(Galaxy Formation @ Durham Univ. 2011/7/21)

Mahalo-Subaru

Mapping Star Formation at the Peak Epoch of Galaxy Formation

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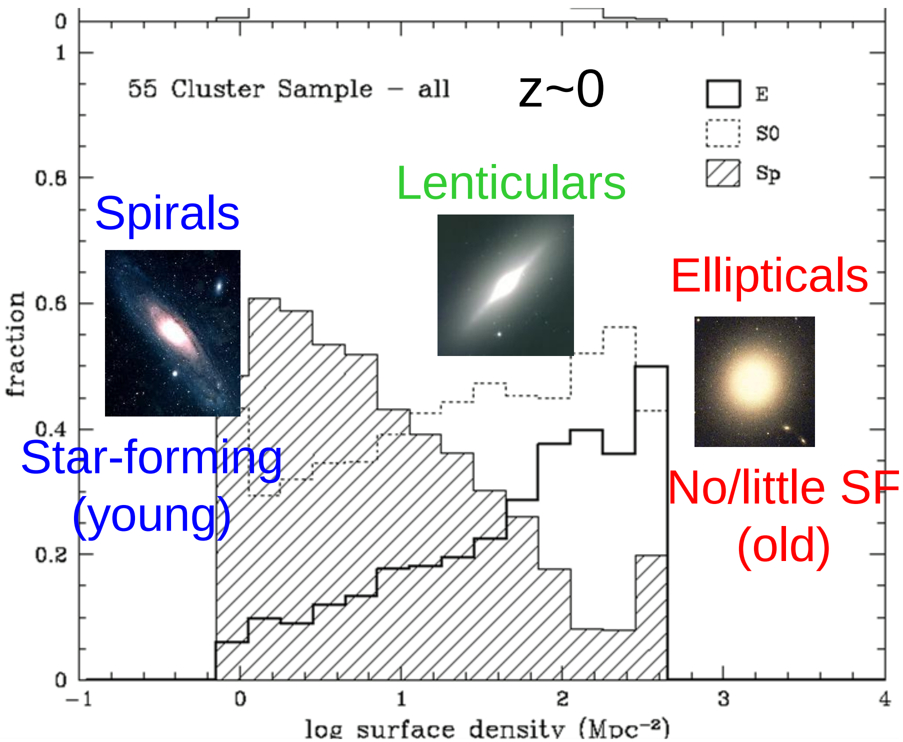
Ken-ichi Tadaki, Ichi Tanaka (NAOJ)
and Mahalo-Subaru Team

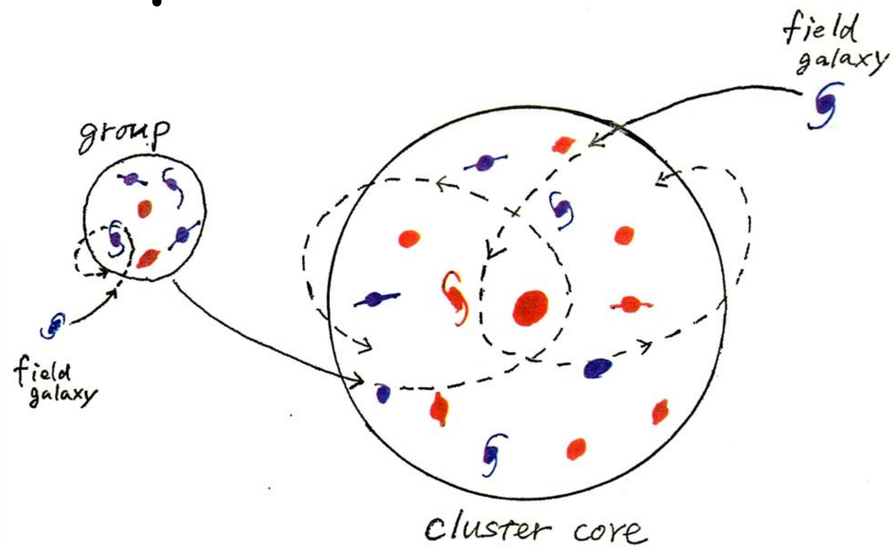
A galaxy cluster RXJ0152 at z=0.83 (Subaru/Suprime-Cam)

What is the origin of the environmental dependence?

Morphology-SFR-density relation
(Dressler 1980)



log surface density (Mpc^{-2})



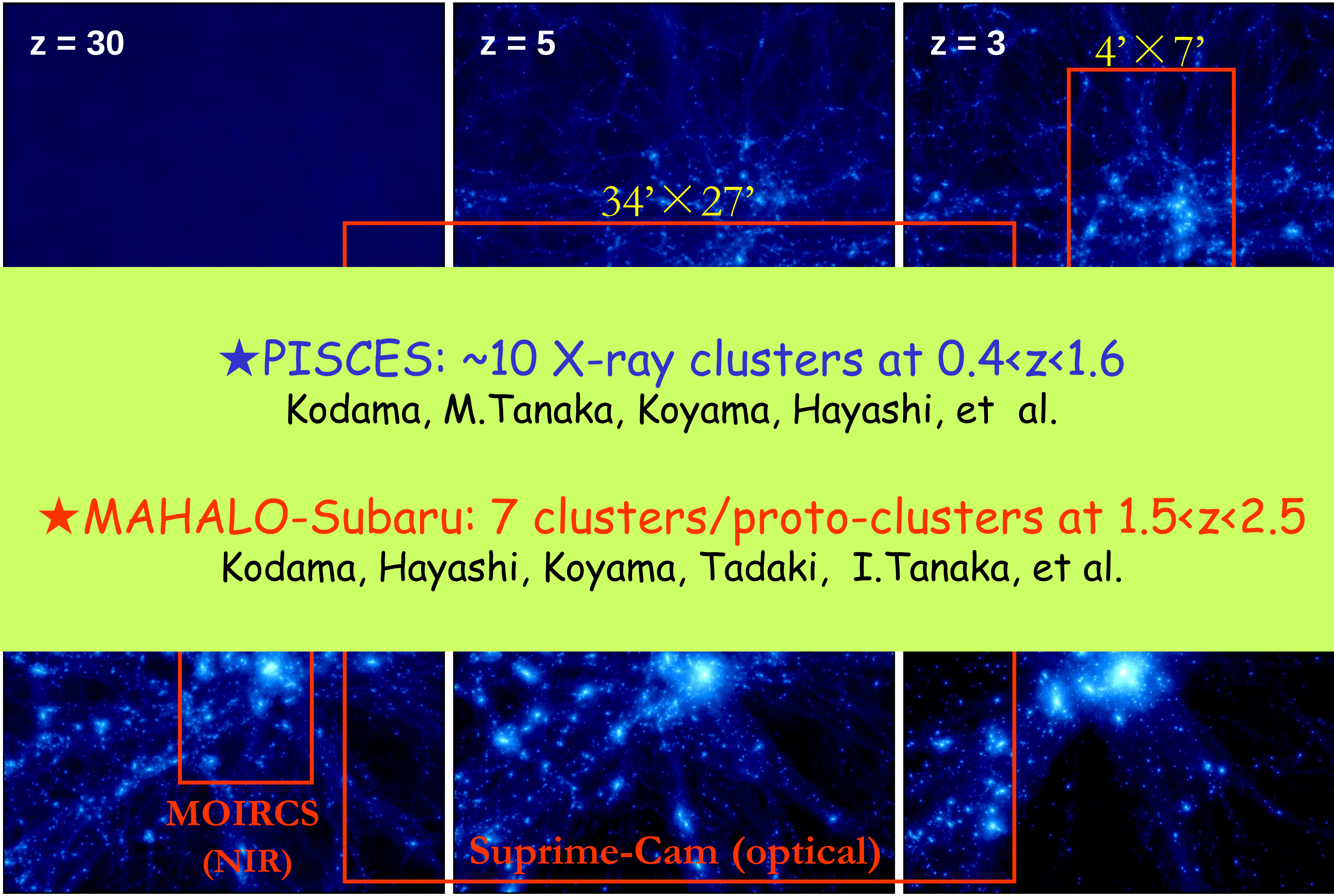
Nature? (intrinsic)

Need to go to high redshifts where age difference is boosted.

Nurture? (external)

Need to go to outer infall regions to see directly what's happening there.

Why Subaru?



★PISCES: ~10 X-ray clusters at $0.4<z<1.6$

Kodama, M.Tanaka, Koyama, Hayashi, et al.

★MAHALO-Subaru: 7 clusters/proto-clusters at $1.5<z<2.5$

Kodama, Hayashi, Koyama, Tadaki, I.Tanaka, et al.

Final cluster with $M=6\times10^{14}\ M_{\odot}$, $20\times20\mathrm{Mpc}^2$ (co-moving)   (Yahagi et al. 2005; ν GC)

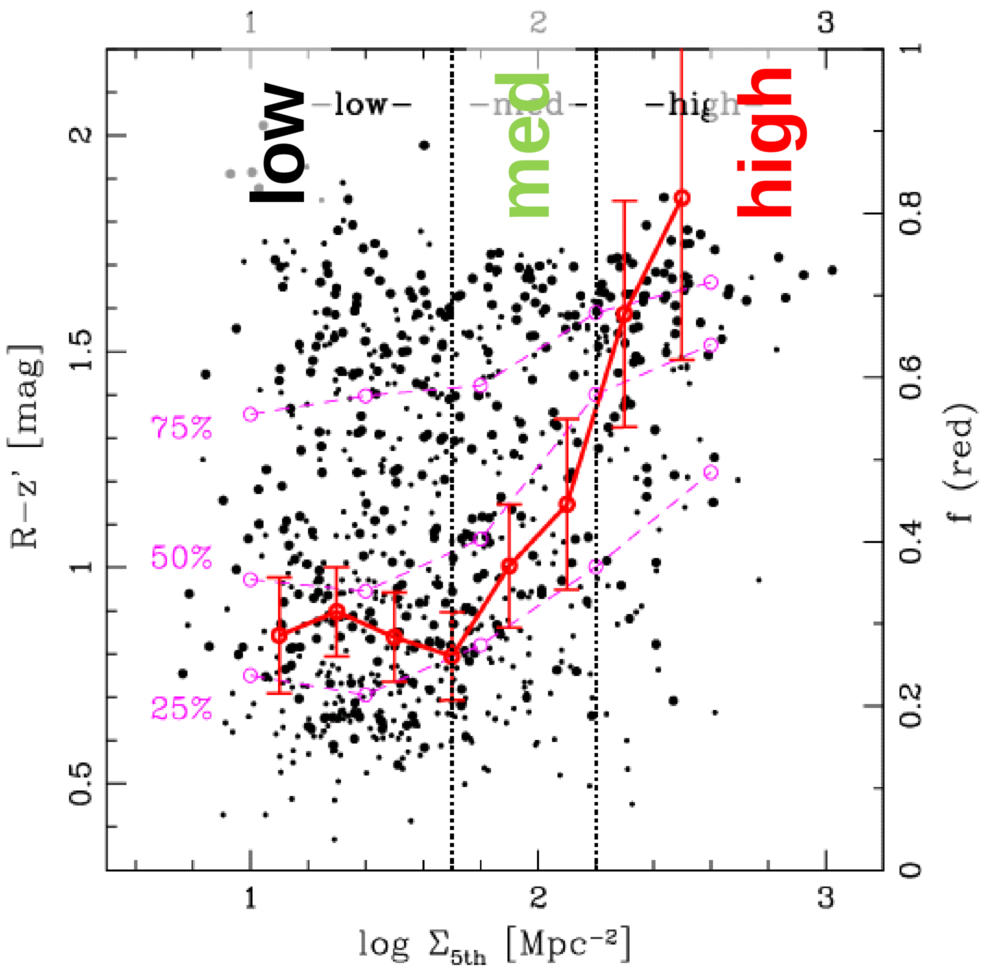
Key questions

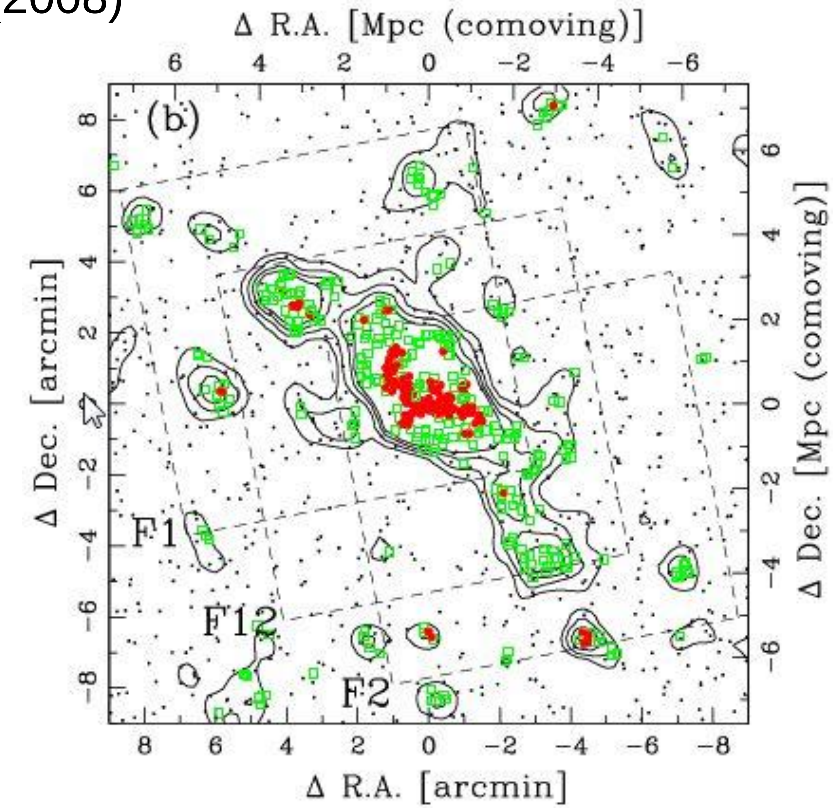
- What's going on in cluster outskirts at $z<1.5$?
- Is star formation activity boosted in high density regions (proto-clusters) at $z>1.5$?
- What triggers star formation activities in the proto-clusters?

Sharp colour transition in groups/outskirts

RXJ1716 cluster (z=0.81)

Koyama et al. (2008)





high ~ cluster core

med ~ group / filament

low ~ field

What's going on in the groups and the outskirts?

"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 $1.5<z<2.5$).

※ Nearly complete and un-biased census of star forming galaxies to a certain limit in SFR.

environment	target	z	line	λ (μm)	camera	NB-filter	continuum	ALMA visibility	status
clusters	CL0024+1652	0.395	Hα	0.916	S-Cam	NB912	z'	Yes	Kodama+ '04
	CL0939+4713	0.407	Hα	0.923	S-Cam	NB921	z'	No	Koyama+ '11
	RXJ1716+6708	0.813	Hα	1.190	MOIRCS	NB1190	z', J	No	Koyama+ '10
	XCSJ2215–1738	1.457	[OII]	0.916	S-Cam	NB912	z'	Yes	Hayashi+ '10
	4C65.22	**1.516**	Hα	1.651	MOIRCS	NB1657	H	No	not yet
	Q1126+101	**1.517**	Hα	1.652	MOIRCS	NB1657	H	Yes	not yet
	Q0835+580	**1.534**	Hα	1.664	MOIRCS	NB1657	H	No	observed
	CL0332–2742	**1.61**	[OII]	0.973	S-Cam	NB973	z, y	Yes	observed/analysed
	CIGJ0218.3–0510	**1.62**	[OII]	0.977	S-Cam	NB973	z', y	Yes	observed/analysed
	PKS1138–262	**2.156**	Hα	2.071	MOIRCS	NB2071	K_s	Yes	scheduled in S11A
	4C23.56	**2.483**	Hα	2.286	MOIRCS	NB2288	K_s, K_{cont}	Yes	Tanaka+ '11
	USS1558–003	**2.527**	Hα	2.315	MOIRCS	NB2315	K_s, K_{cont}	Yes	scheduled in S11A
Fields	GOODS-N	2.19	Hα	2.094	MOIRCS	NB2095	K_s	No	Tadaki+ '11
	(2.5 pointings)		[OII]	1.189	MOIRCS	NB1190	z', J	No	Tadaki+ '11
	SXDF	**2.19**	Hα	2.094	MOIRCS	NB2095	K	Yes	observed
	(3 pointings)		Hβ	1.551	MOIRCS	NB1550	H	Yes	not yet
			[OII]	1.189	MOIRCS	NB1190	z', J	Yes	not yet

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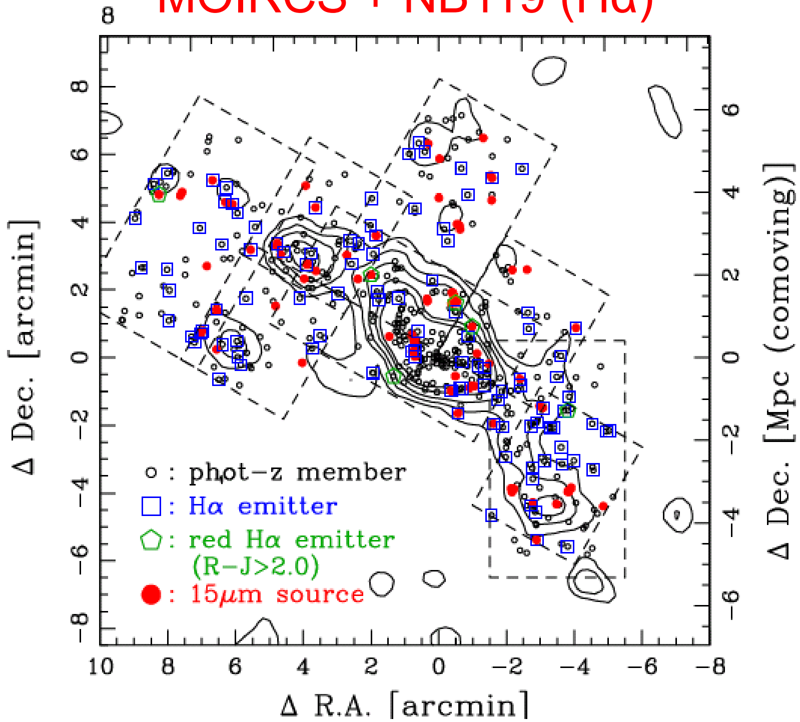
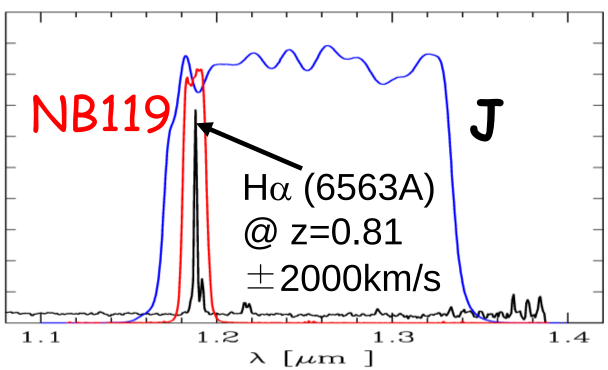
RX J1716.6+6708 (z=0.81)

MOIRCS + NB119 (Hα)

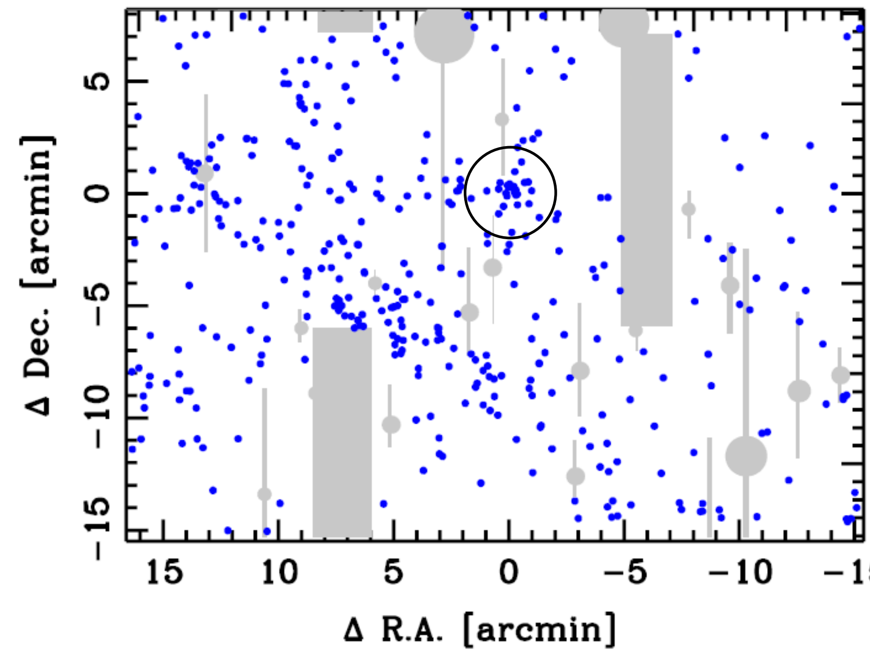


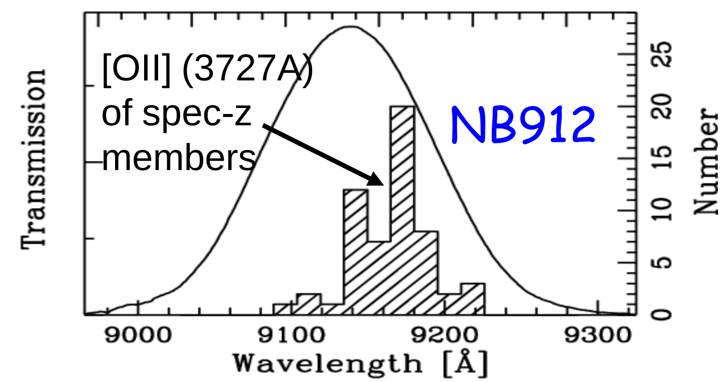


SFR>2M$_\odot$/yr (5σ)

XCS J2215.9-1738 (z=1.46)

Suprime-Cam + NB912 ([OII])





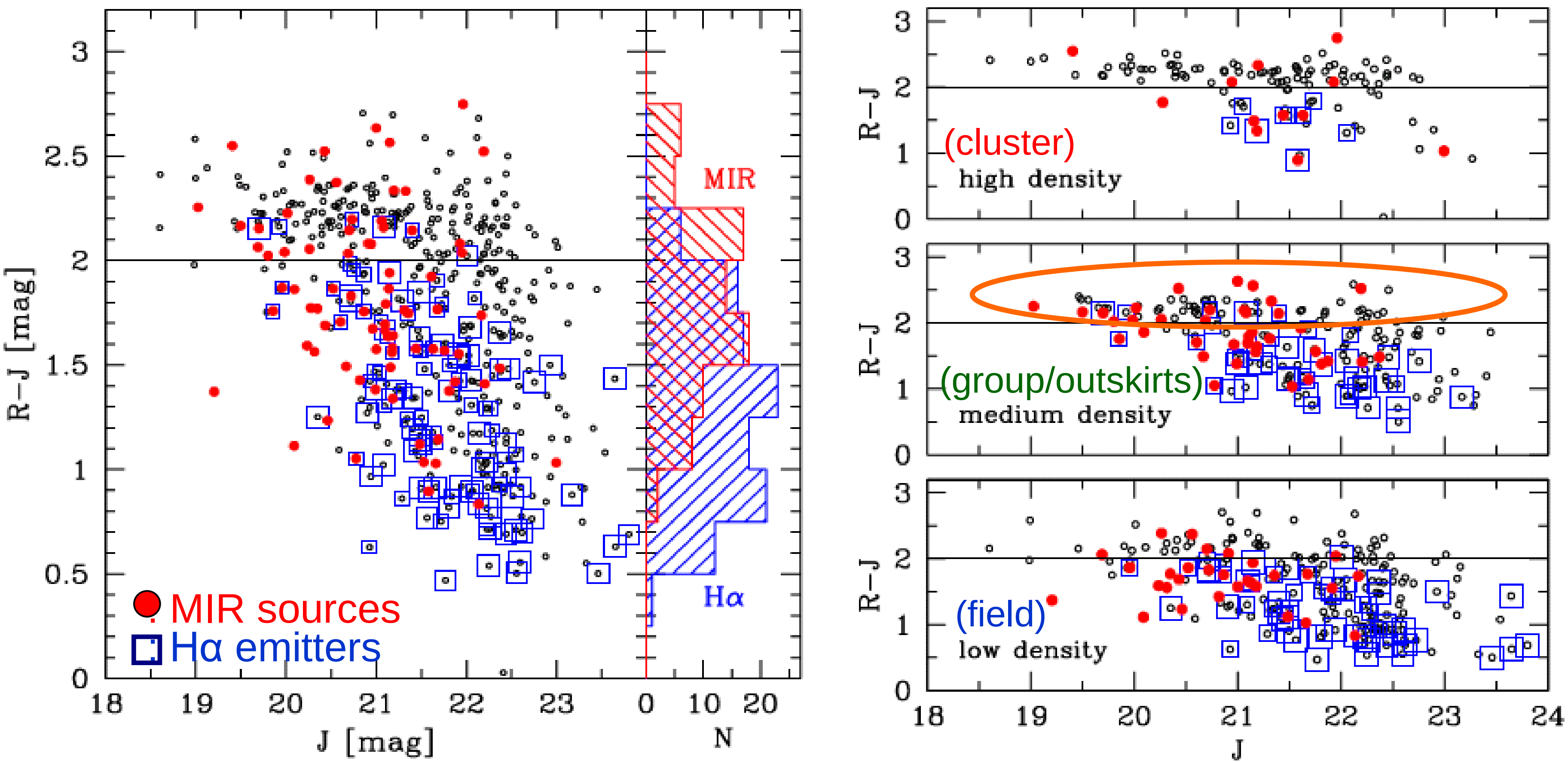
SFR>4M$_\odot$/yr (5σ)

Broad-band colours (phot-z) are used to identify which emission line is in the NB filter.

Hidden star formation in the red sequence

Hα emitters and AKARI 15μm sources on the red sequence

RX J1716.6+6708 (z=0.81)



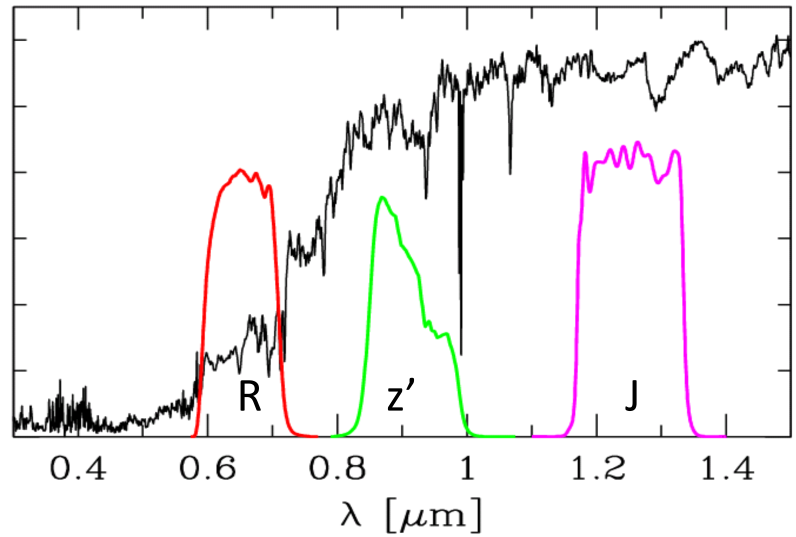
The red emitters tend to be located in group environment!

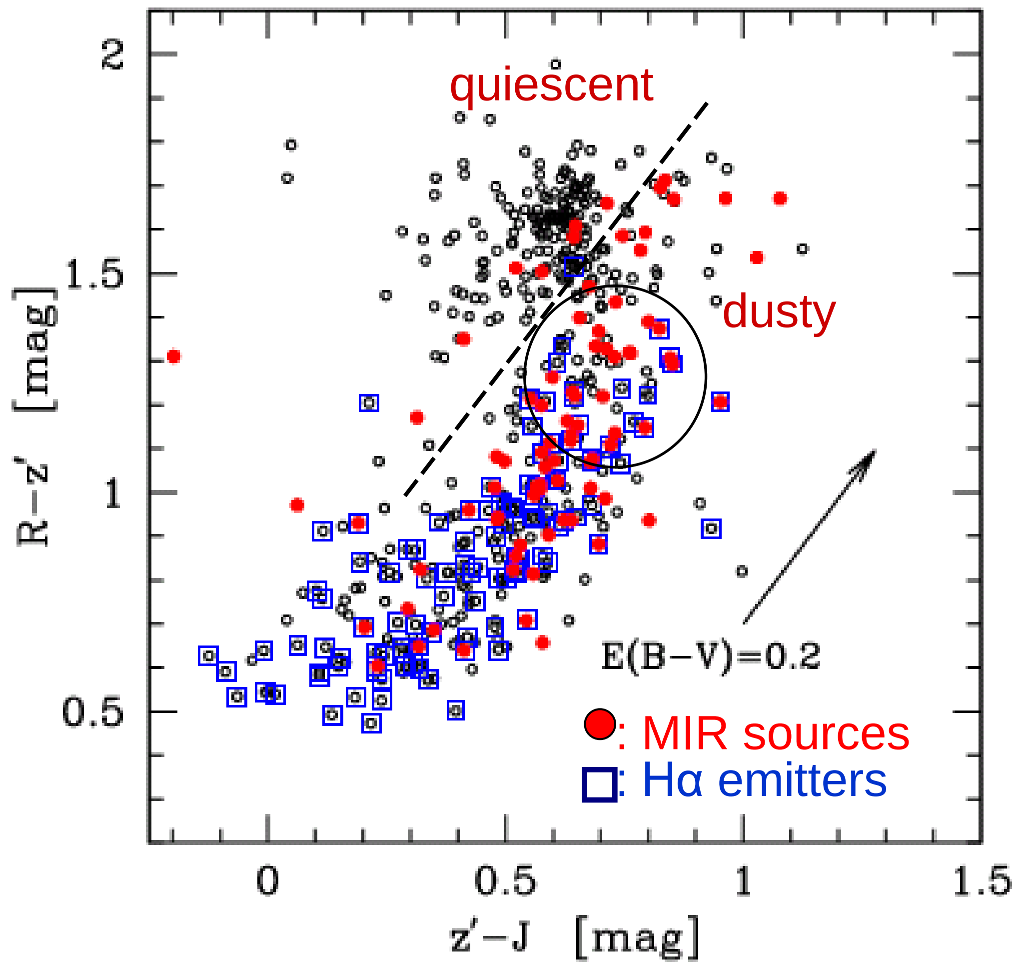
Koyama, et al. (2010)

See Poster #5-19 by Koyama, et al.

Dusty star forming galaxies on the red sequence

RX J1716.6+6708 (z=0.81)　　Koyama, et al. (2010)

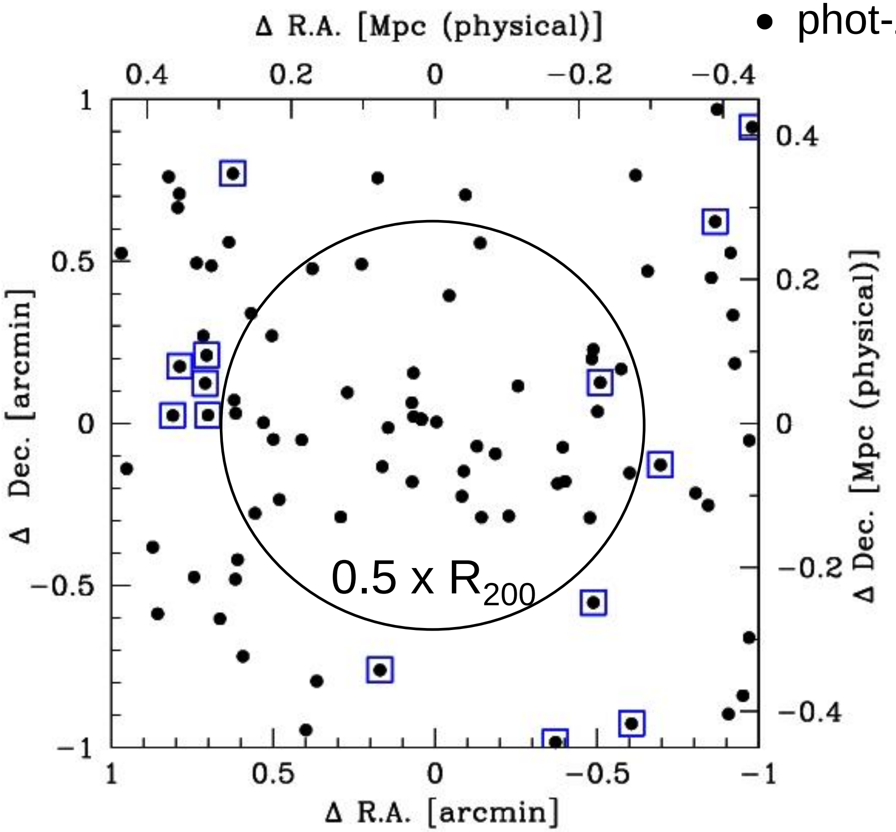




The red Hα emitters are dusty star-forming galaxies in groups, and the key populations under the influence of environmental effects.

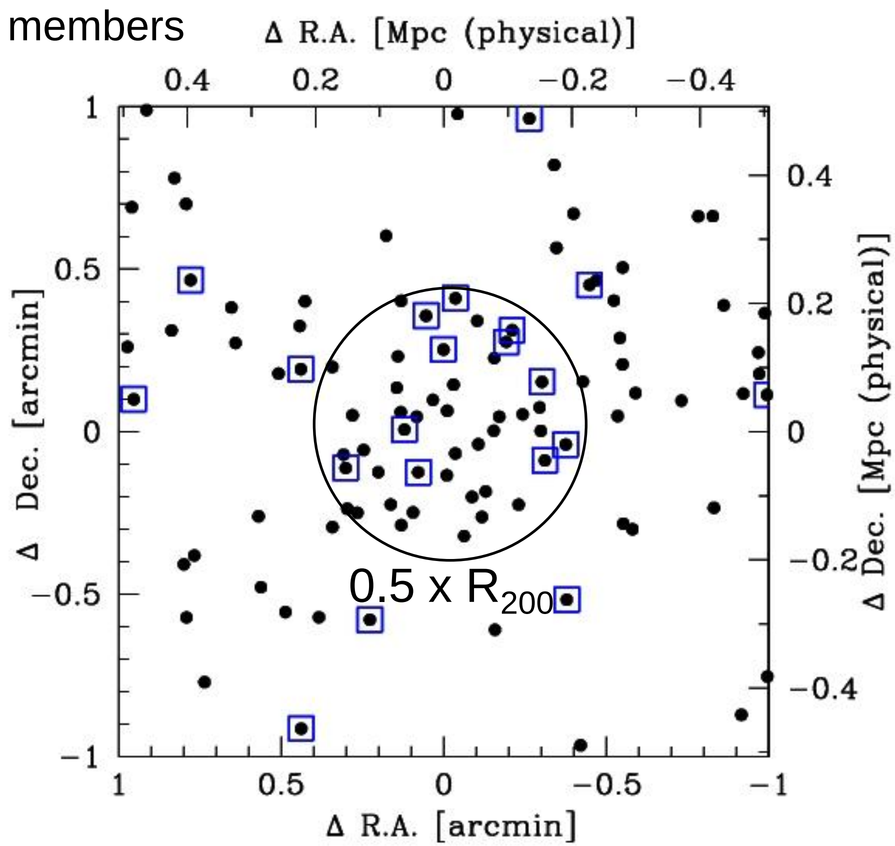
Inside-out propagation/truncation of star formation activities in clusters

□Hα emitters at z=0.81 (RXJ1716) □ [OII] emitters at z=1.46 (XCS2215)



Lx=2.7×10^{44} erg/s

Koyama, et al. (2011)

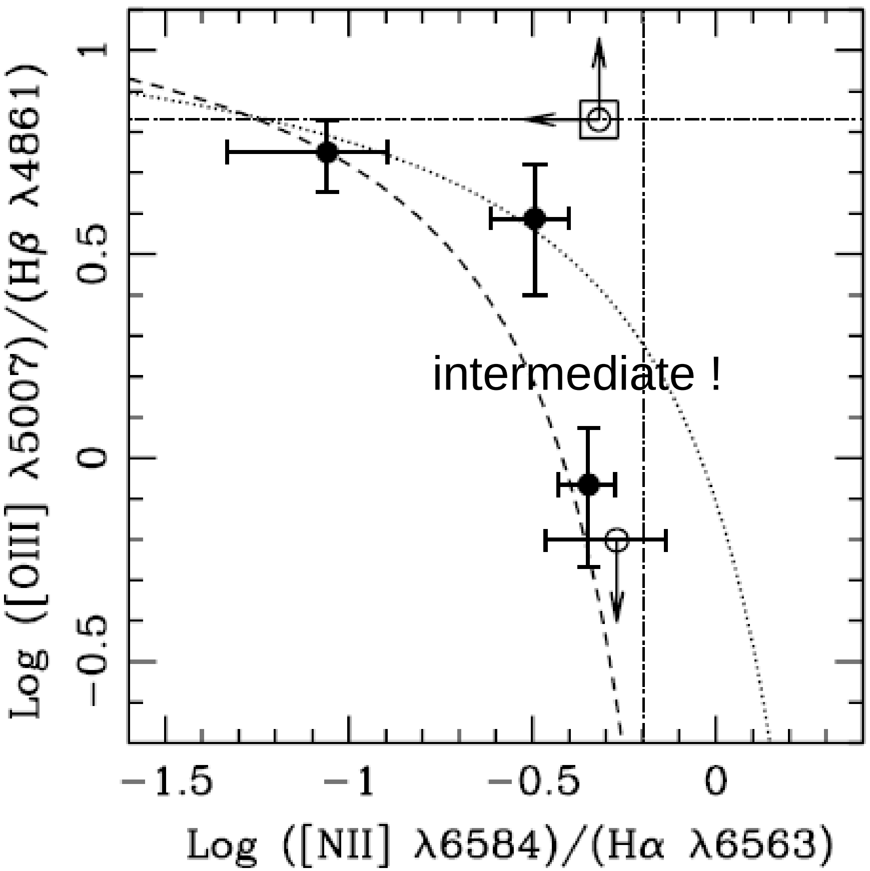


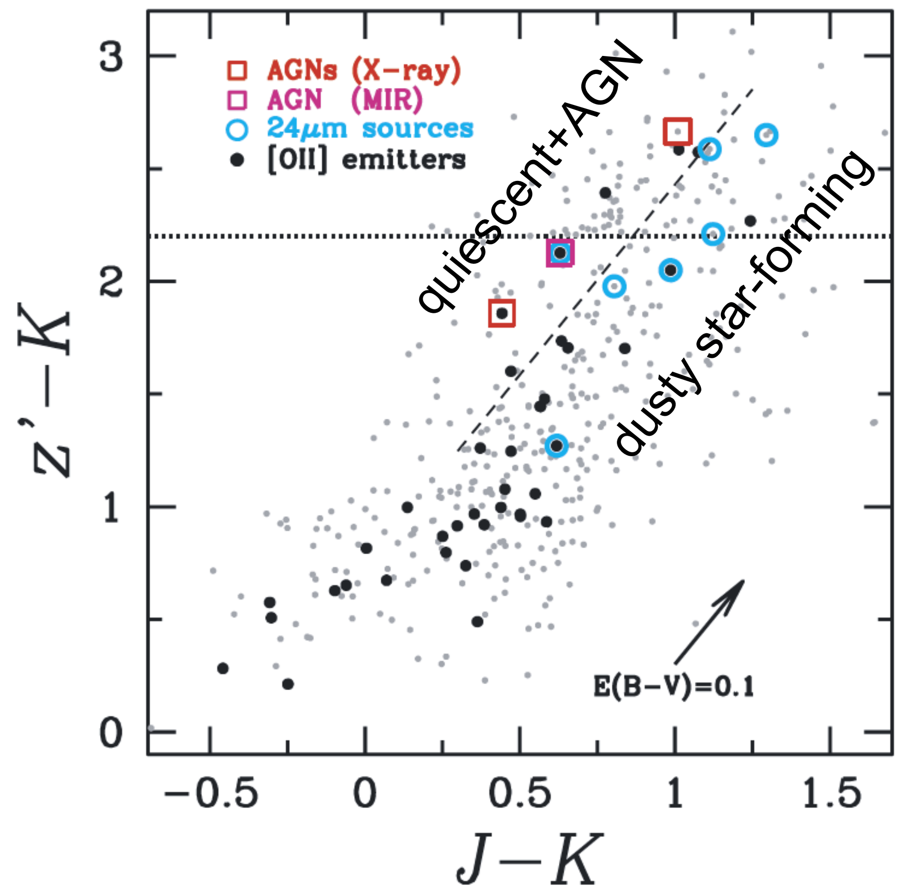
Lx=4.4×10^{44} erg/s

Hayashi, et al. (2010)

AGN contribution is an issue for [OII] at z~1.5

XCS2215 cluster (z=1.46)

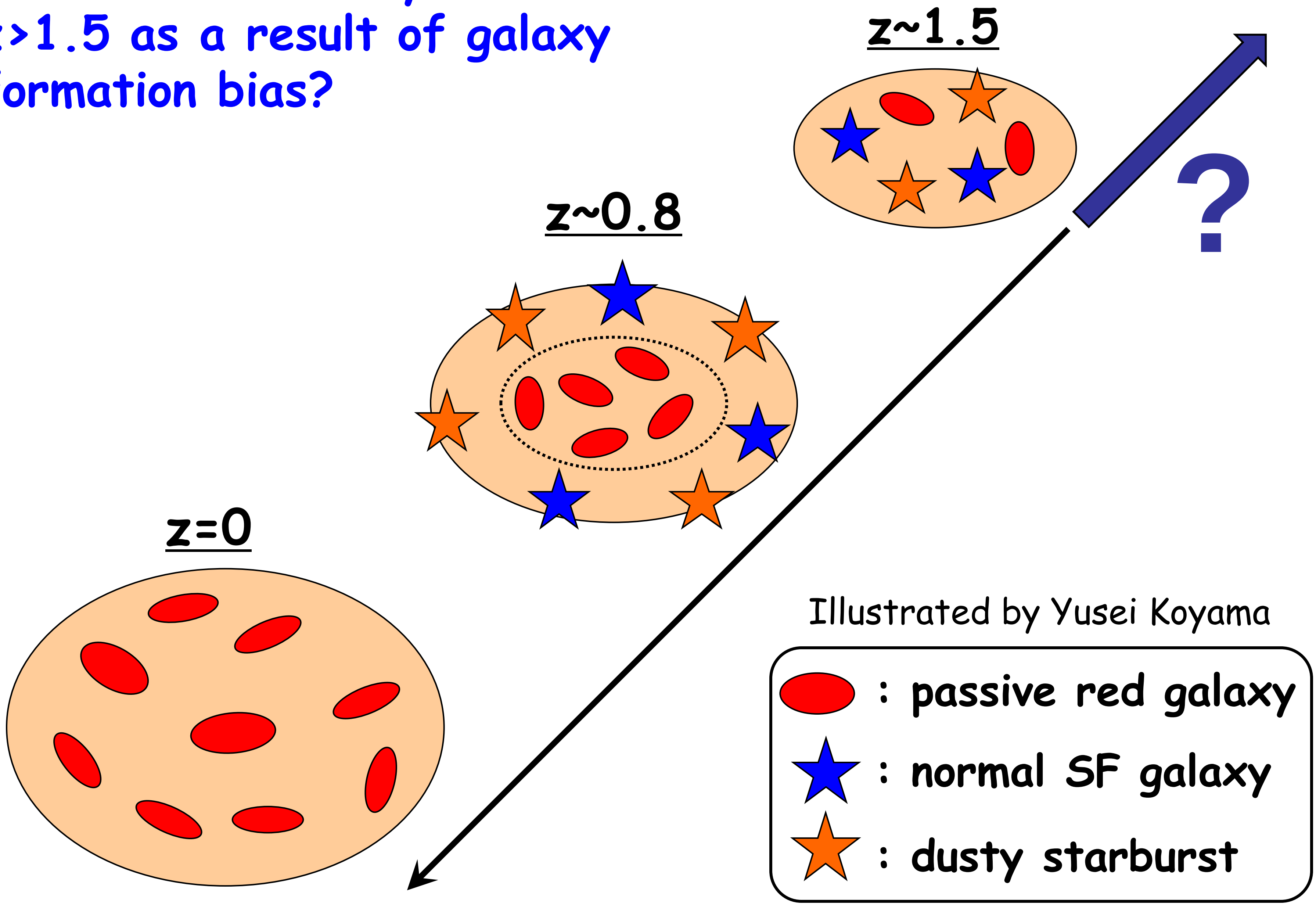




Hayashi et al. (2011)

See Poster #5-17 by Hayashi, et al.

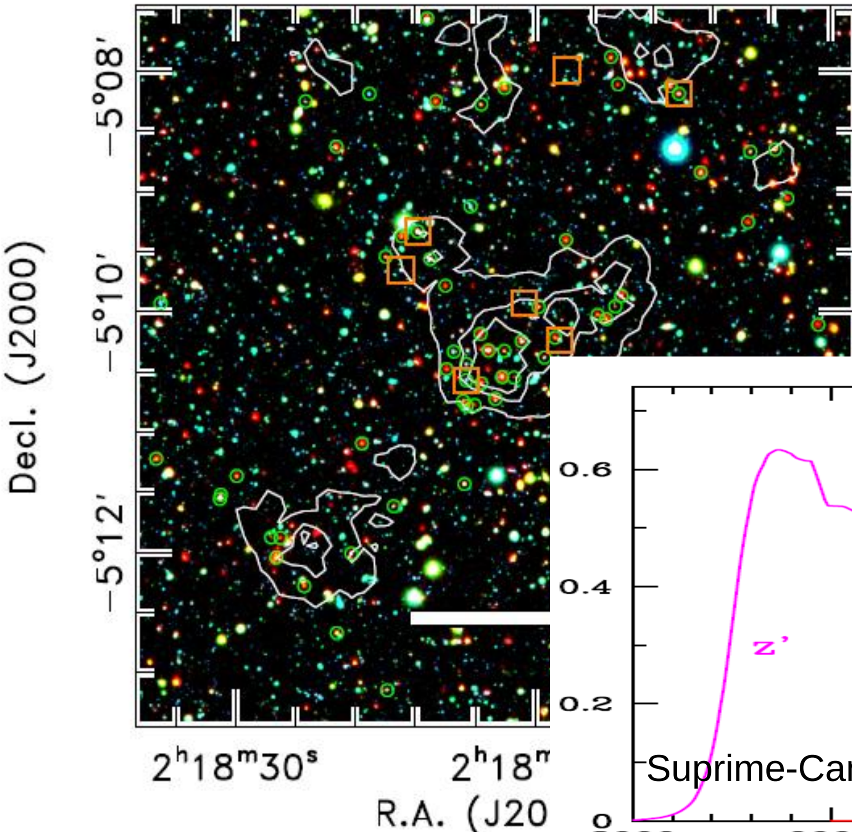
Do we eventually see the reversal of the SFR-density relation at z>1.5 as a result of galaxy formation bias?

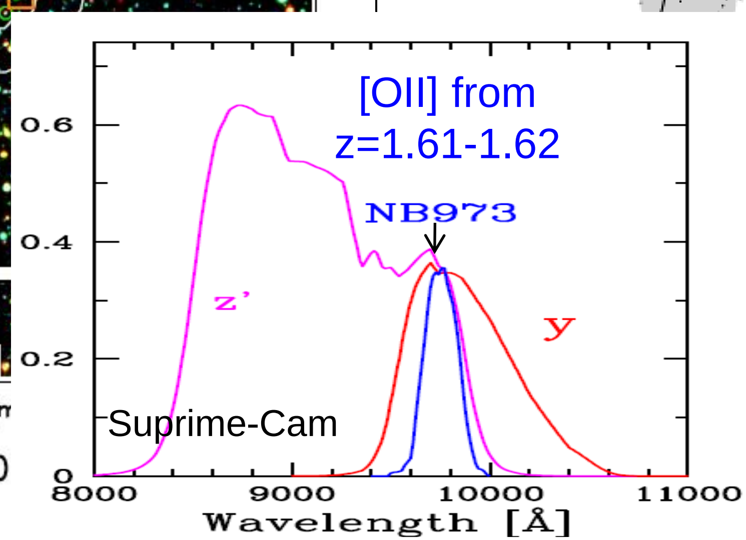


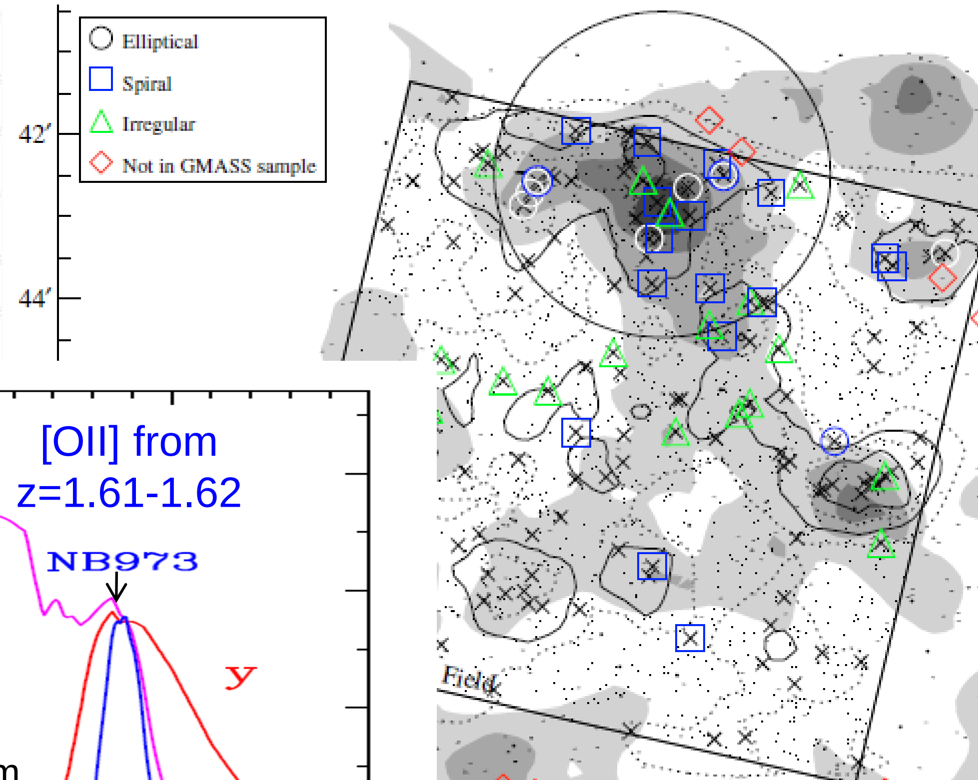
Two recently found, confirmed clusters at z~1.6

ClG J0218.3-0510 (z=1.62) in SXDF

CL0332-2742 (z=1.61) in GOODS-S







9 spec-z members, σ=540km/s

X-ray detection (4.5σ)

(Papovich et al. 2010; Tanaka et al. 2010)

42 spec-z members, σ=500km/s

(Kurk et al. 2009)

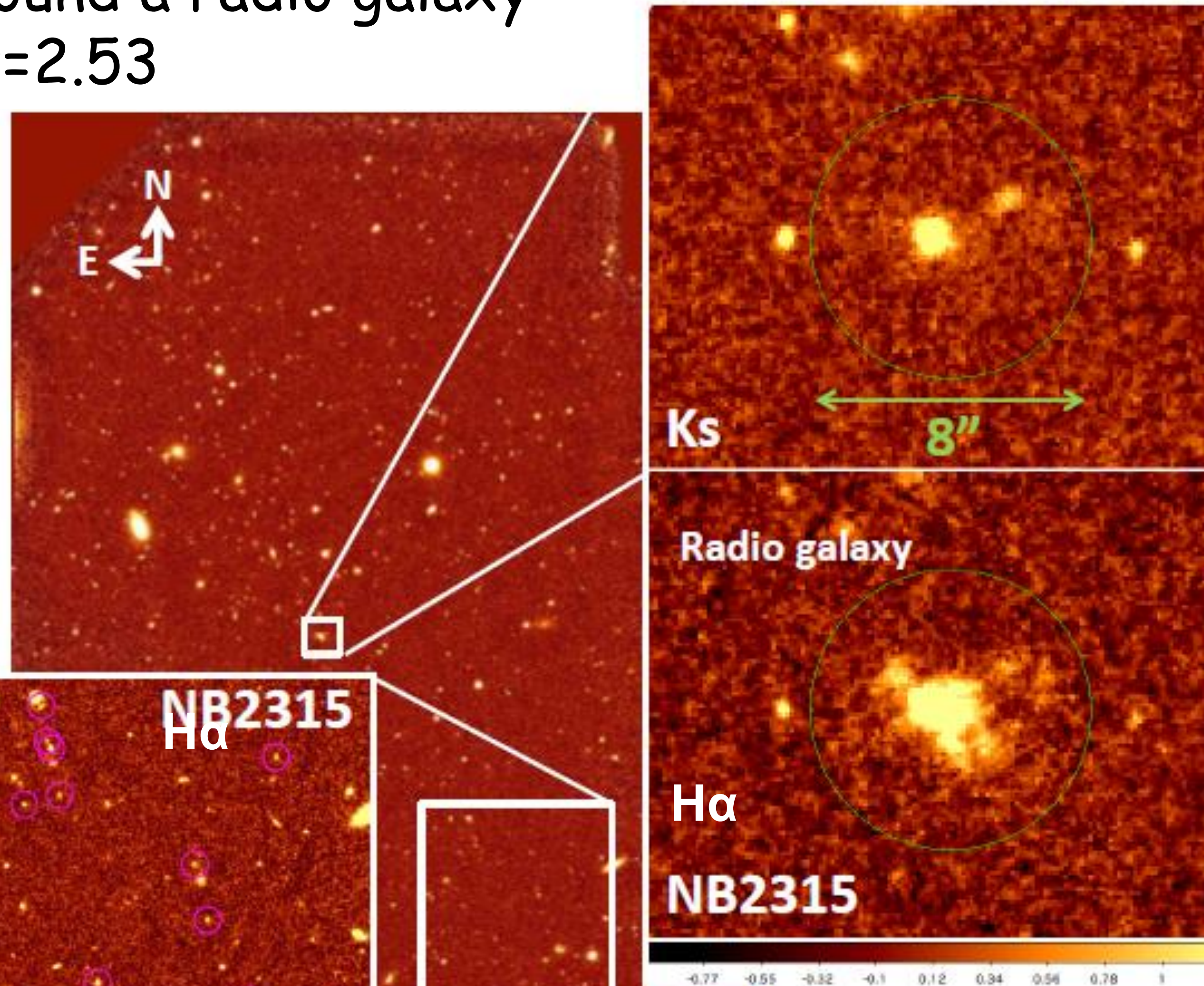
See Poster #5-39 by Tadaki, et al.

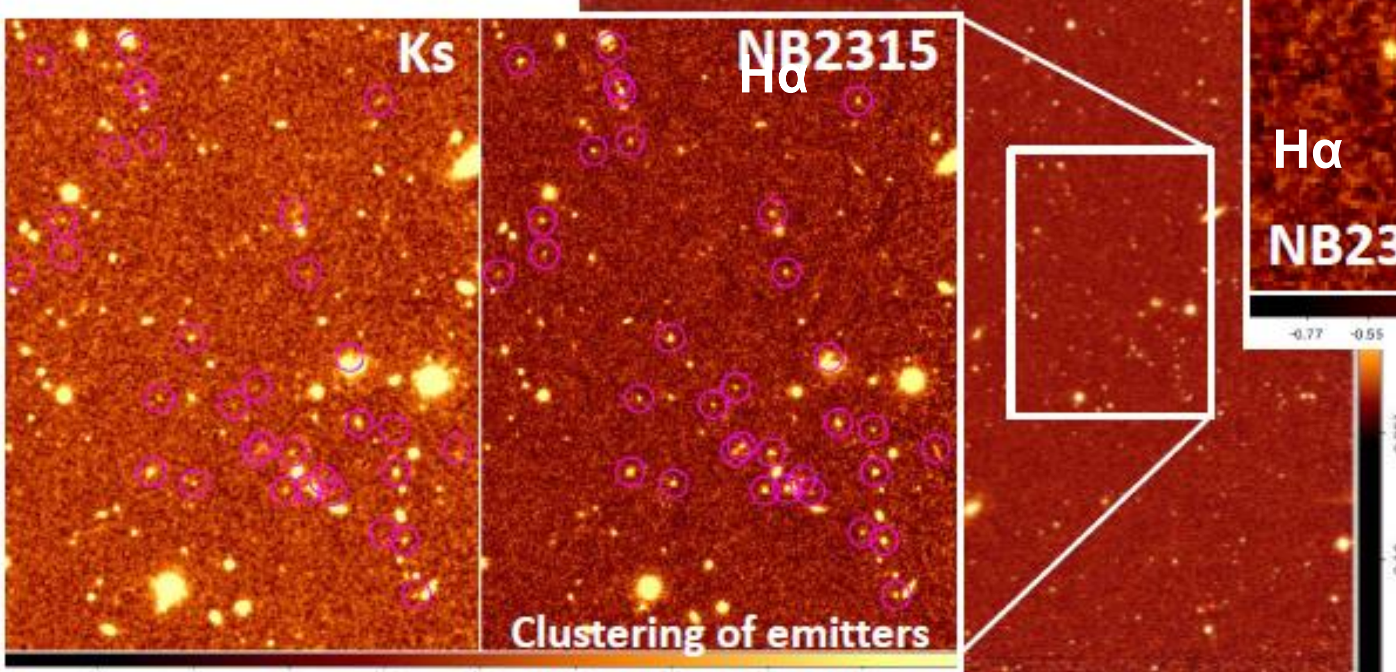
A proto-cluster around a radio galaxy USS1558-003 at z=2.53

known as an overdensity region of DRGs.

3.4 hrs integration on NB2315 (Hα)

0.4-0.5” seeing

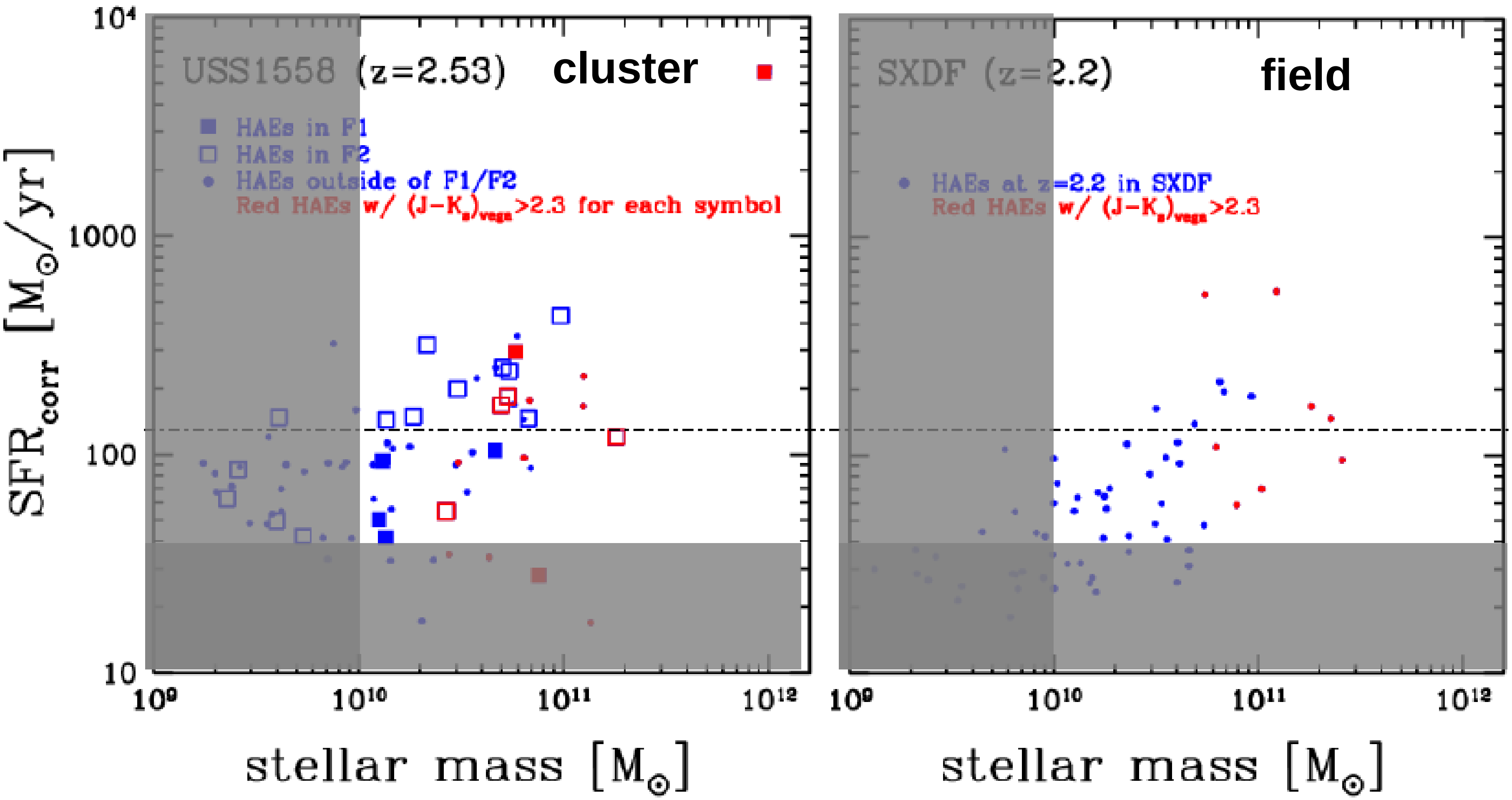




Hayashi et al. in prep.

Environmental dependence in SF activity at z~2.5?

Number density of Hα emitters (>40$M_\odot$/yr) is
30 times larger in USS1558 (F1+F2) than in SXDF.



SF activity is boosted in the proto-cluster compared to the general field.

Why is SF activity boosted in the proto-cluster compared to the field at high-z?

Mergers and centralized starburst?
or
Disk-wide accretion and starburst?

We need to resolve galaxies both spatially and kinematically:

HST/WFC3 morphology (mergers or disk?)

IFU spectroscopy (outflow? rotation?)

ALMA (dense gas distribution? SF mode? kinematics?)

"Mahalo-Subaru"

MApping HAlpha and Lines of Oxygen with Subaru

"Gracias-ALMA"

GRAphing CO Intensity And Submm with ALMA

CO(2→1) for z~1.5, CO(3→2) for z~2.5 @~100GHz SFR~20$M_\odot$/yr (4hrs, 5σ)

Dust continuum @450 μm–1.1 mm @ z>1.5 SFR~10$M_\odot$/yr (2hrs, 5σ)

Summary

- Red emitters (dusty star-forming galaxies) are the key population in transition under the influence of environment.
- Star formation activity is probably biased in high density regions at high redshifts ($z>1.5$), and as time goes on, the peak activity is shifted outwards from cluster cores to the surrounding regions.
- MAHALO-Subaru + Gracias-ALMA will fully reveal the star formation history at the peak epoch of galaxy formation ($1.5<z<2.5$) .

The End