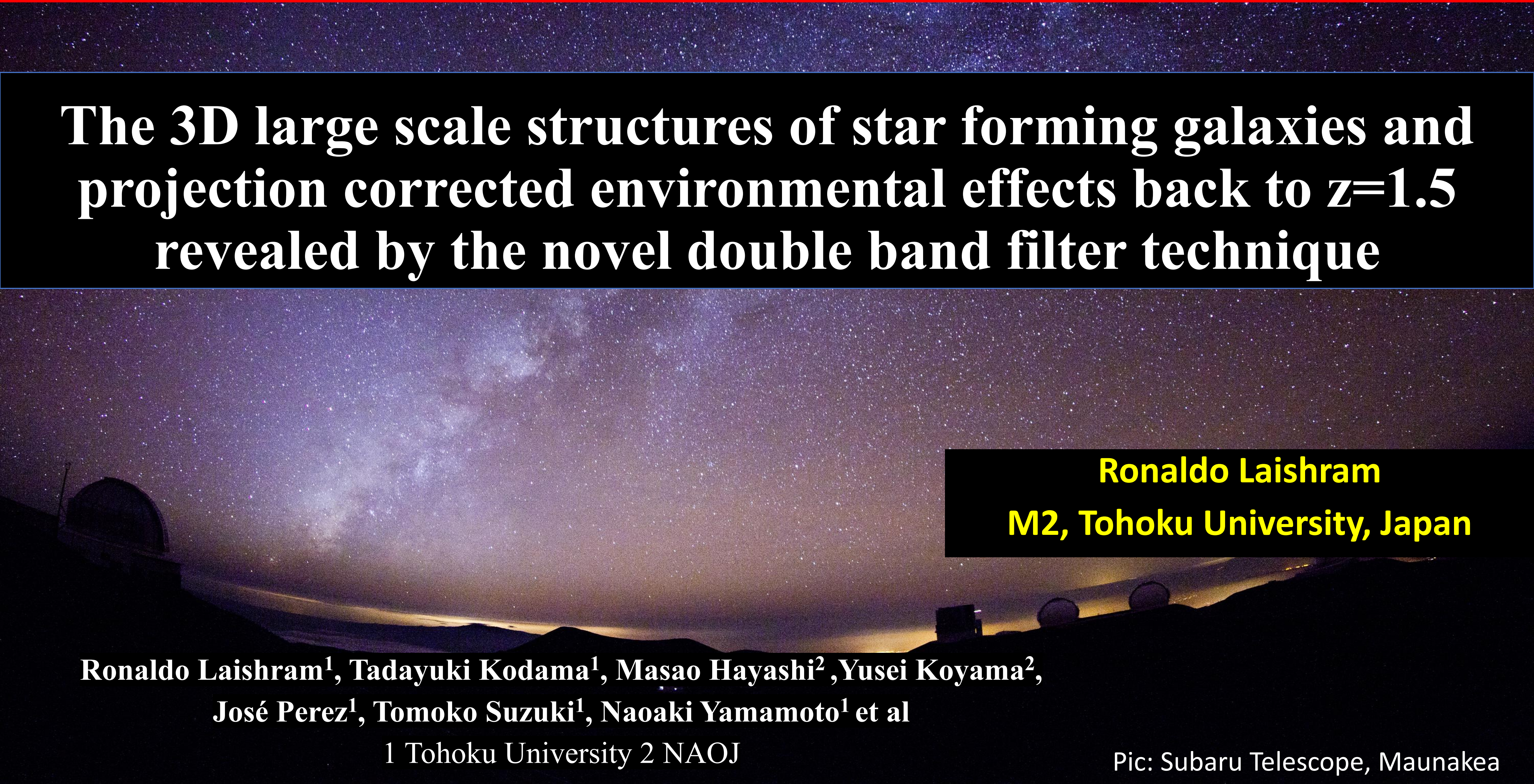
Galaxy Cluster Formation II (GCF 2021)

The 3D large scale structures of star forming galaxies and projection corrected environmental effects back to z=1.5 revealed by the novel double band filter technique

Ronaldo Laishram
M2, Tohoku University, Japan

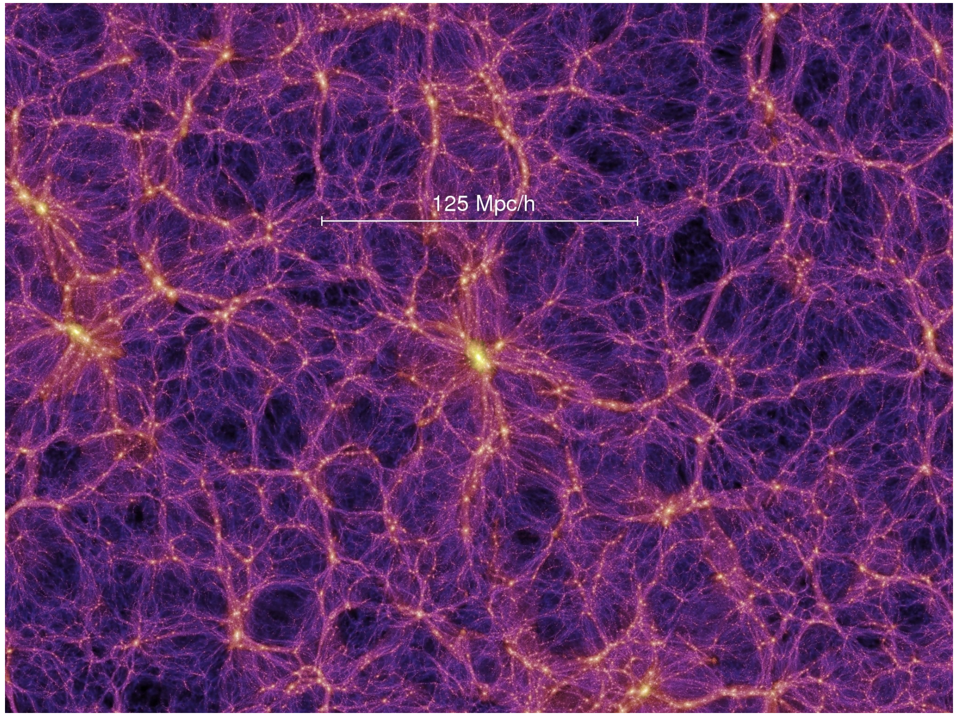
Ronaldo Laishram[1], Tadayuki Kodama[1], Masao Hayashi[2] ,Yusei Koyama[2], José Perez[1], Tomoko Suzuki[1], Naoaki Yamamoto[1] et al
1 Tohoku University 2 NAOJ



Pic: Subaru Telescope, Maunakea

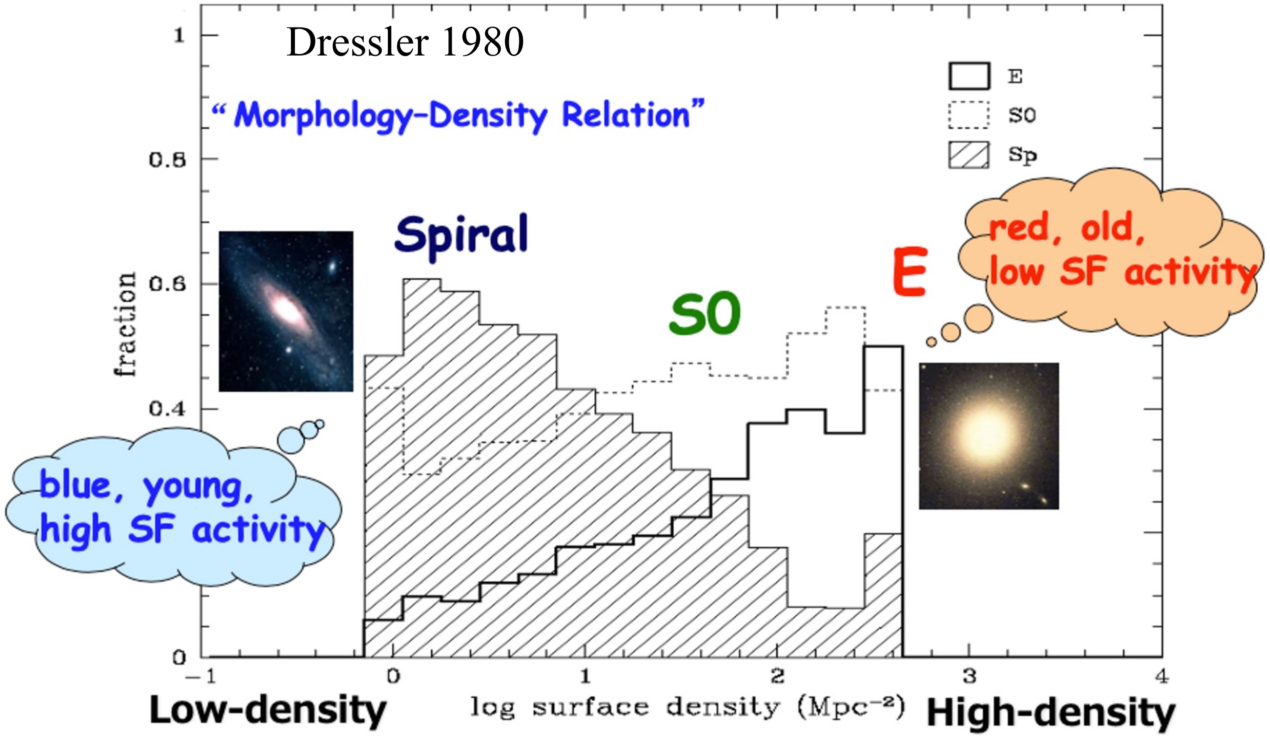
INTRODUCTION

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

→ **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.

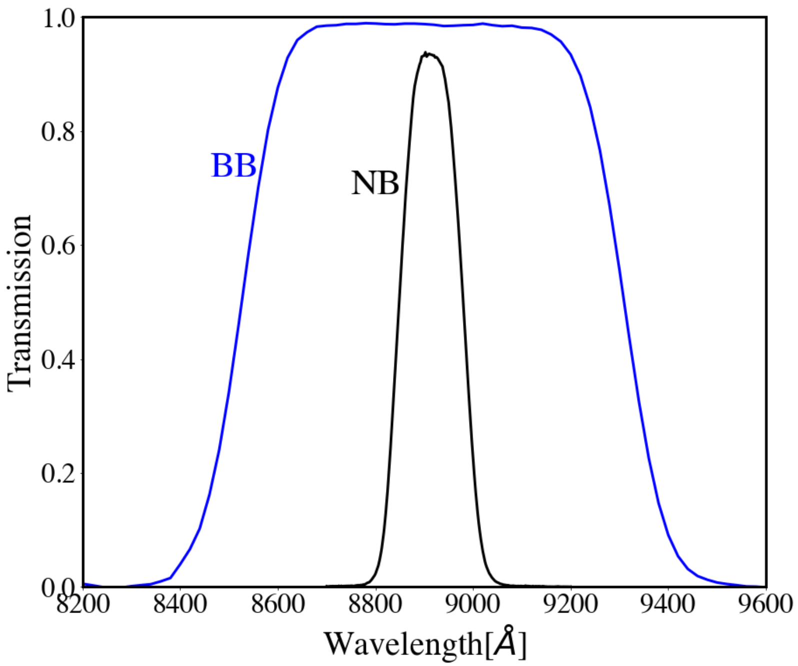
- **Photometric redshift**: uncertainty becomes large at higher redshifts
- **Spectroscopic redshift**: Samples will be too numerous to be observed

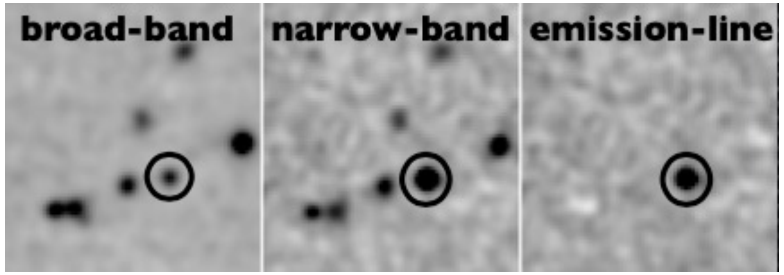
➢ Narrowband filters targeting nebular emission from HII regions of star-forming galaxies.

Accuracy of $\Delta z \sim 0.03$

↓

Comoving depth of 56 Mpc at z~1.46





A novel technique to determine accurate redshift and flux

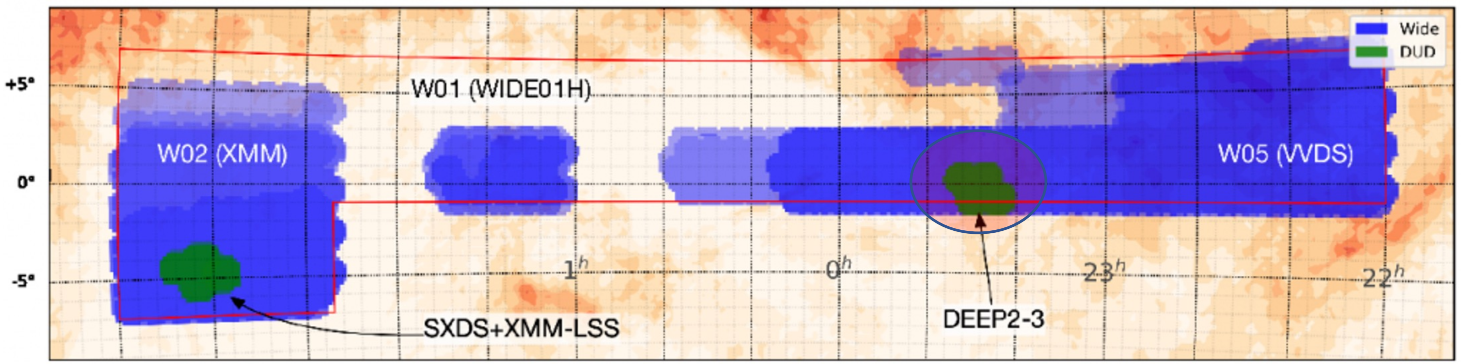
Mapping 3-D structures of the large scale structure

SAMPLE

Hyper Suprime-Cam (HSC)

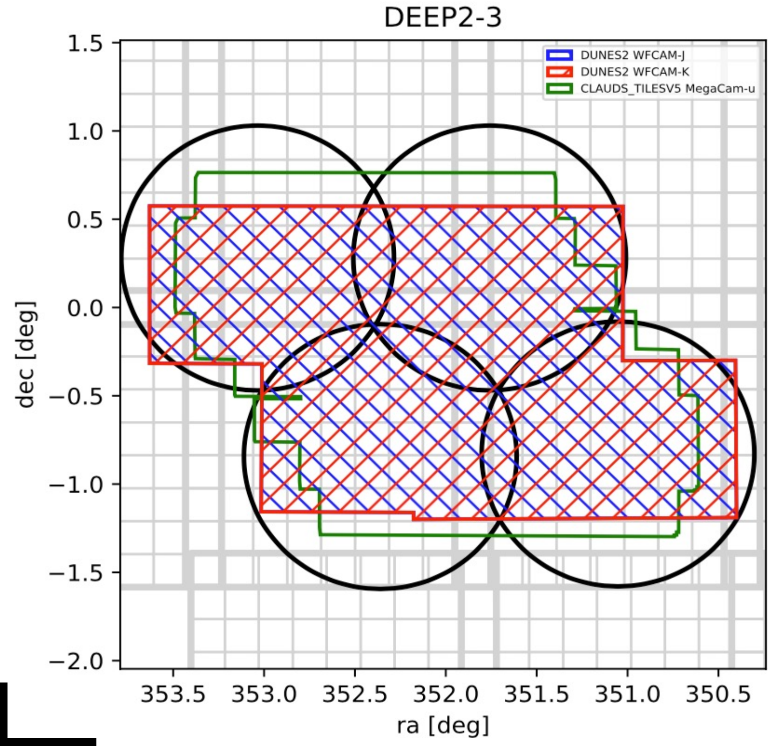
FOV
1.5° diameter

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

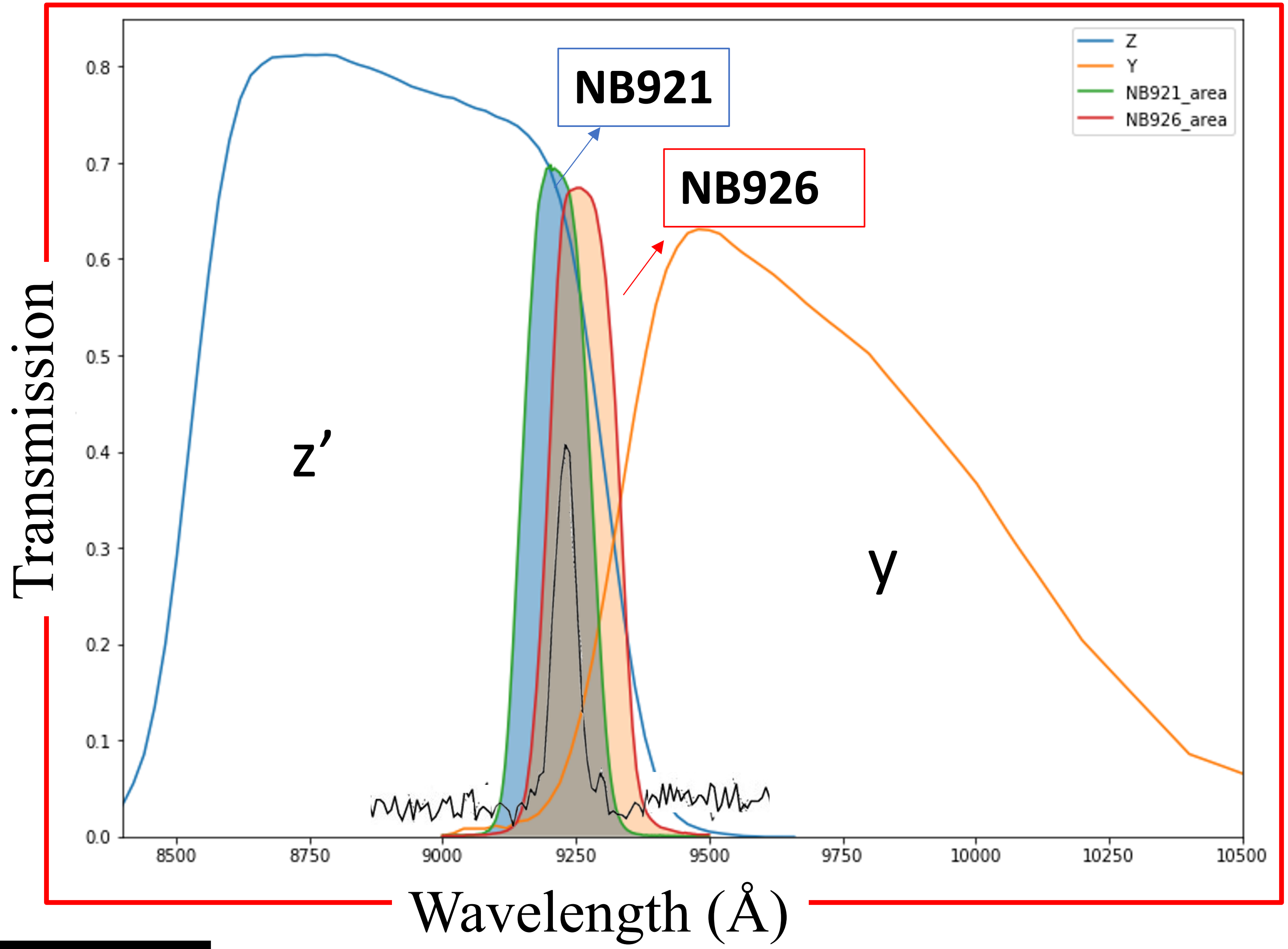


- DEEP 2-3 Field
- HSC-SSP PDR2 data(Aihara et al. 2019) + NB926 (Hayashi et al)
- UKIRT/WFCAM in DEEP2-3 (J,K) DUNES

Area	NB921 Limiting Magnitude (AB)	NB926 Limiting Magnitude(AB)
5.6 deg^2	24.57	24.43

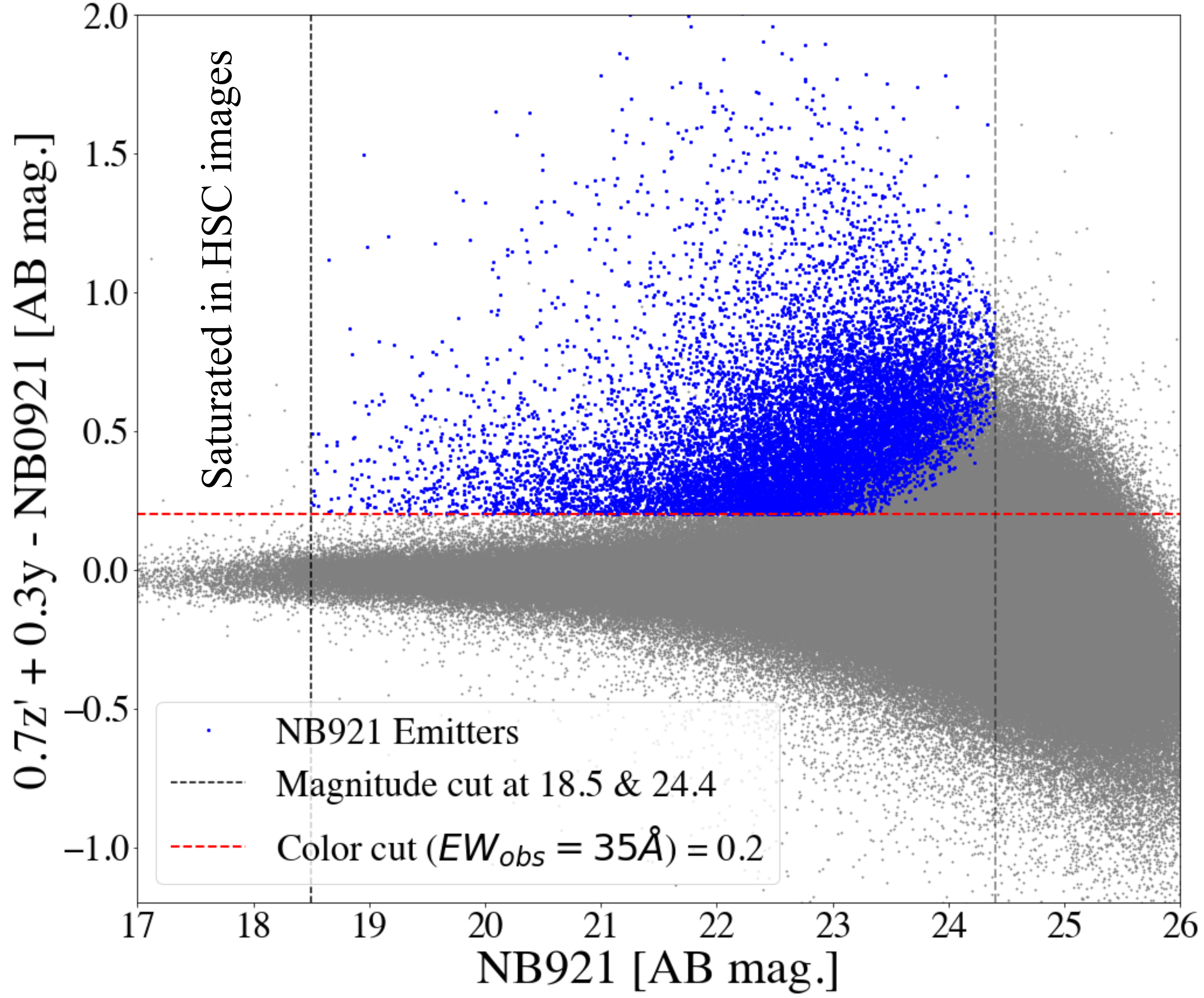


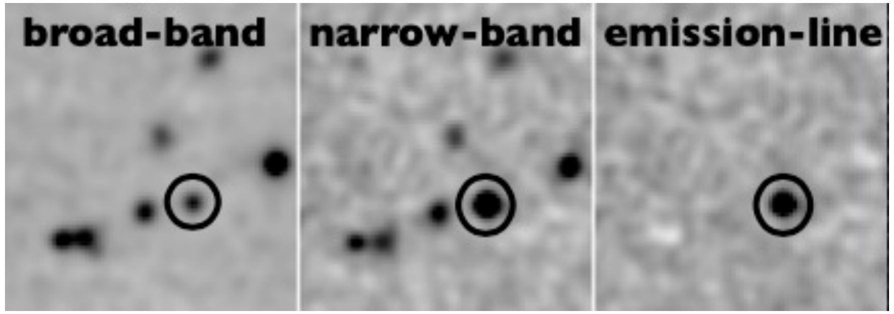
NB921 + NB926



NB921 + NB926
(z' &y BB)

Selection of Emission Line Galaxies





Filters used for the selection of emission-line galaxies.

NB	BBs	weights	mag cut	color cut	EW_{obs}
NB921	z, y	0.643, 0.357	>18.5	>0.20	35Å

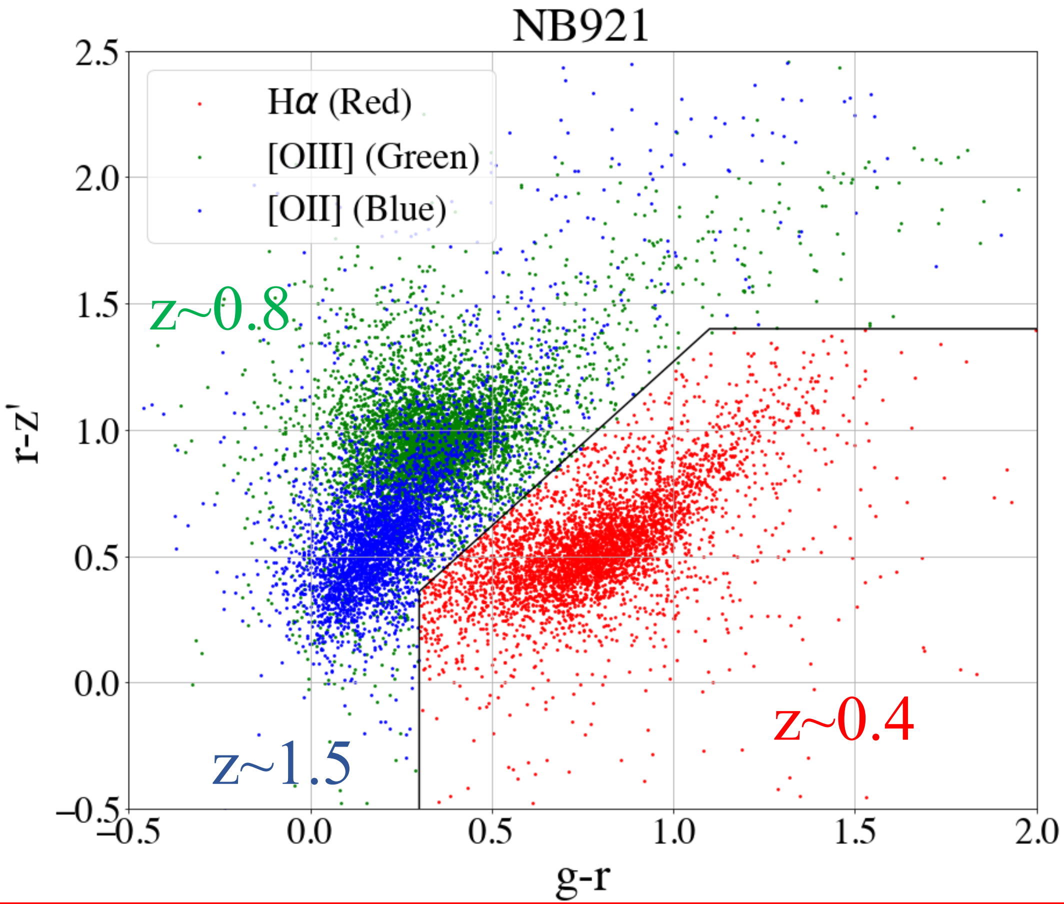
$$z'y = 0.643z' + 0.357y$$

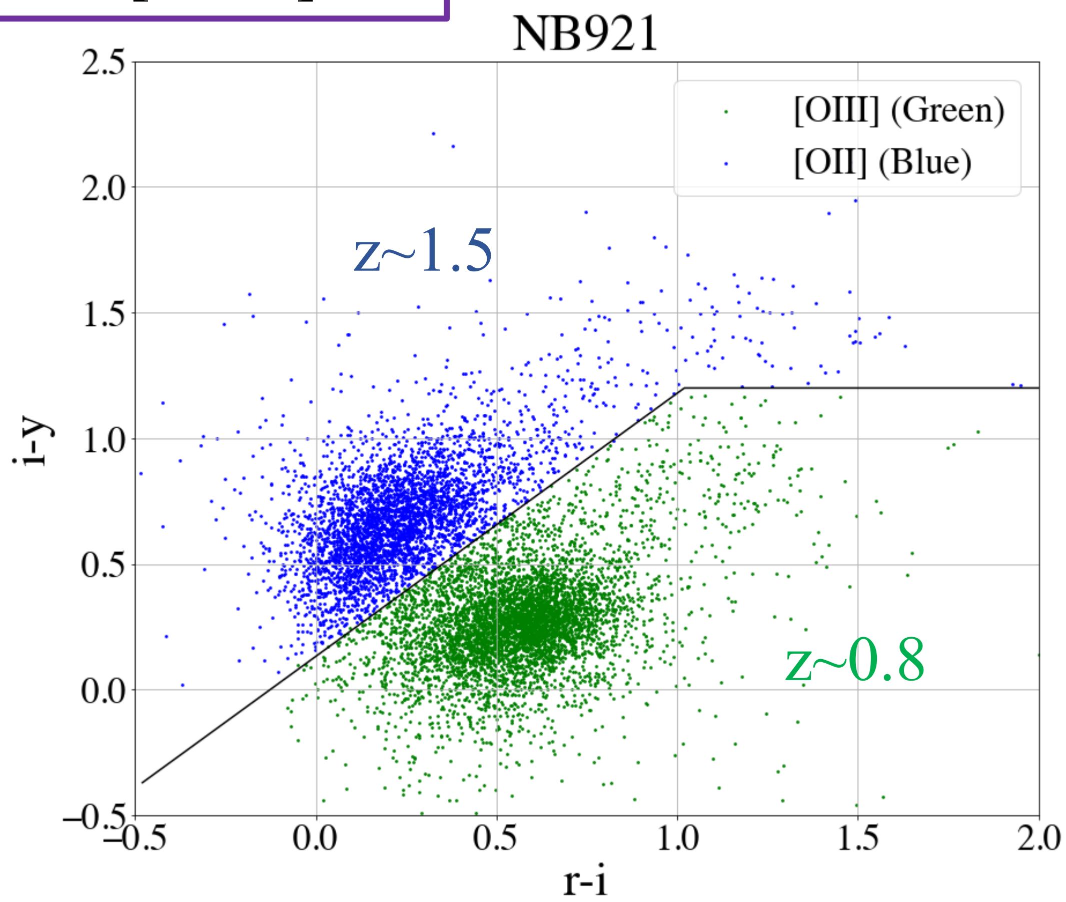
$$z'y - NB921 = -2.5log_{10}\left[1 - \frac{\sqrt{f^2_{5\sigma,z'y} + f^2_{5\sigma,NB921}}}{f_{NB921}}\right]$$

Similarly for NB926 emitter

Observed EW > 35Å is applied to exclude possible contamination

Color-Color selection to separate Hα, [OII] and [OIII]





$r - z \leq 1.4 \bigwedge g - r \geq 0.3 \bigwedge r - z \leq 1.24(g - r)$ — **Hα ~ 0.4**

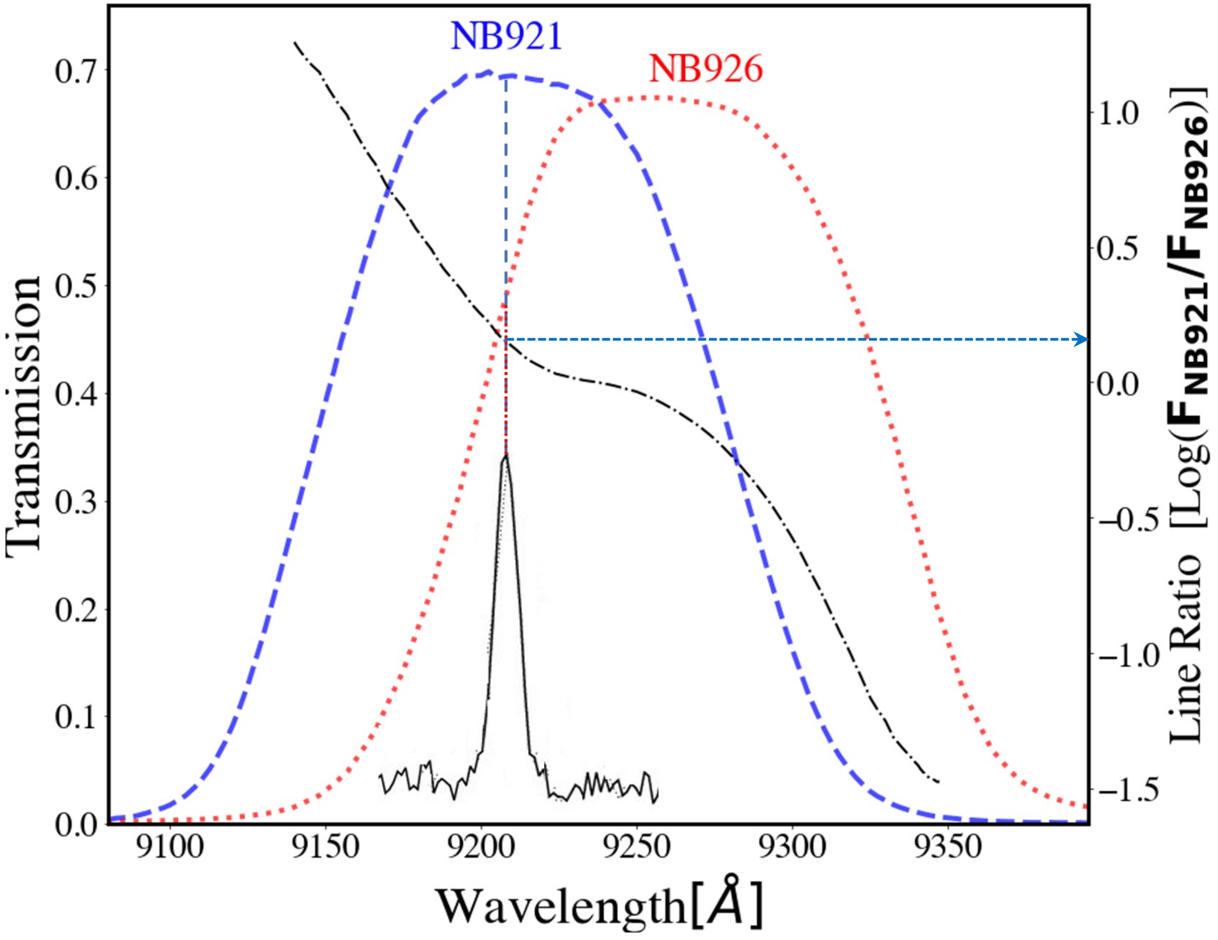
$i - y > 1.2 \bigvee i - y > 1.02(r - i) + 0.15$ — **[OII] ~ 1.5**

Otherwise [OIII] ~ 0.8

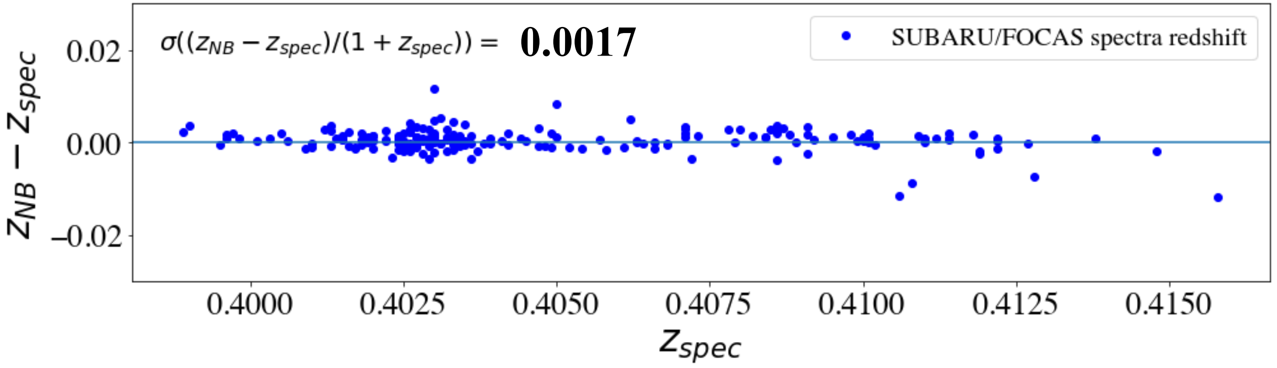
Hα, [OIII] & [OII]Emitters (NB921 + NB926)

(Hayashi+20)

REDSHIFT MEASUREMENTS WITH TWO ADJACENT NARROW-BAND FILTERS



Validating the method using **Hα specz**

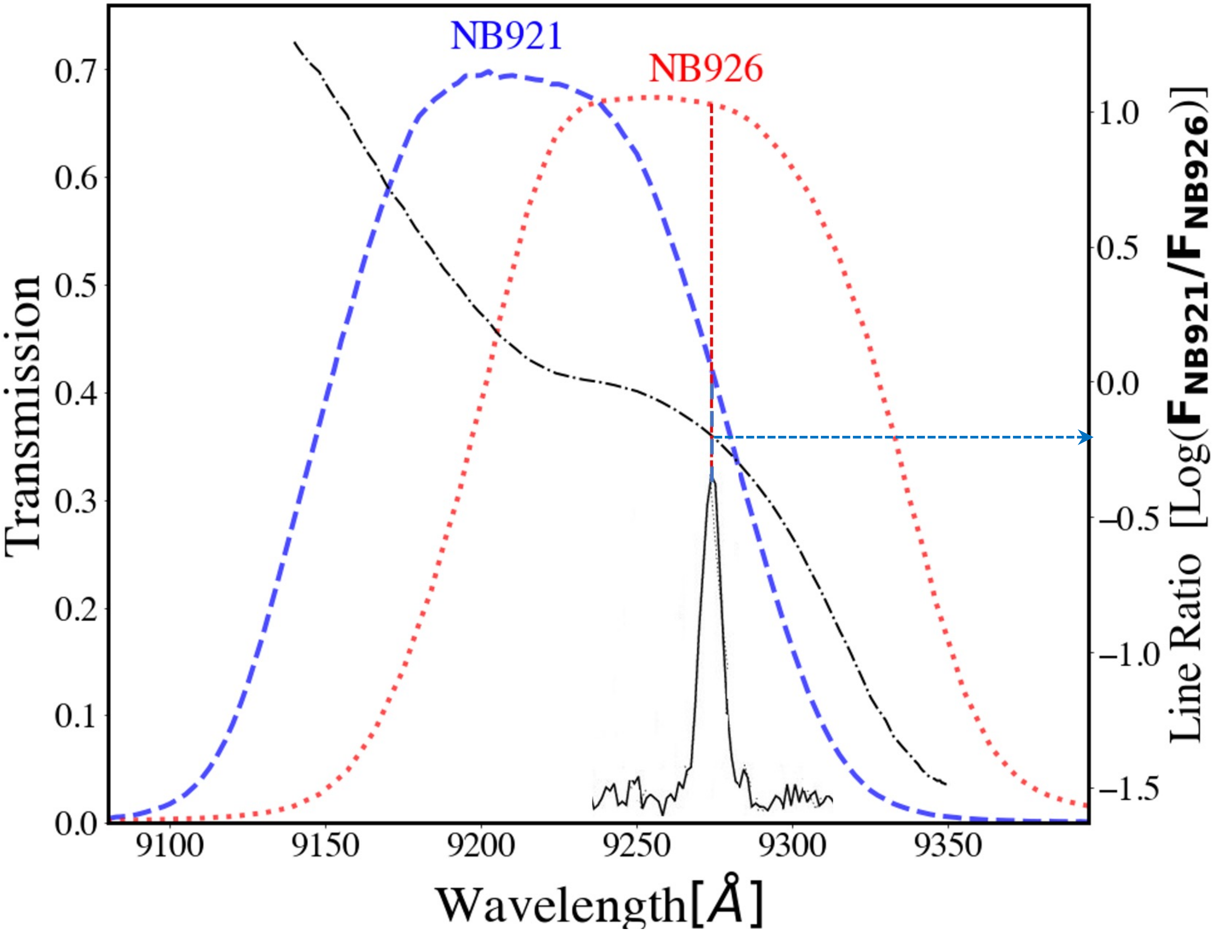


Comparision between the redshift z_{NB} estimated from the method and spectroscopic redshift z_{spec}

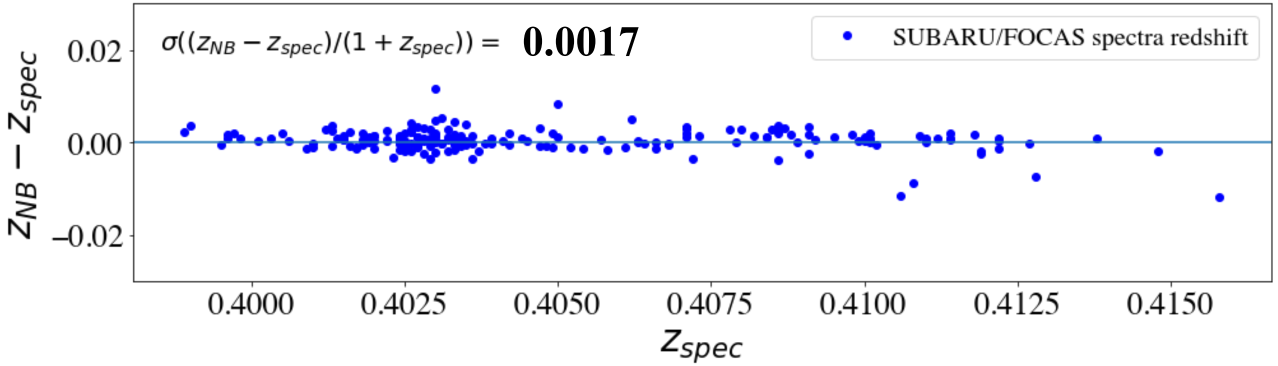
Can measure both accurate fluxes of the emission lines and accurate redshift

❖ 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.

REDSHIFT MEASUREMENTS WITH TWO ADJACENT NARROW-BAND FILTERS



Validating the method using **Hα specz**



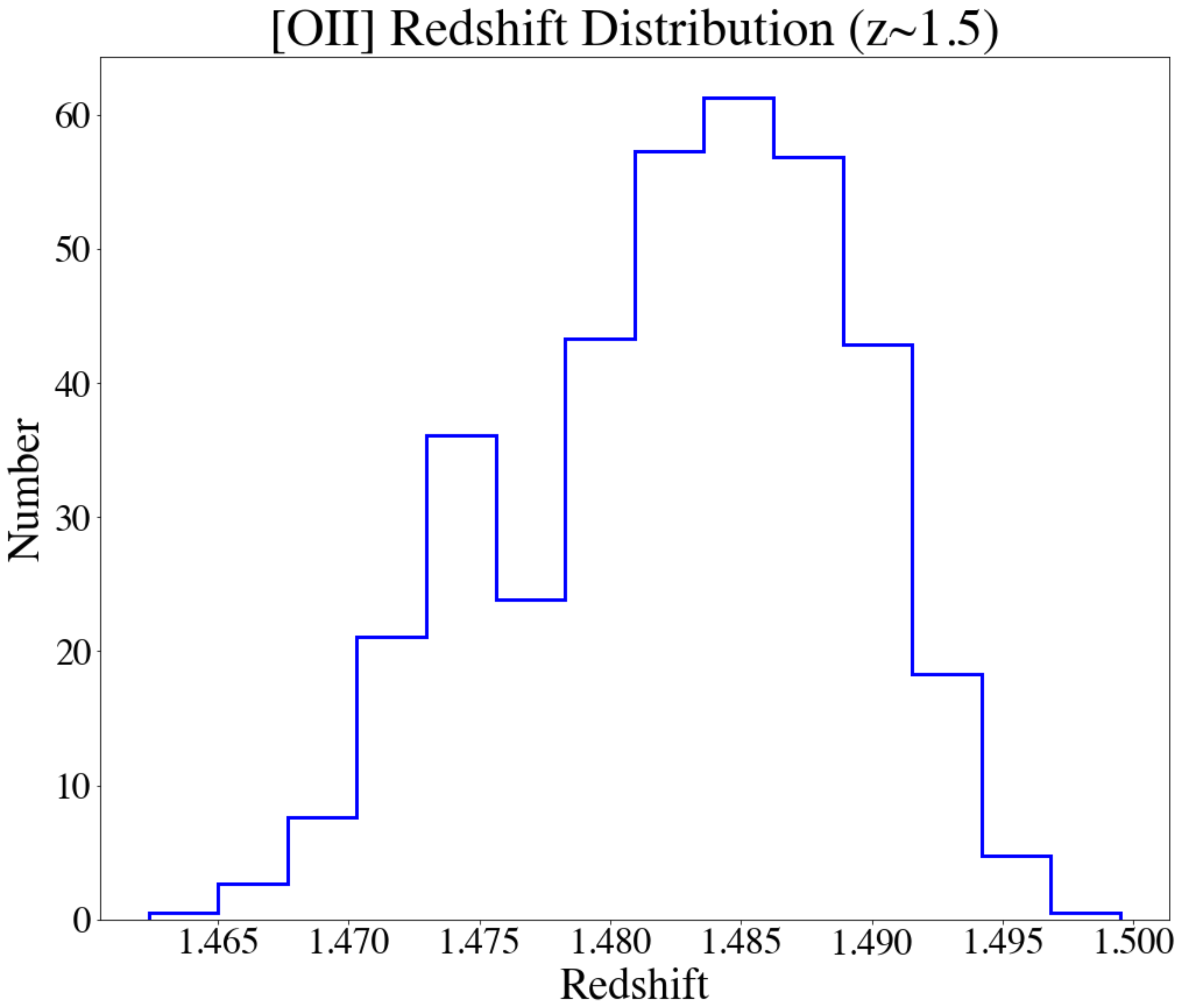
Comparision between the redshift z_{NB} estimated from the method and spectroscopic redshift z_{spec}

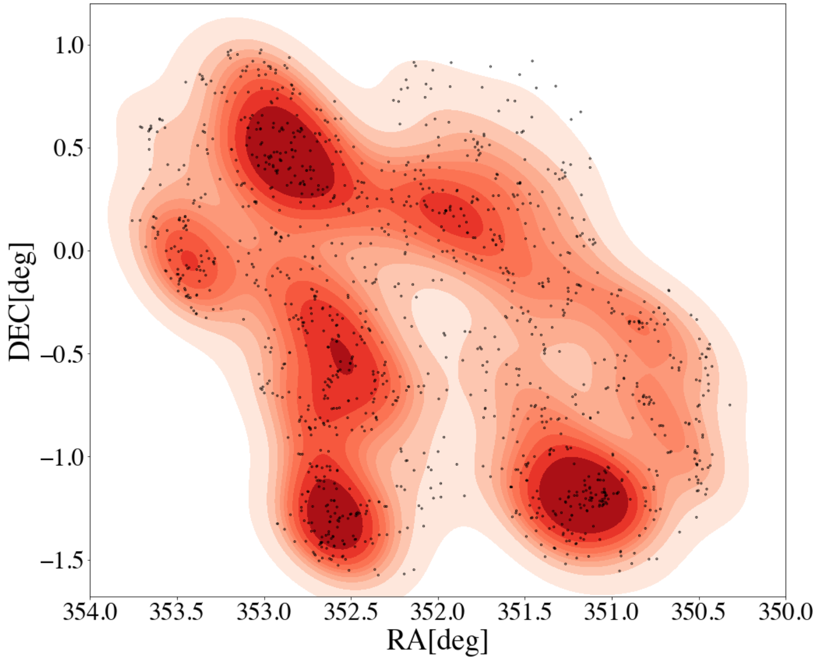
$$\sigma_{\Delta z/(1+z_s)} = 0.007 \text{ at } i^+_{AB} < 22.5$$
$$\sigma_{\Delta z/(1+z_s)} = 0.012 \text{ at } i^+_{AB} < 24 \quad ; z < 1.25$$
$$\sigma_{\Delta z/(1+z_s)} = 0.06 \text{ at } i^+_{AB} \sim 24 \quad ; z \sim 2$$

Ilbert et al 2009

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

REDSHIFT DISTRIBUTION

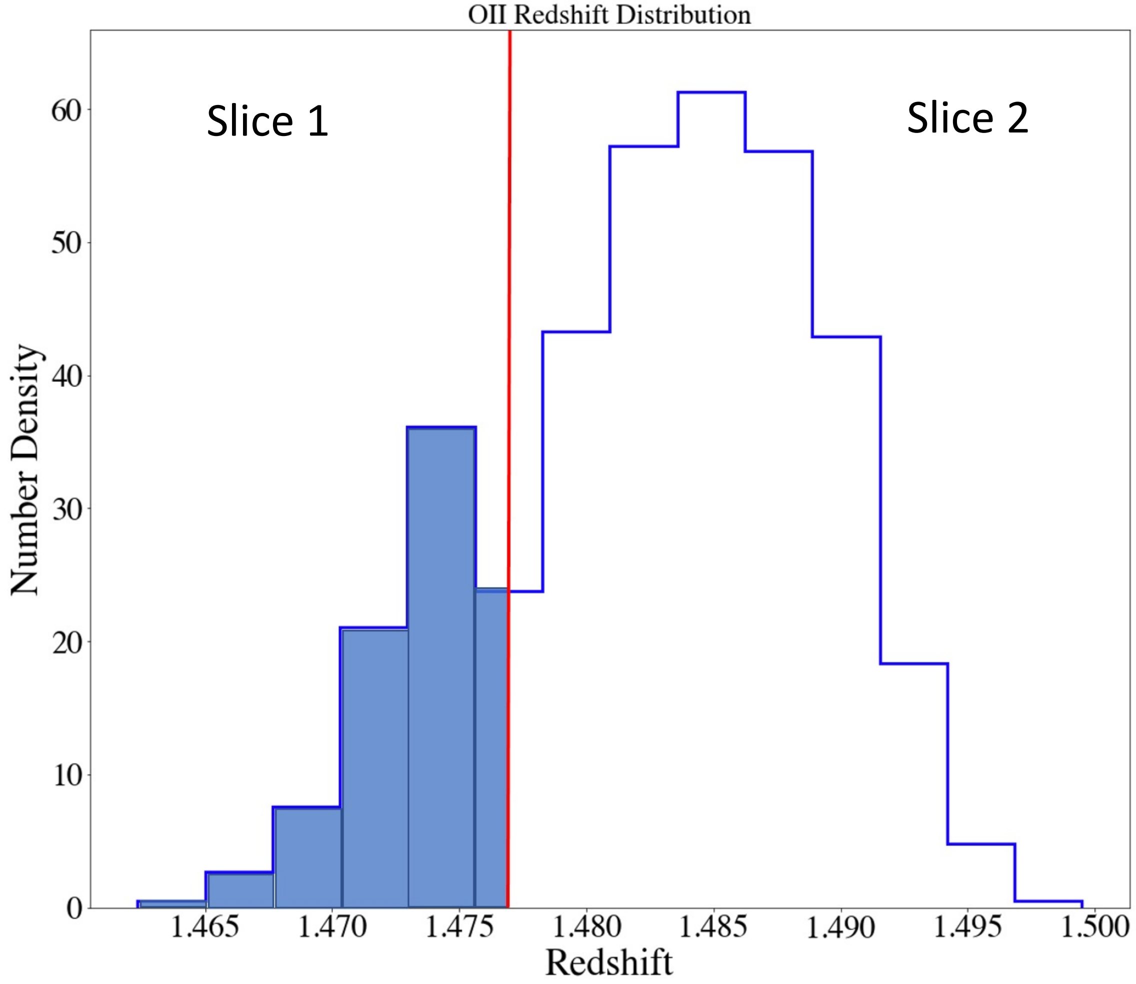


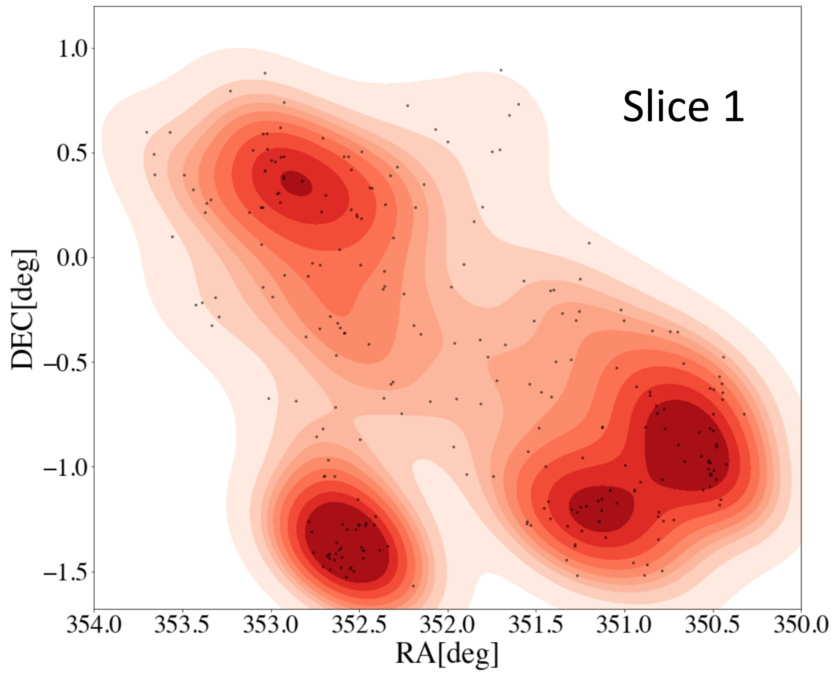


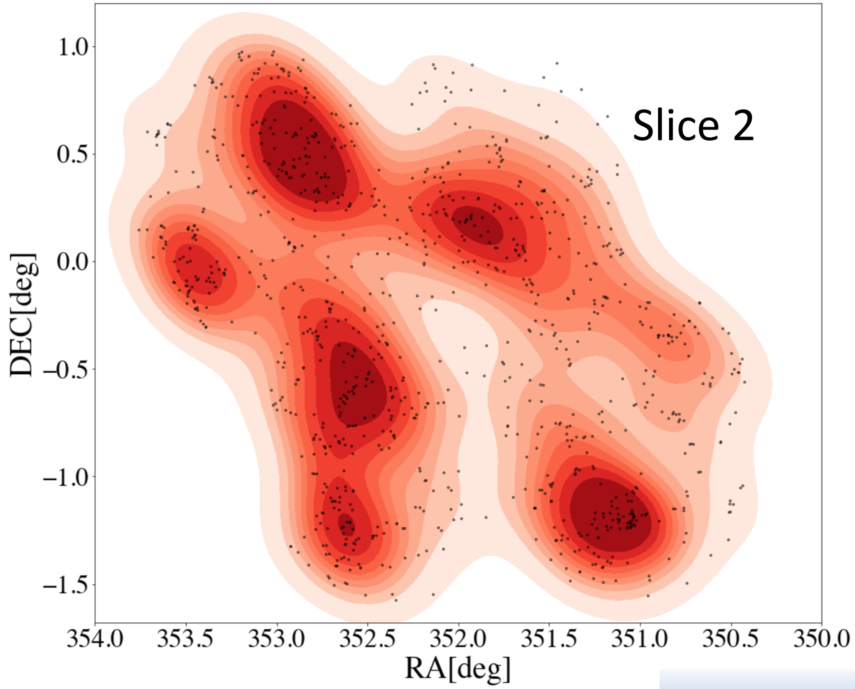
Different
Structures
In each slice?

?

Same can be applied to **Hα emitters at z~0.41** and **[OIII] emitters at z~0.8**







✓ **Different structures in each slices**

✓ **Can map the 3D structures**
(Projected distribution may not reflect the real structure)

Advantages of our novel method

Same can be applied to **Hα emitters at z~0.41** and **[OIII] emitters at z~0.8**

$$SFR_{H\alpha}(M_{\odot}yr^{-1}) = 7.9 \times 10^{-42} \cdot \frac{L_{H\alpha}}{ergs^{-1}}$$

$$SFR_{[OIII]}(M_{\odot}yr^{-1}) = 1.49 \times 10^{-41} \cdot \frac{L_{[OIII]}}{ergs^{-1}}$$

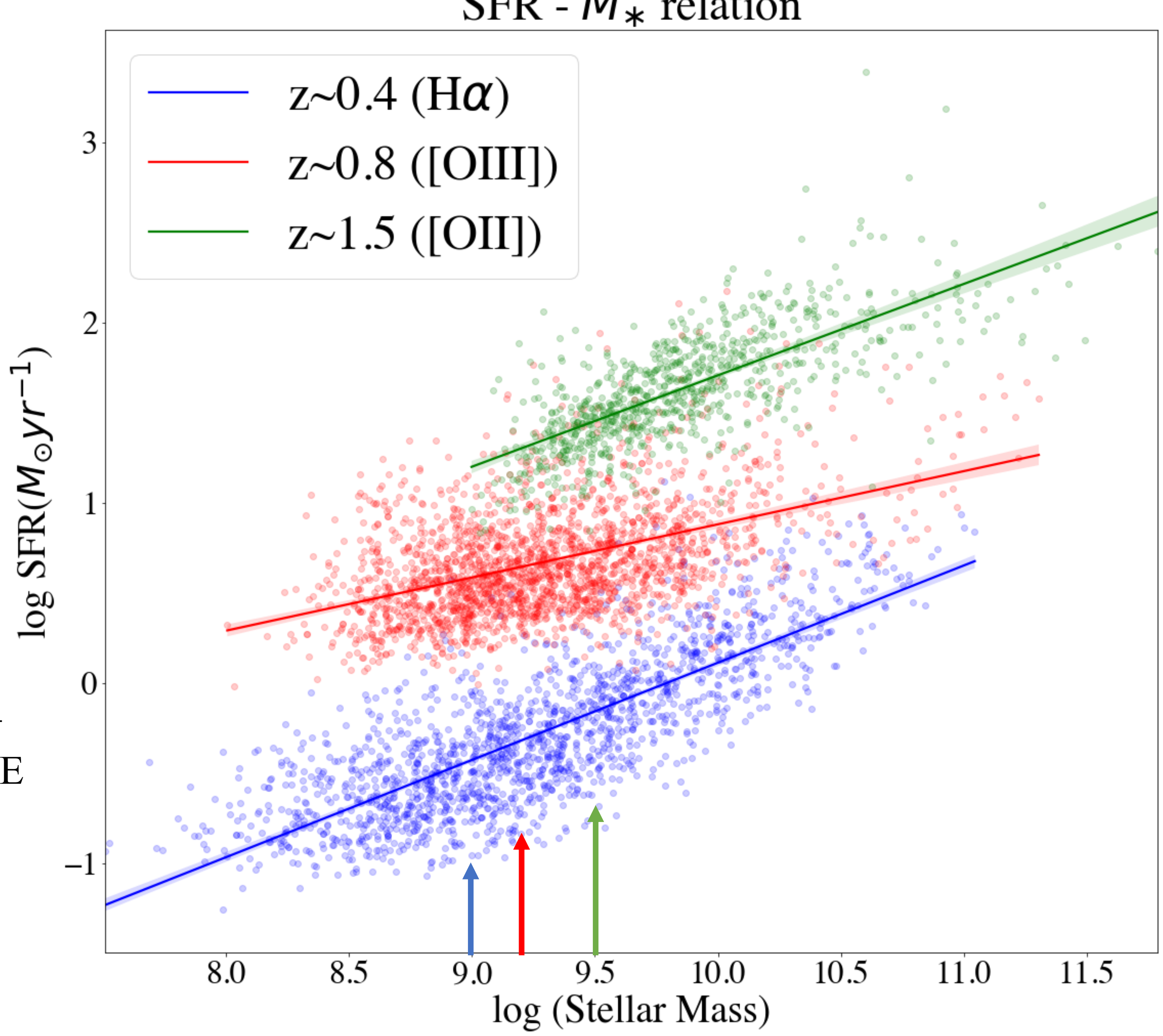
Teplitz H. I. et al 1999

$$SFR_{[OII]}(M_{\odot}yr^{-1}) = (1.4 \pm 0.4) \times 10^{-42} \cdot \frac{L_{[OII]}}{ergs^{-1}}$$

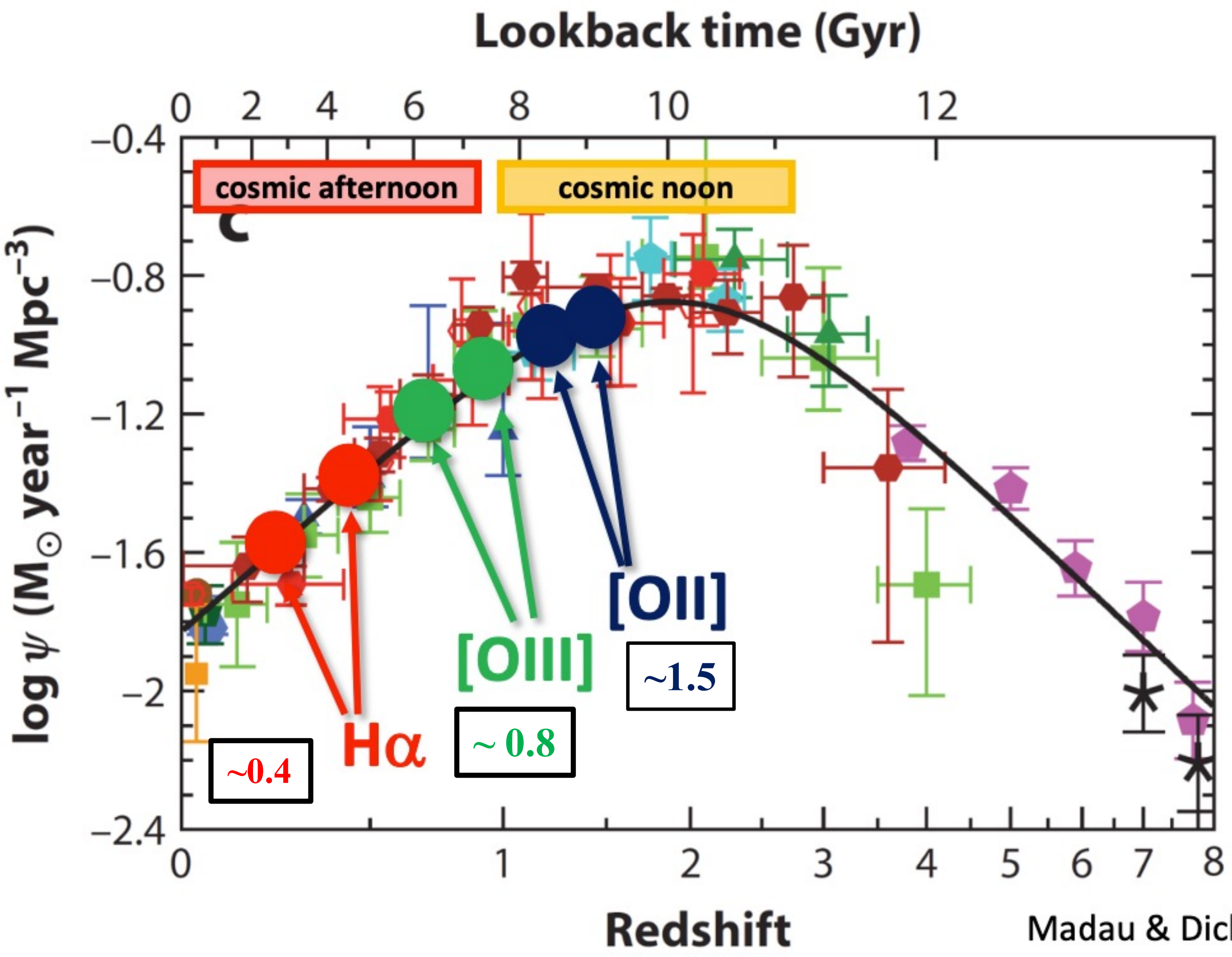
Stellar Mass by SED fitting with five HSC BB data + (WFCAM J +WFCAM K) using the code of CIGALE

The model SED templates are generated by

- Bruzual and Charlot 2003,
- Dust attenuation using modified Calzetti 2000,
- dust emission using Dale2014 templates,
- Chabrier IMF ,
- Metallicity (0.004,0.008, 0.02),
- age of main stellar population based on the redshifts.



The Blue, Red, and Green arrows denote the mass completeness limit for SF galaxies at $z = 0.4$, 0.8, and 1.5



Madau & Dickinson (2014)

z~0.4

Hα selected Cluster

CL1

CL2

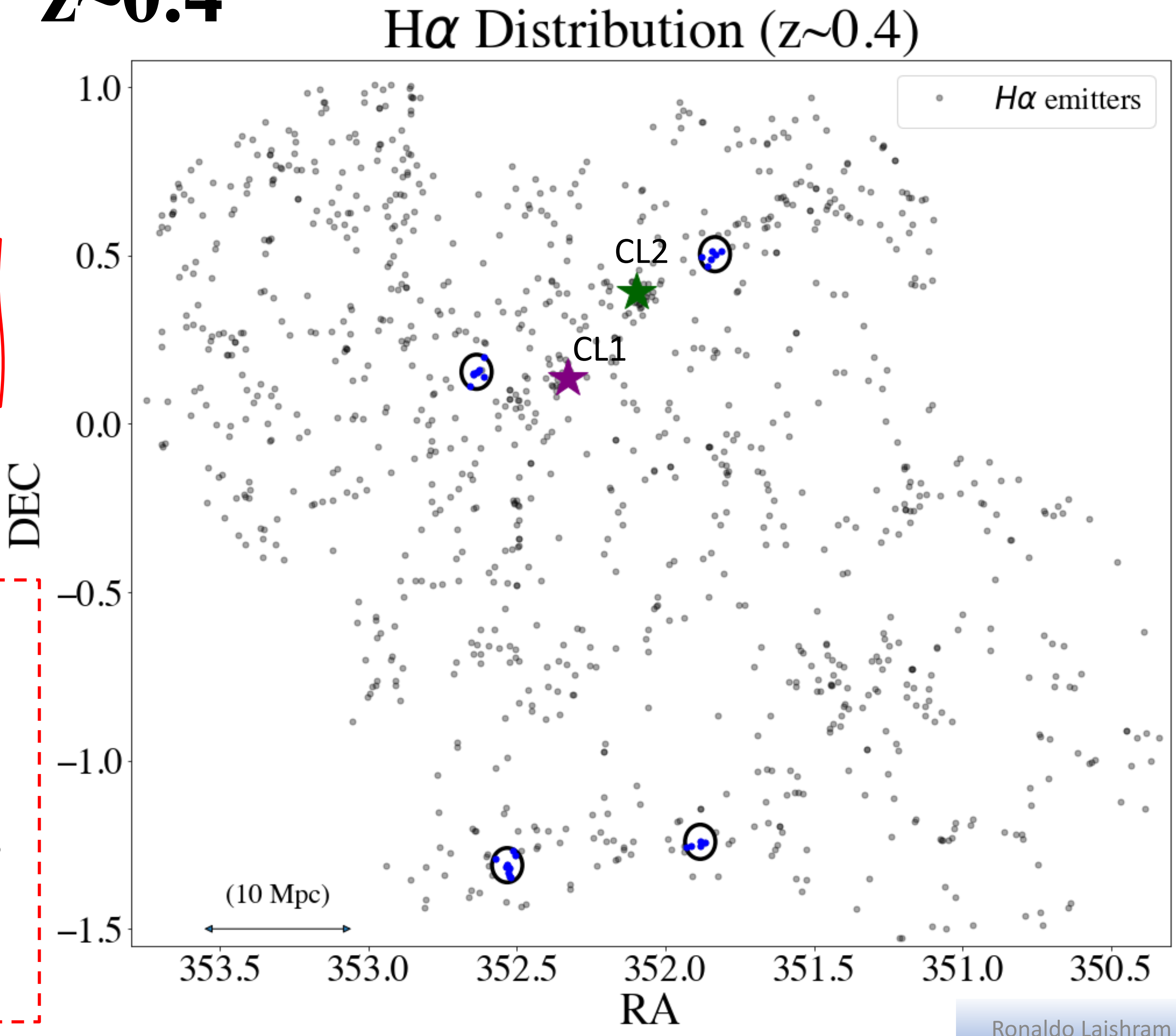
Red Sequence selected Cluster (CAMIRA)

(Oguri et al 2018)

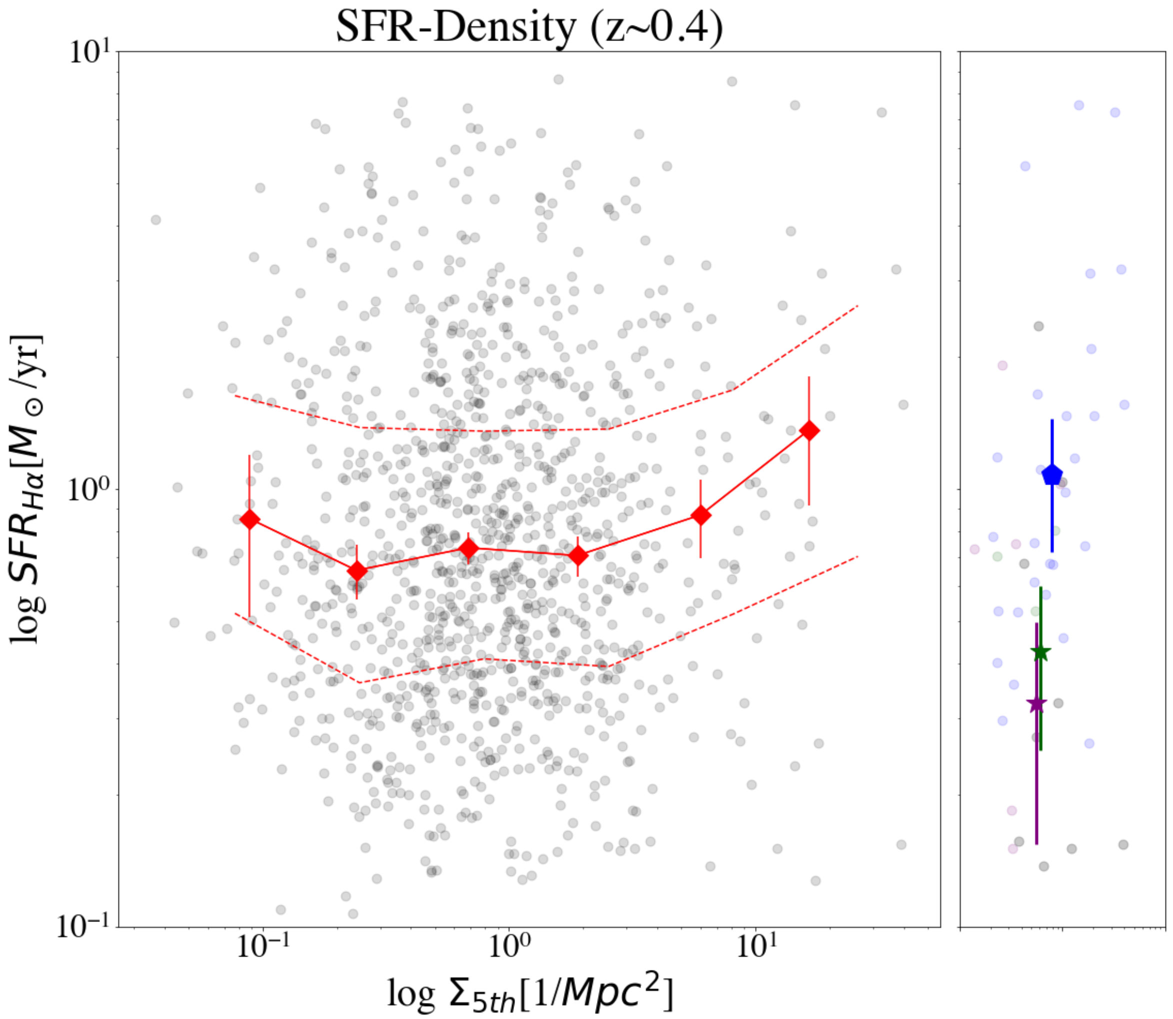
Environment Definition

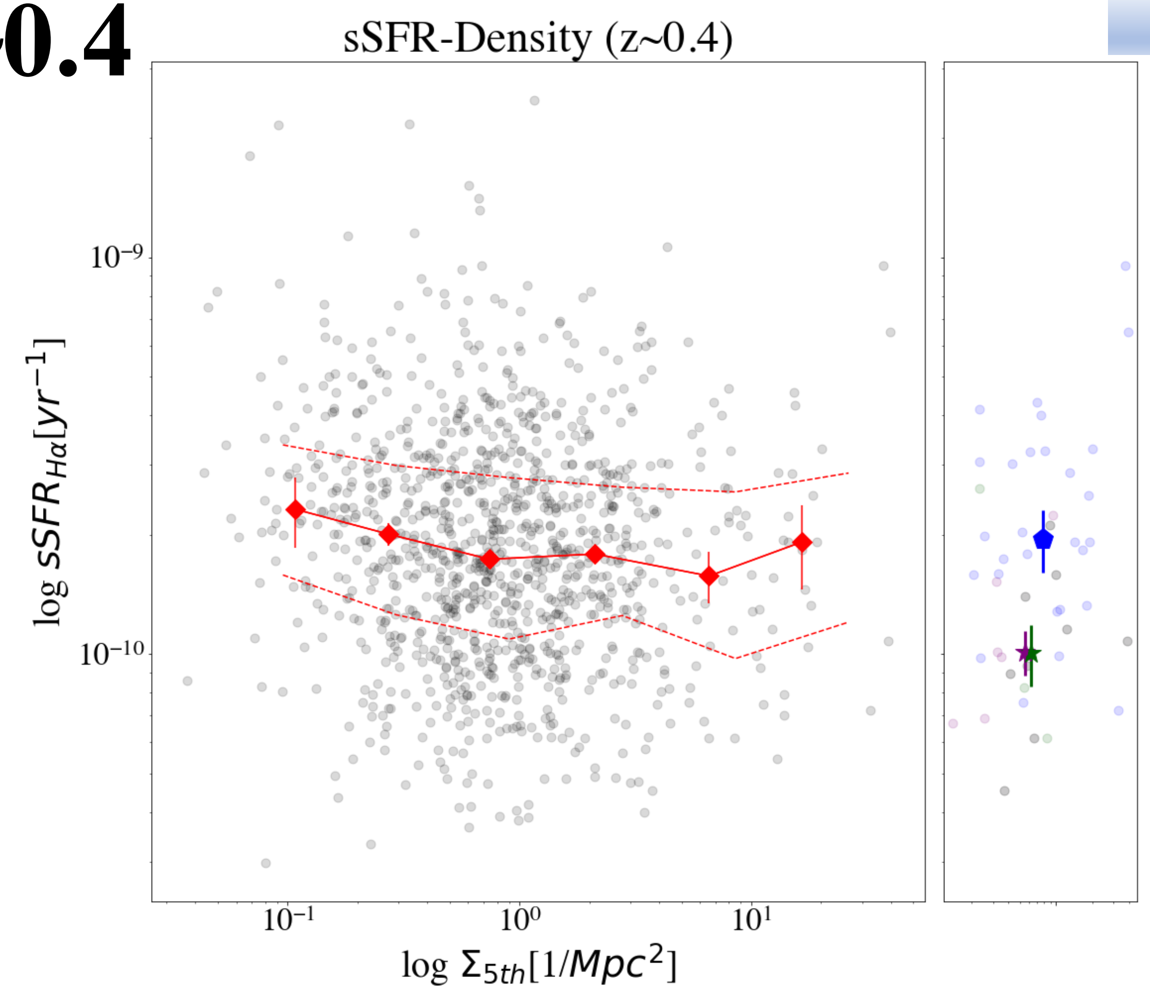
Fifth nearest local density

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



z~0.4





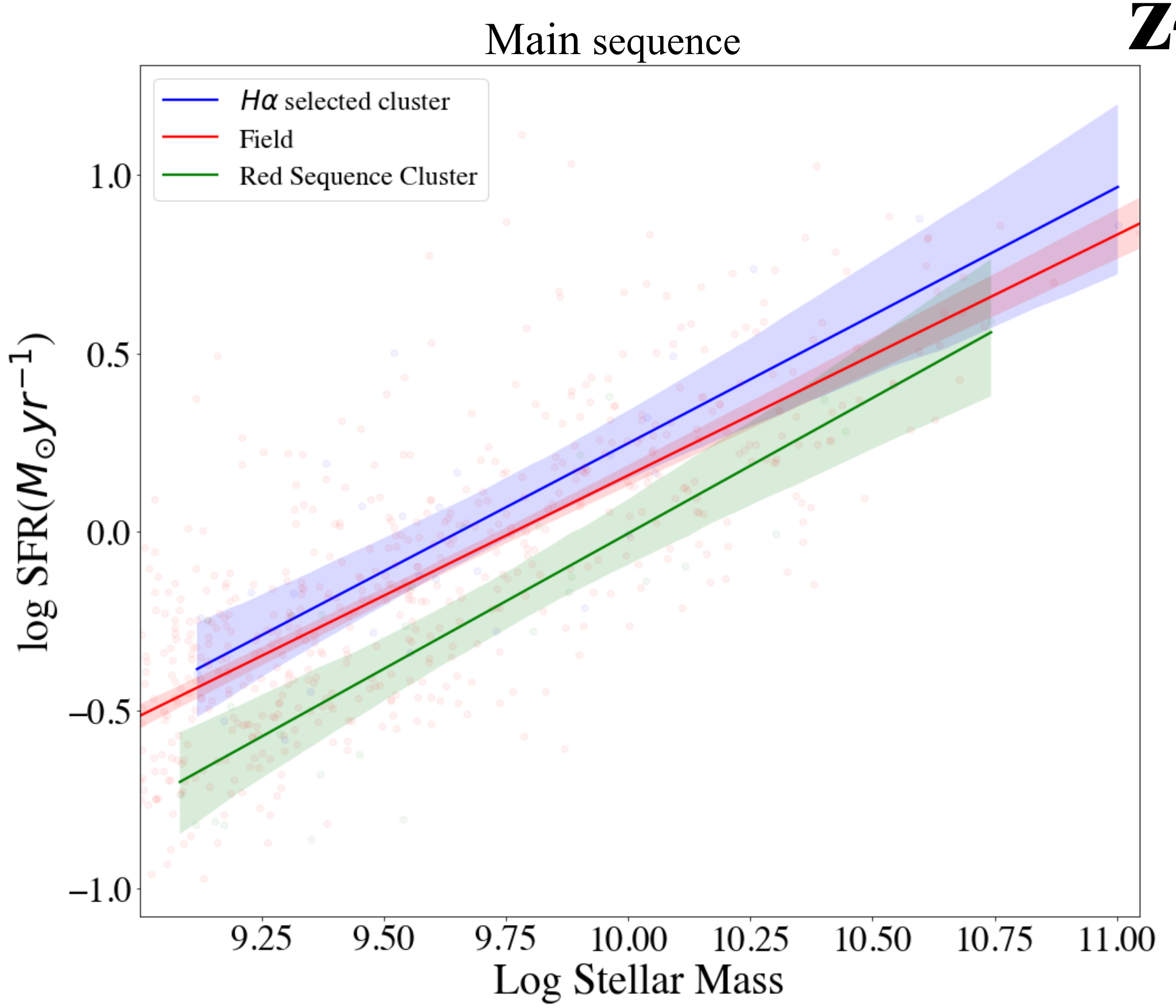
- Mild increase in star forming activity at high density region
- Star forming activity of the dense region selected by Hα emitters is more than the central region of galaxy clusters selected by red sequence at z ~0.4 (dominated by red quiescent galaxies)

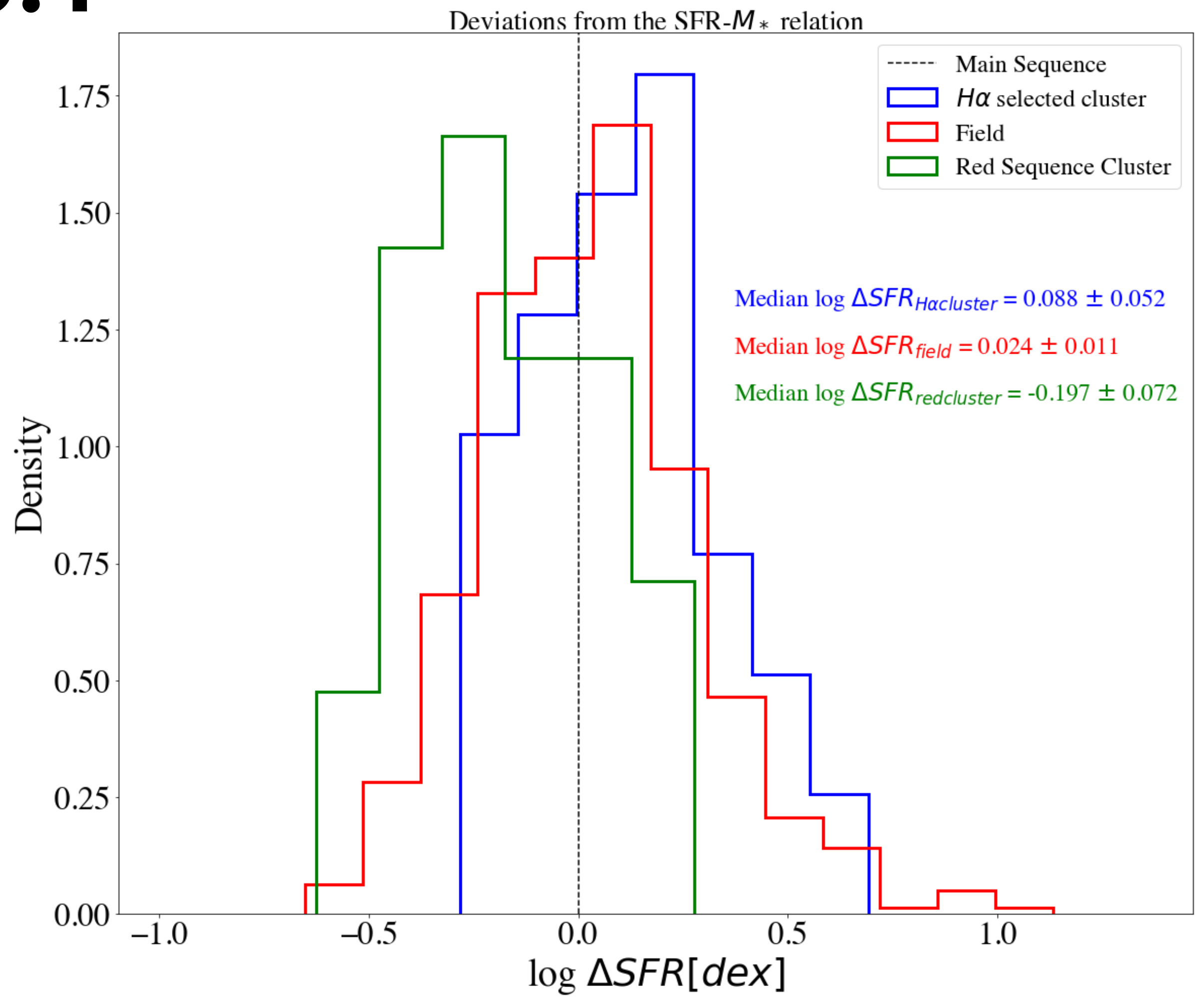
Hα selected Cluster

Red Sequence selected Cluster CL1

Red Sequence selected Cluster CL2

z~0.4





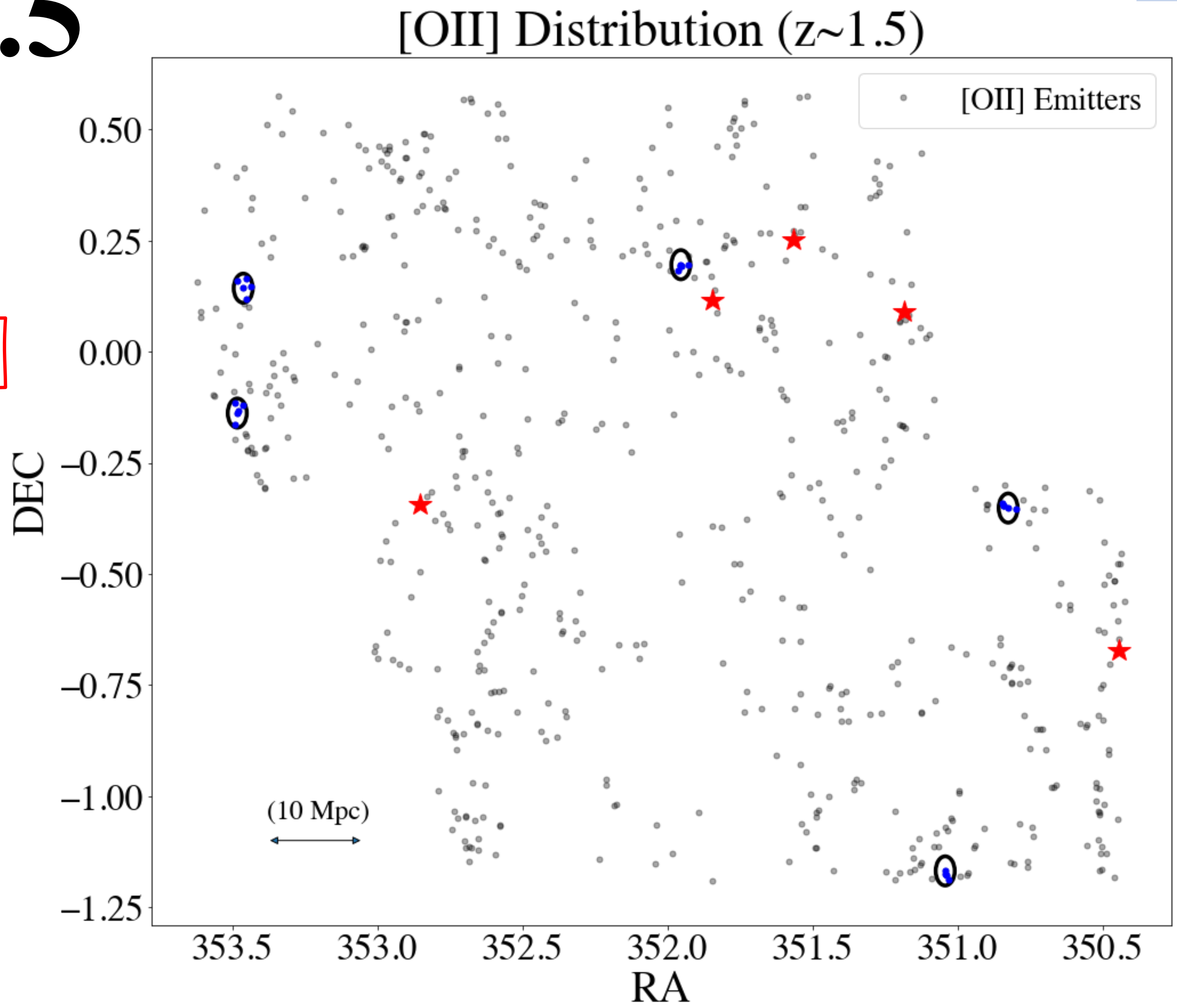
$\Delta SFR_{\text{RED SEQUENCE CLUSTER}} < \Delta SFR_{\text{FIELD}} \lesssim \Delta SFR_{\text{HA SELECTED CLUSTER}}$

!?

z~1.5

[OII] selected Cluster

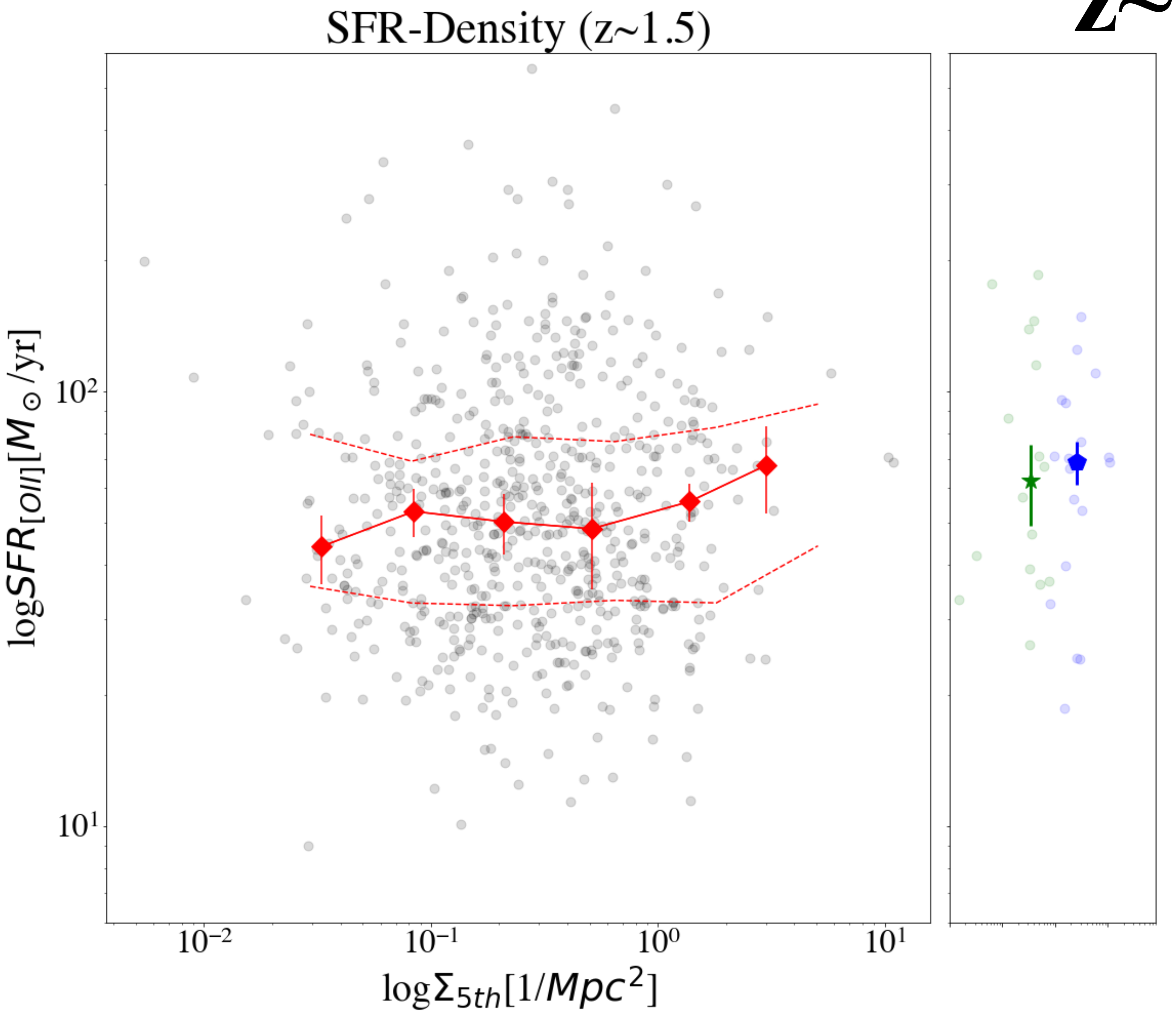
Red Sequence selected Overdensity

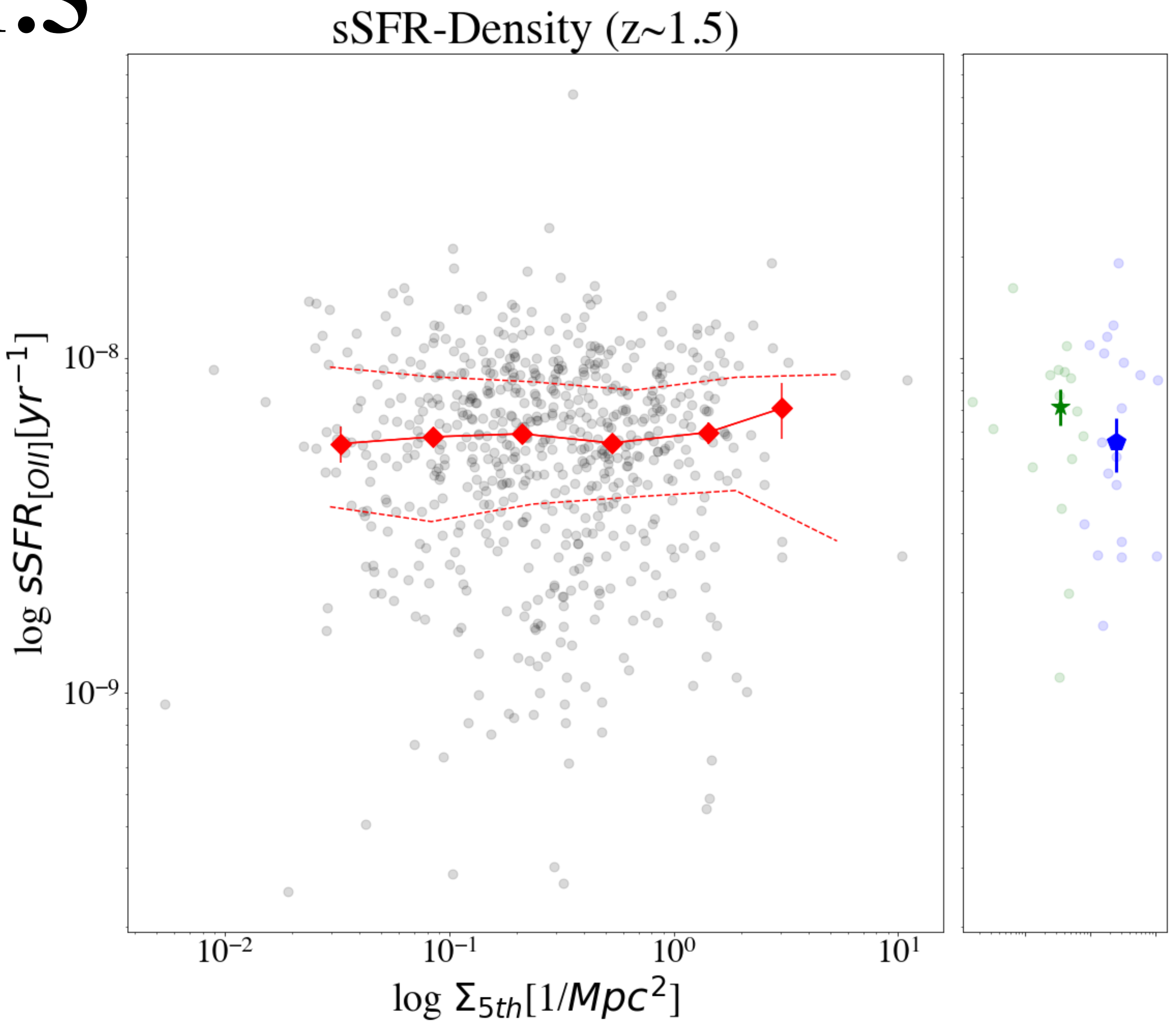


Red Sequence Overdensity Selection

- **19.6 < K <22.1**
- **2.2<z'-K<2.5**

z~1.5



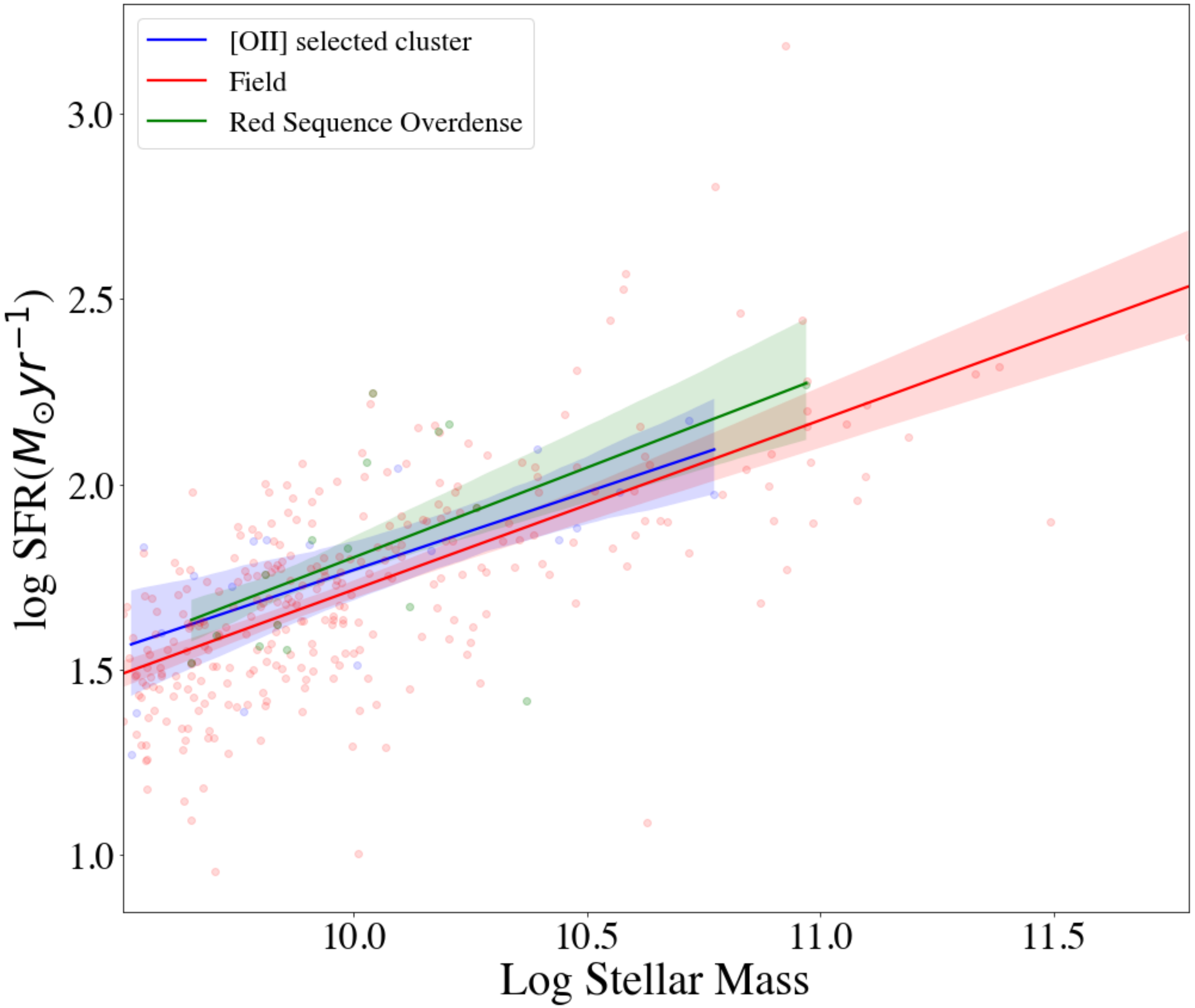


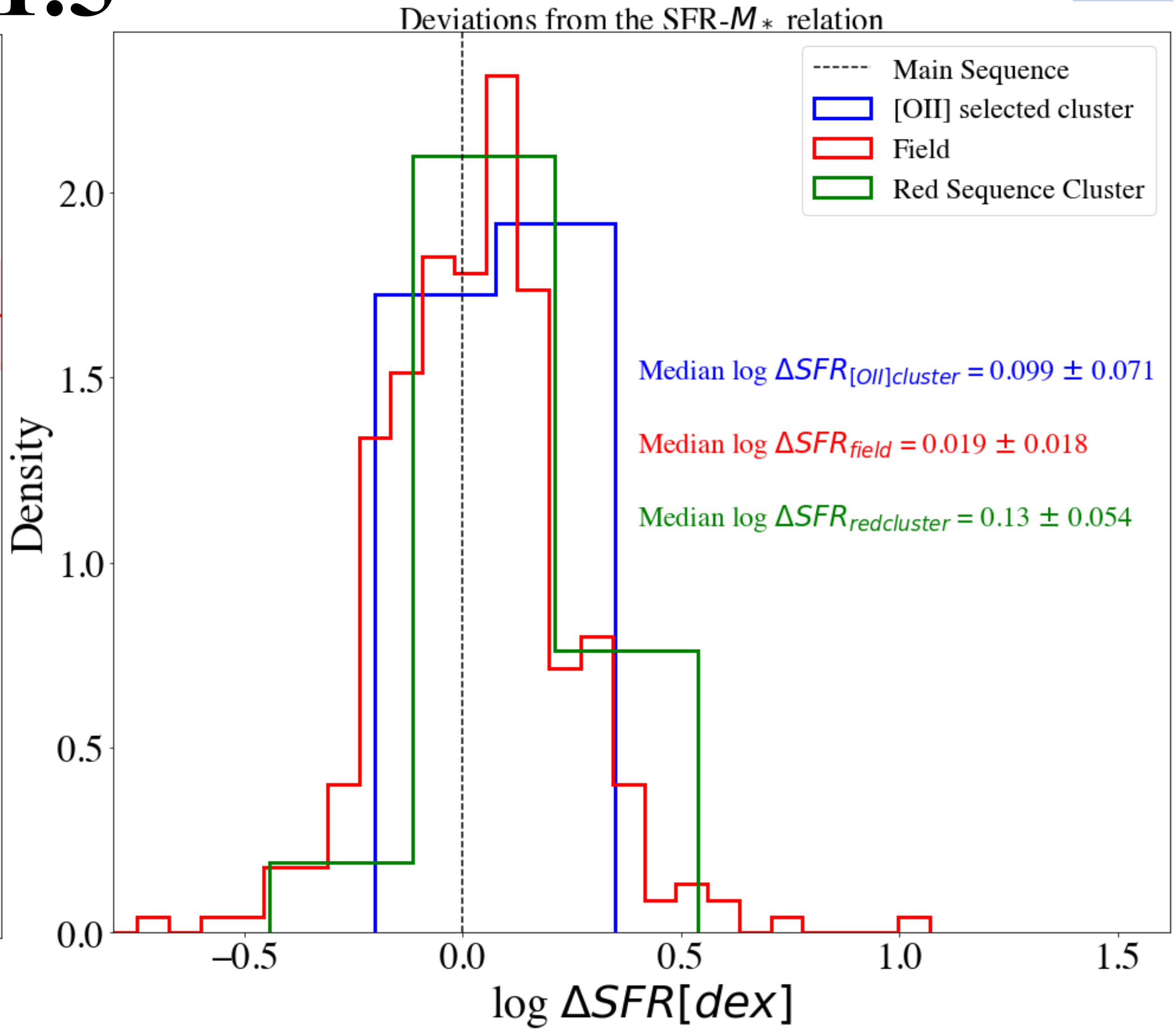
- No significant environmental dependence of Star forming activity

[OII] selected Cluster

Red Sequence selected Cluster CL2

z~1.5





Similar trend in all regions

- Galaxies have experienced a similar, steady history of SF in all environment
- Galaxy clusters are not yet evolved properly at this redshift

Summary and Future Work

- 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.
- Galaxy cluster at z~1.5 are not yet evolved properly unlike the cluster at z~0.4

FUTURE WORK

- Extending the work in other three HSC fields COSMOS, ELAIS-N1, SXDF
- Comparing the properties with Hα(z~0.41) [OIII] (z~0.86) , [OII] (z~1.5) emitters
- Obtaining the spectroscopic data of the sample for understanding the mechanism

THANK YOU