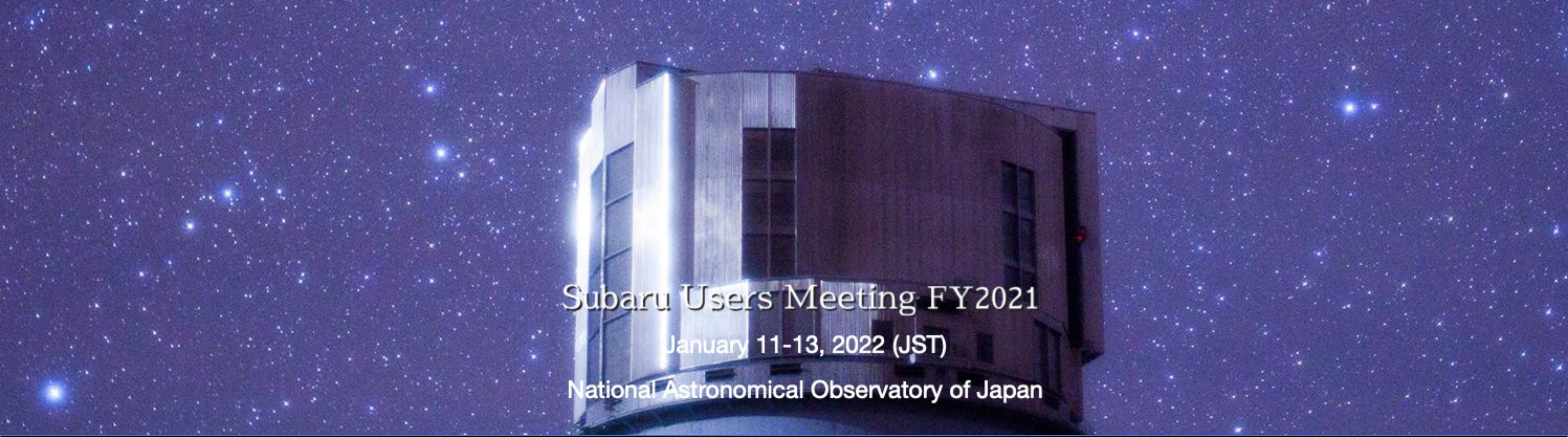


Mapping the large scale structure and projection corrected environmental dependence of star forming galaxies back to z~ 1.5

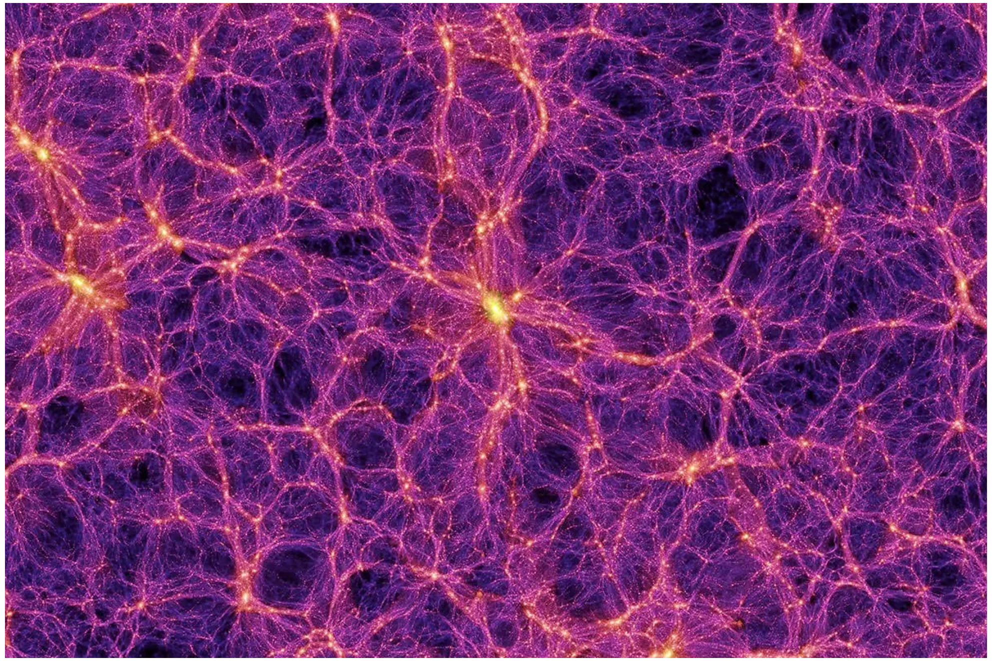
Ronaldo Laishram[1], Tadayuki Kodama[1], Masao Hayashi, José Perez[1], Yusei Koyama(NAOJ) , Tomoko Suzuki (IPMU)

1 Tohoku University

Ronaldo Laishram
D1, Tohoku University, Japan

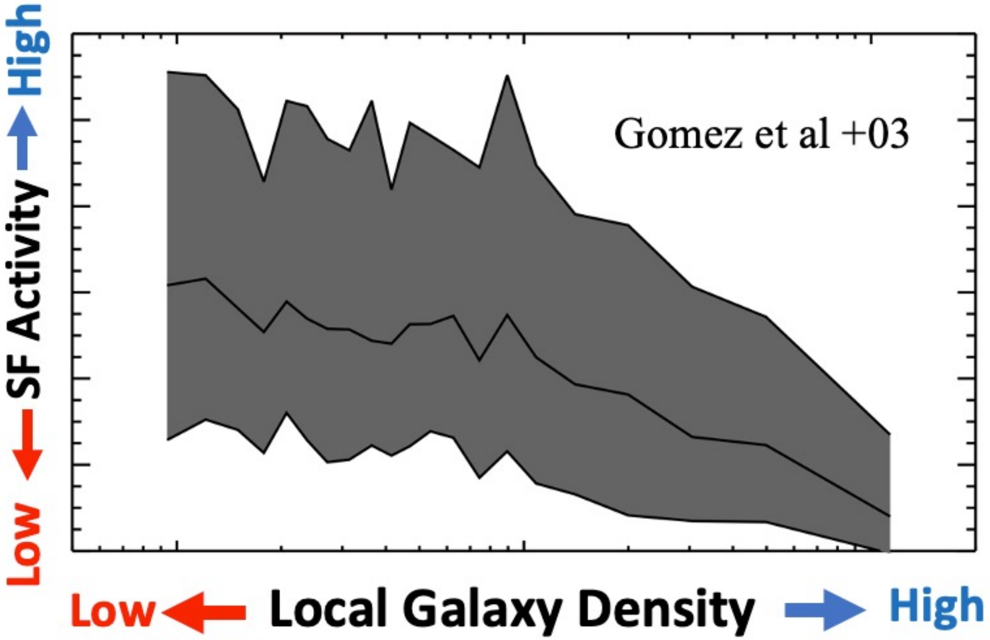
INTRODUCTION

Large-scale structures



Springel 2005

Environment dependence at z~0



Understanding precisely how galaxies change their properties as a result of the hierarchical growth of LSSs

At high redshift ?

How or why? *What makes this environmental dependence ?*

When? *epoch/timescale for the emergence of the environmental effect?*

Difficulty is the need for accurate determination of the redshift to determine the precise environment of the galaxies.

Spectroscopic redshift:

- ❖***Ideal*** but Expensive and Samples will be too numerous to be observed
- ❖Require pre-selection of spectroscopic targets which can introduce sampling bias

Narrow Band Imaging:

Narrowband filters targeting nebular emission from HII regions of star-forming galaxies.

- ❑Powerful approach to identify star-forming (SF) galaxies along the cosmic web in the distant universe based on their strong emission lines

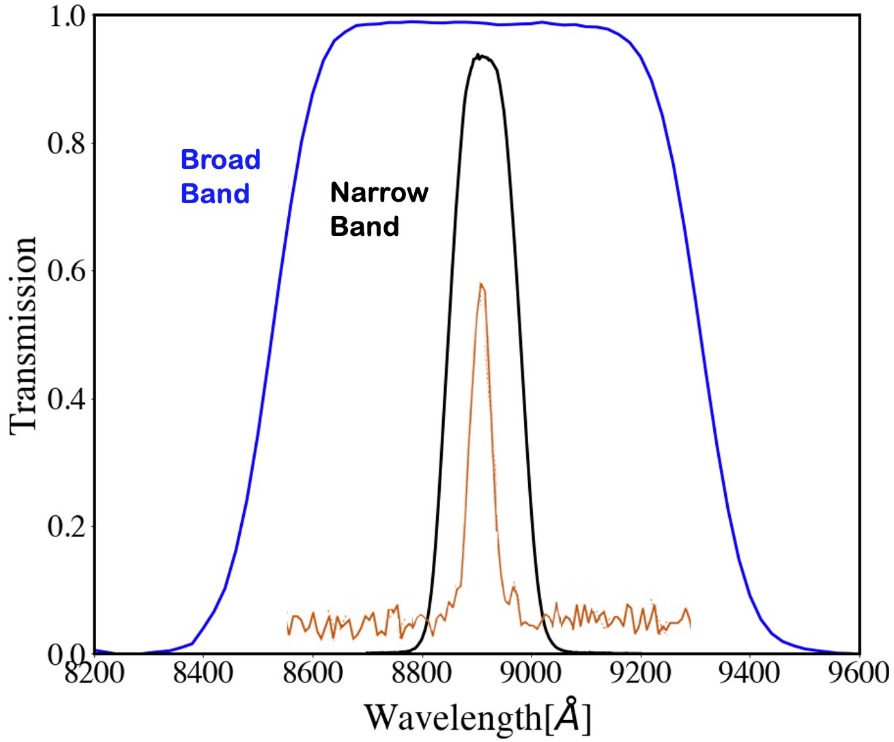
Photometric redshift:

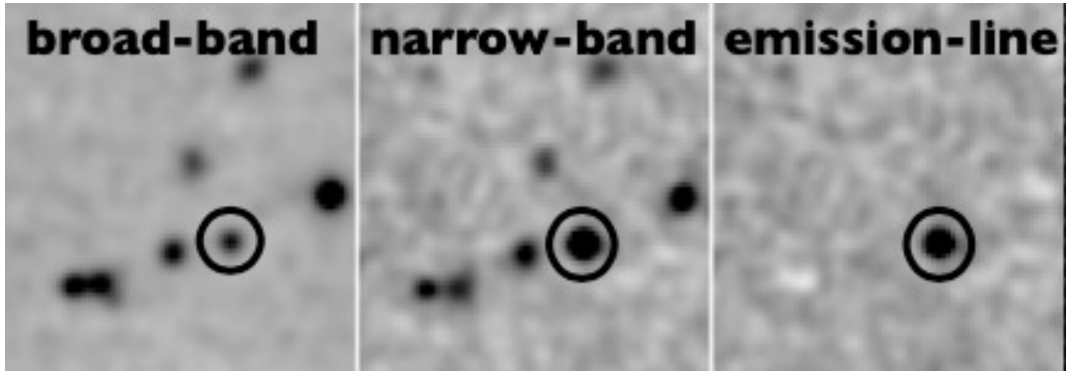
- ❖Easy to get but uncertainty becomes large at higher redshifts

Difficulty is the need for accurate determination of the redshift to determine the precise environment of the galaxies.

Narrow Band Imaging:

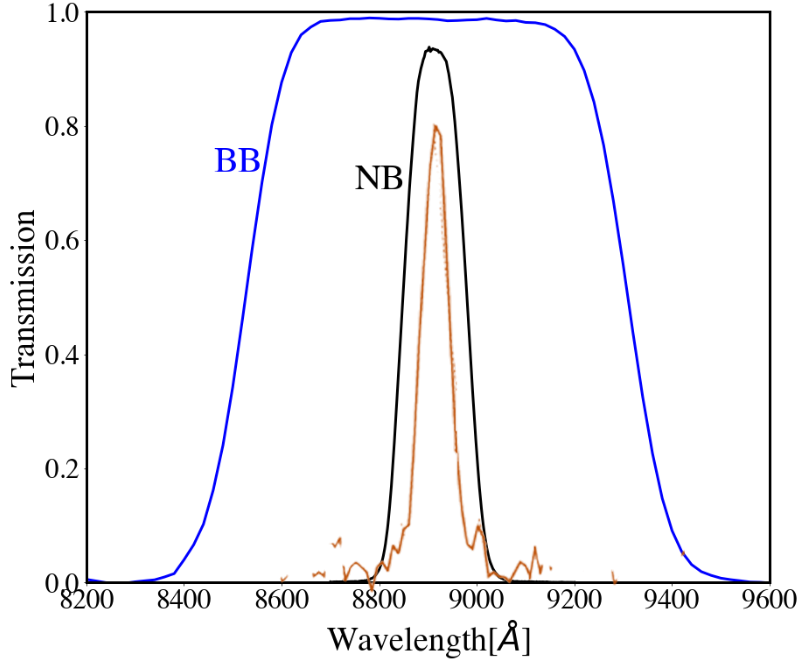
Narrowband filters targeting nebular emission from HII regions of star-forming galaxies.





Accuracy of $\Delta z \sim 0.03$

Narrow Band Imaging:

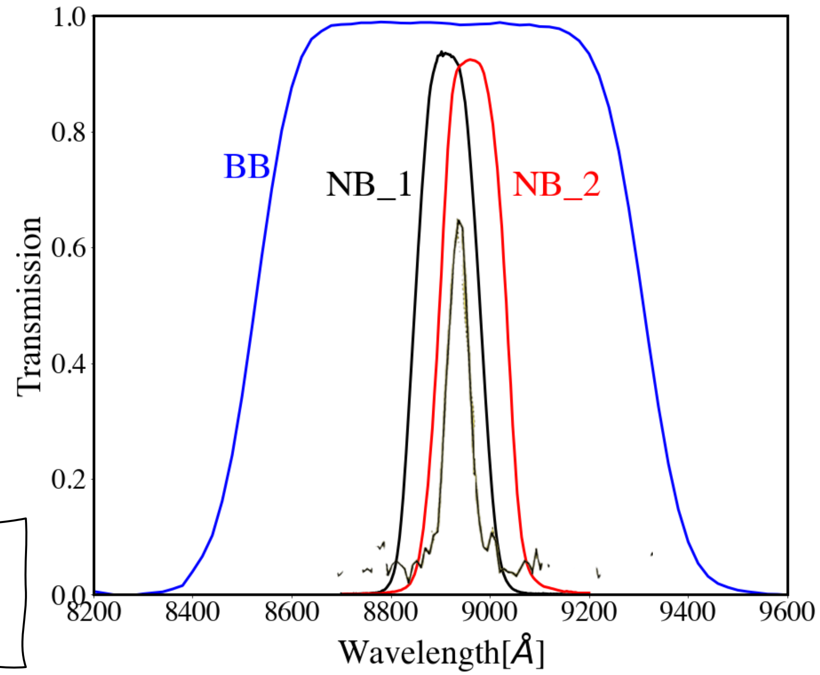


Accuracy of Δz~0.03

Comoving depth of 56 Mpc at z~1.46

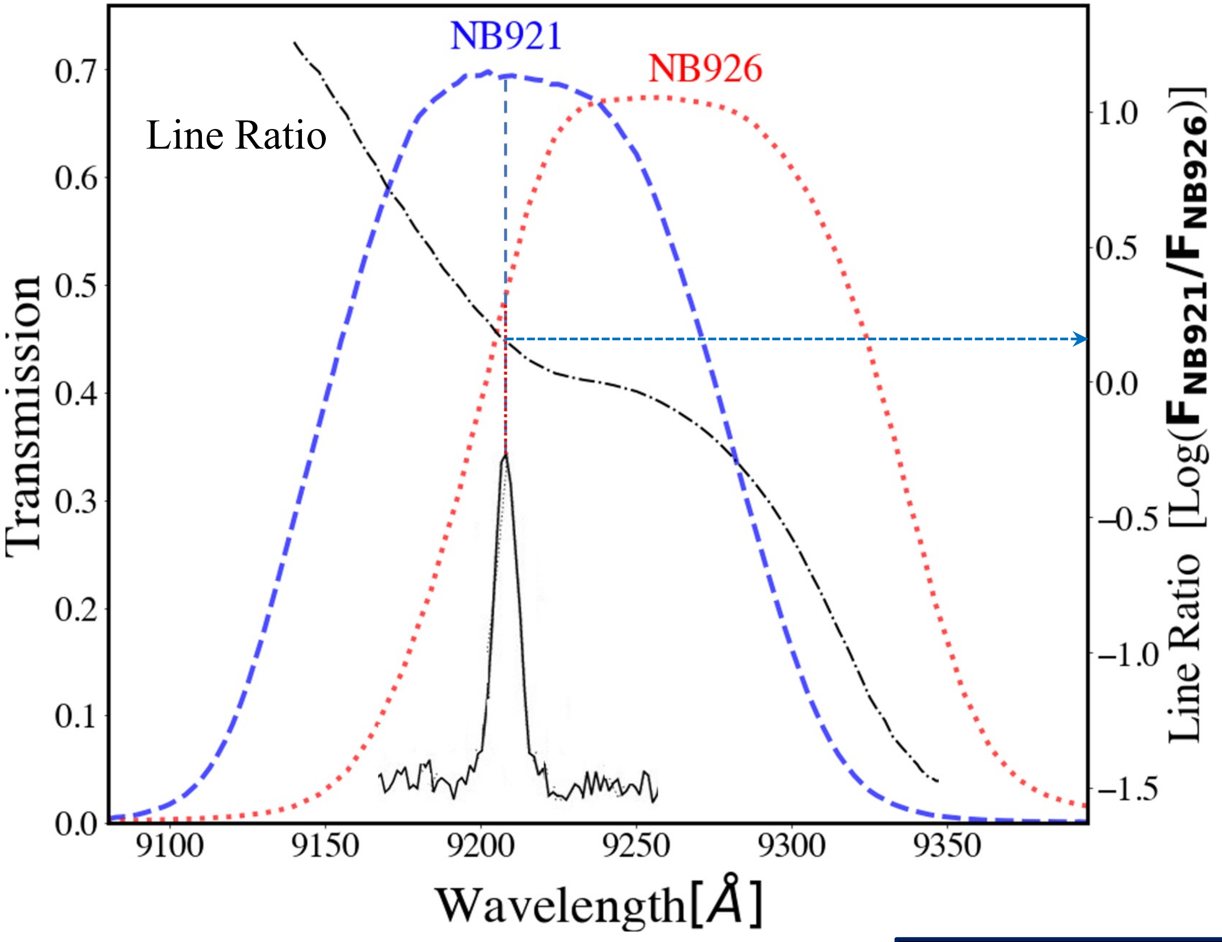
Too uncertain for measuring
Precise Environment

How to solve this?

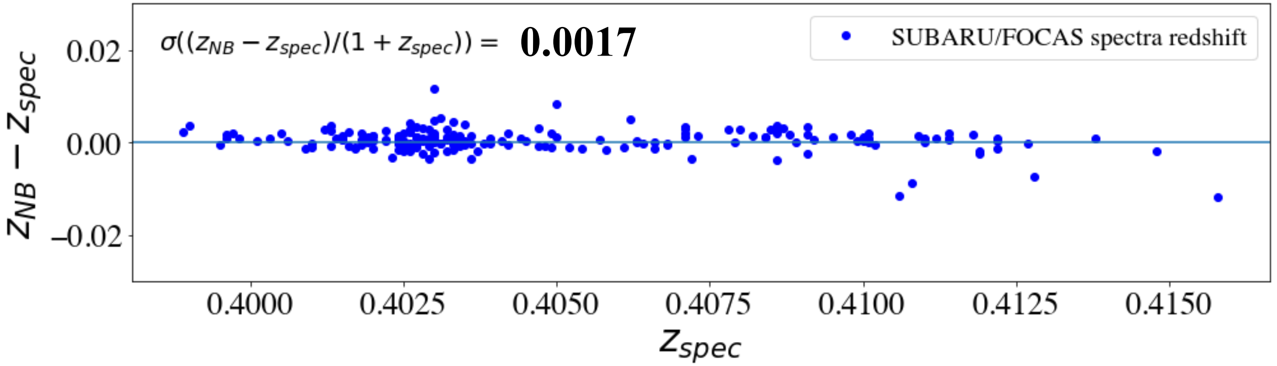


A novel technique to determine accurate redshift and flux using two Narrow-band filters

REDSHIFT MEASUREMENTS WITH TWO ADJACENT NARROW-BAND FILTERS



Validating the method using **Hα specz(z~0.4)**



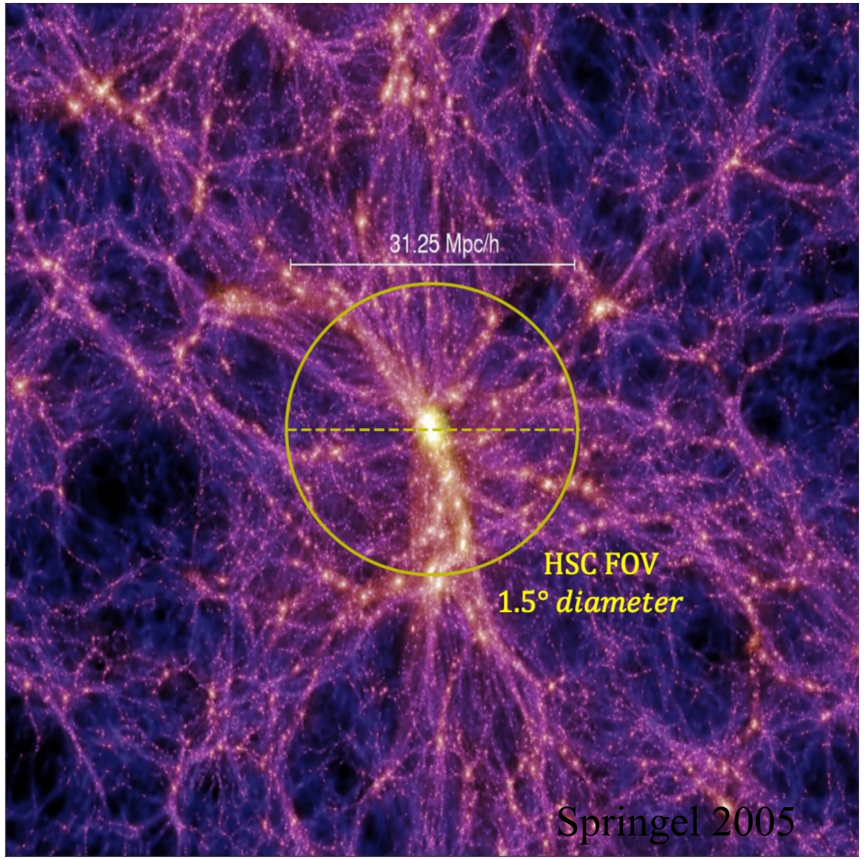
$$\sigma_{\Delta z/(1+z_s)} = 0.012 \text{ at } i^+_{AB} < 24 \quad ; z < 1.25$$
$$\sigma_{\Delta z/(1+z_s)} = 0.06 \text{ at } i^+_{AB} \sim 24 \quad ; z \sim 2$$

Photometric redshift comparison; Ilbert et al 2009

Can measure both accurate fluxes of the emission lines and accurate redshift

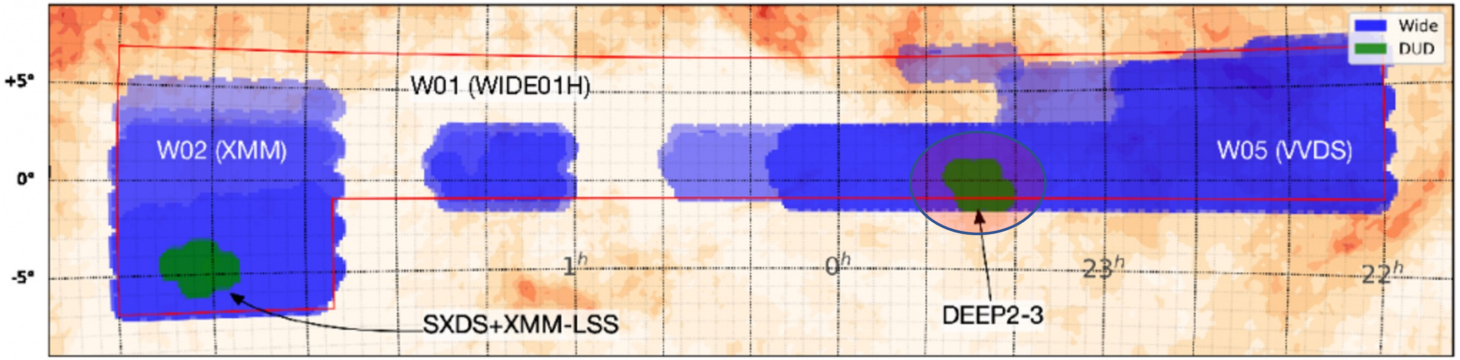
❖ The overlap with a slight difference in the response curves allows us to estimate the redshift based on the difference of emission line fluxes measured in the NB921 and NB926 images.

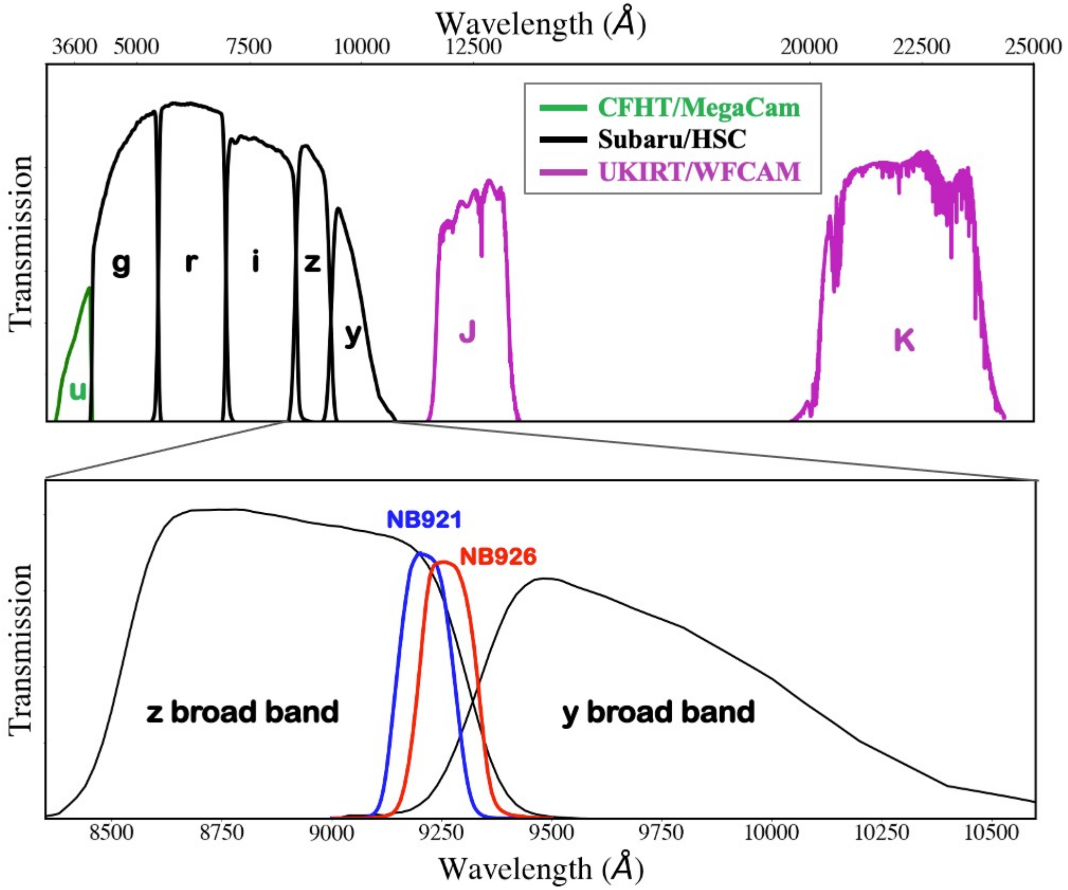
SAMPLE



- DEEP 2-3 Field (5.6 deg^2)
- HSC-SSP PDR2 data(Aihara et al. 2019)
  - g, r, i, z, y, NB921
- NB926 (Hayashi et al) (Open-use program S17B)
- CFHT/MegaCam *u*, UKIRT/WFCAM (J,K) DUNES

Subaru Strategic Program (SSP) with **Hyper Suprime-Cam (HSC)** provides us with one of the widest and deepest imaging data



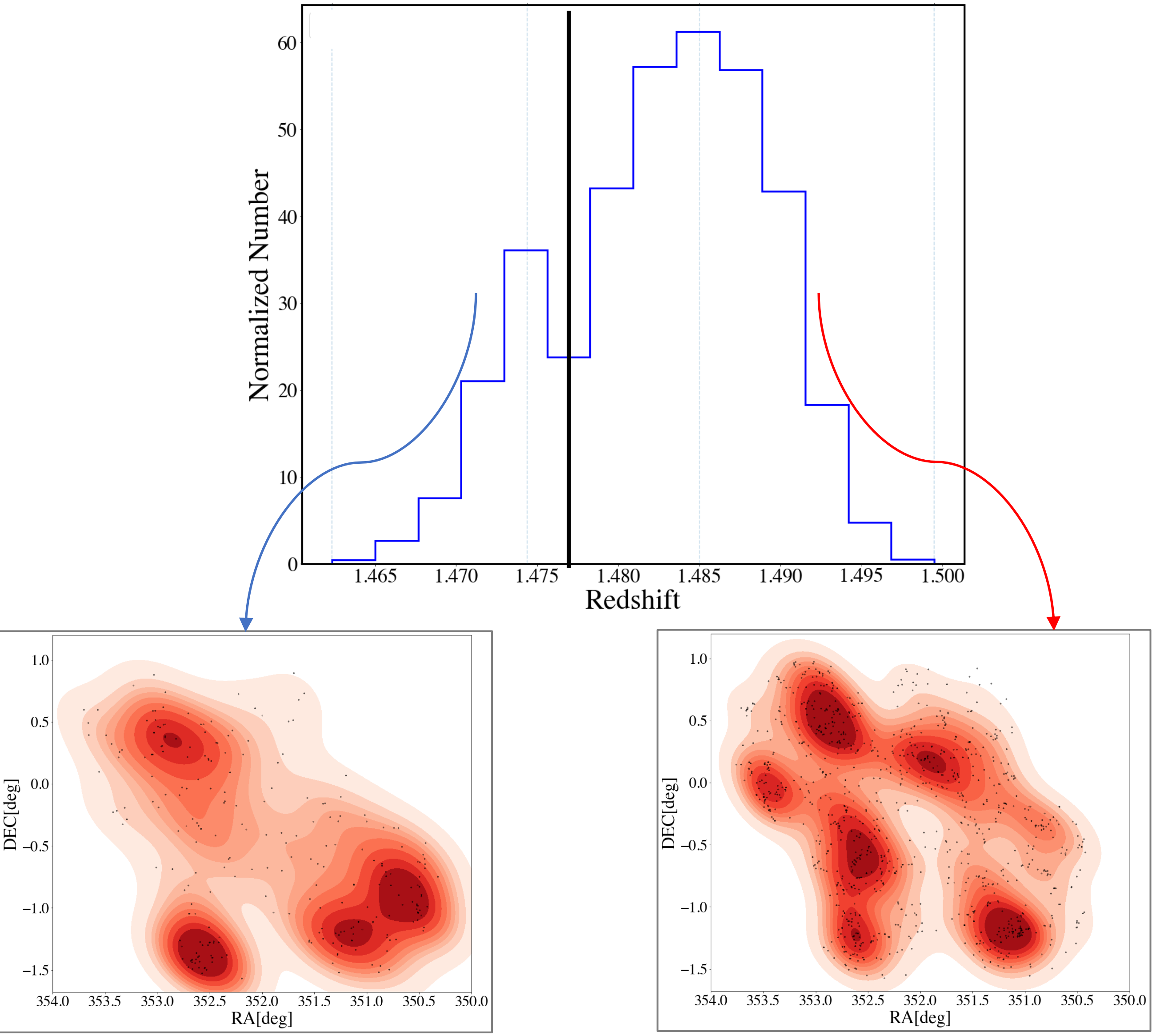


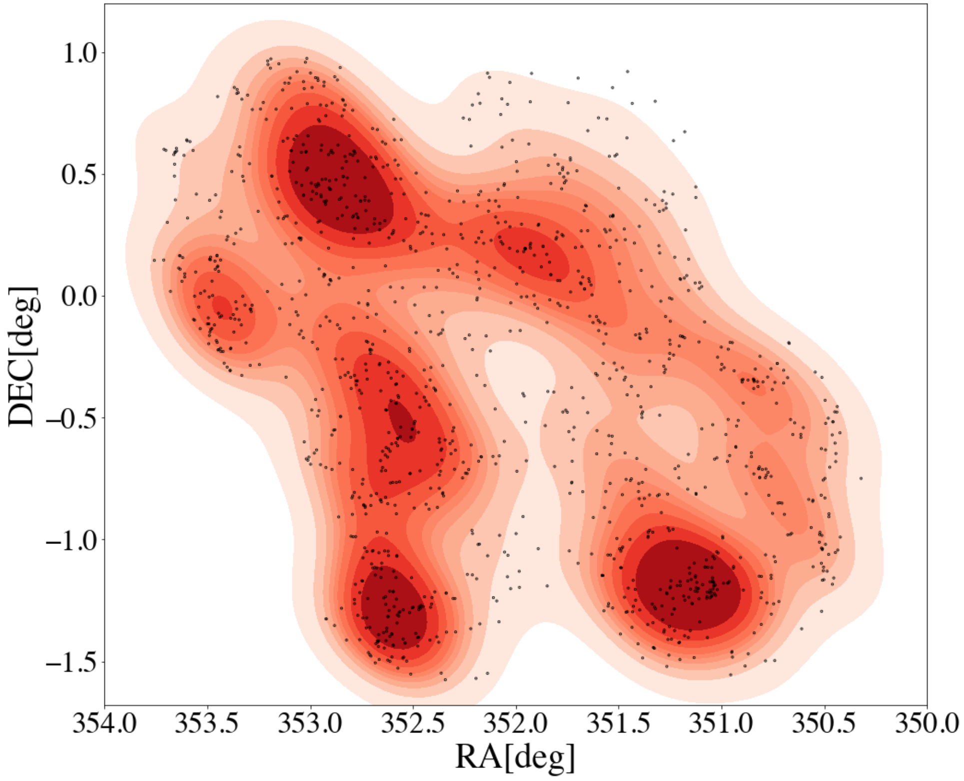
Hα ~ 0.4

[OII] ~ 1.5

STRUCTURE

Redshift Distribution (z~1.5)





✓ **Can map 3D structure**

PROJECTION CORRECTION is IMPORTANT.

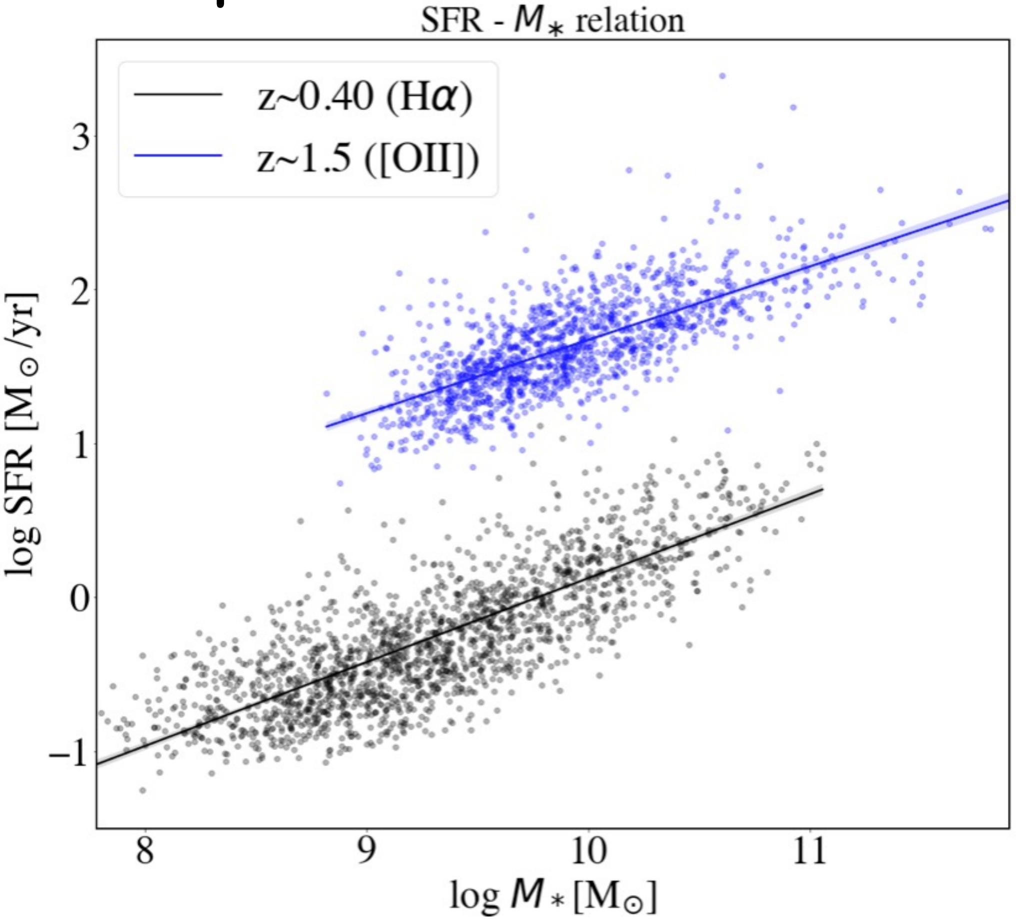
Advantages of our novel method

- ✓ ACCURATE REDSHIFT & FLUX MEASUREMENT
- ✓ CAN MAP 3D STRUCTURE & SEPARATE STRUCTURE

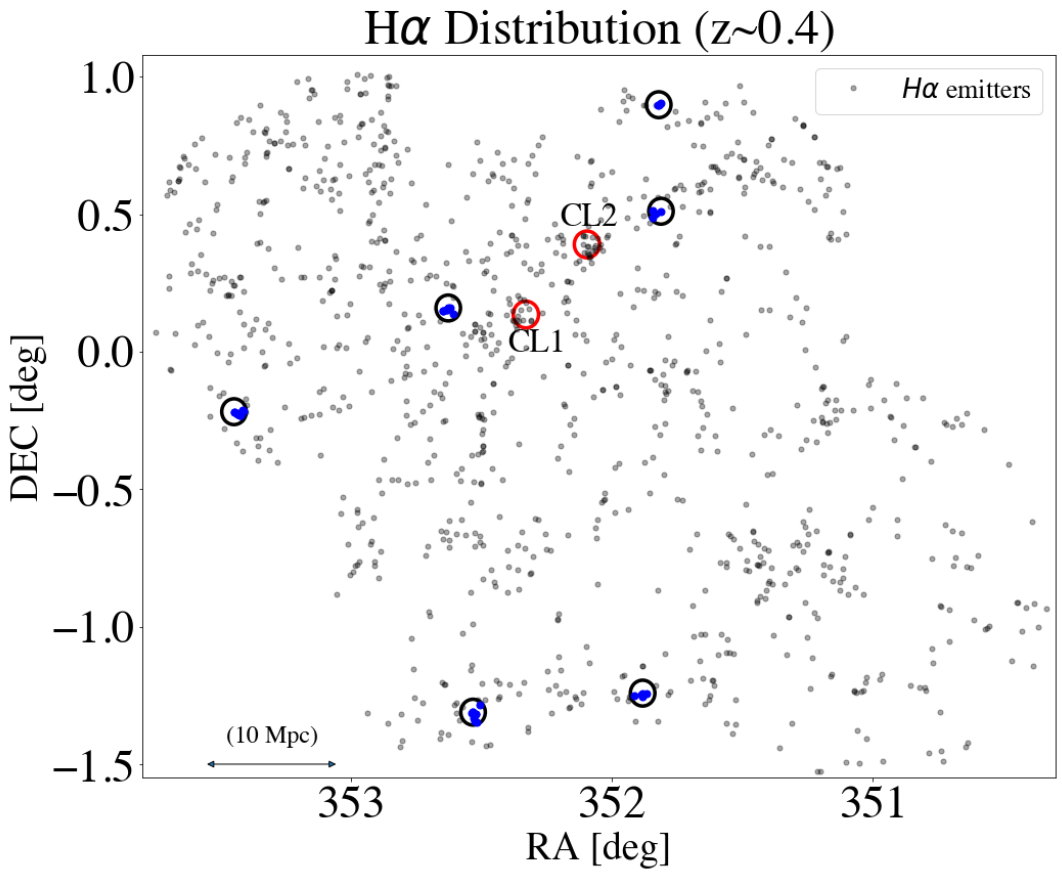
NEXT

Investigate Galaxy properties with environment at different epochs

Main sequence relation



Hα distribution at z~0.4



Local environment definition

Fifth nearest local density

- **ΔVel = ± 1000 km/s**
- $\Sigma_{5th} = 5/\pi r^2$
- Local environmental effects
- Sensitive to all possible structures

Global environment

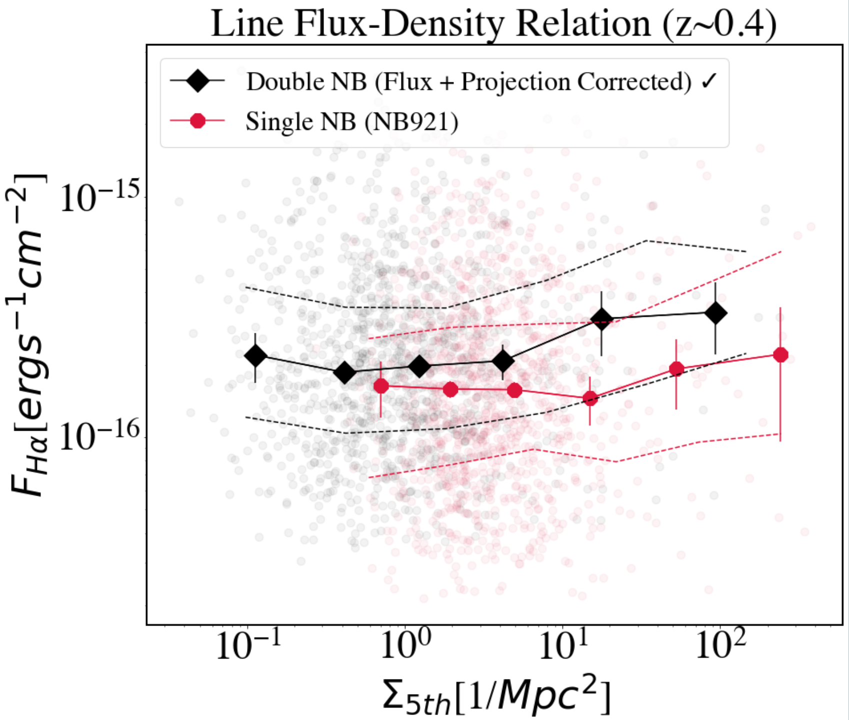
Hα selected Cluster (3σ overdense)

Red Sequence selected Cluster (CAMIRA) (Oguri et al 2018)

Close Companion galaxies ($R_{neighbour}$<=20Kpc)

ΔVel = ± 1000 km/s

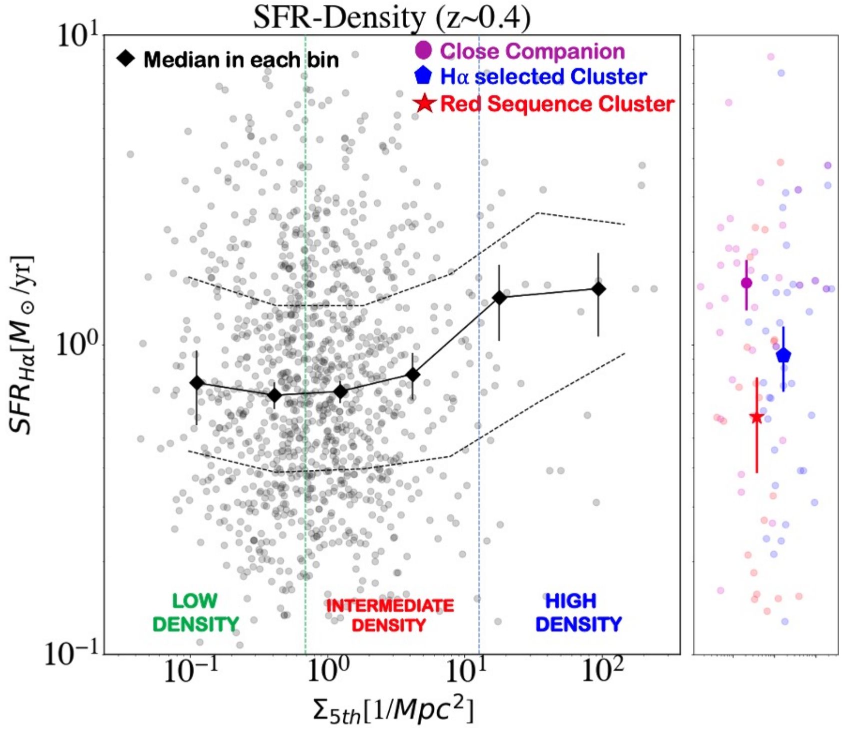
Comparison of single NB and double NB filters

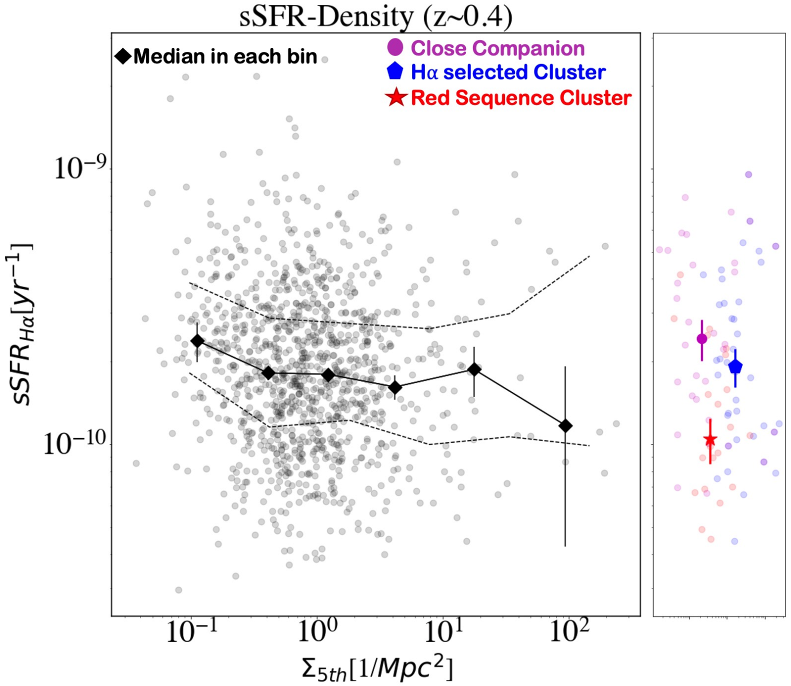


Double Narrow Bands filter improved

- ✓ Filter Response Correction
- ✓ Projection Effect Correction

SFR-Density and sSFR-Density relation at z~0.4





$SFR_{HIGH\ DENSITY}$ > $SFR_{INTERMEDIATE\ DENSITY}$ ~$SFR_{LOW\ DENSITY}$

Low-Density	Intermediate-Density	High Density
0.21 ± 0.02	0.20± 0.02	0.4 ± 0.12

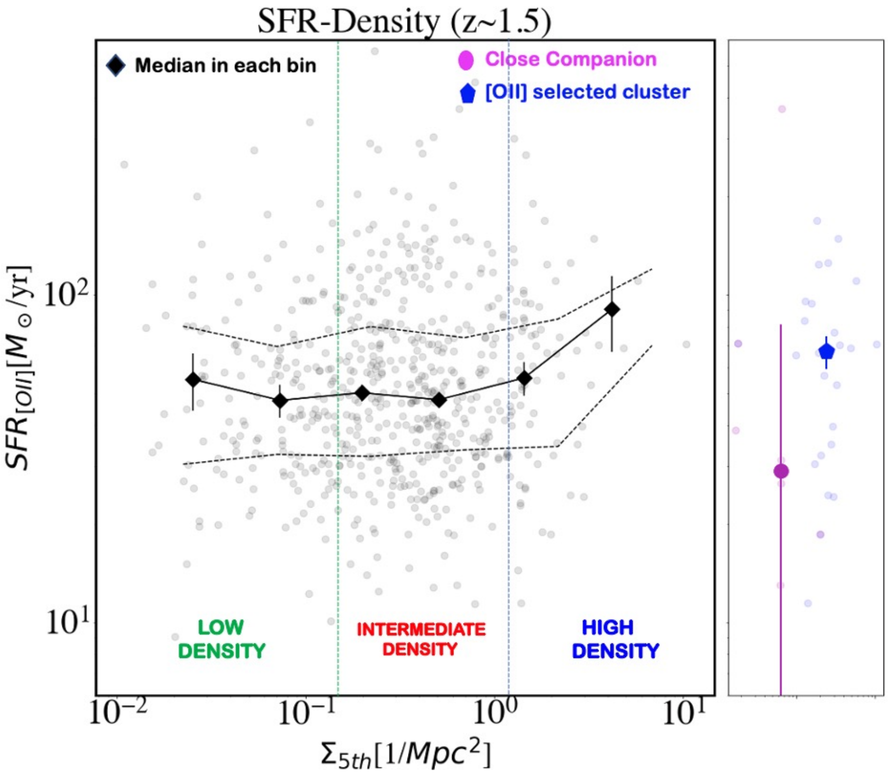
- **Massive galaxies ($M>10^{10}$) at higher-density environments**

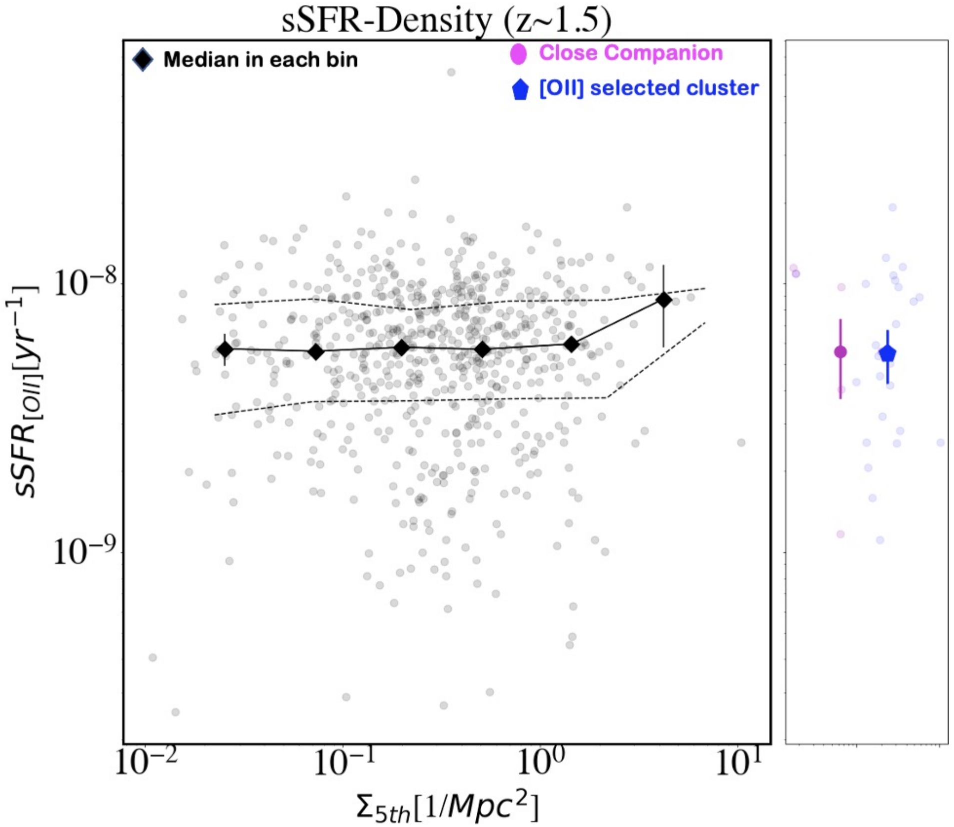
- No significant environmental dependence of sSFR

Star forming activity at red sequence cluster is less compared to Hα cluster & Close Companion

- dominated by red quiescent galaxies

SFR-Density and sSFR-Density relation at z~1.5





$SFR_{HIGH\ DENSITY} > SFR_{INTERMEDIATE\ DENSITY} \sim SFR_{LOW\ DENSITY}$

- No significant environmental dependence of sSFR

➢ **Massive galaxies at higher-density environments**

$\Delta MS_{Close\ Companion} \sim \Delta MS_{[OII]\ Overdensity} \sim \Delta MS_{Field}$

We will not consider red sequence cluster since there is spectroscopic confirmed red sequence clusters at z~1.5

Hα emitters at z~0.4 Vs [OII] emitters at z~1.5

SAME TREND

$SFR_{HIGH\ DENSITY} > SFR_{INTERMEDIATE\ DENSITY} \sim SFR_{LOW\ DENSITY}$

But, No significant environmental dependence in sSFR

Above trend is driven by increased fraction of massive galaxies at higher-density environments.

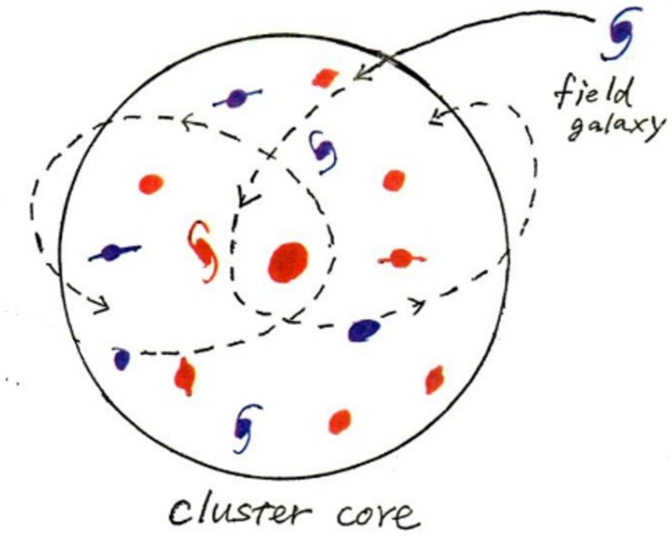
- **Galaxy evolution is accelerated in dense environment.**
  - galaxies in higher-density regions formed earlier than galaxies of similar mass in lower-density environments.
  - Their sizes grew rapidly through merging

- **Dynamical mass segregation**
  - Massive galaxies tend to move toward the high density region, while lighter members tend to move farther away from the center.

z~0.4 $\Delta MS_{\text{Close Companion}} \gtrsim \Delta MS_{\text{H}\alpha\text{ selected Cluster}} \sim \Delta MS_{\text{Field}} > \Delta MS_{\text{Red Sequence Cluster}}$

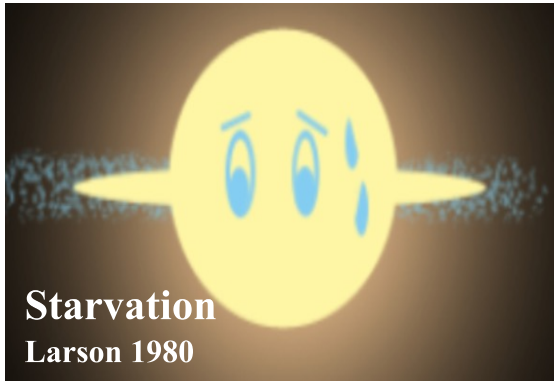
DIFFERENT TREND

z~1.5 $\Delta MS_{\text{Close Companion}} \sim \Delta MS_{\text{[OII] selected Cluster}} \sim \Delta MS_{\text{Field}}$

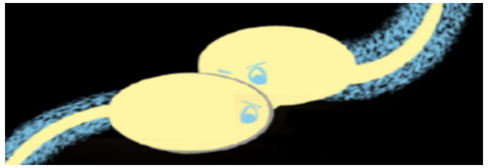


Illustrated bt Aeree Chung

Stars | ISM | ICM



- At low redshift, Red Sequence cluster are older, more developed and there are cluster specific quenching processes such as ram pressure stripping, starvation etc which reduce the SF activity
- As for emission line selected clusters or high redshift clusters, they are too young and are not evolved well yet. Galaxies have experienced a similar, steady history of SF.
- Close Companion galaxies are interacting and may induce star formation activity.



METHODS

- Novel method to estimate accurate redshifts and emission line fluxes of SF galaxies
- 3D Mapping and Structure separation at thin redshift slice and reduce the projection effect
- Investigate the projected corrected environmental dependence of galaxy properties with local density.

RESULTS & INTERPRETATION

- At low redshift, Red Sequence cluster are older, more developed and there are cluster specific quenching processes such as ram pressure stripping, starvation etc which reduce the SF activity
- As for emission line selected clusters or high redshift clusters, they are too young and are not evolved well yet. Galaxies have experienced a similar, steady history of SF.
- Close Companion galaxies are interacting and may induce star formation activity
- Significant positive correlation between SFR and overdensity at z ~1.5 and 0.4 which is weak or absent locally. These trends are associated with the existence a population of bright, massive blue galaxies in dense regions . (Cooper et al. (2006))