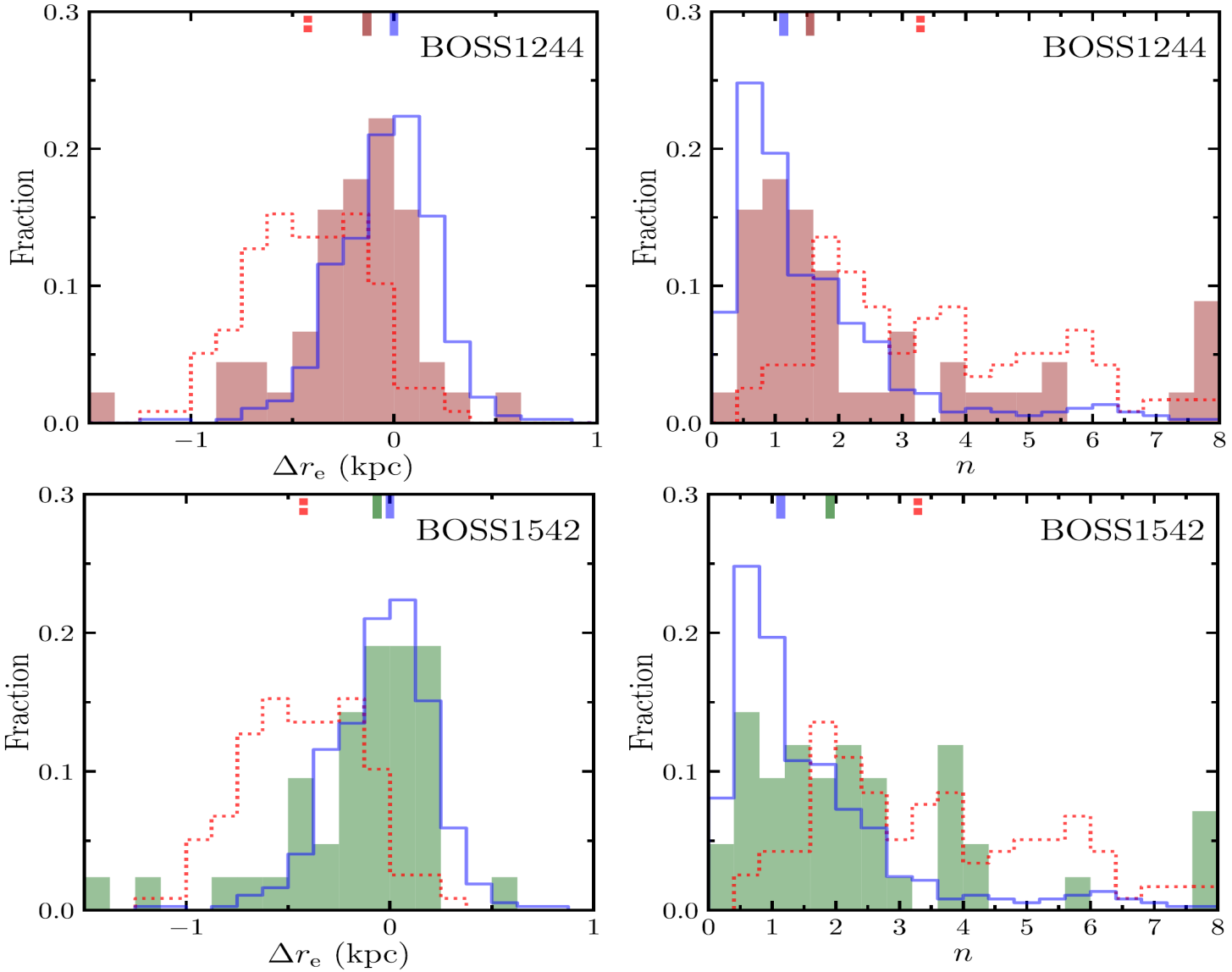
➢ Mass-Size Relation




- The majority of HAEs follow the trend of the field massive SFGs, but with larger scatter for re and n → wild structure evolution.
- Nine (six) extremely massive (logM/Msun>11) compact galaxies in BOSS1244/1542. Disk-dominated in BOSS1244, and bulge-dominated in BOSS1542.

# ◆ Stellar-Mass-Size Relation

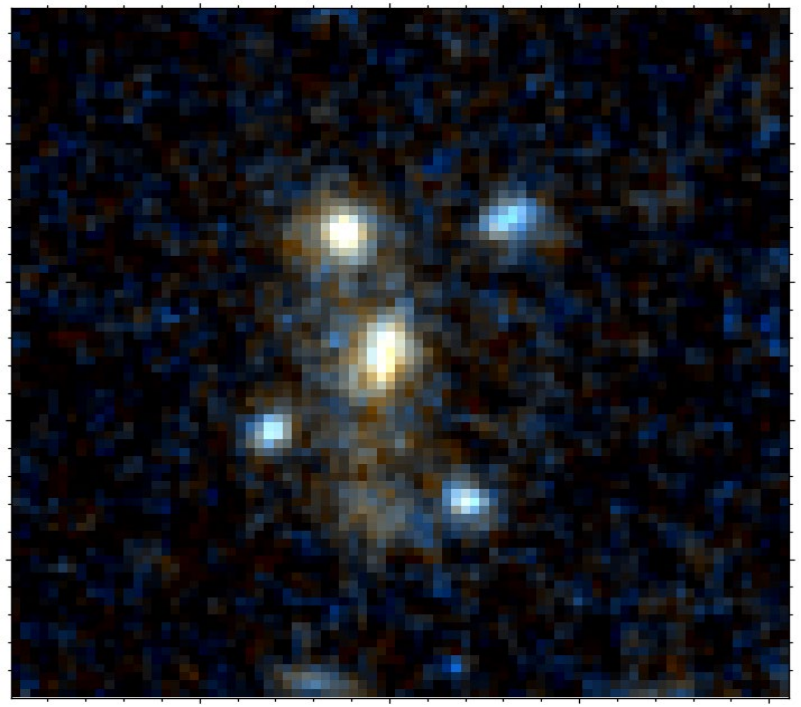
## ➢ Mass-Size Relation

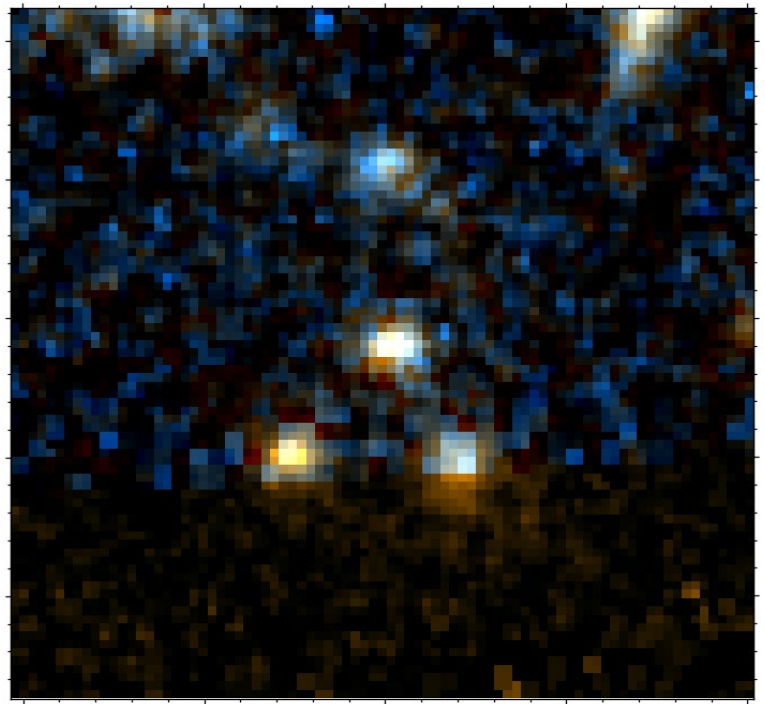



- The median re (n) of the HAEs in BOSS1244/1542 are 2.80/2.97 kpc (1.55/2.97), smaller (larger) than re=3.27 kpc (n=1.13) in general field.
- Two-dimensional KS-test (KS2D2S) for re and n: p-value of 0.024 (0.055) for BOSS1244 (BOSS1542) and field SFGs.

# ◆ BOSS1244 versus BOSS1542

➢ Groups within protoclusters



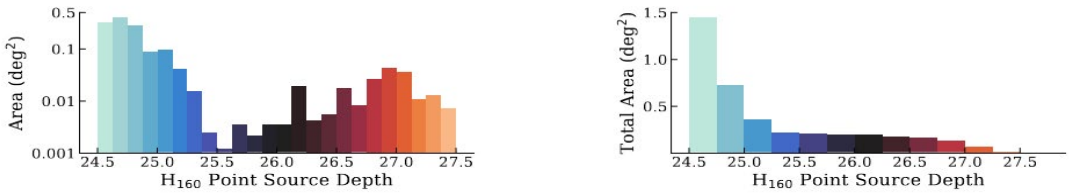


RGB color:
Blue: F125W (PI: X. Wang);
Green: F125W+F160W;
Red: F160W.

Group-scale overdensities are inclined to locate in BOSS1542, less seen in BOSS1244
→Both global and environments play important role in raising galaxy merger rates.

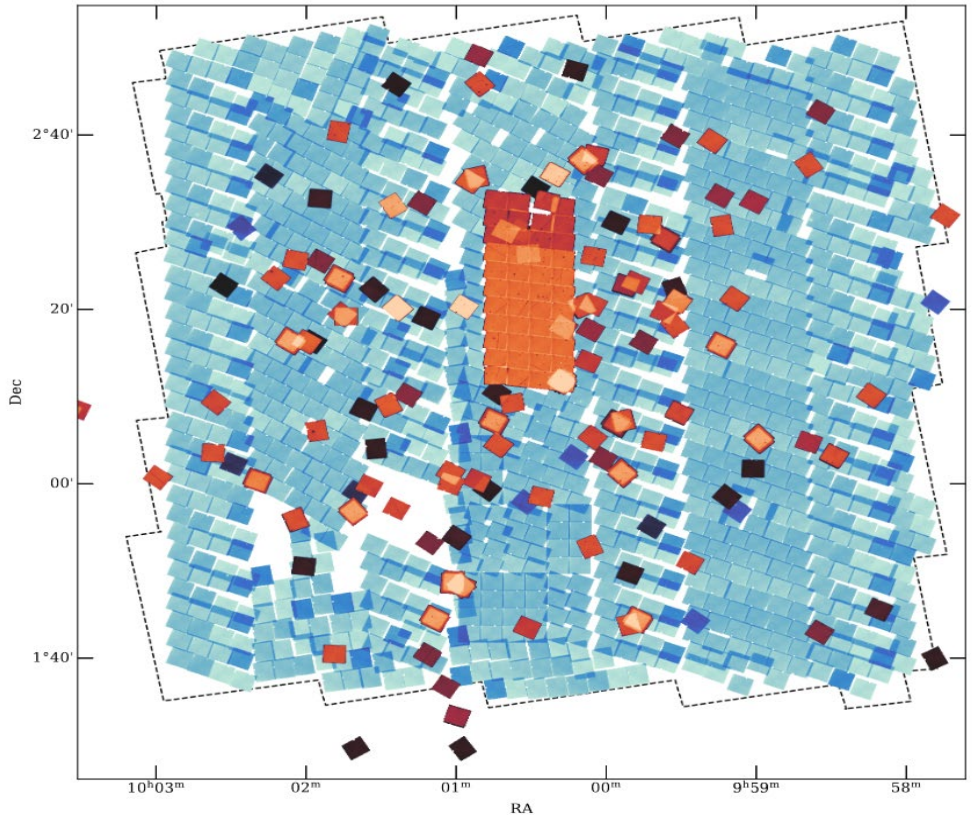
# ◆ Protoclusters at z=2-3

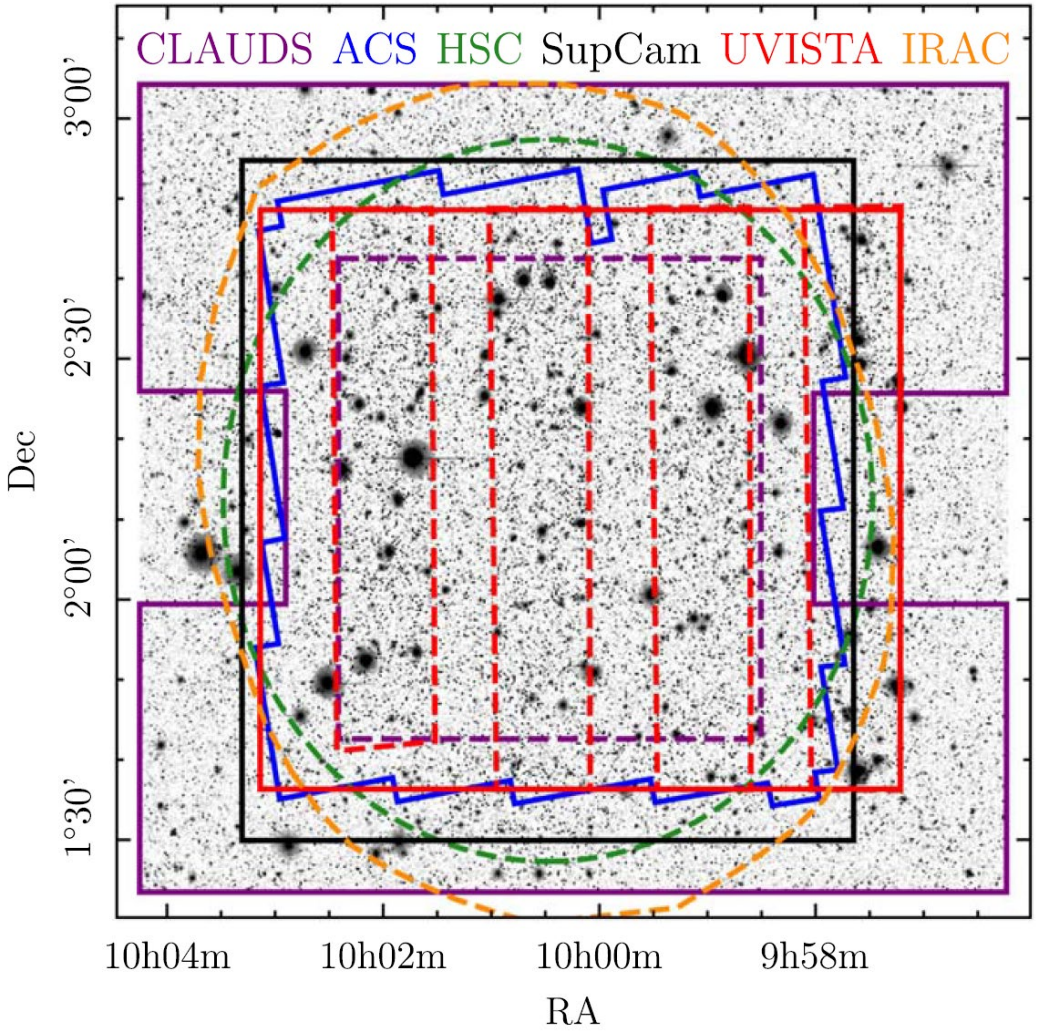
➢ 3D-DASH: The Widest Near-Infrared Hubble Space Telescope Survey





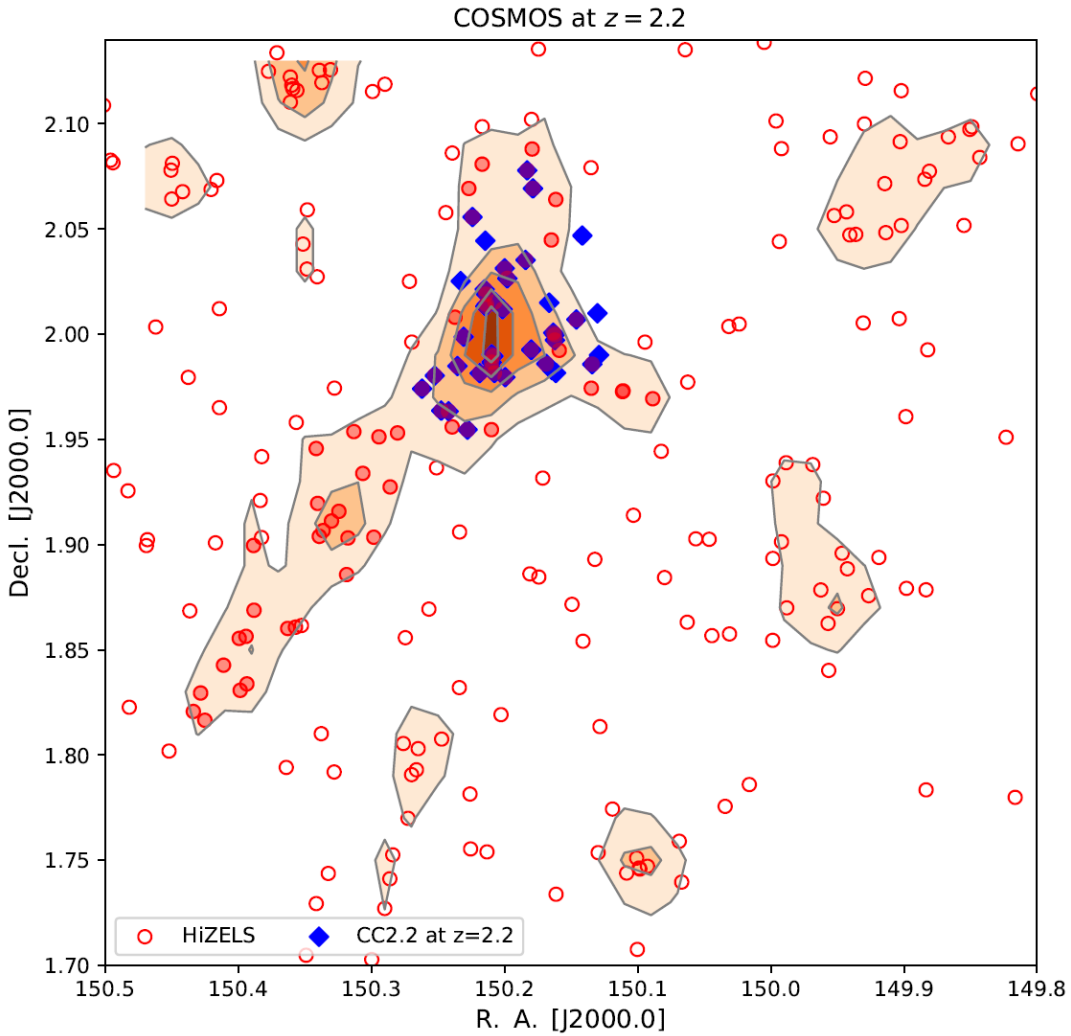


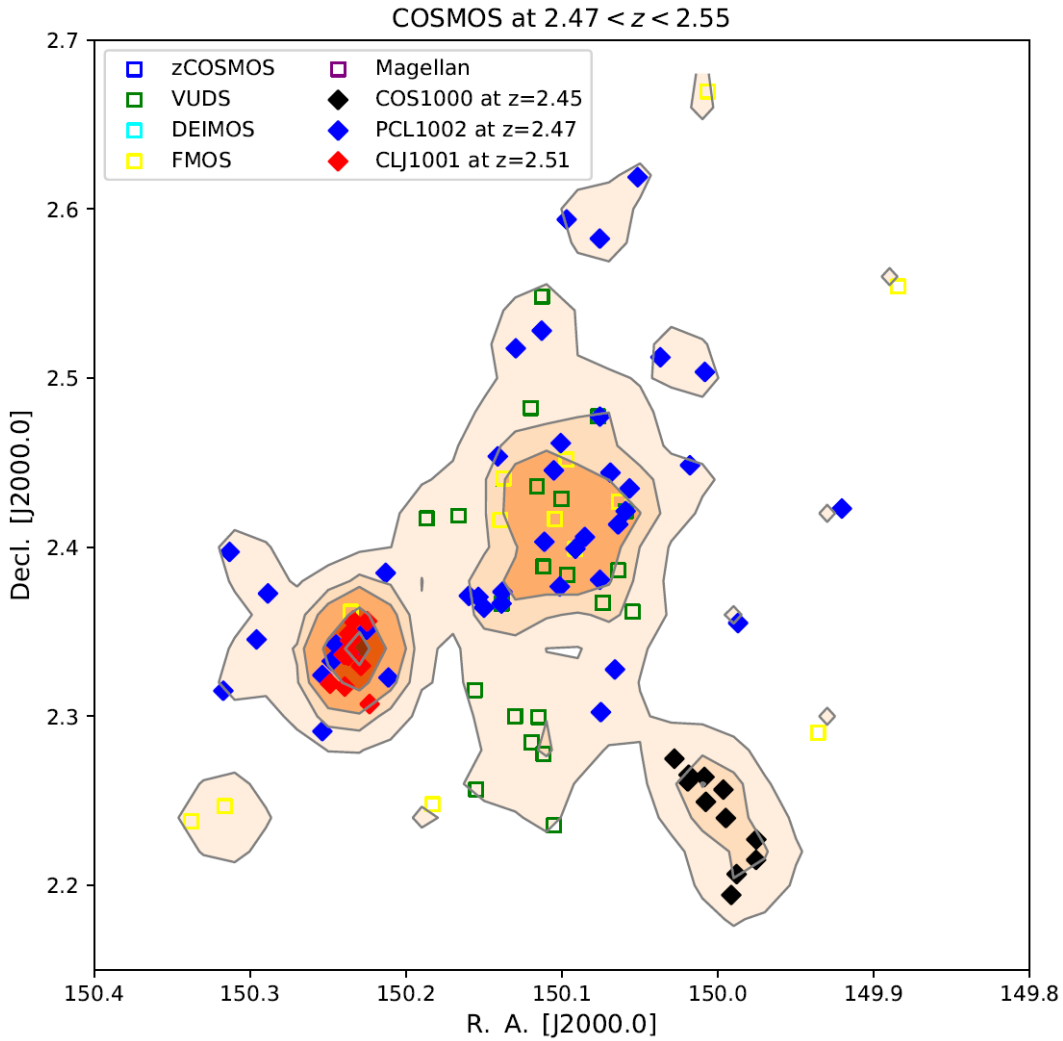


# ◆ Protoclusters at z=2-3

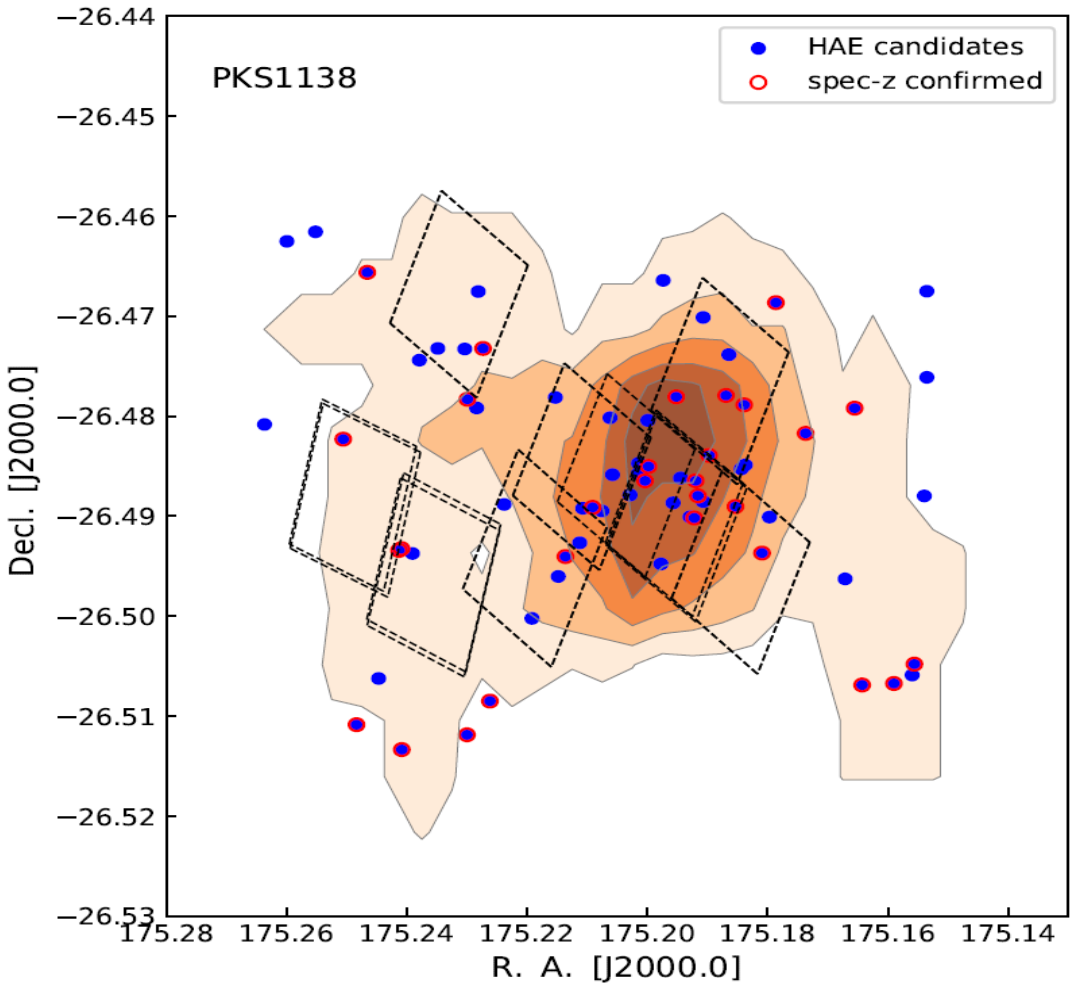
➢ COSMOS2.2 + COSMOS2.5



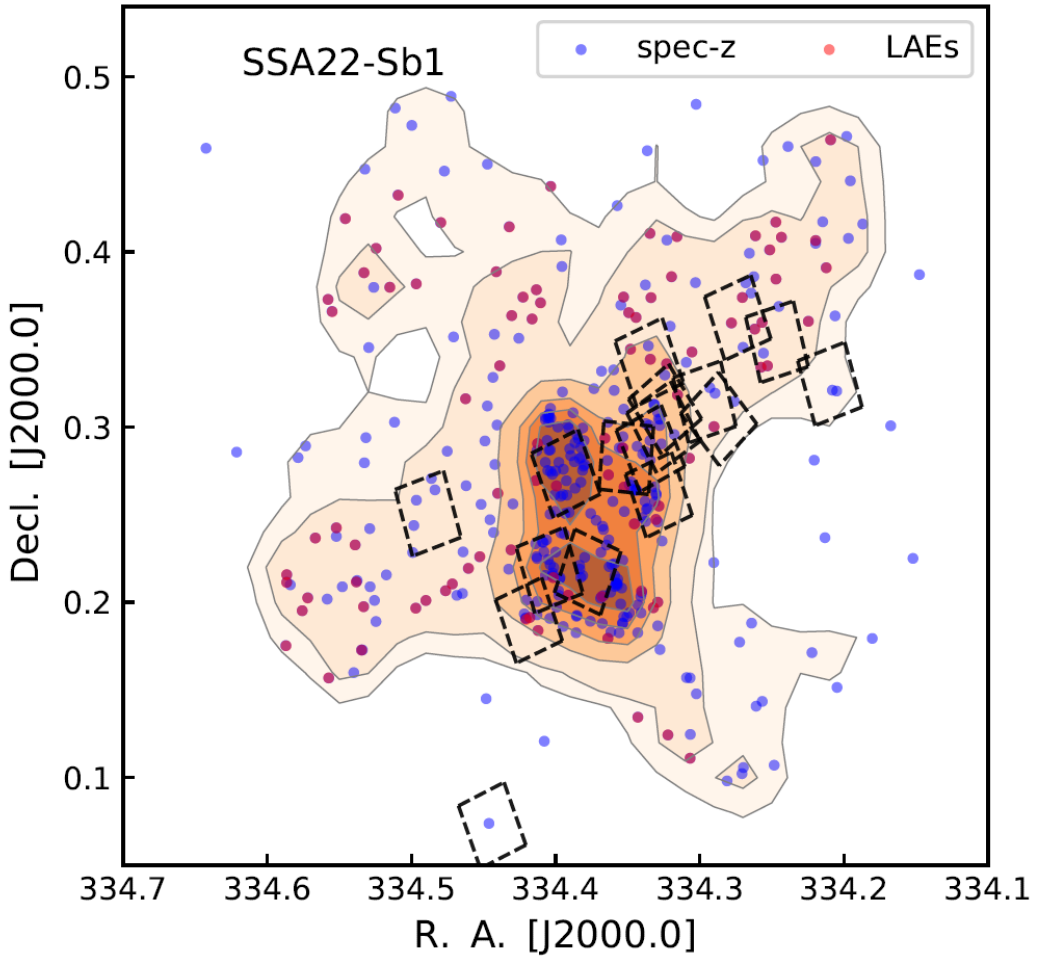



# ◆ Protocclusters at z=2-3

➢ PKS1138 protocluster at z=2.16




➢ SSA22 at z=3.09



# ◆ Summary

- The merger rate in BOSS1244 and BOSS1542 is 1.8 (2.8) times higher than that of the general fields at the same epoch.

- Protocluster HAEs exhibits broader range of re and n than field SFGs + About 15 per cent of the HAEs are massive compact population ➔ high galaxy density and cold dynamical state are key factors to drive galaxy mergers.

- The galaxy structure difference between BOSS1244 and BOSS1542 shows that both the local environment (on group scales) and the global environment play essential roles in shaping galaxy morphologies in protoclusters.

Thank You!