Unveiling biased galaxy formation across IGM environments at z>2

IGM Tomography WS   Aug.2016

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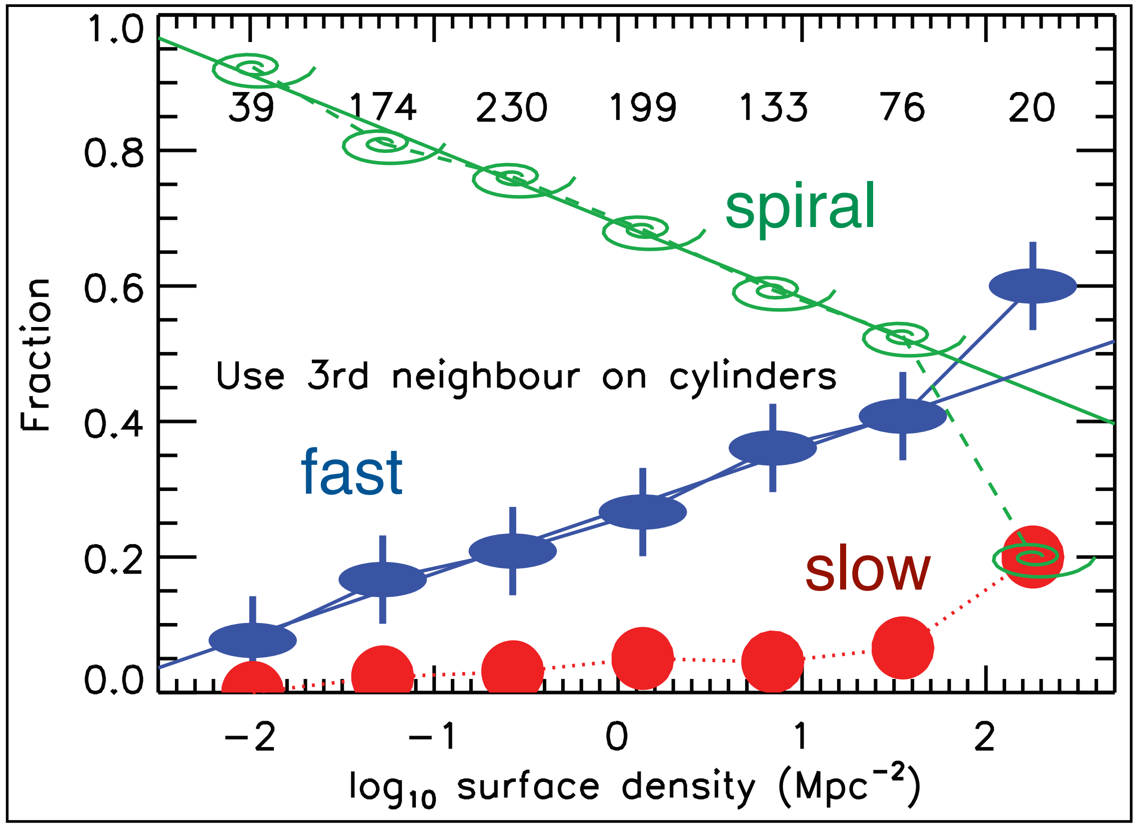
Galaxy diversity within LSSs

Scientific motivation:
physical origins causing diversity of galaxy properties across LSSs in the local Universe



Morphology density relation
Cappellari et al. 2011

MAHALO-Subaru

P.I. Tadayuki (Taddy) Kodama

MAHALO-Subaru

MApping HAlpha and Lines of Oxygen with Subaru

MAHALO ALOHA STATE

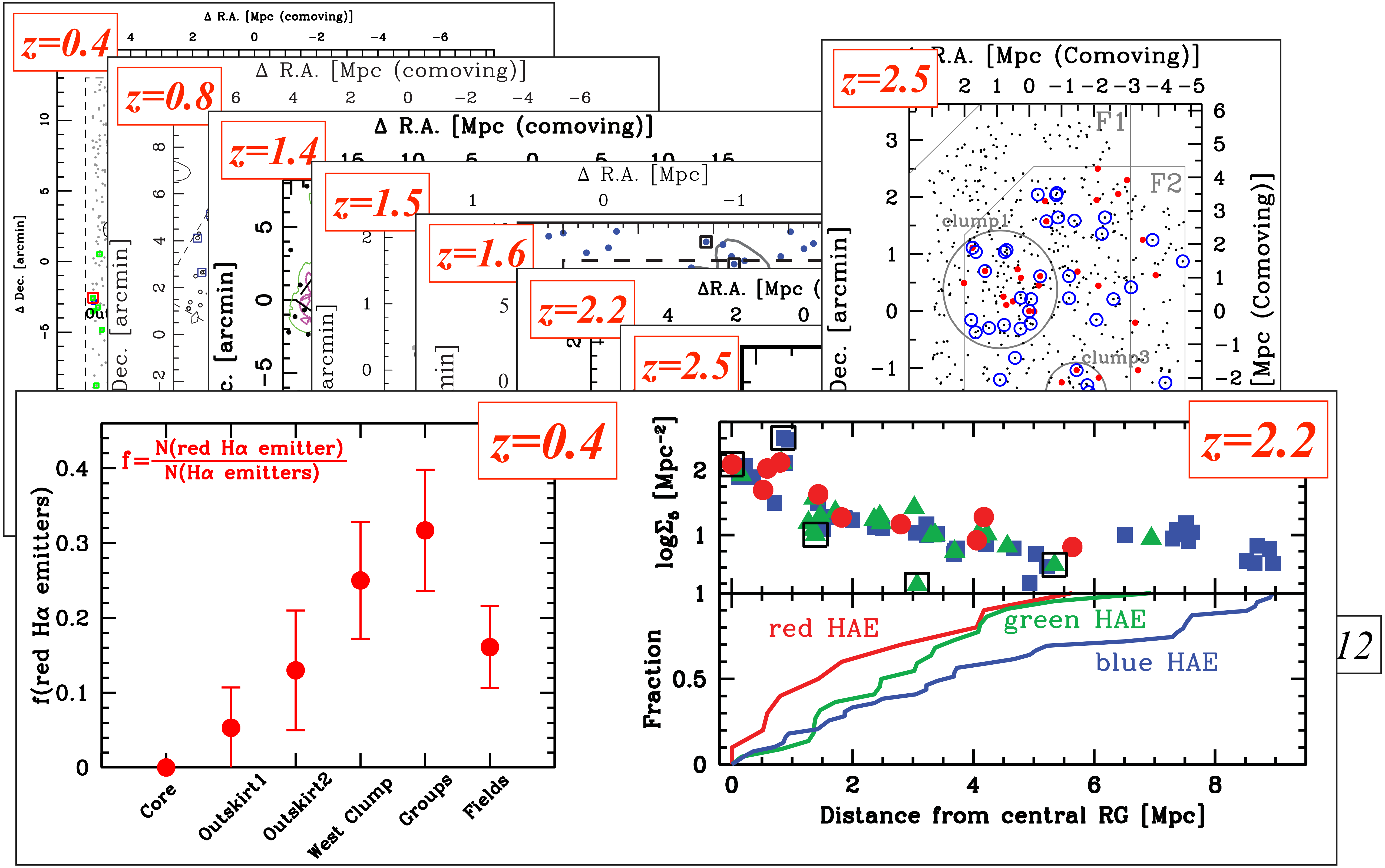
Unique sample of NB-selected SF galaxies across environments and cosmic times

	environment	target	z	line	λ (μm)	camera	NB-filter	continuum	status (as of Apr 2015)
z<1 clusters	Low-z clusters	CL0024+1652	0.395	Hα	0.916	Suprime-Cam	NB912	z'	Kodama+'04
		CL0939+4713	0.407	Hα	0.923	Suprime-Cam	NB921	z'	Koyama+'11
		CL0016+1609	0.541	Hα	1.011	Suprime-Cam	NB1006	z'	not yet
		RXJ1716.4+6708	0.813	Hα	1.190	MOIRCS	NB1190	J	Koyama+'10
				[OII]	0.678	Suprime-Cam	NA671	R	observed
		RXJ0152.7-1357	0.837	[OIII]	0.920	Suprime-Cam	NB921	z'	not yet
z~1.5 clusters	High-z clusters	XCSJ2215-1738	1.457	[OII]	0.916	Suprime-Cam	NB912, NB921	z'	Hayashi+'10, '12
		4C65.22	1.516	Hα	1.651	MOIRCS	NB1657	H	Koyama+'14
		CL0332-2742	1.61	[OII]	0.973	Suprime-Cam	NB973	y	observed
		ClGJ0218.3-0510	1.62	[OII]	0.977	Suprime-Cam	NB973	y	Tadaki+'12
z>2 clusters	Proto-clusters	PKS1138-262	2.156	Hα	2.071	MOIRCS	NB2071	K_s	Koyama+'12
		HS1700+64	2.30	Hα	2.156	MOIRCS	BrG	K_s	observed
				[OIII]	1.652	MOIRCS	[Fe II]	H	not yet
		4C23.56	2.483	Hα	2.286	MOIRCS	CO	K_s	Tanaka+'11
		USS1558-003	2.527	Hα	2.315	MOIRCS	NB2315	K_s	Hayashi+'12
		MRC0316-257†	3.130	[OII]	1.539	MOIRCS	NB1550	H	not yet
				[OIII]	2.068	MOIRCS	NB2071	K_s	observed
z>2 field	General fields	SXDF-CANDELS	2.16	Hα	2.071	MOIRCS	NB2071	K_s	observed
		(90 arcmin^2)	2.19	Hα	2.094	MOIRCS	NB2095	K_s	Tadaki+'13
			2.53	Hα	2.315	MOIRCS	NB2315	K_s	Tadaki+'13
			3.17	[OIII]	2.093	MOIRCS	NB2095	K_s	Suzuki+'14
			3.63	[OIII]	2.317	MOIRCS	NB2315	K_s	Suzuki+'14
		COSMOS-CANDELS	2.16	Hα	2.071	MOIRCS	NB2071	K_s	partly observed
		(90 arcmin^2)	2.19	Hα	2.094	MOIRCS	NB2095	K_s	partly observed
		GOODS-N	2.19	Hα	2.094	MOIRCS	NB2095	K_s	Tadaki+'11
		(70 arcmin^2)		[OII]	1.189	MOIRCS	NB1190	J	observed

~20 nights for imaging, >15 nights for spectroscopy

Kodama et al. (2013)

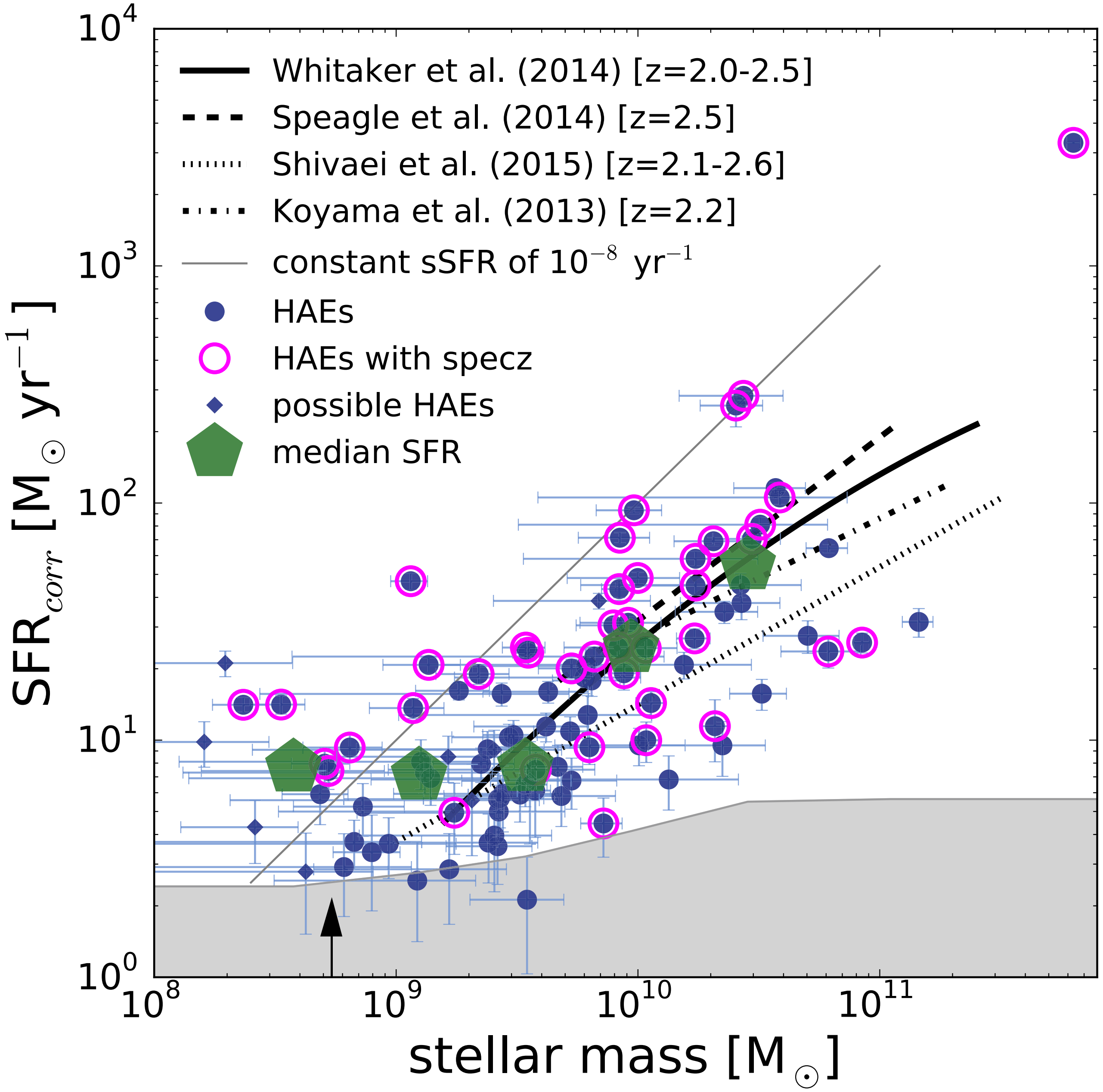
Mapping line emitters by MAHALO-Subaru

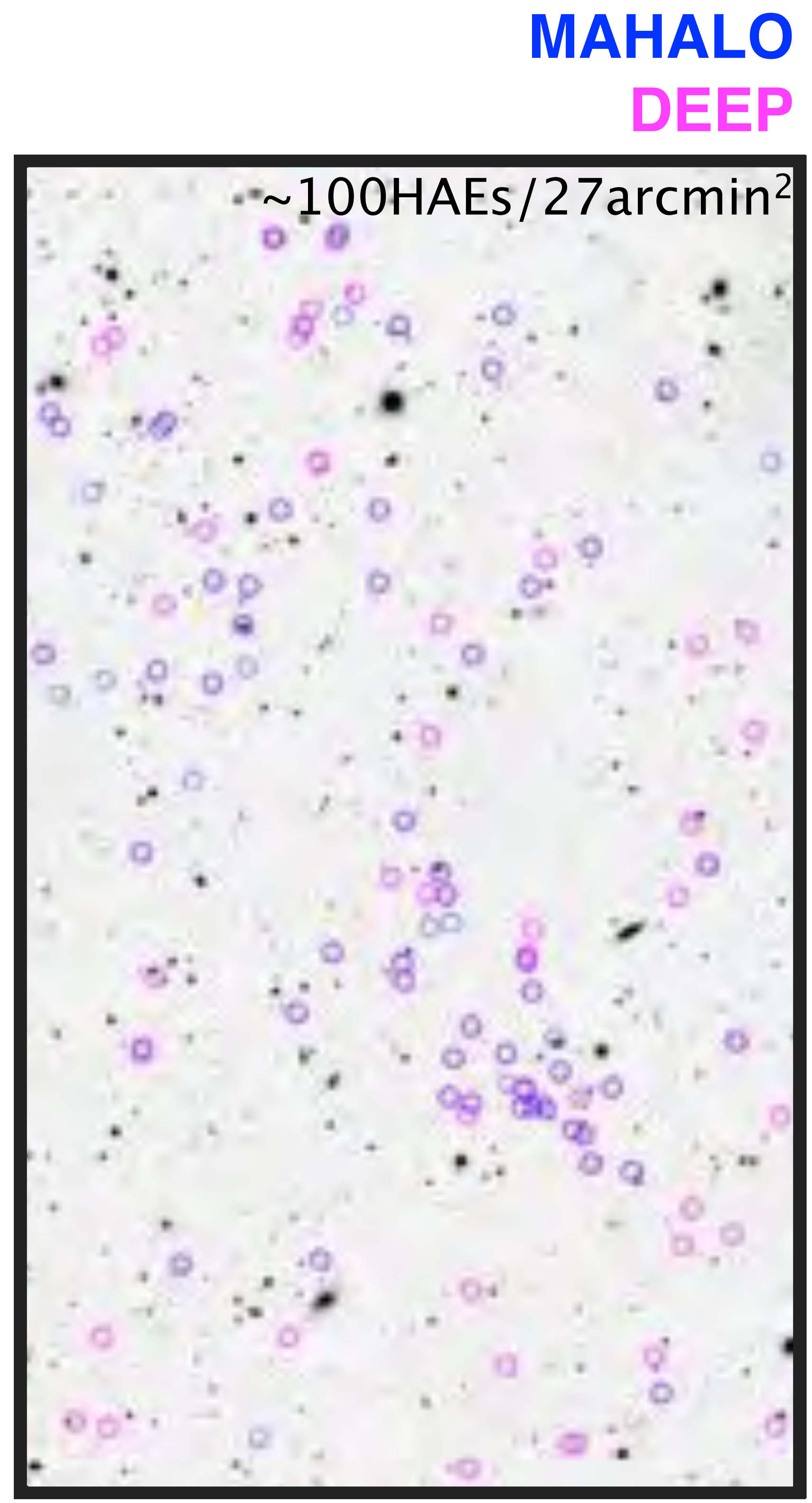


MAHALO-Subaru is now going deeper

MAHALO-DEEP (~10 hrs integration)

increased the number of HAEs ×~1.5
found low-mass starburst systems





Hayashi et al. 2016

Galaxy properties: fields vs. clusters

Reds claim the presence of environmental dependence

Morphology	Low-z	High-z	What about clusters?
Morphology-density	***Cappellari+11***	***Hine+16***	**more slow rotators (mergers)**
Mass-size relation	***Cooper+12***	***Belli+14***	**larger sizes**
Star-formation			
Main sequence	*Popesso+07*	*Koyama+13*	**more red SFGs**
Starbursts & AGNs	***Poggianti+09***	***Umehata+15***	**more E+A, AGNs**
Metal abundance			
Stellar	***Thomas+05***	***Tanaka+13***	**earlier t_{formed}**
Gas-phase	***Ellison+09***	*Kacprzak+15*	same/higher [O/H]

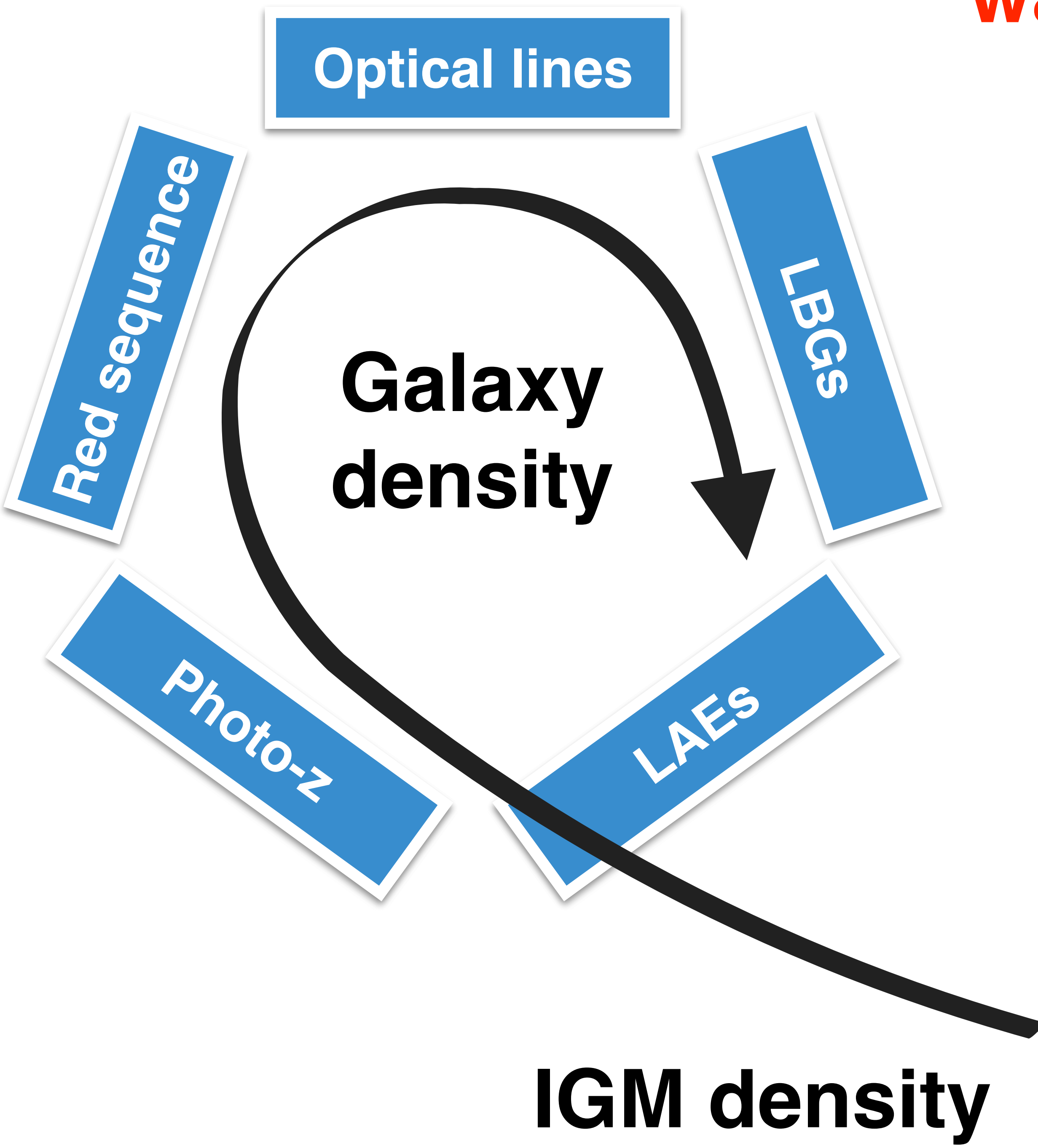
Selection uncertainty

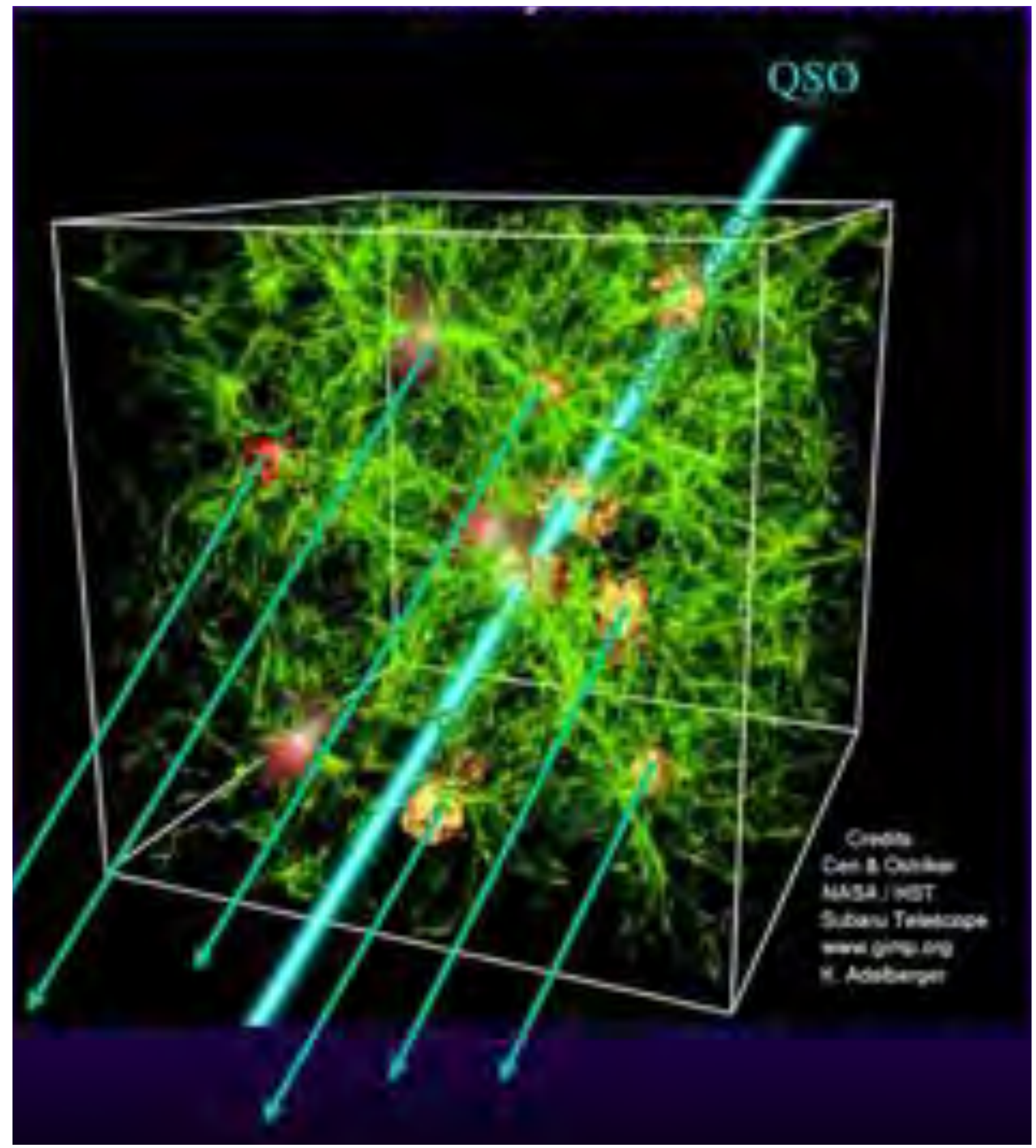
Technique	Redshift	Issues
Photo-z	any	expensive, model dependent
Red sequence	$z < 5$	quite expensive at higher-z
Optical lines	$z < 3–5$	limited to narrow field, high EW
LBGs	$z > 2$	depends on UV light, foreground IGM
LAEs	$z > 2$	CGM, dust, unresolved effects
Radio galaxies	any	unknown bias

These problems are related to estimation of galaxy overdensity !!

Lyα forest analyses

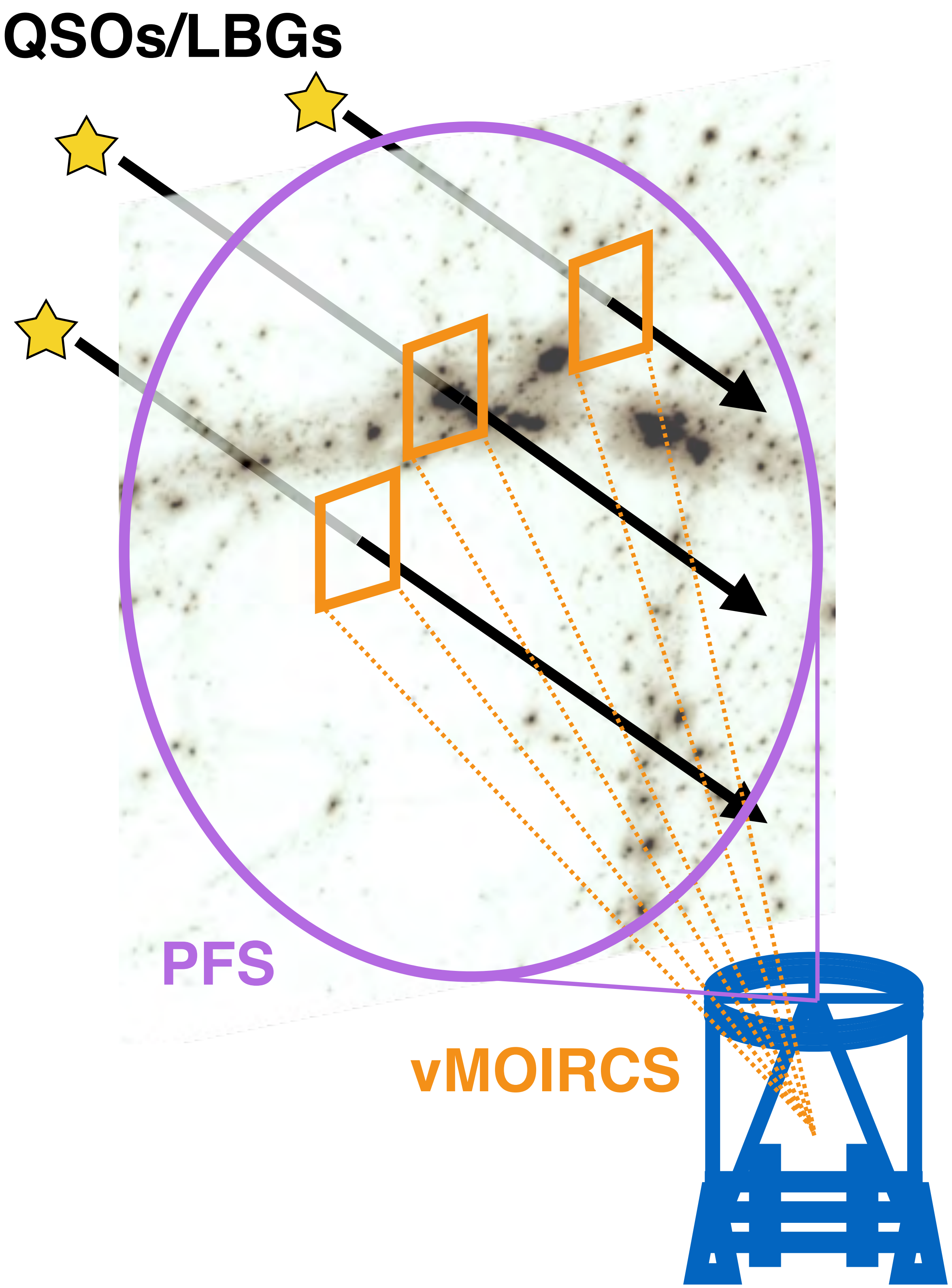
Lyα forest analyses is the fairest way to assess environments



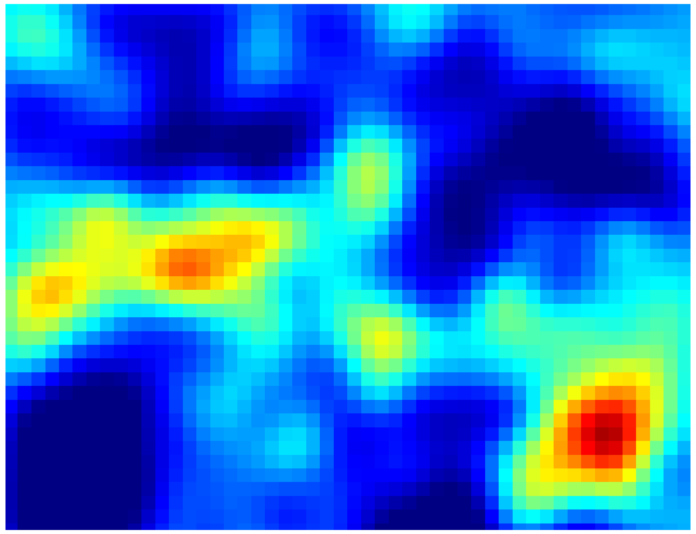


C. C. Steidel (Caltech)

Unveiling galaxy formations across IGM densities



(1) IGM tomography by PFS



K. G. Lee et al. 2014

(2) MOIRCS NB imaging

General fields

~ 10 / MOIRCS FoV (7'x4')

Protoclusters (~1/deg²)

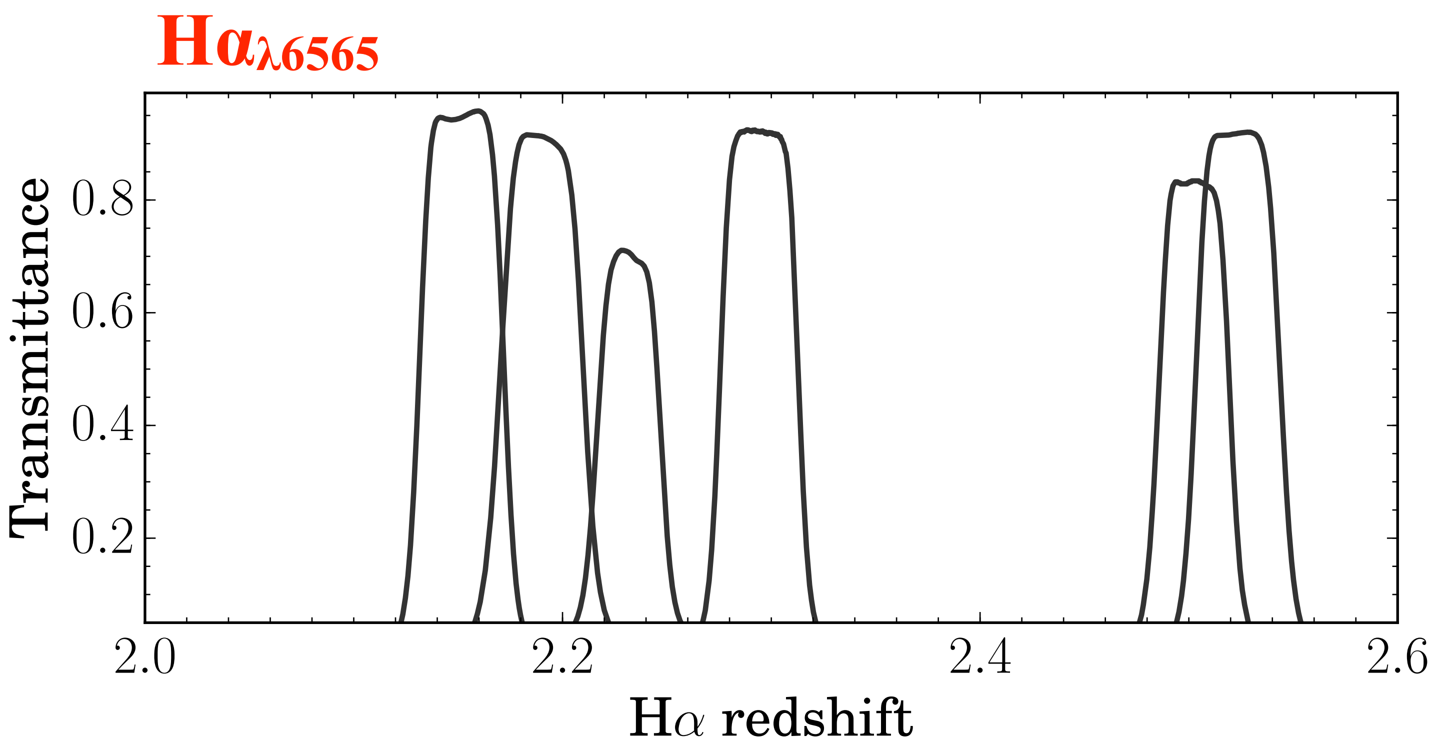
> 50 / MOIRCS FoV

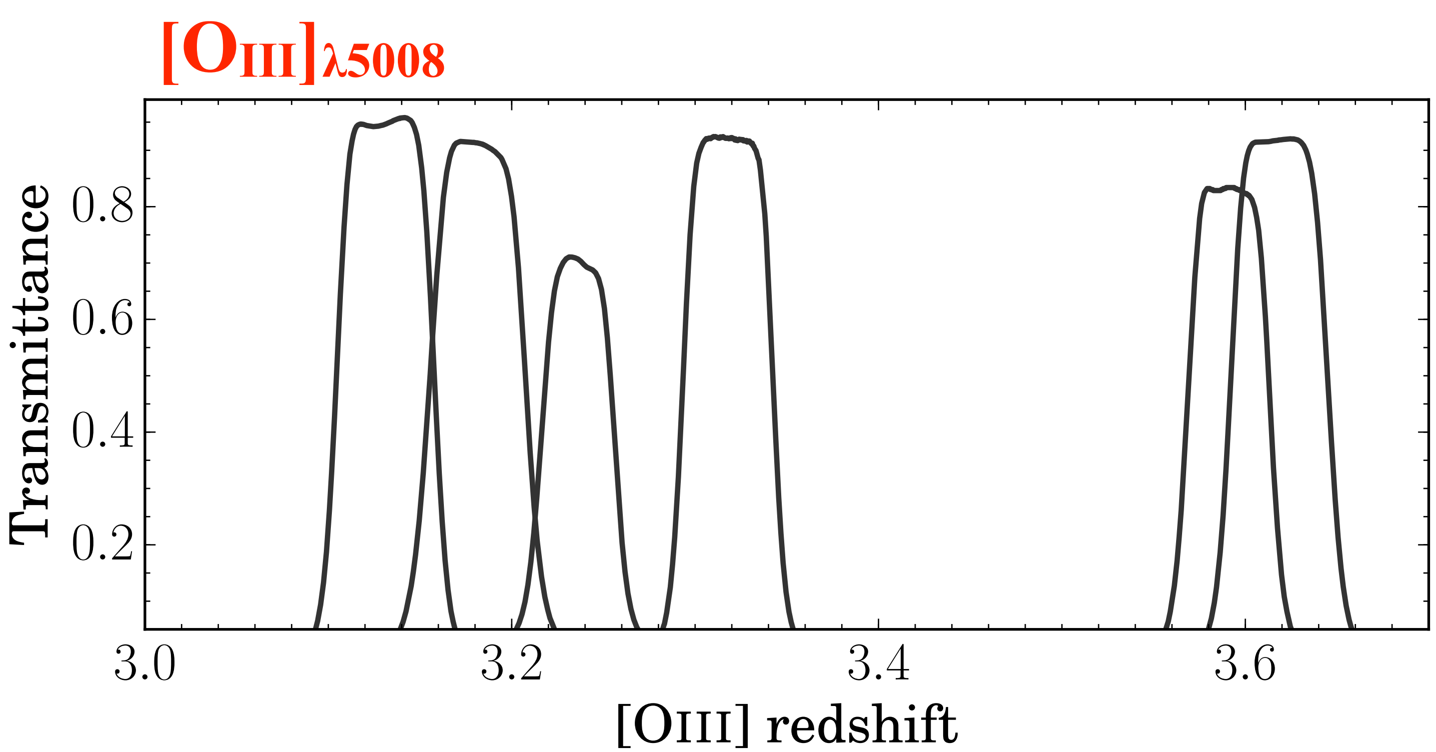
Void regions

< 3 / MOIRCS FoV

* t_{exp}~3hrs

νMOIRCS narrow-band filters





NB Filters

NB2071/2095/2315
(provided by T. Kodama)

NB2288
(provided by Y. Taniguchi)

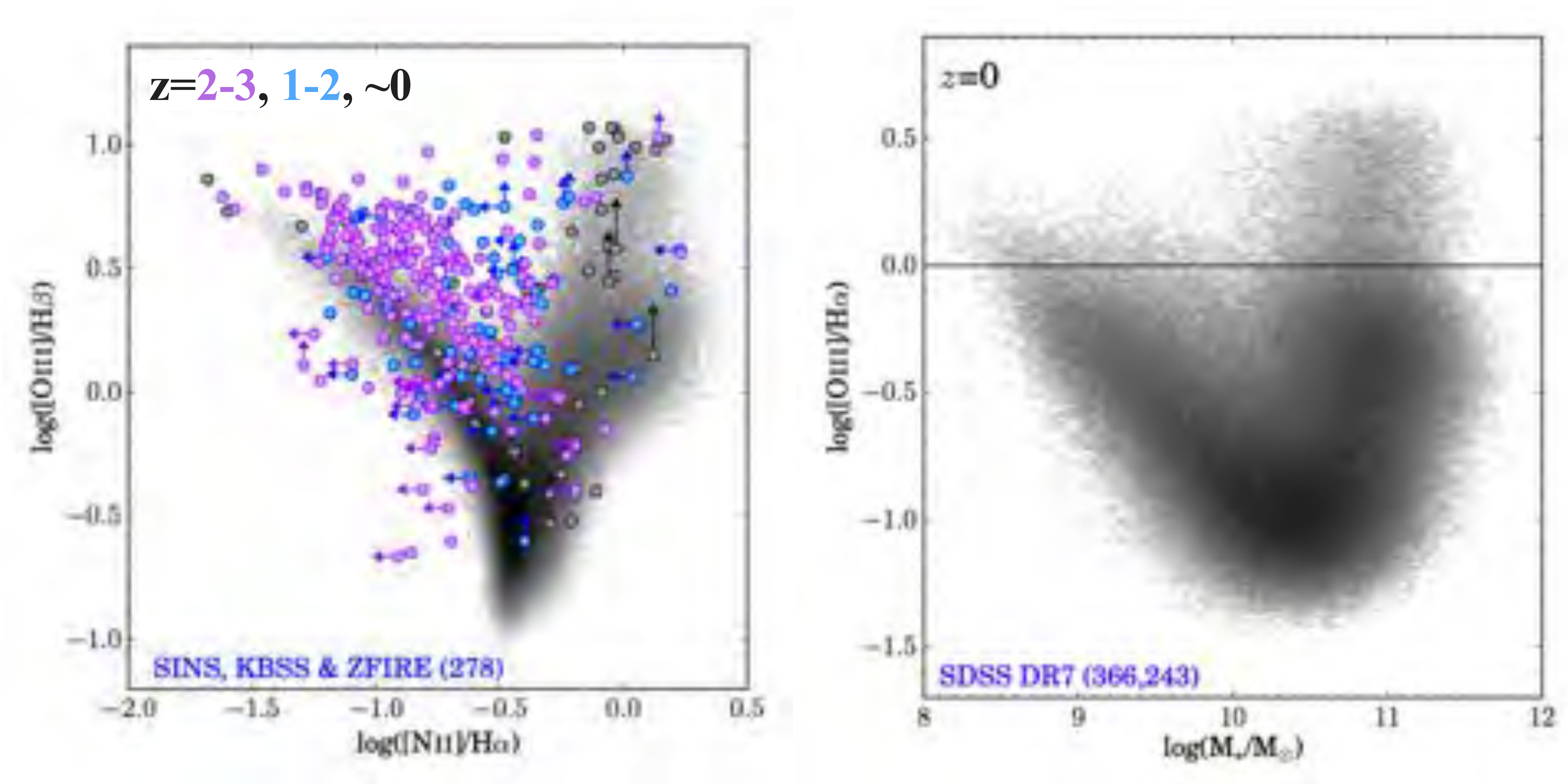
H2/BrG

Those cover $z_{H\alpha,[OIII]}$=2-4

[OIII] emitters as proxy of Hα emitters

Hα line is no longer observable at z>2.6

[OIII] line is useful tracer for z>3 SFGs instead of Hα from ground



see also Suzuki et al. 2015,2016

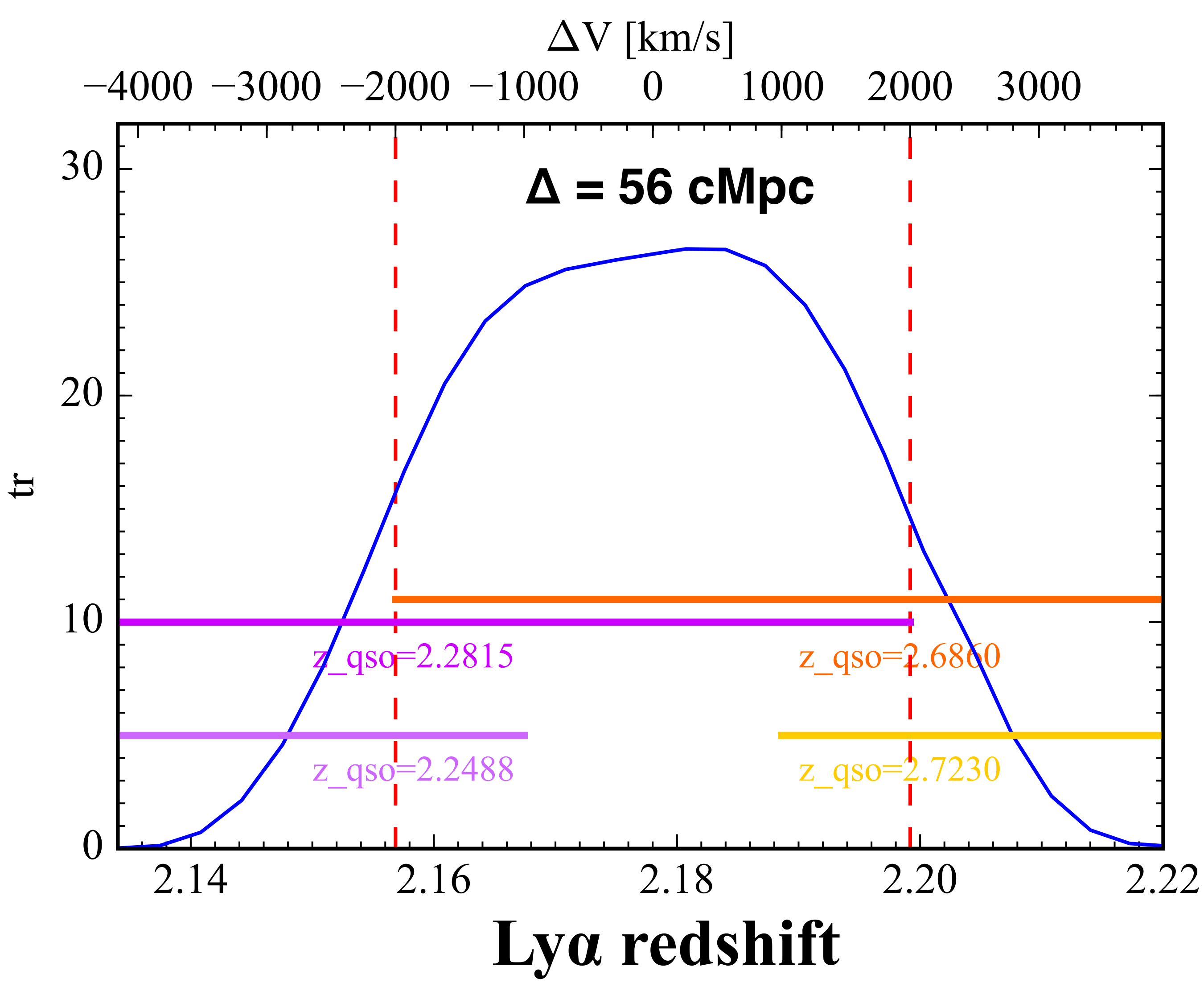
Lyα line mapping in HSC-DEEP

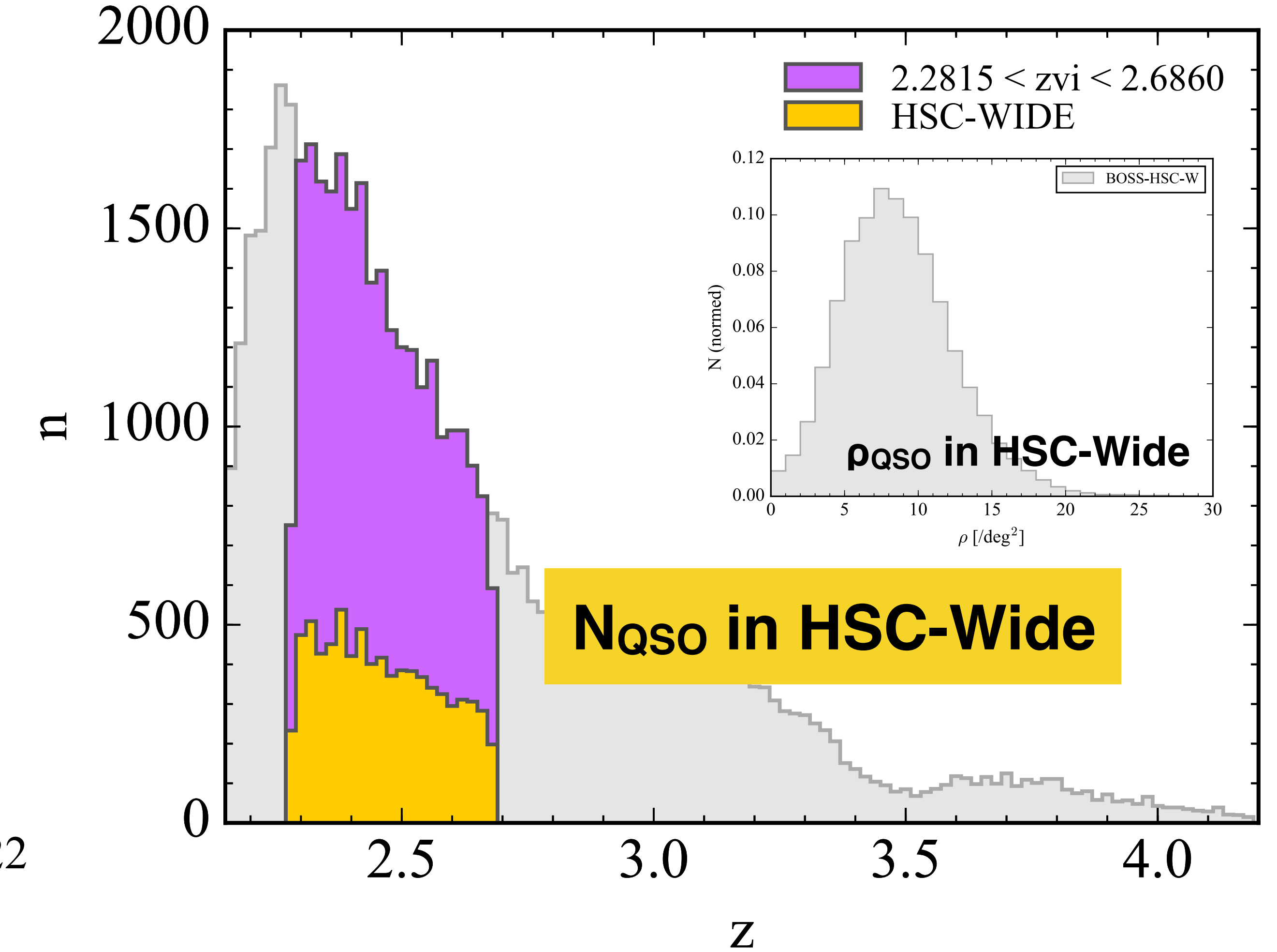
Comparison of LAE (NB387) density with nearby IGM density

SDSS/BOSS - Lyα forest catalogue (K. G. Lee et al. 2013)

Calculation of transmission based on QSOs whose Lyα forest (1041-1185Å) falls within NB387 centre ±2000 km/s (~FWHM)

➡ **~140 QSOs (z_{QSO}=2.282-2.686) are available in HSC-DEEP field**





IGM transmissions in HSC-DEEP

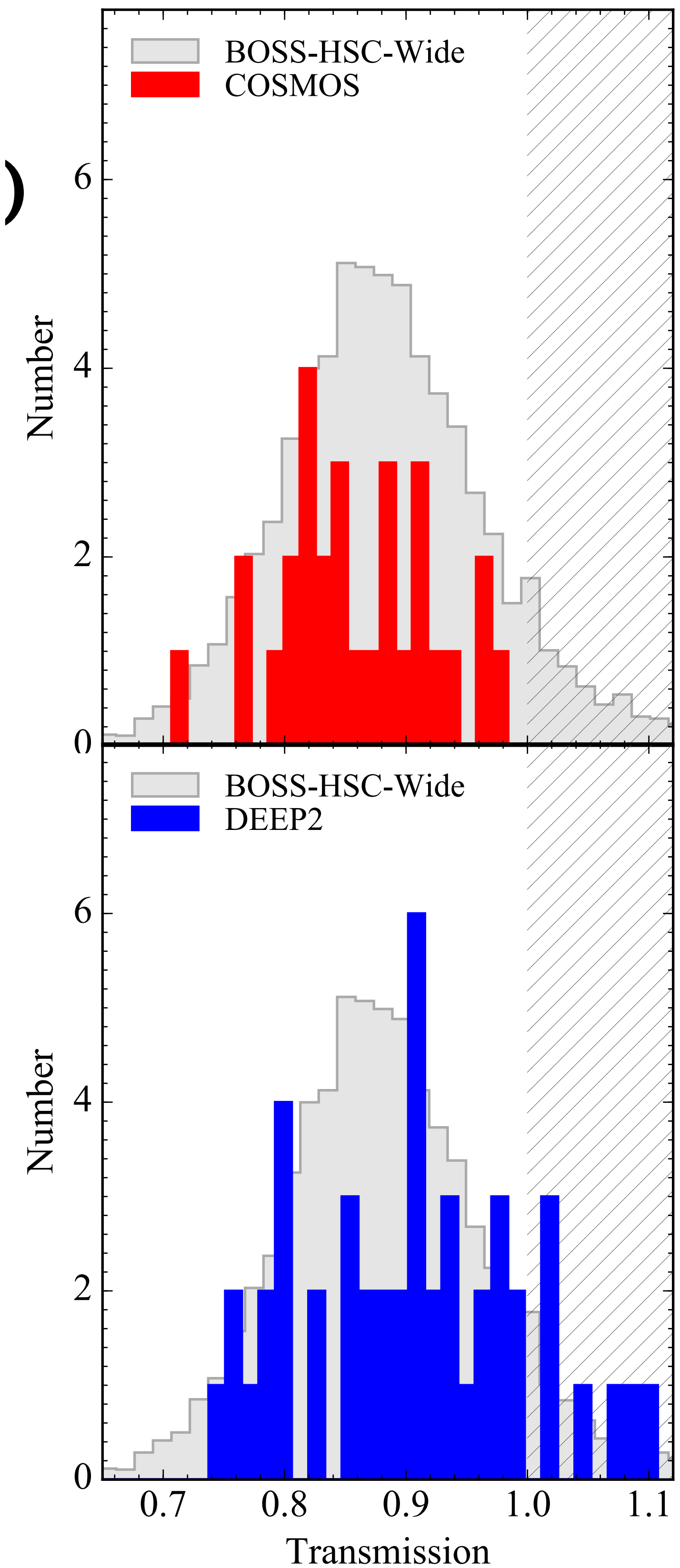
average values within 0.8 deg diameter
smoothed with gaussian kernel of σ=3 deg
assuming $Tr_{z=2.18}$ = 0.87 in no-QSO region

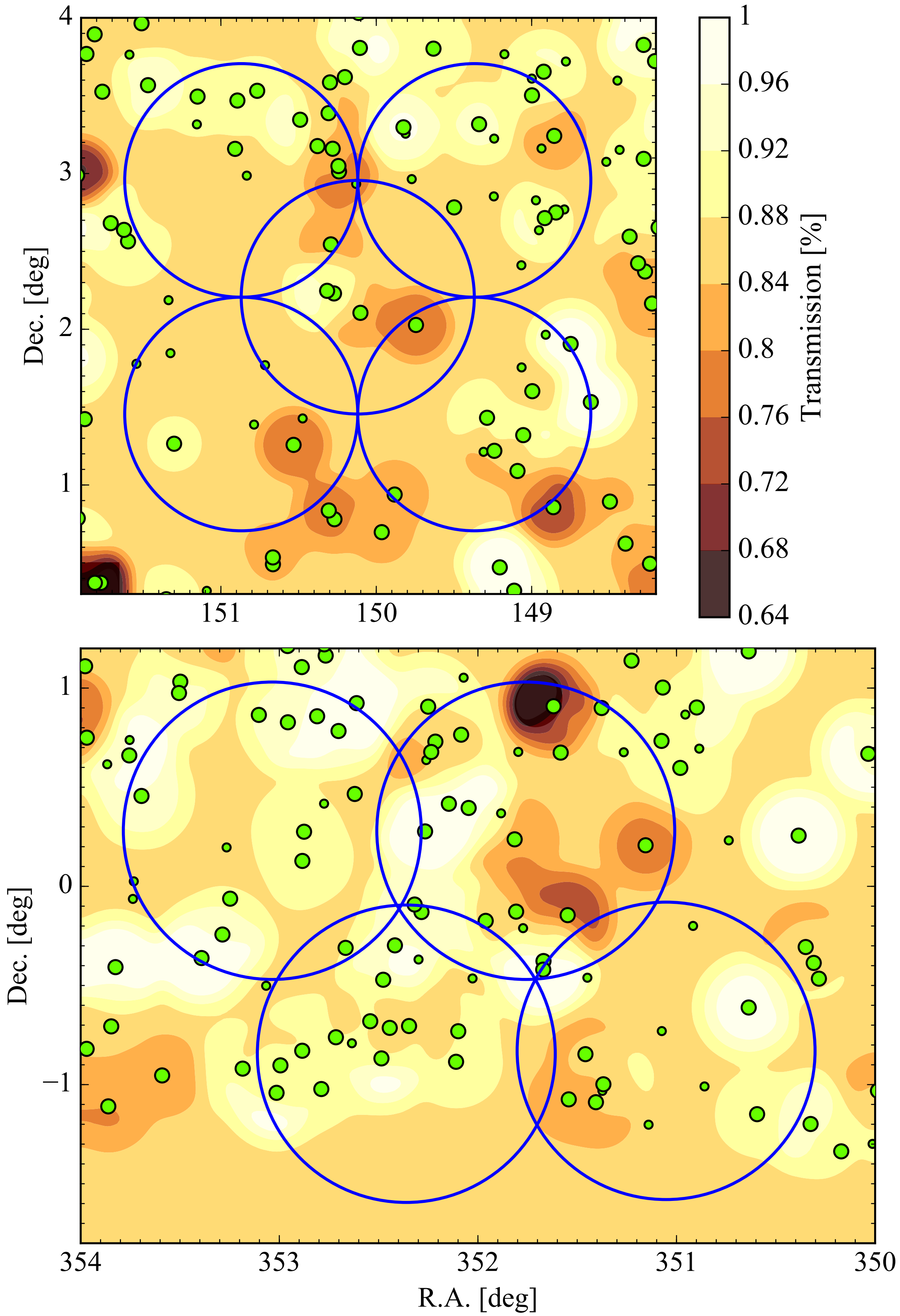
Tr_{ave}=0.88±0.09
(SNLAF>1, ×~60pix)

HSC-COSMOS
50 QSOs
SNLAF>1: 30
Tr=0.87±0.09

HSC_DEEP2
66 QSOs
SNLAF>1: 48
Tr=0.90±0.10

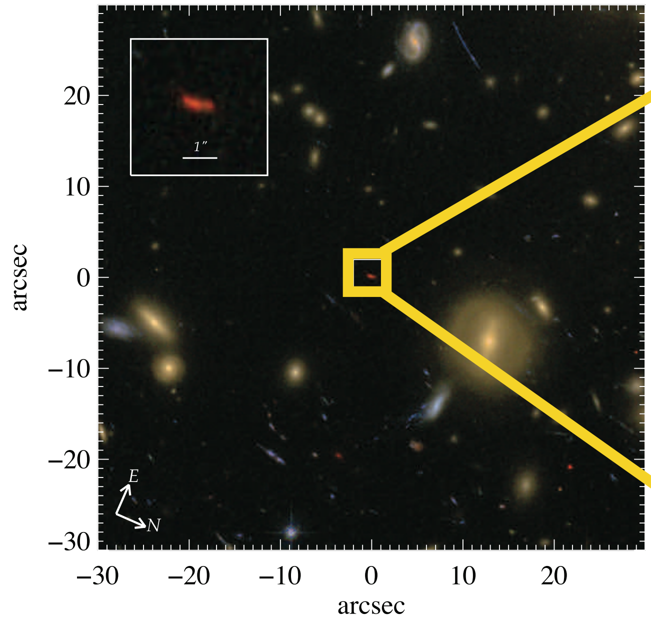
We are waiting for NB387 data

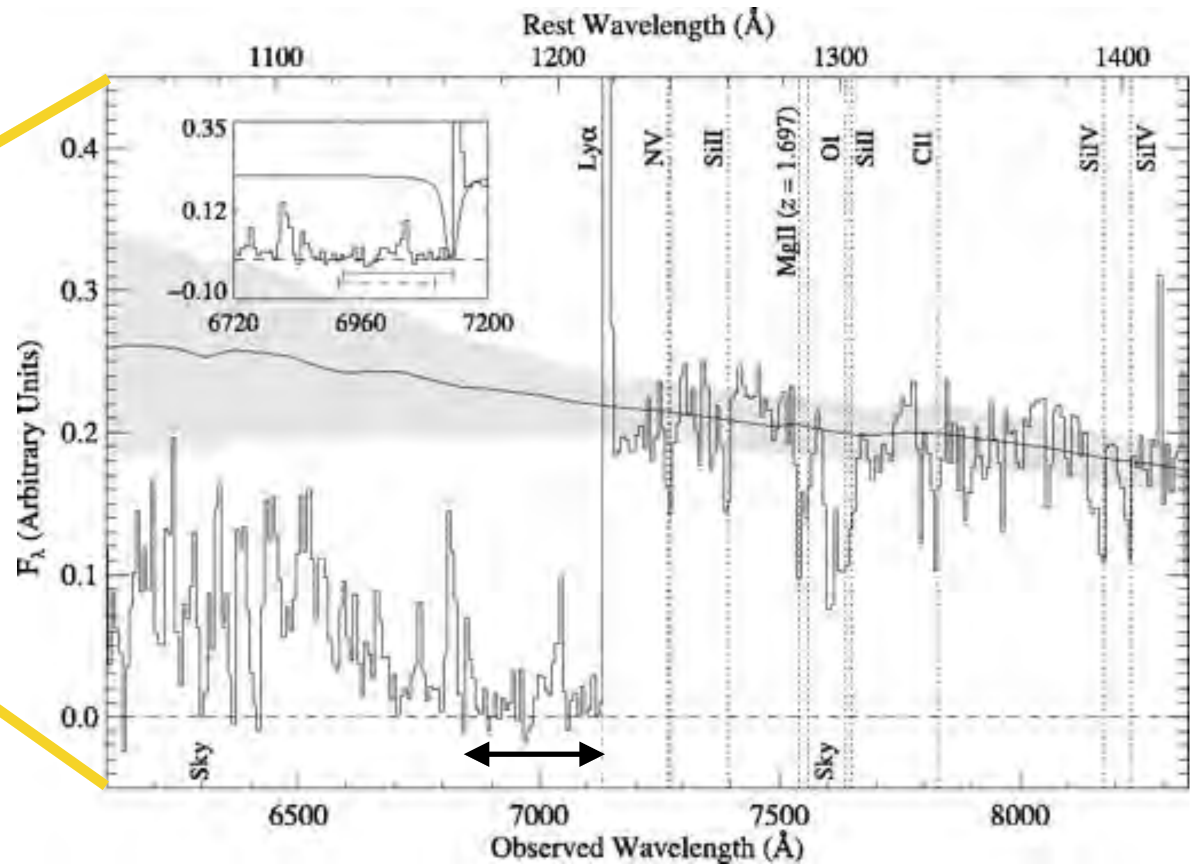




Higher redshift space

Frye et al. 2008

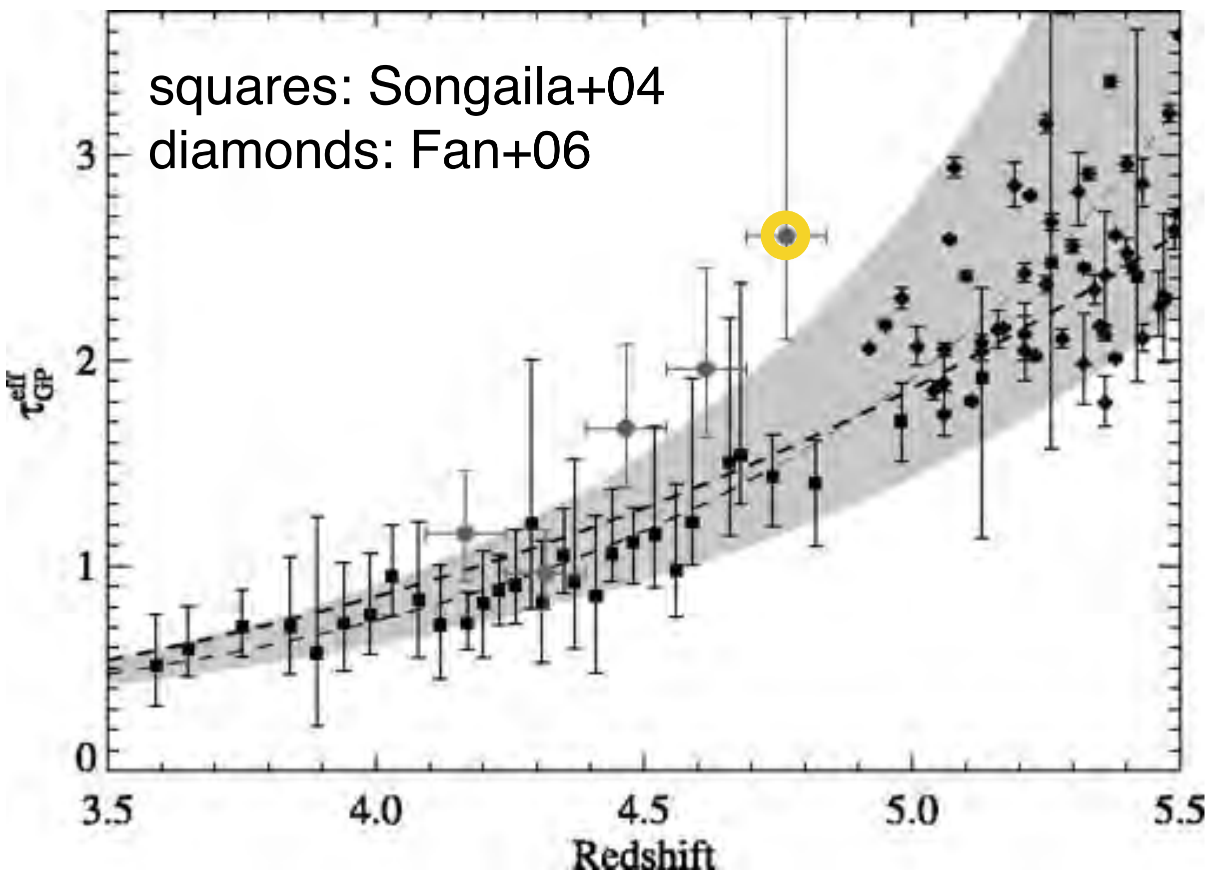




A1689-7.1 at z=4.9 (Frye+08)
Lensed galaxy in HFF (A1689)

showing strong absorption at z~4.8 suggesting overdense regions

A unique protocluster candidate at z~5



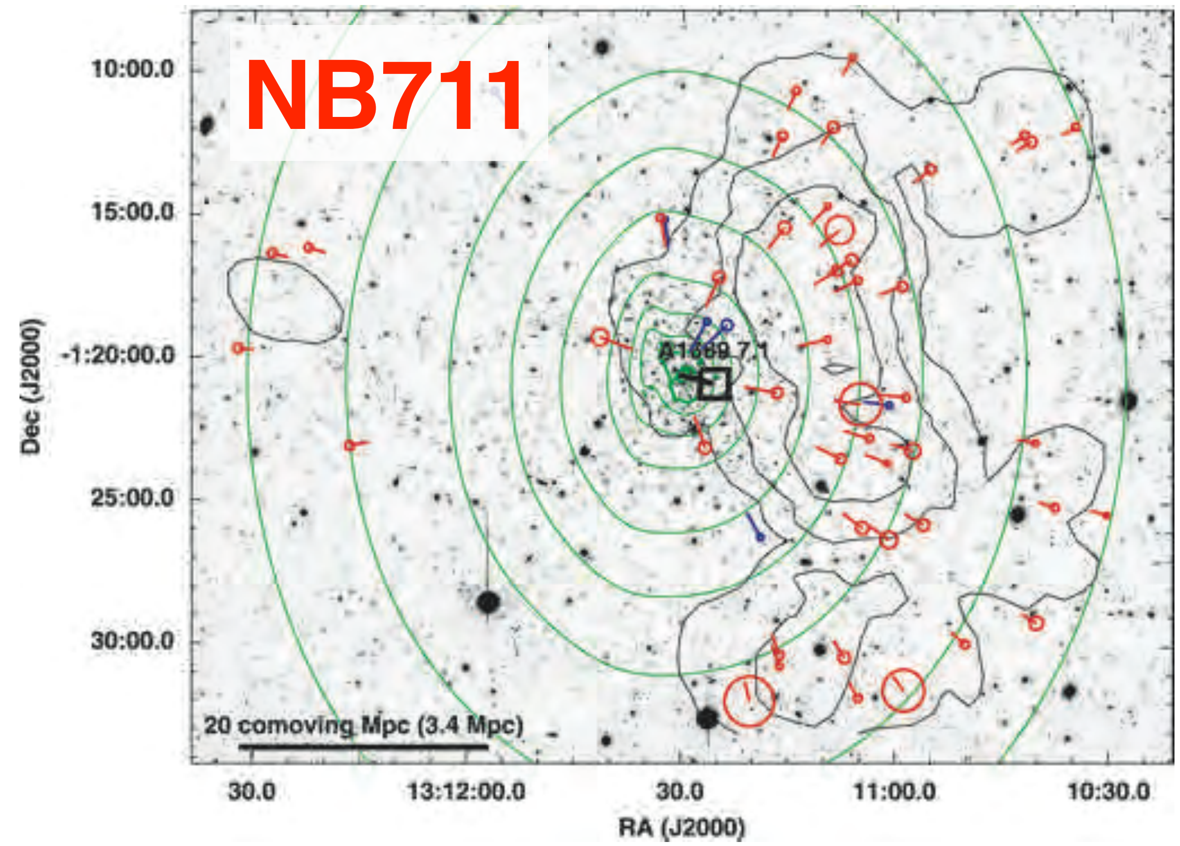
A1690 HFF field

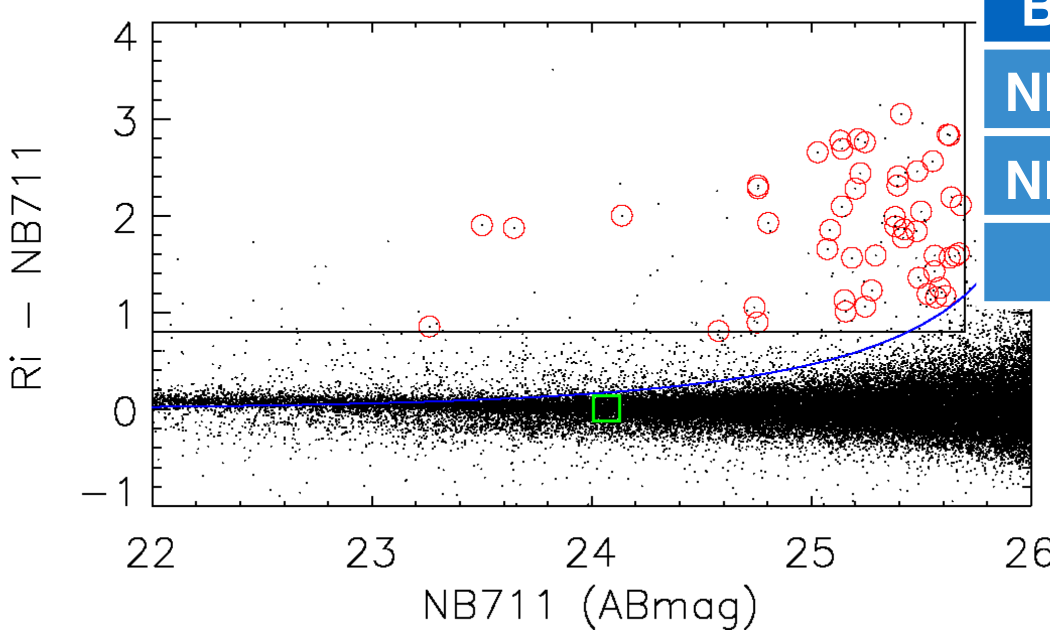
Matsuda et al. 2010

An overdense structure
found by S-cam NB711
(Matsuda+11)

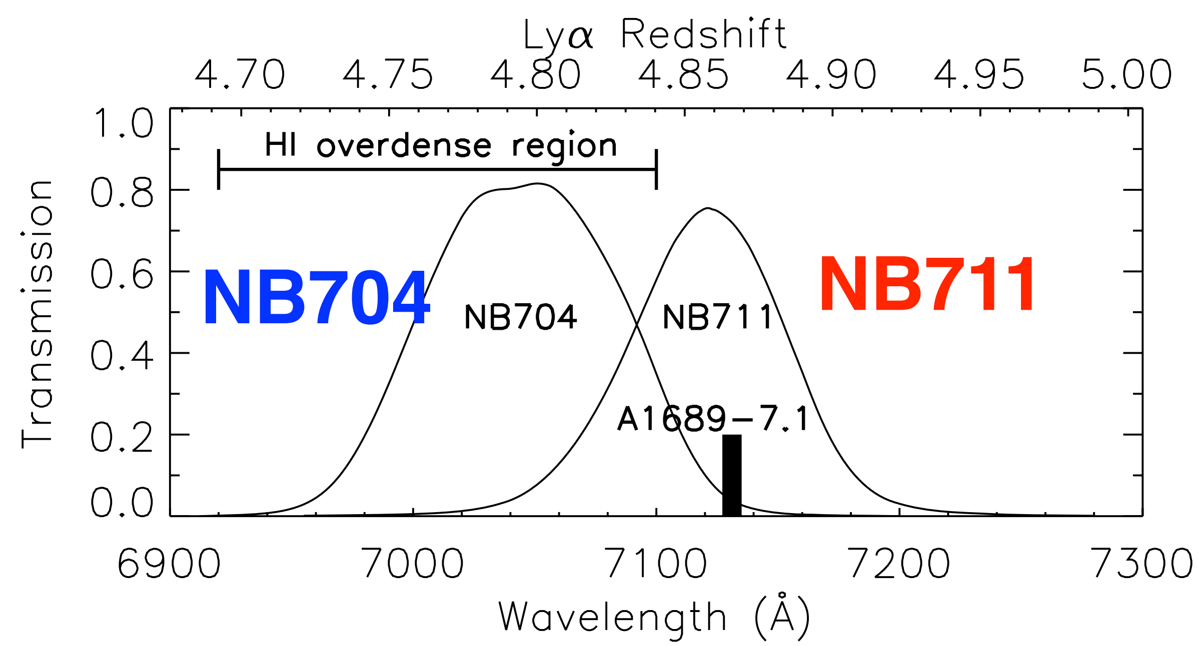
- NB 3Σ excess
- NB < 5σ limit mag
- EW>85Å (observed)
- Color selection

(Ouchi+03; Shimasaku+03)

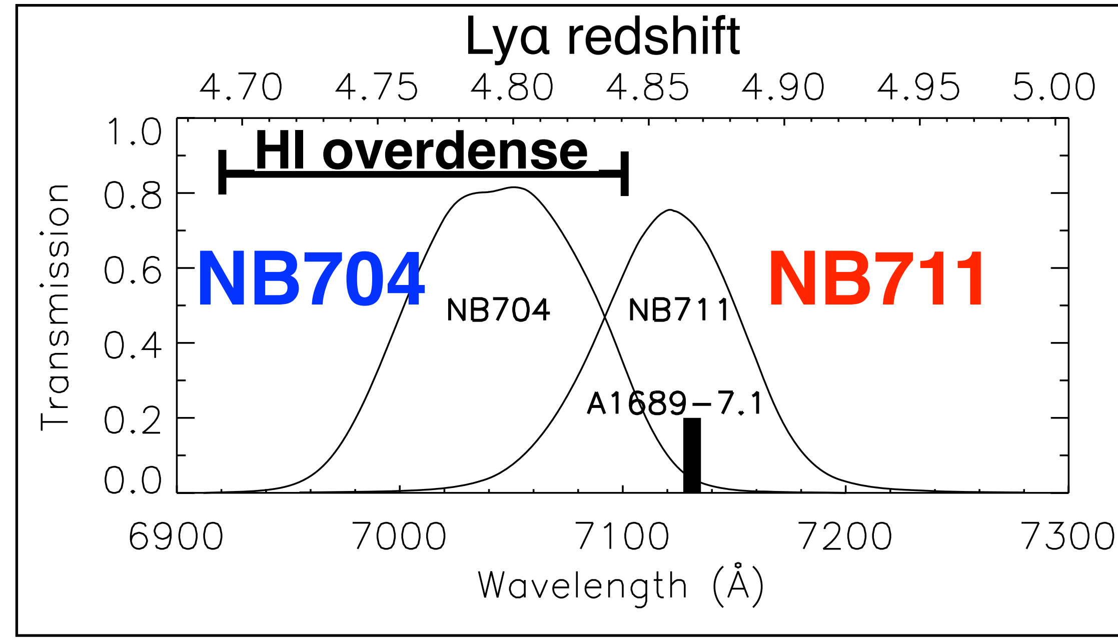


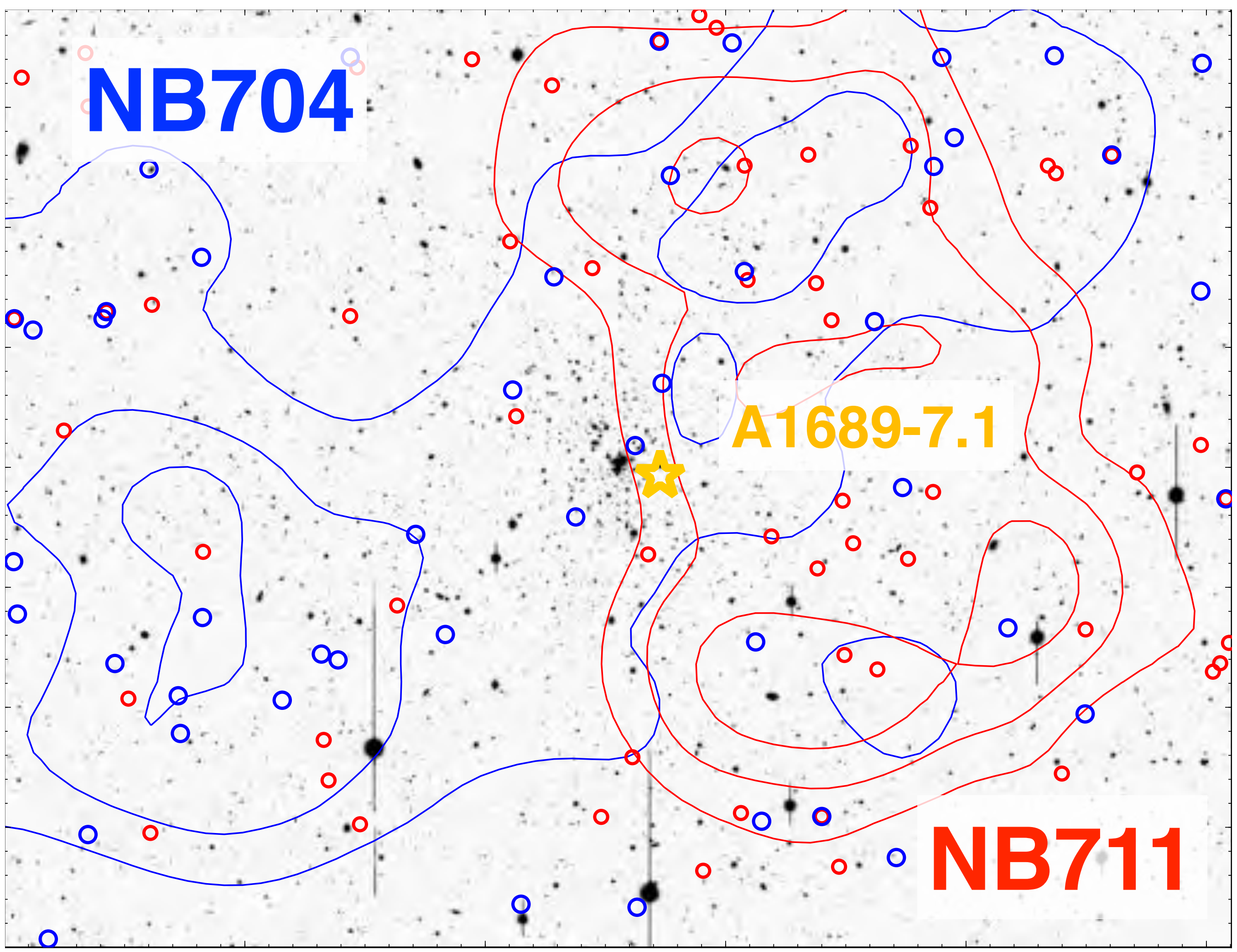


Band	5σ
NB704	25.98
NB711	25.66
RI	26.78



Preliminary result of LAE distribution at z=5





Shimakawa, Matsuda, Kashikawa et al.

Summary

- ✓ **IGM tomography +patchy NB survey at K-band**
  - ➡ **Mapping HAEs & O3Es should be complementary**
  - ➡ **This can advance our MAHALO-Subaru**

- ✓ **IGM density vs. LAEs in HSC-DEEP**
  - ➡ **Useful information on IGM tomography by PFS**

- ✓ **IGM study for the early Universe**
  - ➡ **Perhaps meaningful to observe lensed sources, however MUSE or LRIS/DEIMOS is more suitable for tomography in such narrow fields**