Star formation activity in and around high-z clusters revealed with Subaru

Masao Hayashi

National Astronomical Observatory of Japan

Collaborators

T. Kodama (Subaru), Y. Koyama (NAOJ/Durham Univ.),
K. Tadaki (Univ. of Tokyo), I. Tanaka (Subaru)

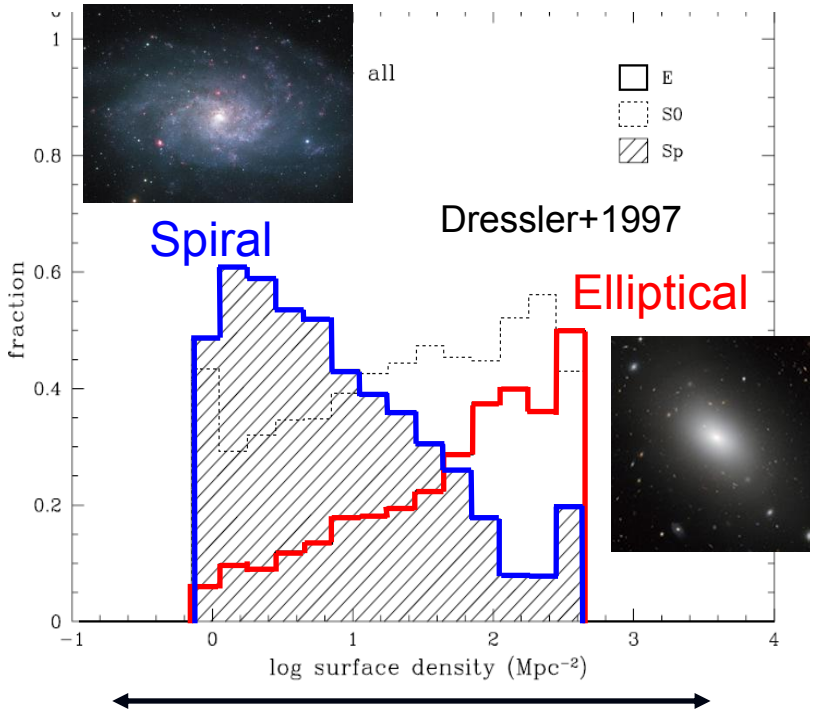
2013.01.28

Lunch talk at IPMU

Properties of local galaxies

Strongly dependent on mass and environment

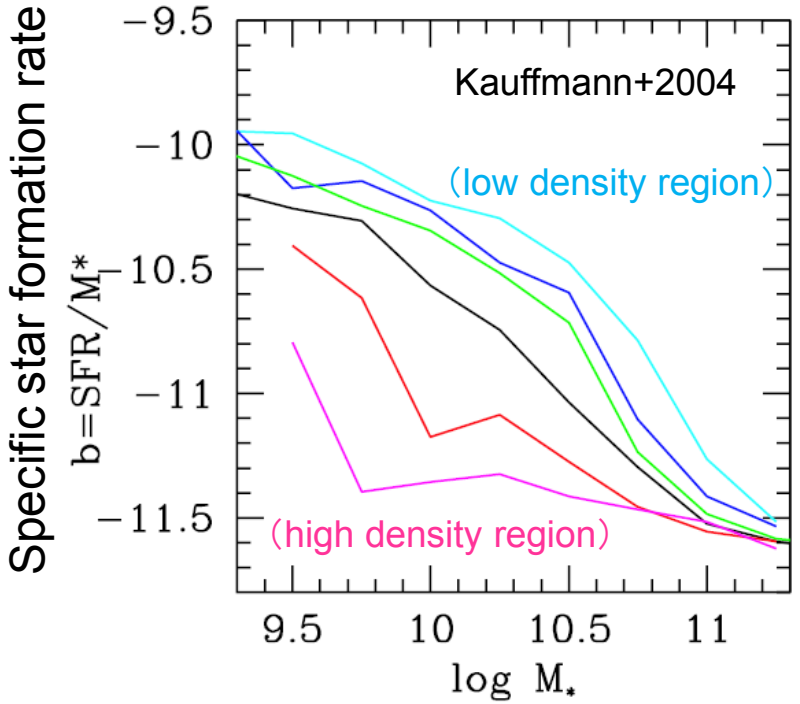
Fraction of each population



Low density region
such as general field

High density region
such as galaxy cluster

Star formation activity of galaxy



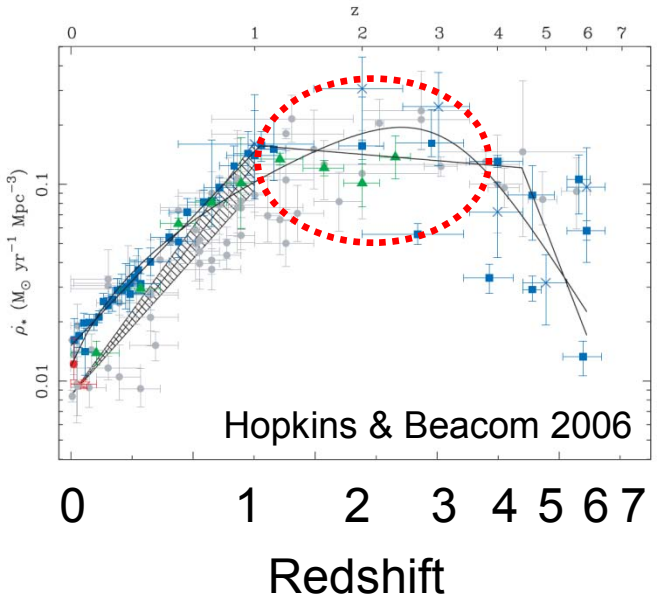
Stellar mass

- Elliptical galaxies are preferentially found in higher density regions
- Massive galaxies tend to have elliptical morphology, older stellar population, lower star formation activity, and higher metallicity

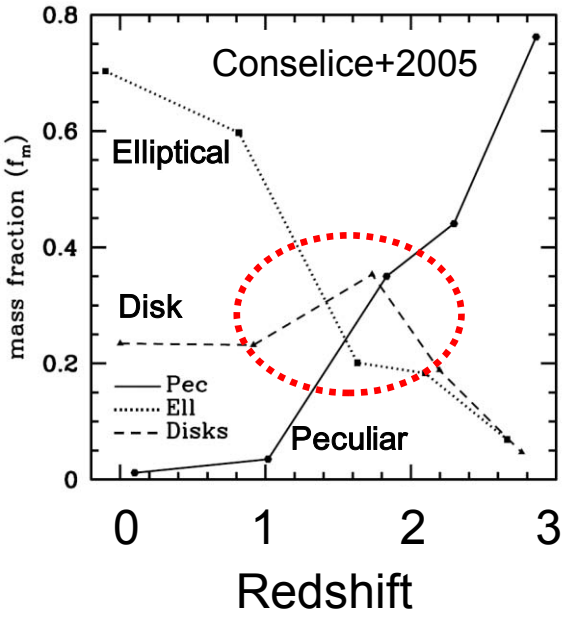
The era of vigorous galaxy evolution

The redshifts of z=1-3 are an important to understand galaxy evolution

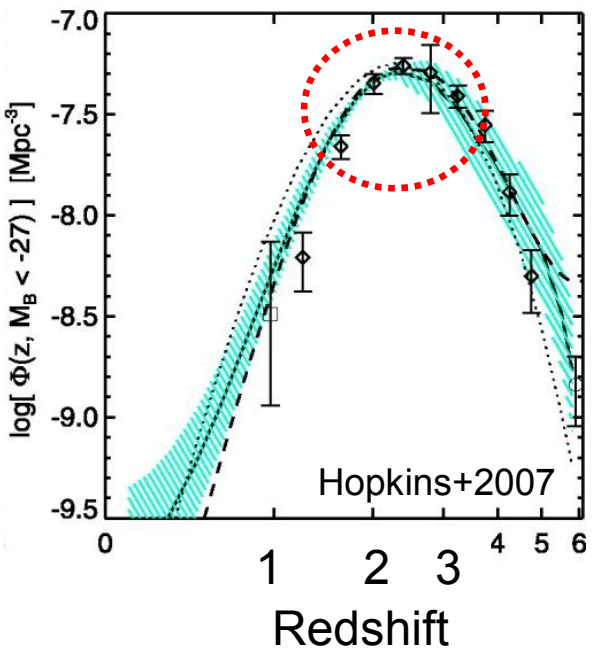
Star formation activity of galaxy



Fraction of galaxy with a given morphology



Number density of AGN



- More than half of stellar mass that galaxy contains are formed at z>1 (e.g., Perez-Gonzalez+ 2008)
- Galaxy morphology seen in local Universe appears (Kajisawa & Yamada 2001)
- Peak of AGN activity (e.g., Hopkins+ 2007)

Questions

- When does the dependence of galaxy properties on mass and environment appear?

- How are the galaxy properties formed?

→ We must investigate galaxies growing vigorously

Our approach to address the issues

"MAHALO-Subaru"

MApping HAlpha and Lines of Oxygen with Subaru

A narrow-band mapping of star forming galaxies at the peak epoch of galaxy formation at 0.4<z<2.5 (primarily at 1.5<z<2.5).

Pilot obs (5 nights) + Intensive (10 nights @S10B-11A) + Normal (3 nights @S11B)

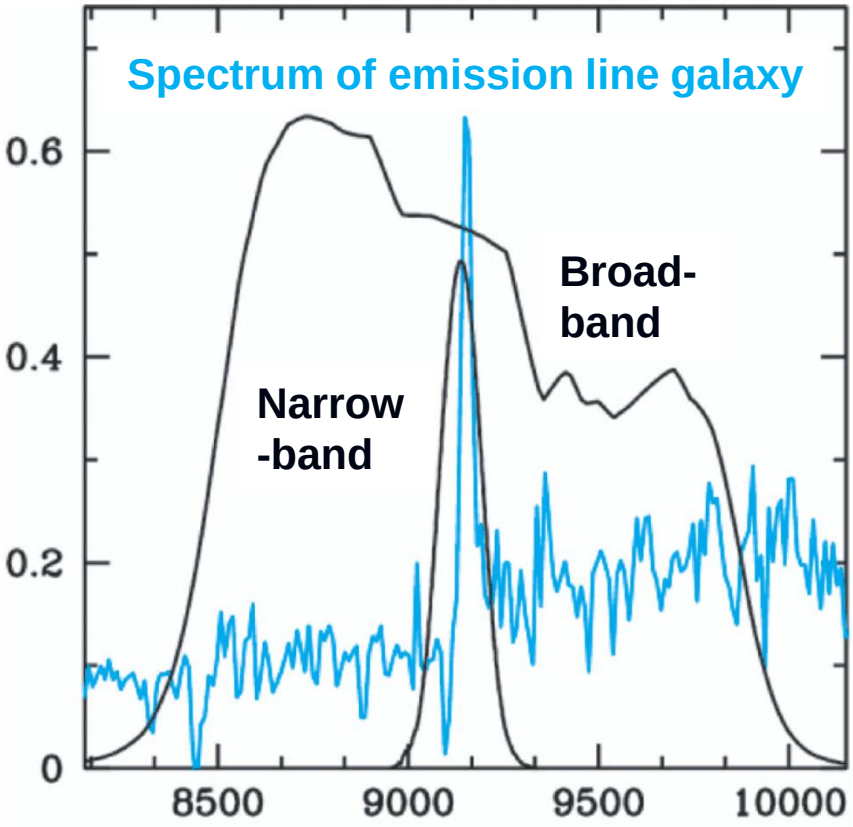
environ-ment	target	z	line	λ (μm)	camera	NB-filter	conti-nuum	status
Low-z cluster	CL0024+1652	0.395	Hα	0.916	Suprime-Cam	NB912	z'	Kodama+'04
	CL0939+4713	0.407	Hα	0.923	Suprime-Cam	NB921	z'	Koyama+'11
	RXJ1716+6708	0.813	Hα	1.190	MOIRCS	NB1190	J	Koyama+'10
			[O II]	0.676	Suprime-Cam	NA671	R	observed
High-z cluster	XCSJ2215–1738	1.457	[O II]	0.916	Suprime-Cam	NB912, NB921	z'	Hayashi+10,11
	4C65.22	1.516	Hα	1.651	MOIRCS	NB1657	H	observed
	Q0835+580	1.534	Hα	1.664	MOIRCS	NB1657	H	observed
	CL0332–2742	1.61	[O II]	0.973	Suprime-Cam	NB973	y	observed
	ClGJ0218.3–0510	1.62	[O II]	0.977	Suprime-Cam	NB973	y	Tadaki+'11b
Proto-cluster	PKS1138–262	2.156	Hα	2.071	MOIRCS	NB2071	K_s	Koyama+13
	4C23.56	2.483	Hα	2.286	MOIRCS	NB2288	K_s	Tanaka+'11
	USS1558–003	2.527	Hα	2.315	MOIRCS	NB2315	K_s	Hayashi+12
General field	GOODS-N (62 arcmin^2)	2.19	Hα	2.094	MOIRCS	NB2095	K_s	Tadaki+'11a
			[O II]	1.189	MOIRCS	NB1190	J	observed
	SXDF (110 arcmin^2)	2.19	Hα	2.094	MOIRCS	NB2095	K	Tadaki+ in prep.
			Hβ	1.551	MOIRCS	NB1550	H	not yet
			[O II]	1.189	MOIRCS	NB1190	J	not yet

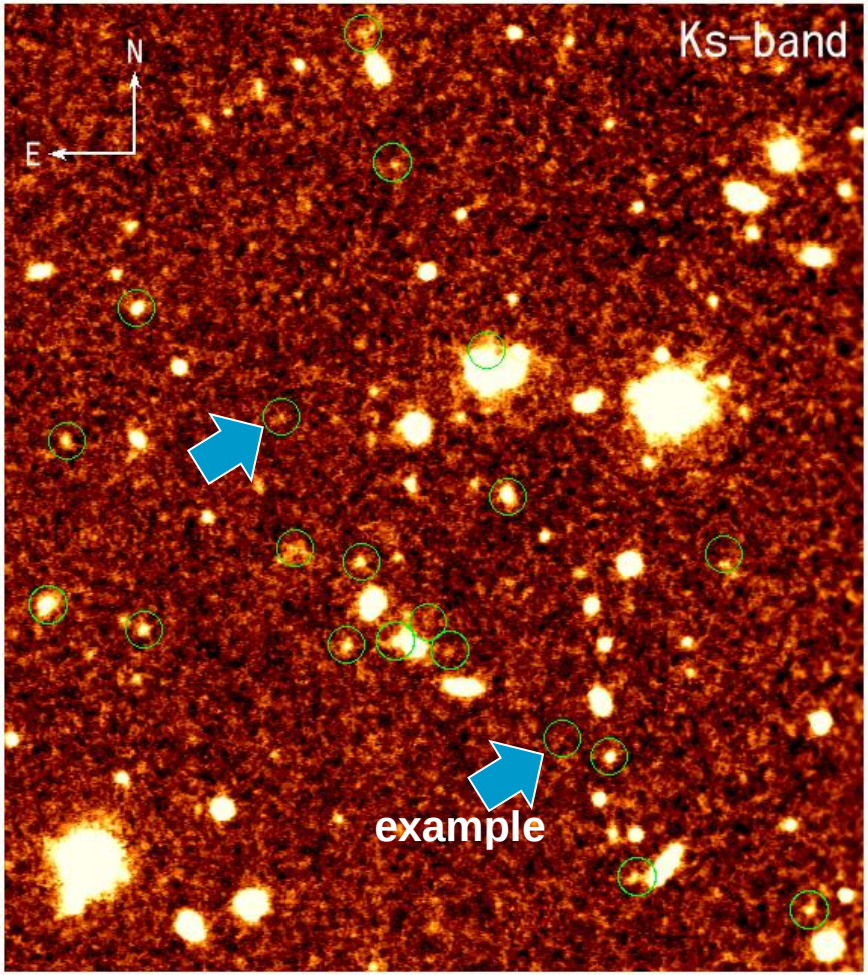
Tadayuki Kodama (Subaru; PI), Masao Hayashi (NAOJ), Yusei Koyama (Durham), Ken-ichi Tadaki (Univ. of Tokyo), Ichi Tanaka (Subaru), et al.

Narrow-band imaging

Aim to detect nebular emission from star-forming regions in a galaxy

(Hα and [OII] lines are good indicators of star formation rate)





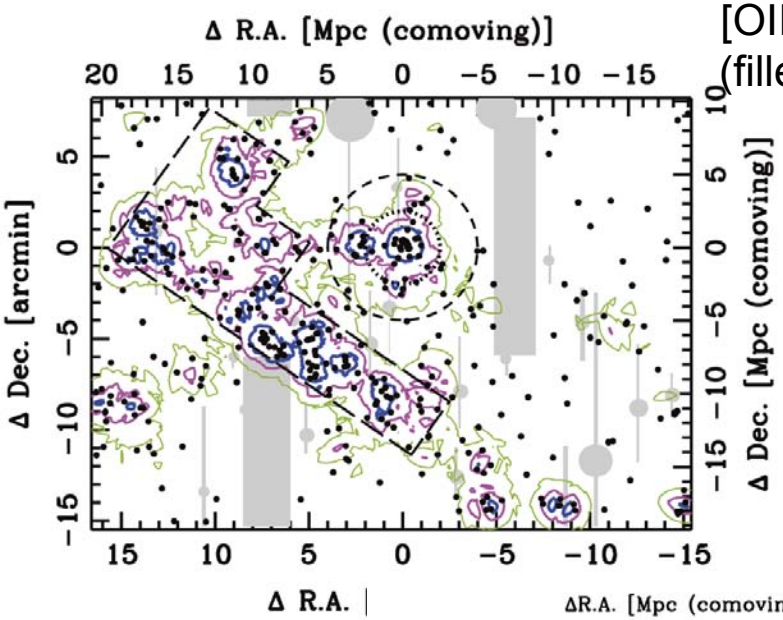
Much brighter in narrow-band if an emission line enters the filter

○ Emission line galaxies

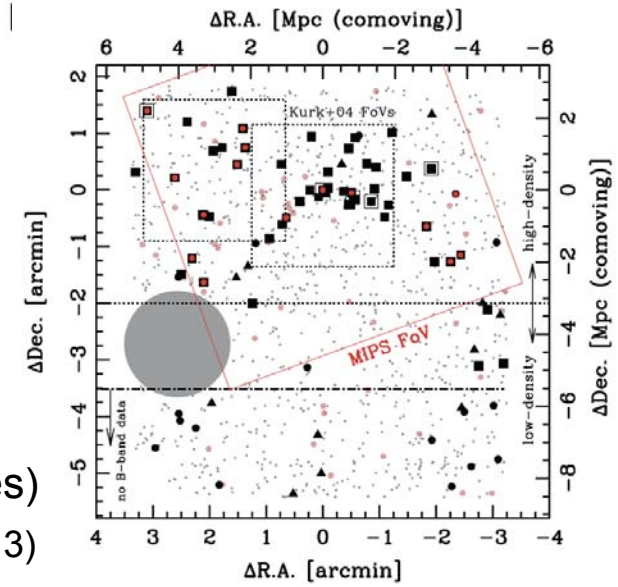
Large scale structure of SF galaxies

XMMXCS J2215.9-1738 (z=1.46)

[OII] emitters (filled circles)



Hayashi et al. (2010, 2011)



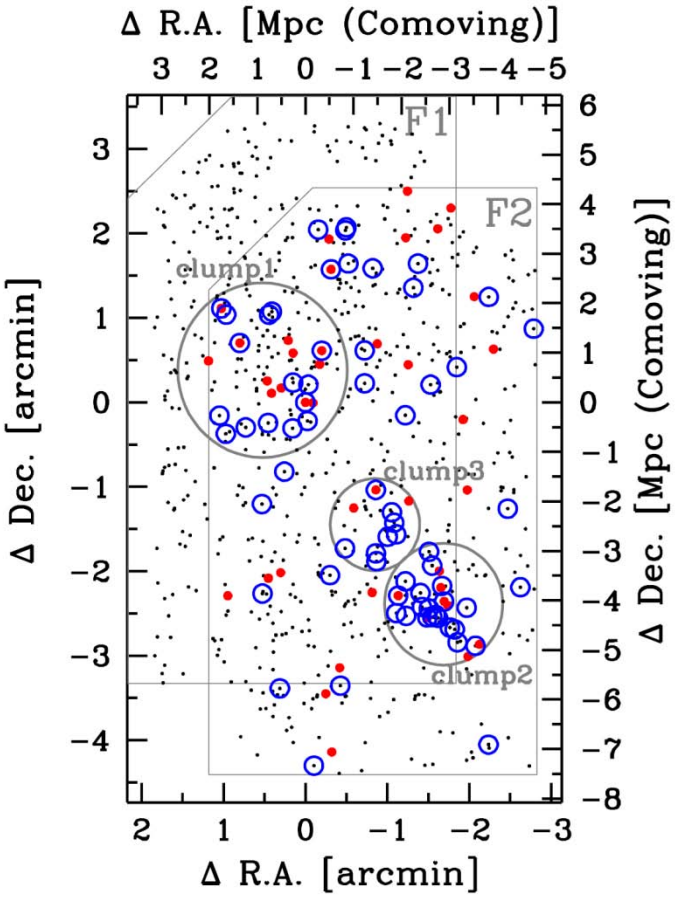
PKS 1138-262 (z=2.16)

Hα emitters (filled circles)

Koyama et al. (2013)

USS 1558-003 (z=2.53)

Hα emitters (blue open circles)



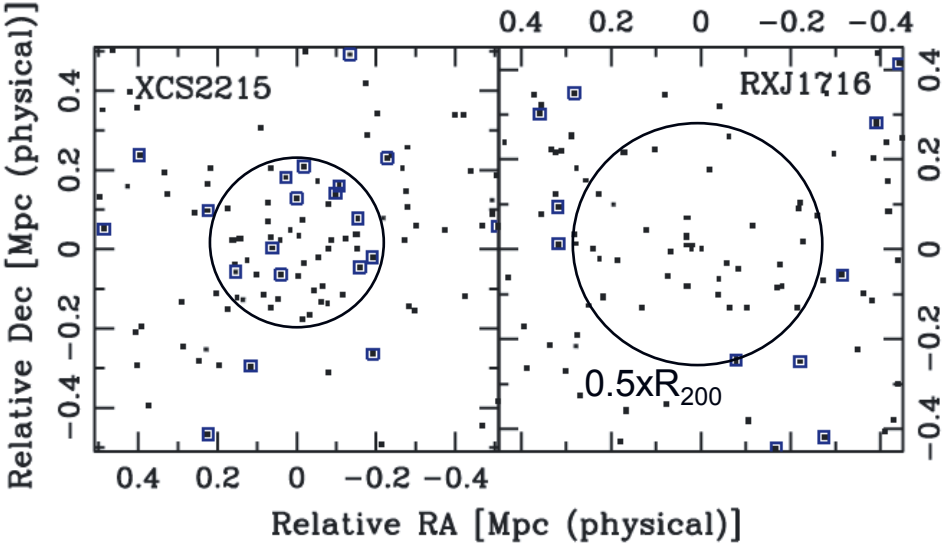
Hayashi et al. (2012)

Active star formation in high-z clusters

Comparison of cluster core region

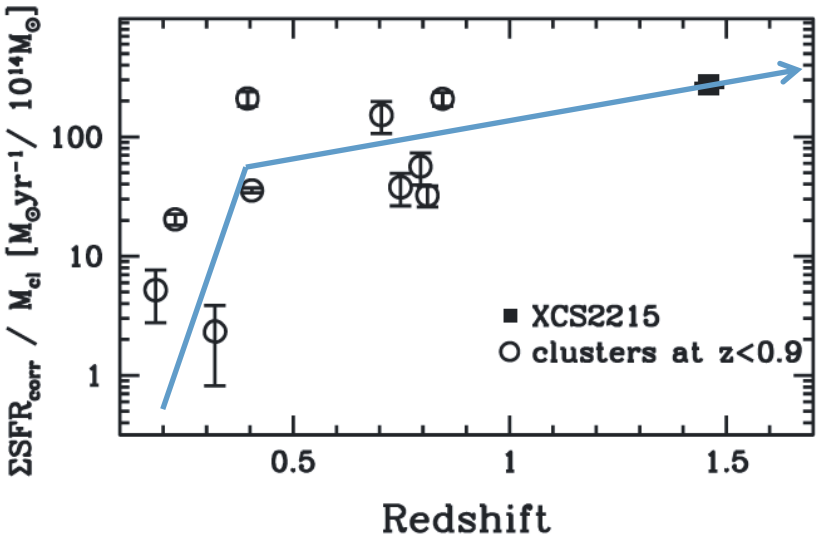
■ **Emission line galaxies**

XCS2215 (z=1.46) **RXJ1716 (z=0.81)**



Hayashi et al. (2010)

Star formation activity of galaxy cluster

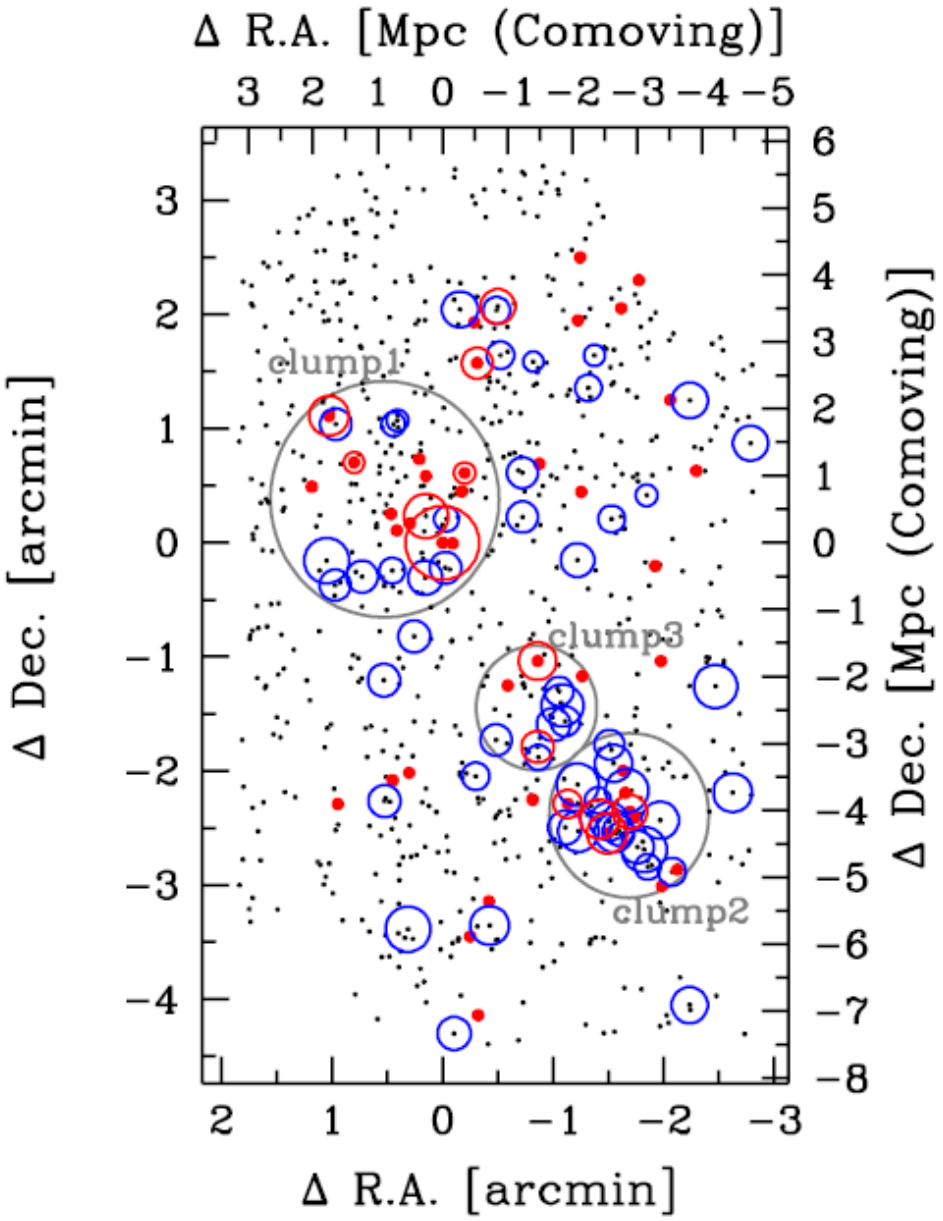


Hayashi et al. (2011)

Integrated SFR per unit cluster mass as a function of redshift

- **A lot of star-forming galaxies in the core of z=1.46 cluster in contrast with z<1 clusters**
- **higher star forming activity in galaxy cluster with redshift increasing**

Dusty starbursts inhabiting dense regions



USS 1558-003 (z=2.53)

Red open circles shows dusty starburst galaxies (i.e., HAEs with red colors of (J-Ks)vega > 2.3), which are thought to be a population in transitional phase.

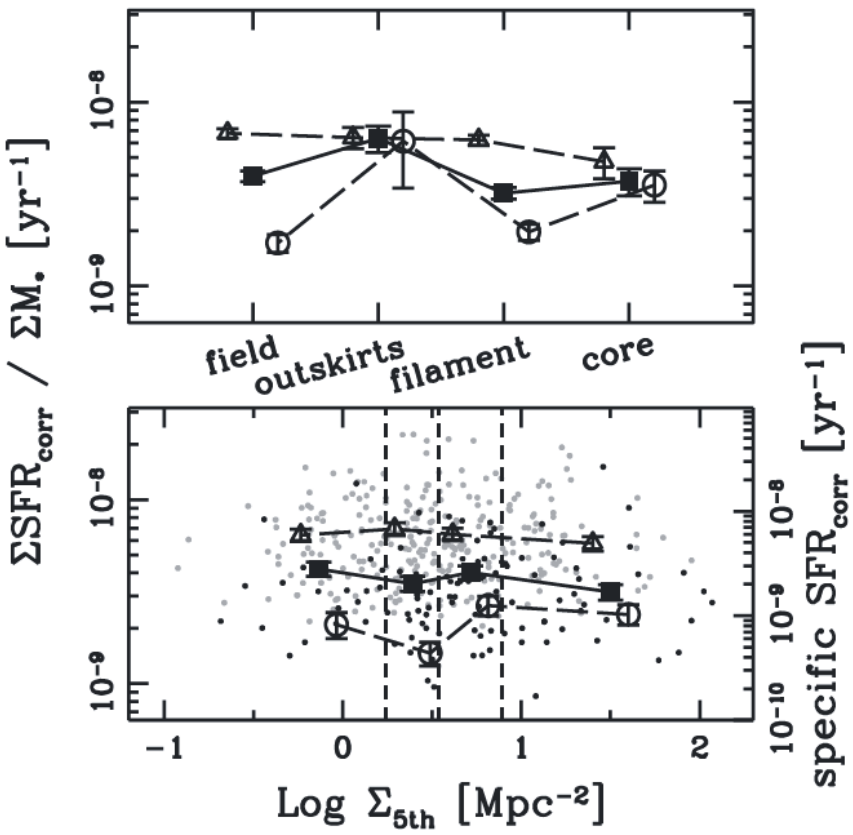
HAEs with higher SFR are shown by larger open circles

- **Dusty starbursts galaxies tend to be located in clumps, which is different situation to that in lower-z clusters**

Environment dependence of SF activity

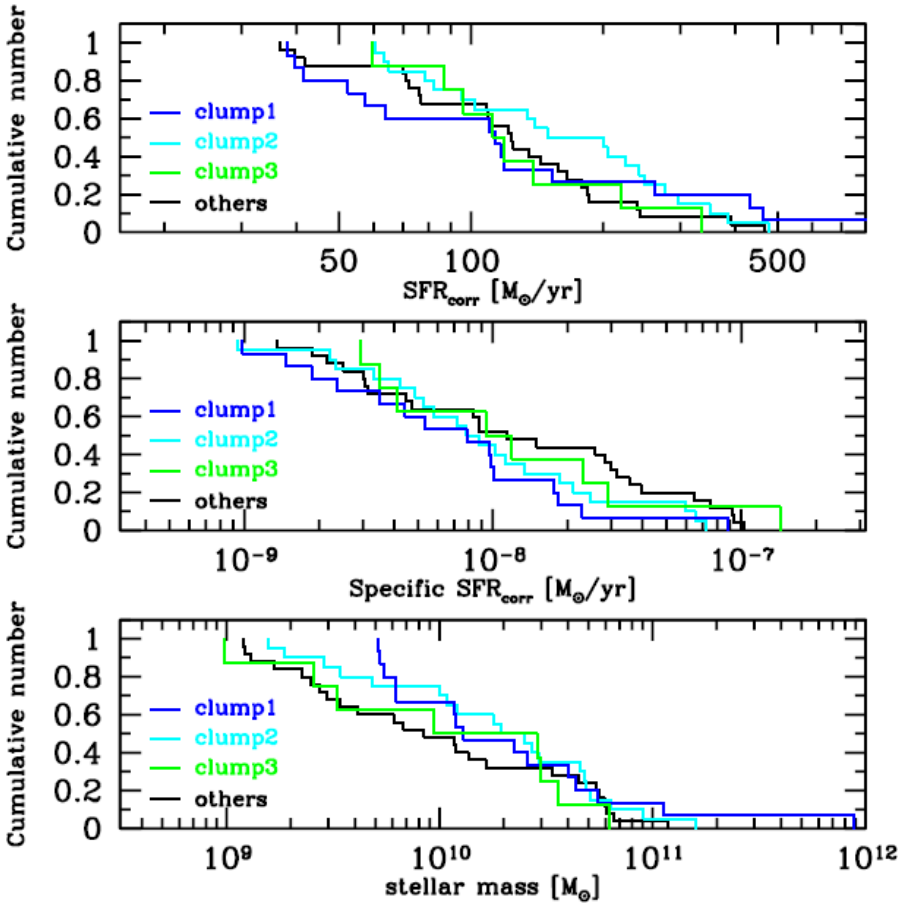
XMMXCS J2215.9-1738
(z=1.46)

Specific SFR



USS 1558-003 (z=2.53)

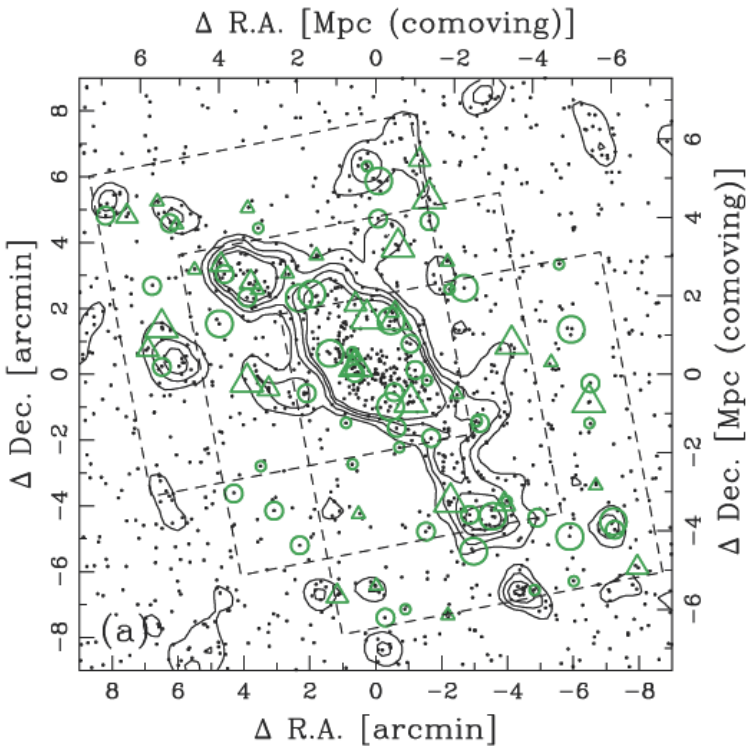
Cumulative number of SFR, sSFR and Mstar



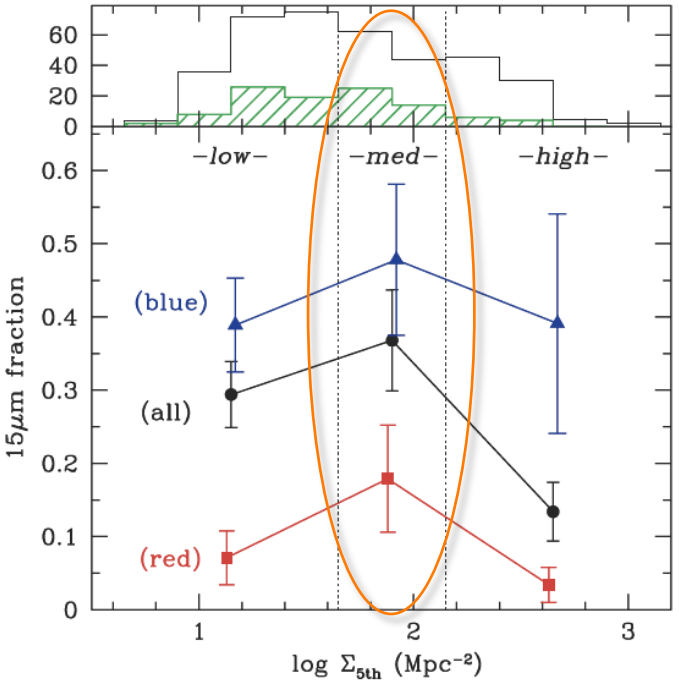
- **No strong dependence of SF activity on environment at z>1.5**

Inside-out evolution of galaxies in cluster

RXJ1716 (z=0.81)



Most active star formation in **Medium** density region at z=0.8



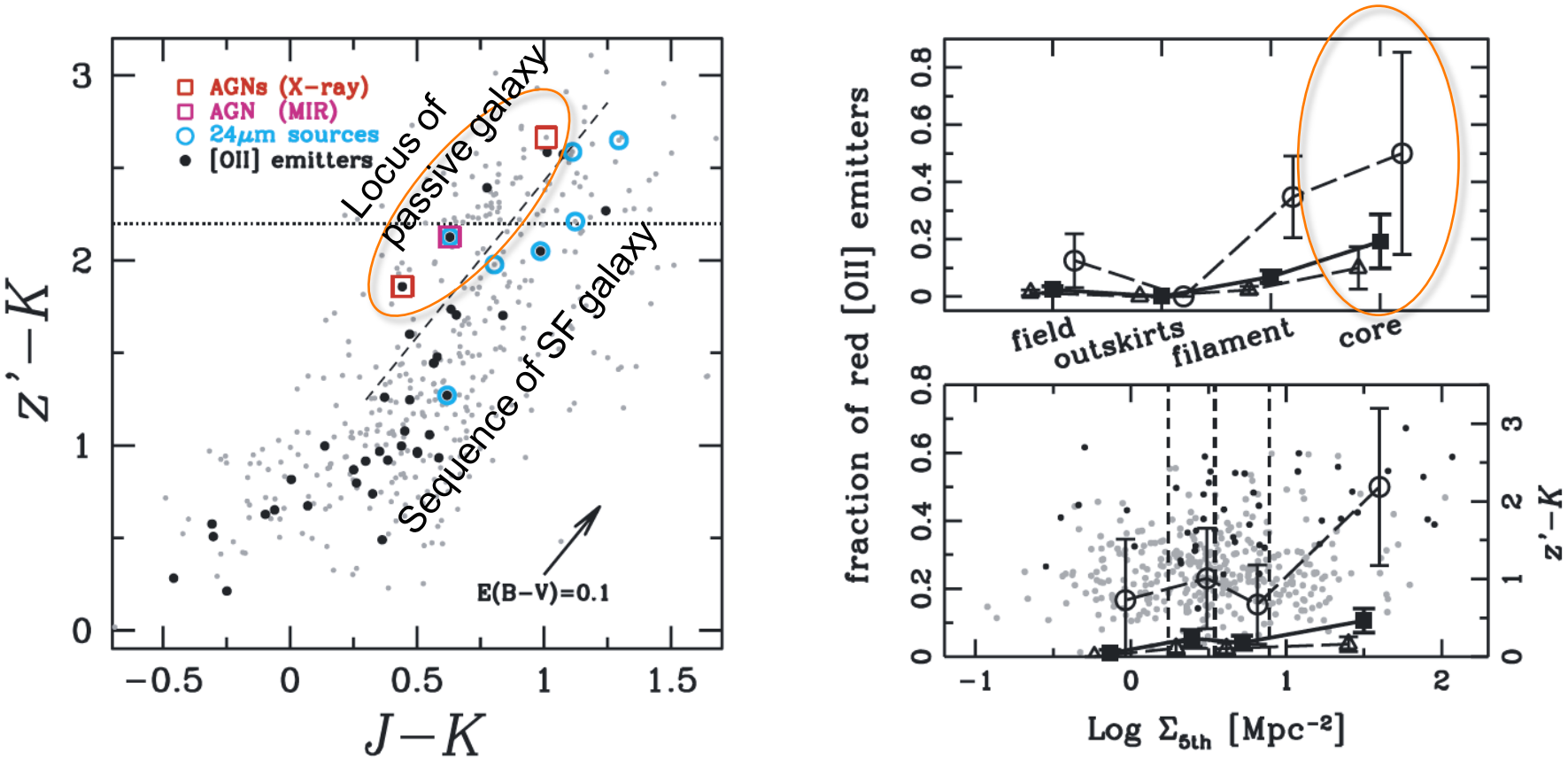
Local number density

Koyama et al. (2008)

- The region where galaxies are growing vigorously is likely to gradually shift to lower density regions from high density regions with time

Enhanced fraction of AGN candidate

[OII] emitters with red color are likely to be AGN

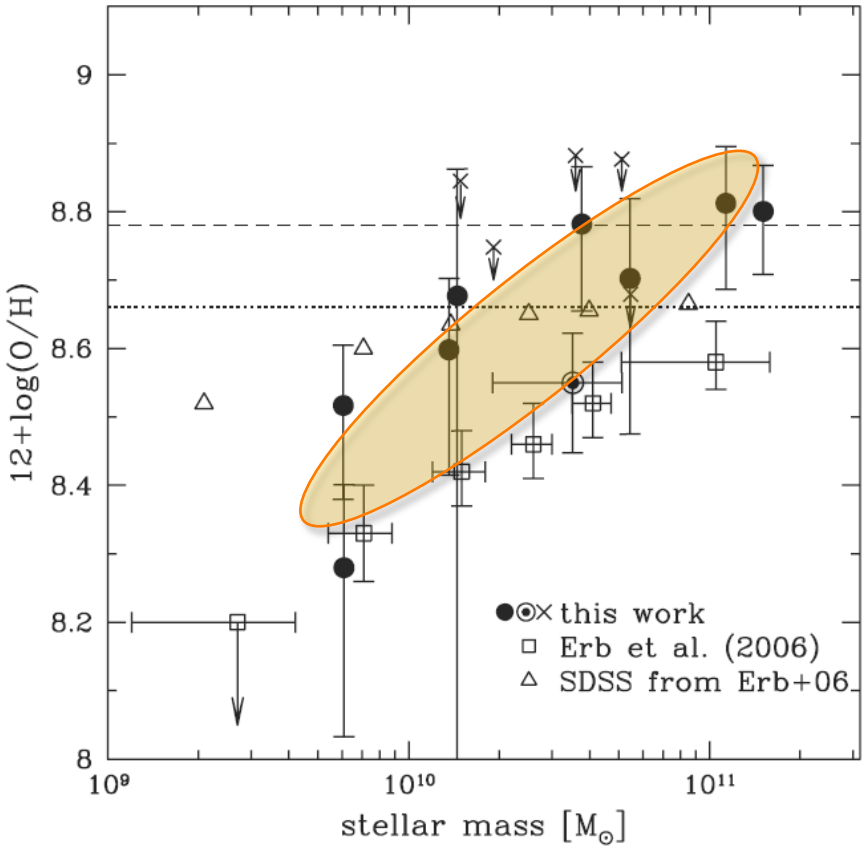


Hayashi et al. (2011)

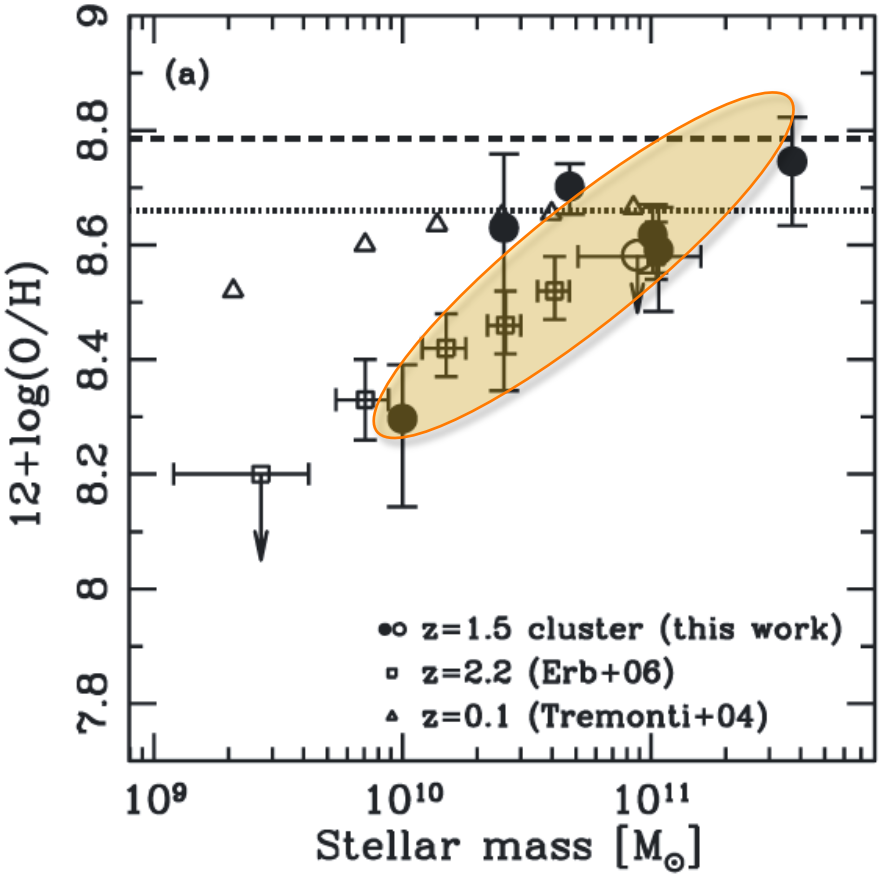
- Perhaps, AGN feedback plays an important role in quenching star formation of galaxies in the cluster core

Mass-metallicity relation

Subaru Deep Field (z~1.5-2.0)



XMMXCS J2215.9-1738 (z=1.46)



- **No strong difference between MZR in the SDF and the cluster core at z~1.5**

Brief summary

- ✓ A lot of star-forming galaxies in dense regions at $z>1.5$ in contrast with $z<1$ clusters
- ✓ The region where galaxies are growing vigorously is likely to gradually shift from high density regions to lower density regions with time
- ✓ AGN feedback may play a important role in quenching star formation of galaxies in the cluster core

Future works

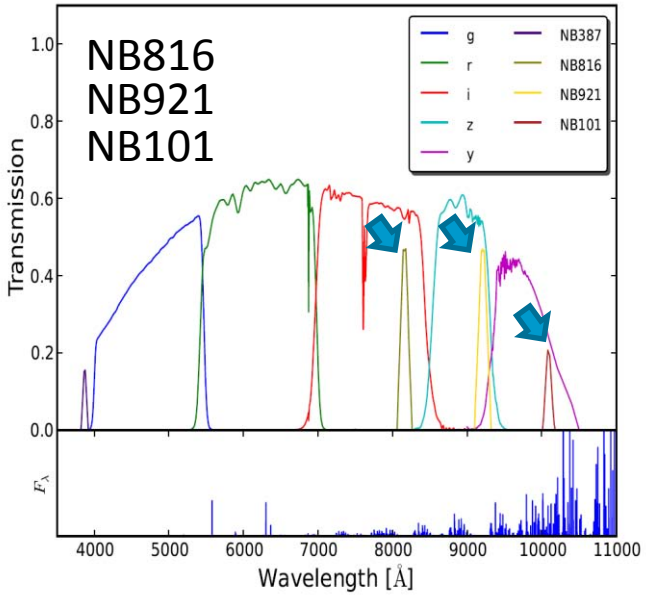
- Investigate ionized and molecular gas of individual galaxies with Subaru and ALMA
- Expand our study with HSC and PFS

Expanding our study with HSC and PFS

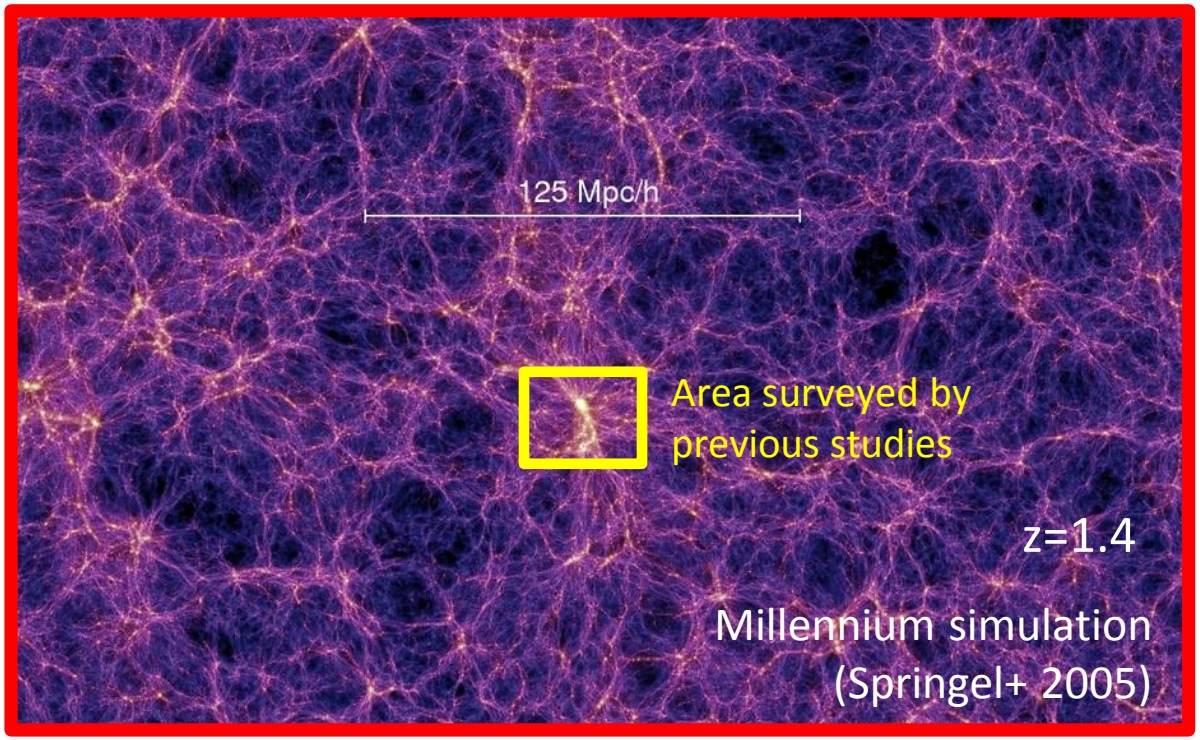
- **Hyper Suprime-Cam (HSC)**

Filter set

HSC Subaru strategic proposal



Width of deep survey **(~27 deg^2)**



- Revealing larger scale structure and discussing galaxy properties along LSS
- Follow-up with PFS

Summary

MAHALO-Subaru: Mapping Halpha and Lines of Oxygen with Subaru

Narrow-band mapping of nebular emissions in and around high-z clusters

- A lot of star-forming galaxies in dense regions at z>1.5 in contrast with z<1 clusters
- The region where galaxies are growing vigorously is likely to gradually shift from high density regions to lower density regions with time
- AGN feedback may play a important role in quenching star formation of galaxies in the cluster core
- No strong dependence of SF activity and MZR on environment at z~1.5

Future works

- Investigate ionized gas with Subaru
- Investigate molecular gas with ALMA
- Expand our study with HSC and PFS