MApping HAlpha and Lines of Oxygen with Subaru

Mapping star formation at the peak epoch of galaxy formation and evolution

A Subaru Intensive Program for S10B-S11A

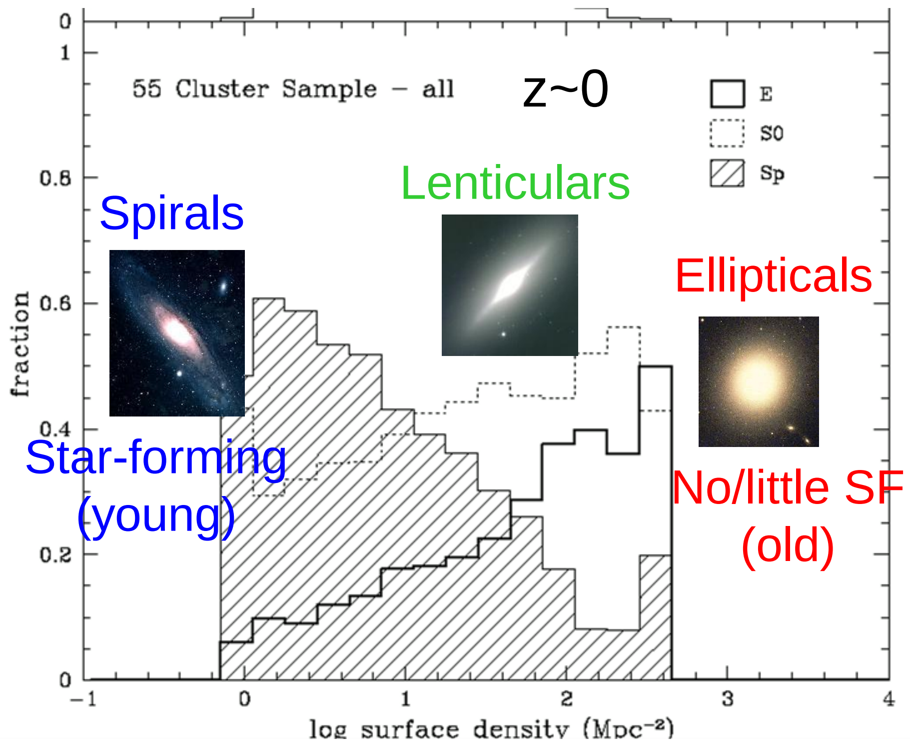
"MAHALO-Subaru"

Taddy Kodama (Subaru Telescope),

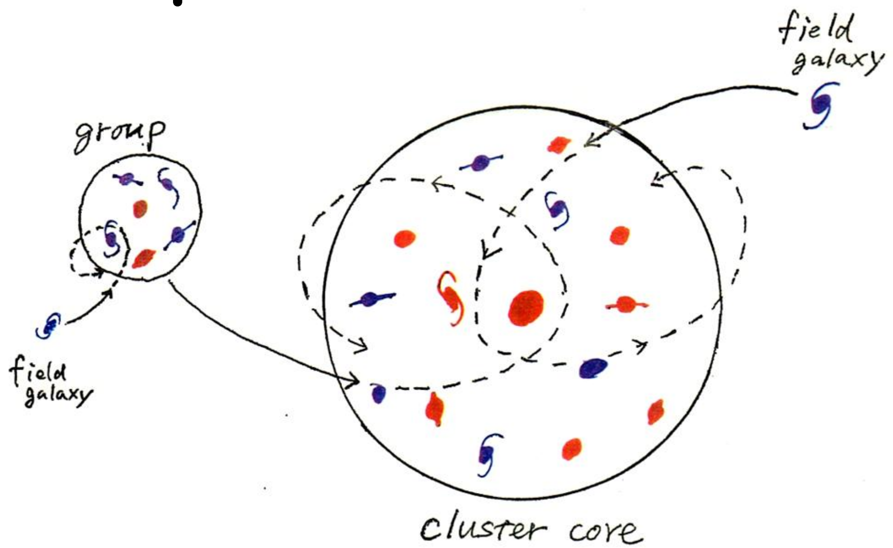
Masao Hayashi (NAOJ) "Hα survey in USS1558 (z=2.53)",
Yusei Koyama (Univ of Durham, UK / NAOJ),
Kenichi Tadaki (NAOJ/Univ of Tokyo),
Ichi Tanaka (Subaru Telescope), et al.

What's the origin of the environmental dependence

morphology – density relation
(Dressler 1980)



log surface density (Mpc^{-2})



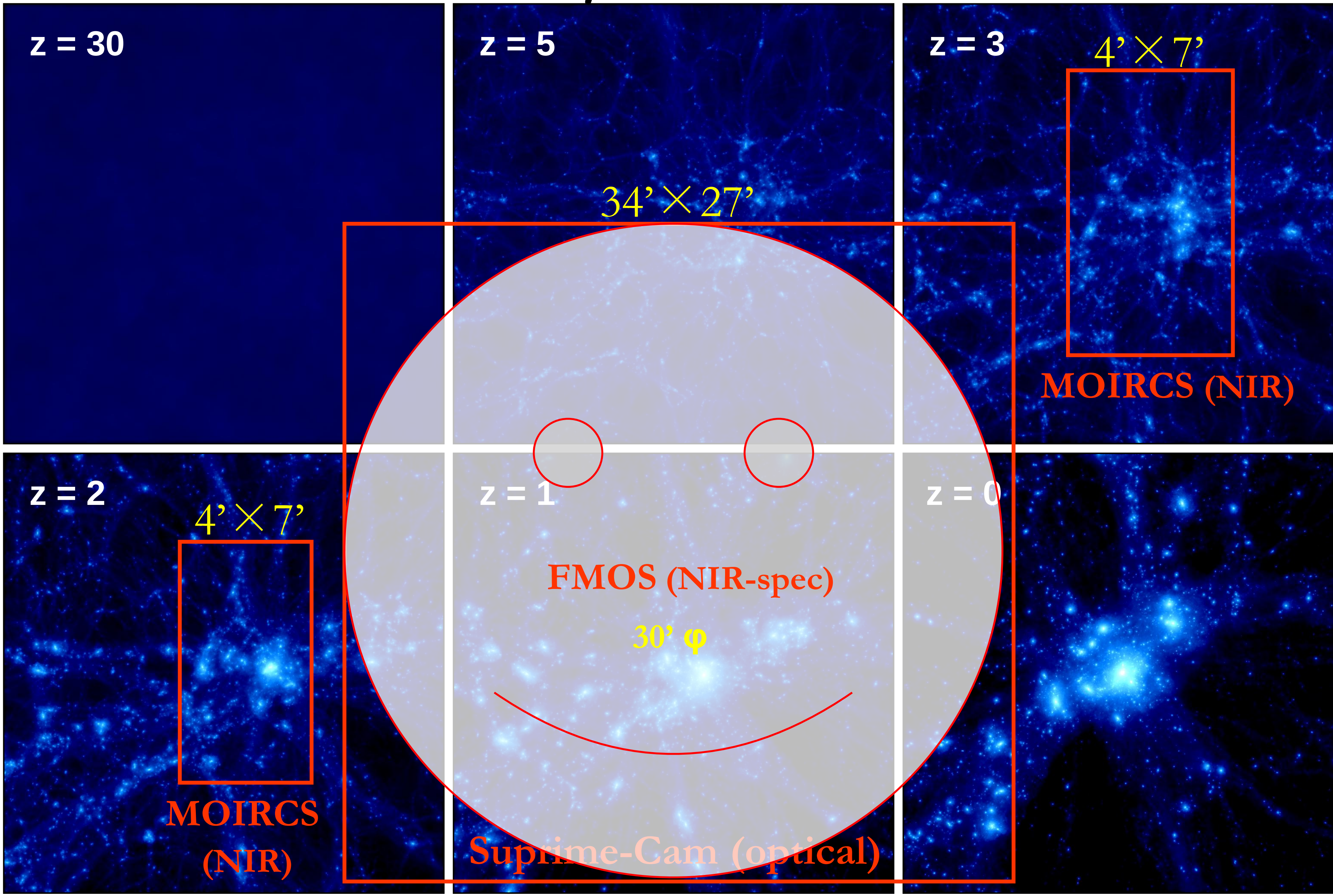
Nature? (intrinsic)

Need to go higher redshifts when it becomes more evident.

Nurture? (external)

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

Why Subaru?



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

"MAHALO-Subaru"

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NB mapping of star forming galaxies at the peak epoch of galaxy formation

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

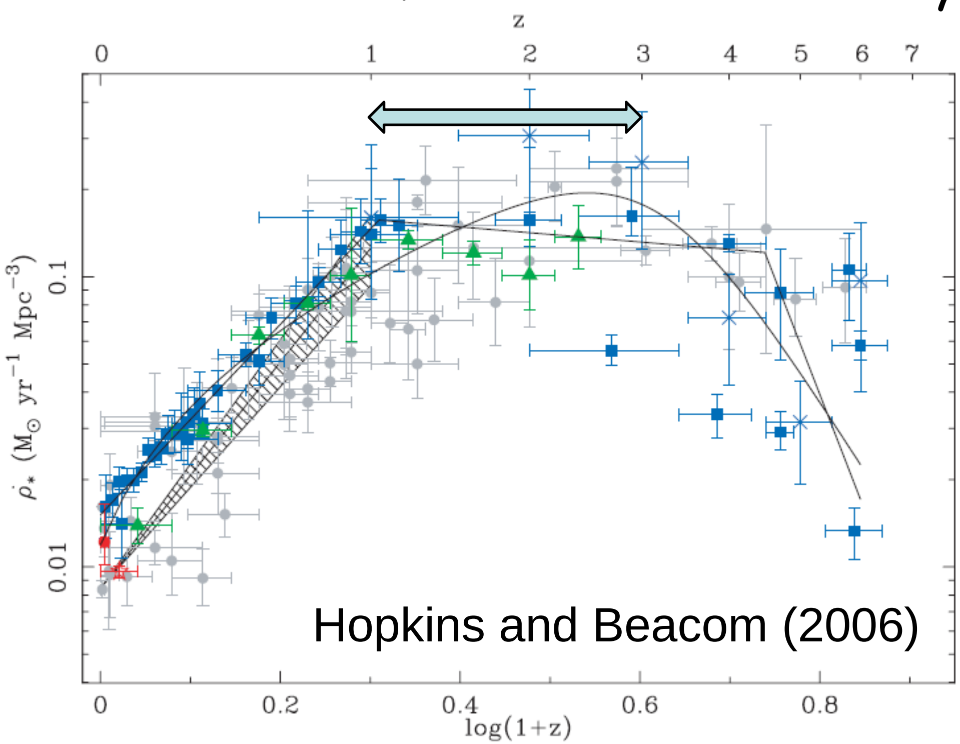
environment	target	z	line	λ (μm)	camera	NB-filter	continuum	status (as of Jan 2012)
Low-z cluster	CL0024+1652	0.395	Hα	0.916	Suprime-Cam	NB912	z'	Kodama+'04
	CL0939+4713	0.407	Hα	0.923	Suprime-Cam	NB921	z'	Koyama+'11
	RXJ1716+6708	0.813	Hα	1.190	MOIRCS	NB1190	J	Koyama+'10
			[O II]	0.676	Suprime-Cam	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
	CIGJ0218.3–0510	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	This paper
	4C23.56	2.483	Hα	2.286	MOIRCS	NB2288	K_s	Tanaka+'11
	USS1558–003	2.527	Hα	2.315	MOIRCS	NB2315	K_s	This paper
	MRC0316–257	3.130	[O II]	1.539	MOIRCS	NB1550	H	not yet
	TNJ0924–2201	5.195	[O II]	2.309	MOIRCS	NB2315	K_s	observed
General field	GOODS-N	2.19	Hα	2.094	MOIRCS	NB2095	K_s	Tadaki+'11a
	(62 arcmin^2)		Hβ	1.551	MOIRCS	NB1550	H	not yet
			[O II]	1.189	MOIRCS	NB1190	J	observed
	SXDF	2.19	Hα	2.094	MOIRCS	NB2095	K	This paper
	(110 arcmin^2)		Hβ	1.551	MOIRCS	NB1550	H	not yet
			[O II]	1.189	MOIRCS	NB1190	J	not yet
		2.53	Hα	2.313	MOIRCS	NB2315	K_s	observed

Kodama, T. (PI), Hayashi, M., Koyama, Y., Tadaki, K., Tanaka, I., et al.

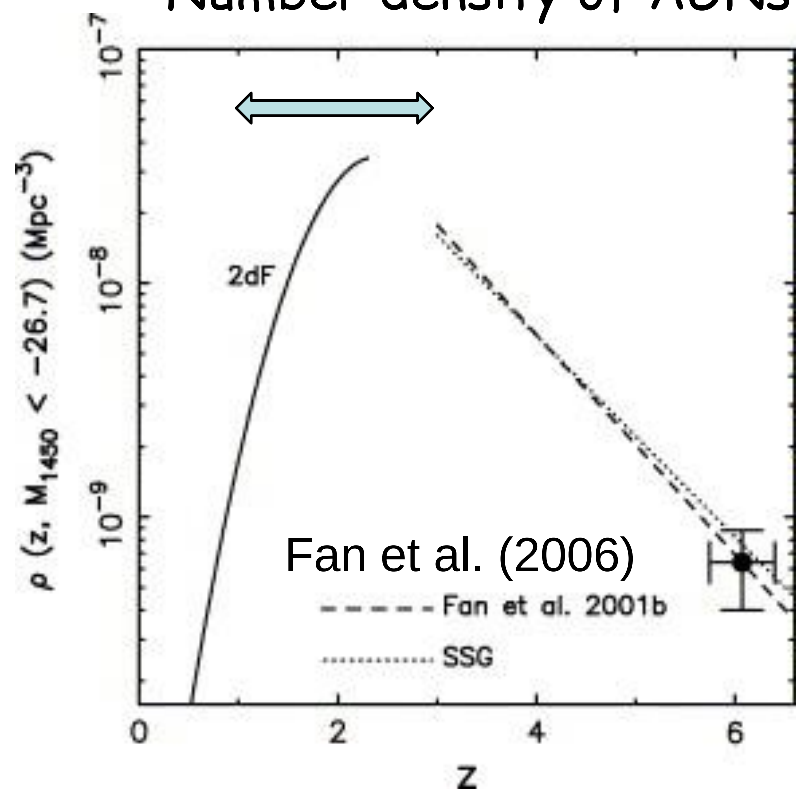
Why 1.5 < z < 3 ? ($4 > T_{univ}(Gyr) > 2$)

The peak epoch of star formation and AGN activities.
The formation epoch of massive galaxies (SMG, red sequence).

Cosmic star formation rate density



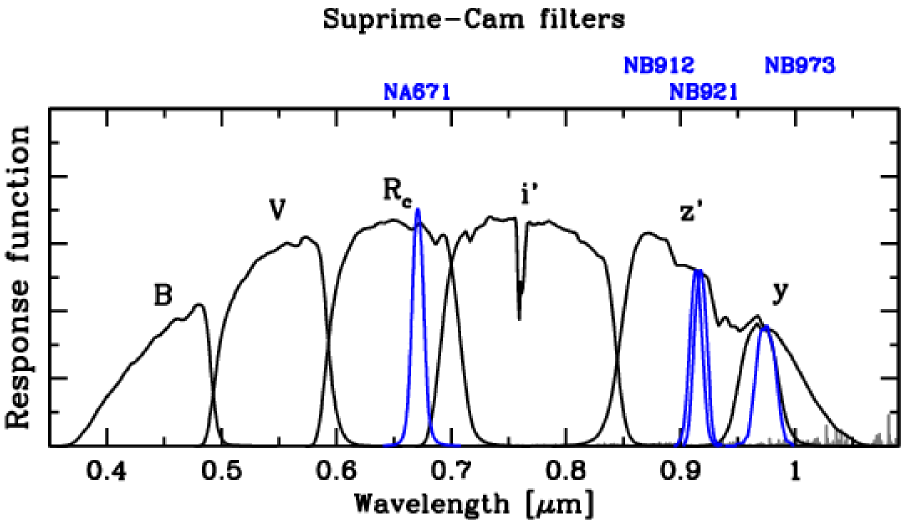
Number density of AGNs



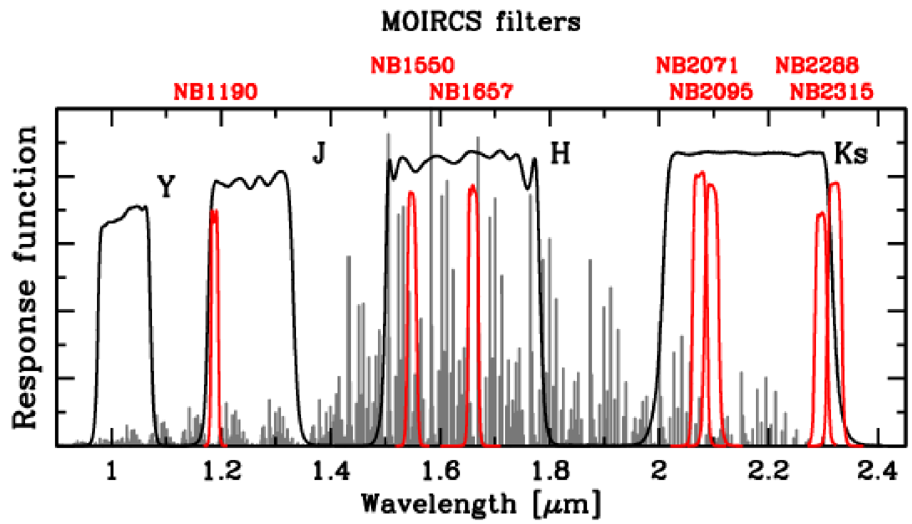
※z~2.8 is the upper limit where we can capture Hα (~2.5μm) from the ground.

Unique sets of Narrow-Band Filters on Suprime-Cam and MOIRCS

The existing Suprime-Cam NB-filters capture emission lines from known good targets.
The MOIRCS NB-filters were specifically designed for good targets at frontier redshifts.



4 narrow-band filters

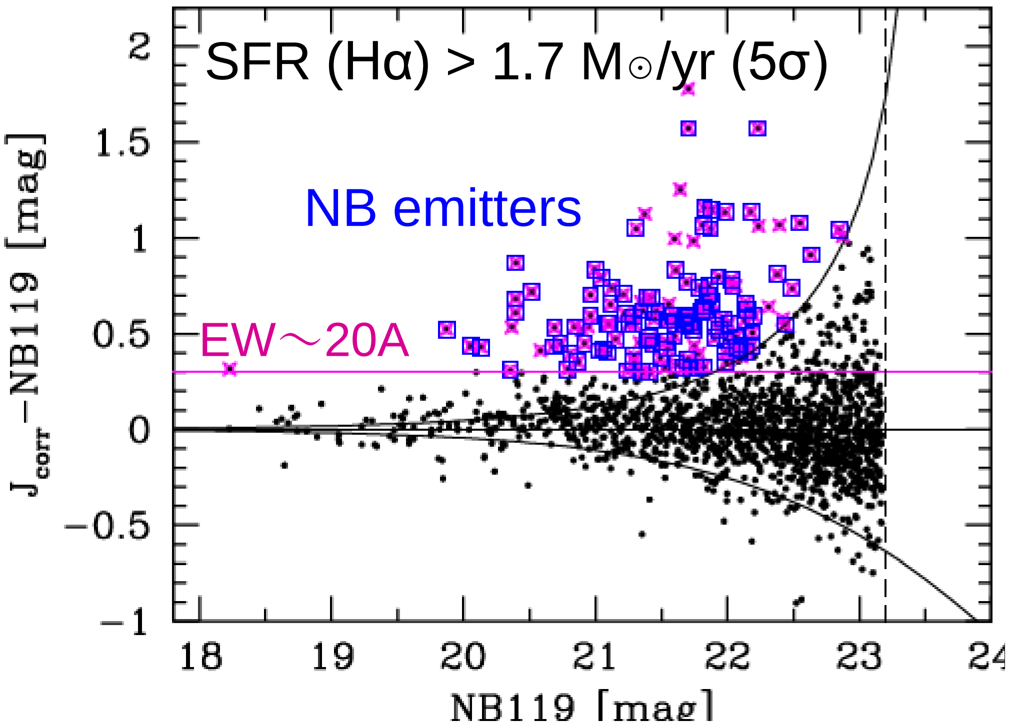


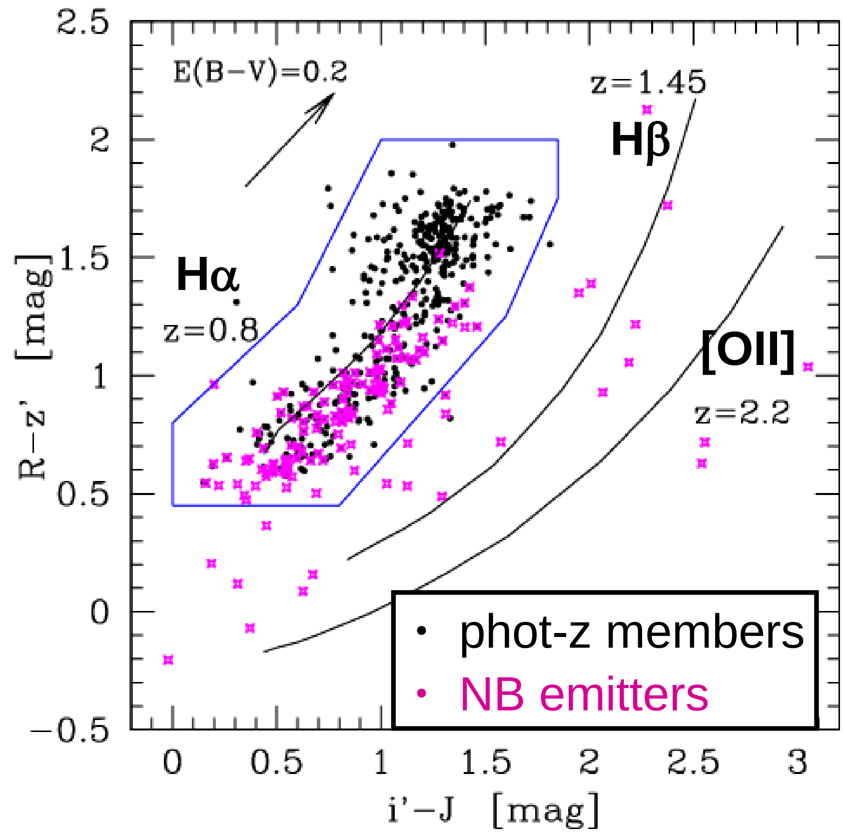
7 narrow-band filters

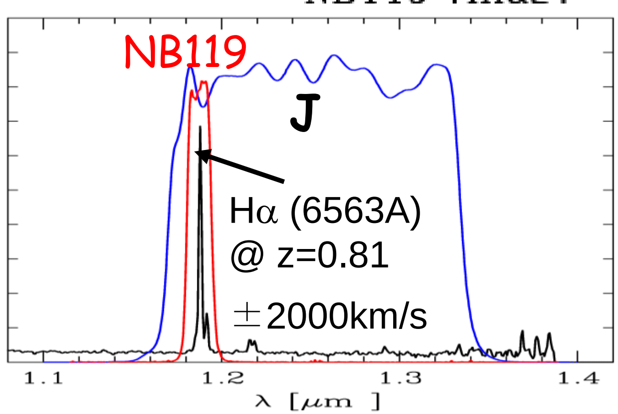
NB1190, NB1550, and NB2095
are a coordinated set filter to target
[OII], Hβ, Hα lines at z=2.19

How does NB imaging work?

Hα emitters in and around RXJ1716 cluster (z=0.81)







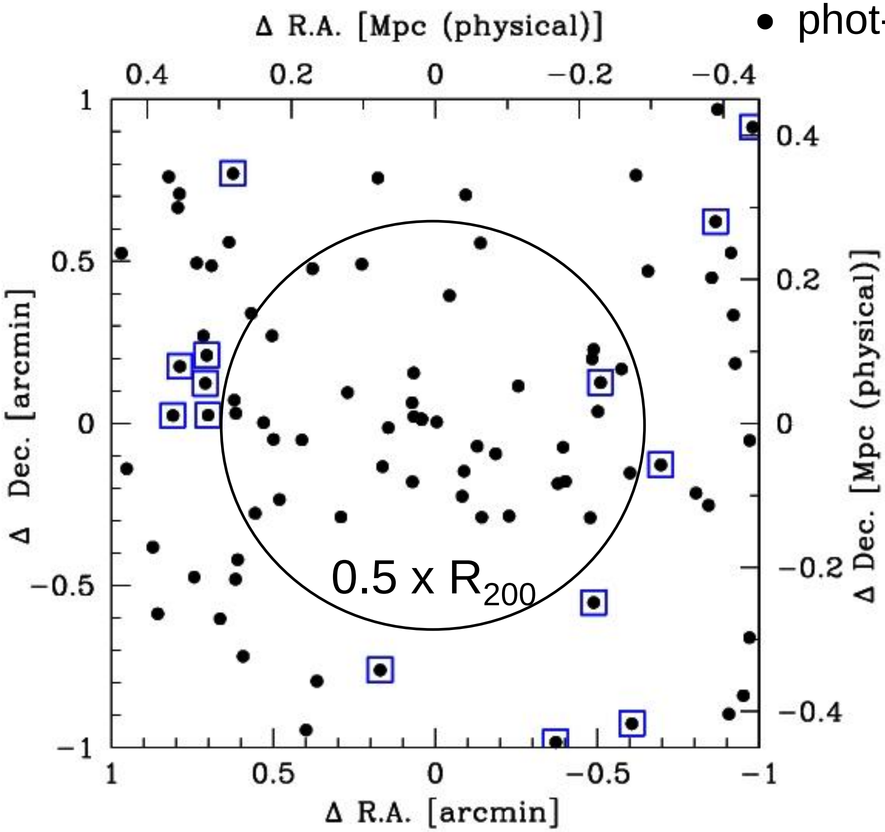
A colour-colour diagram is used to separate out our wanted line from other contaminant lines.
(or photometric redshifts can be used)

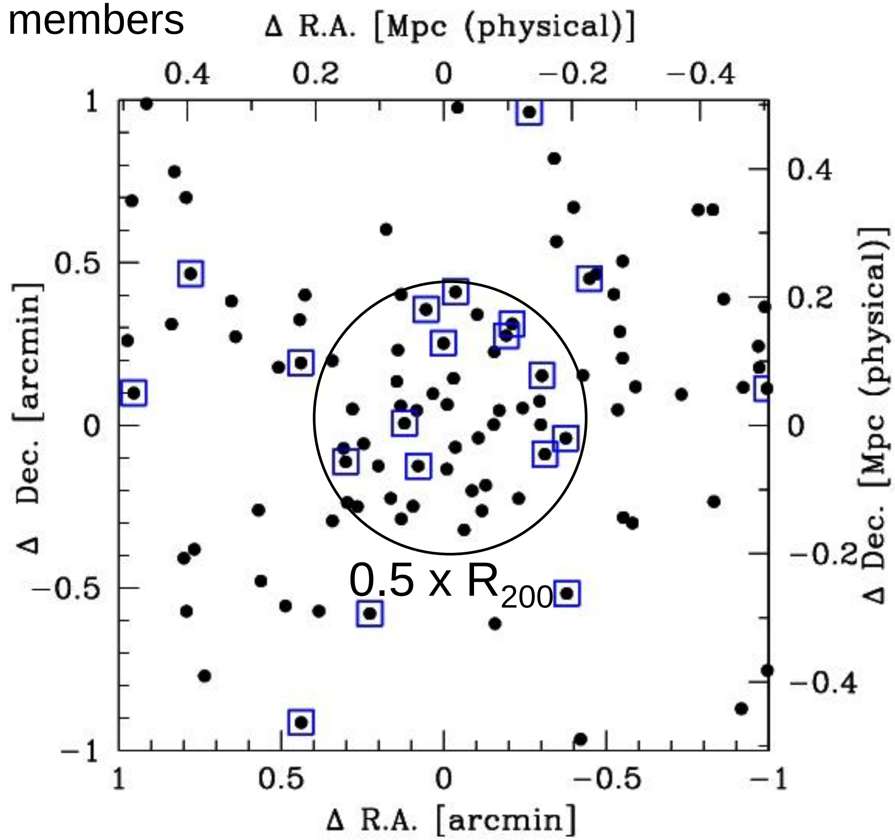
Koyama et al. (2010)

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

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

• phot-z members





Lx=2.7×10^{44} erg/s

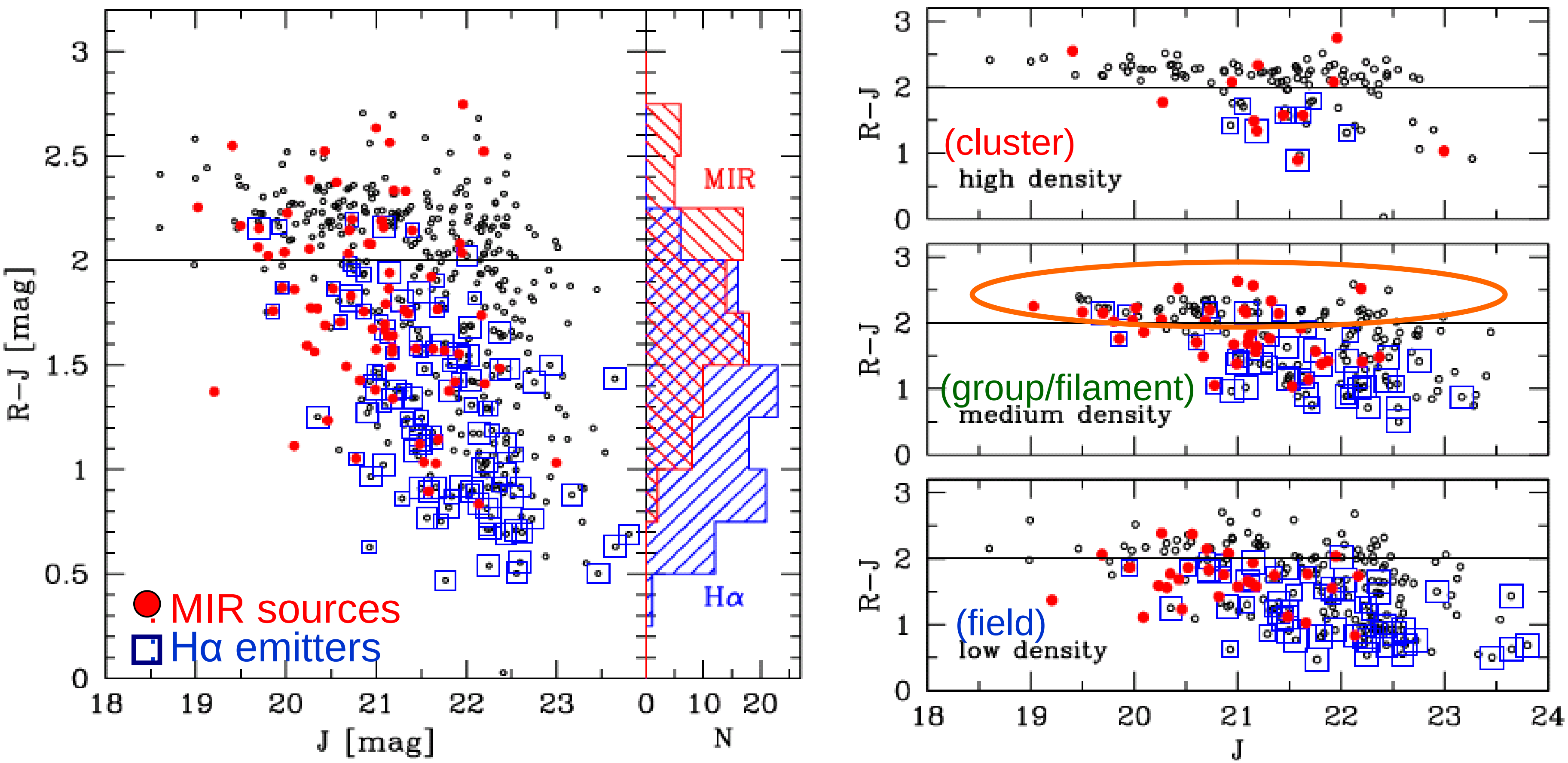
Koyama, et al. (2011)

Lx=4.4×10^{44} erg/s

Hayashi, et al. (2010)

Hidden star formation in the red sequence and in groups?

Hα emitters and AKARI 15μm sources on the red sequence!

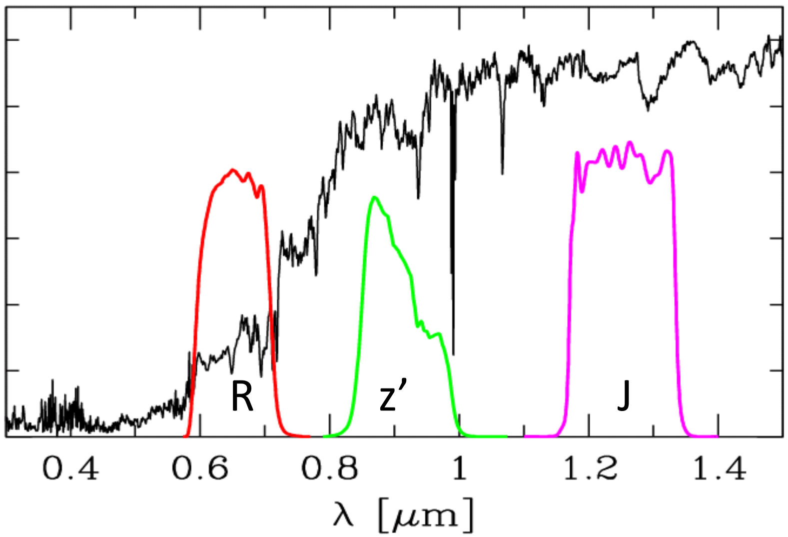


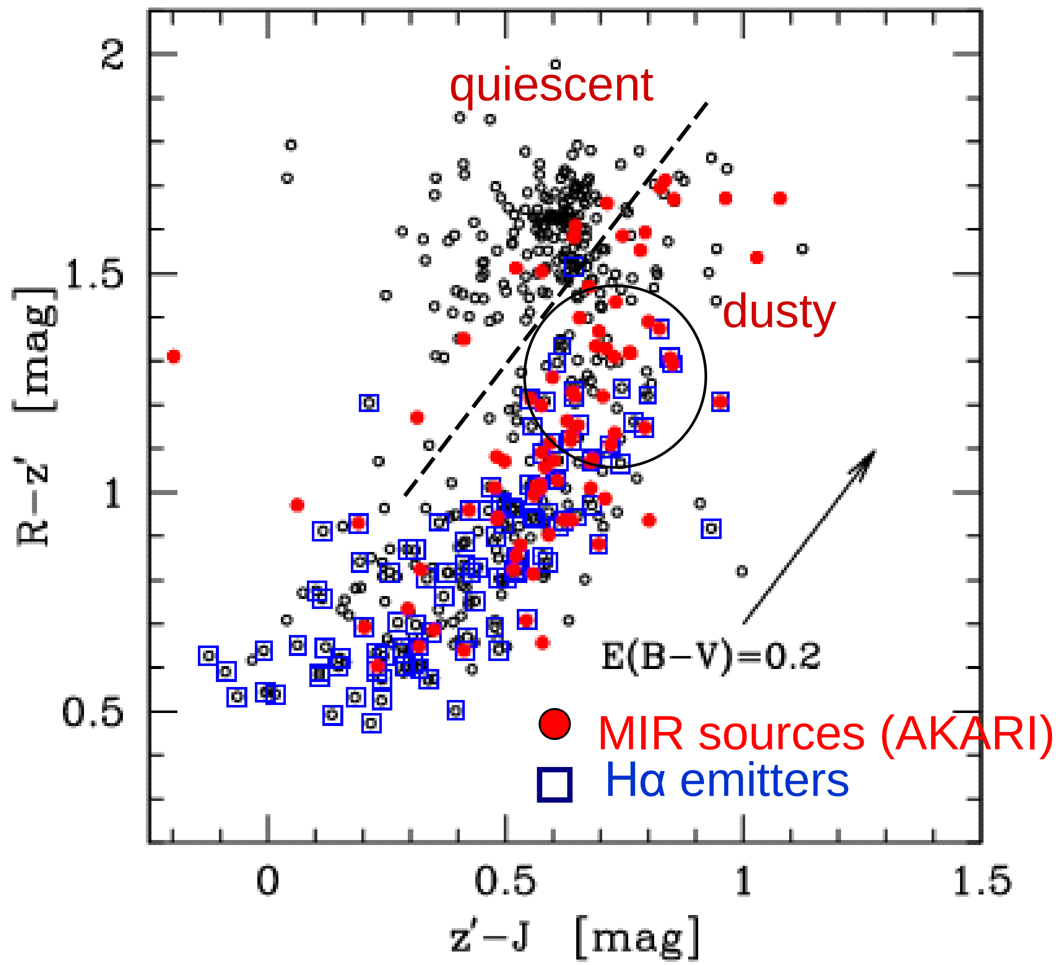
Lots of star formation is hidden in the optical (rest UV) surveys!

Koyama, TK, et al. (2010)

Dusty star forming galaxies on the red sequence

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

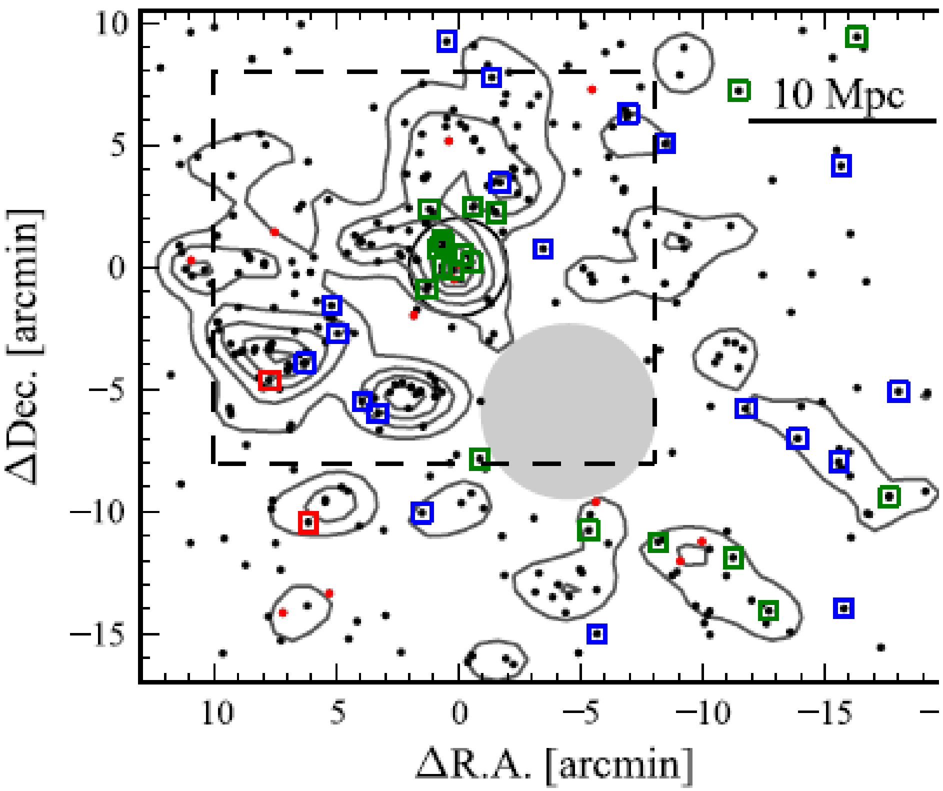


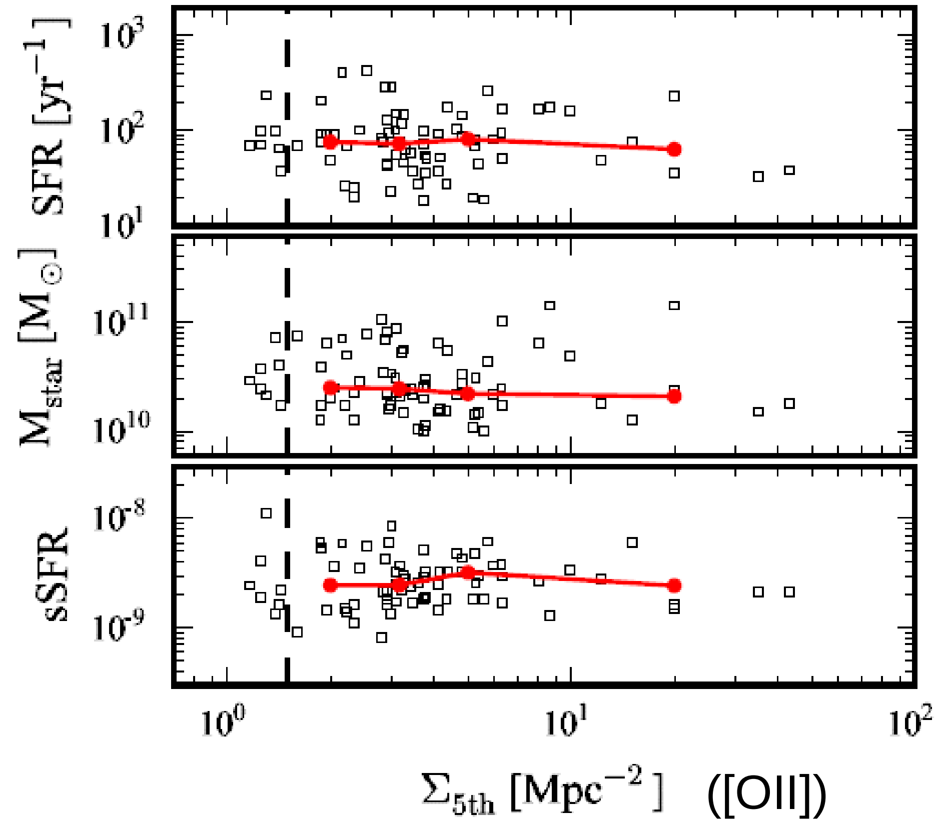


The red Ha emitters are dusty star-forming galaxies in groups, and the key populations under the influence of environmental effects.

ClG J0218.3-0510 (a x-ray cluster at z=1.62) in SXDF

[OII] emitters are traced by Suprime-Cam/NB973-filter





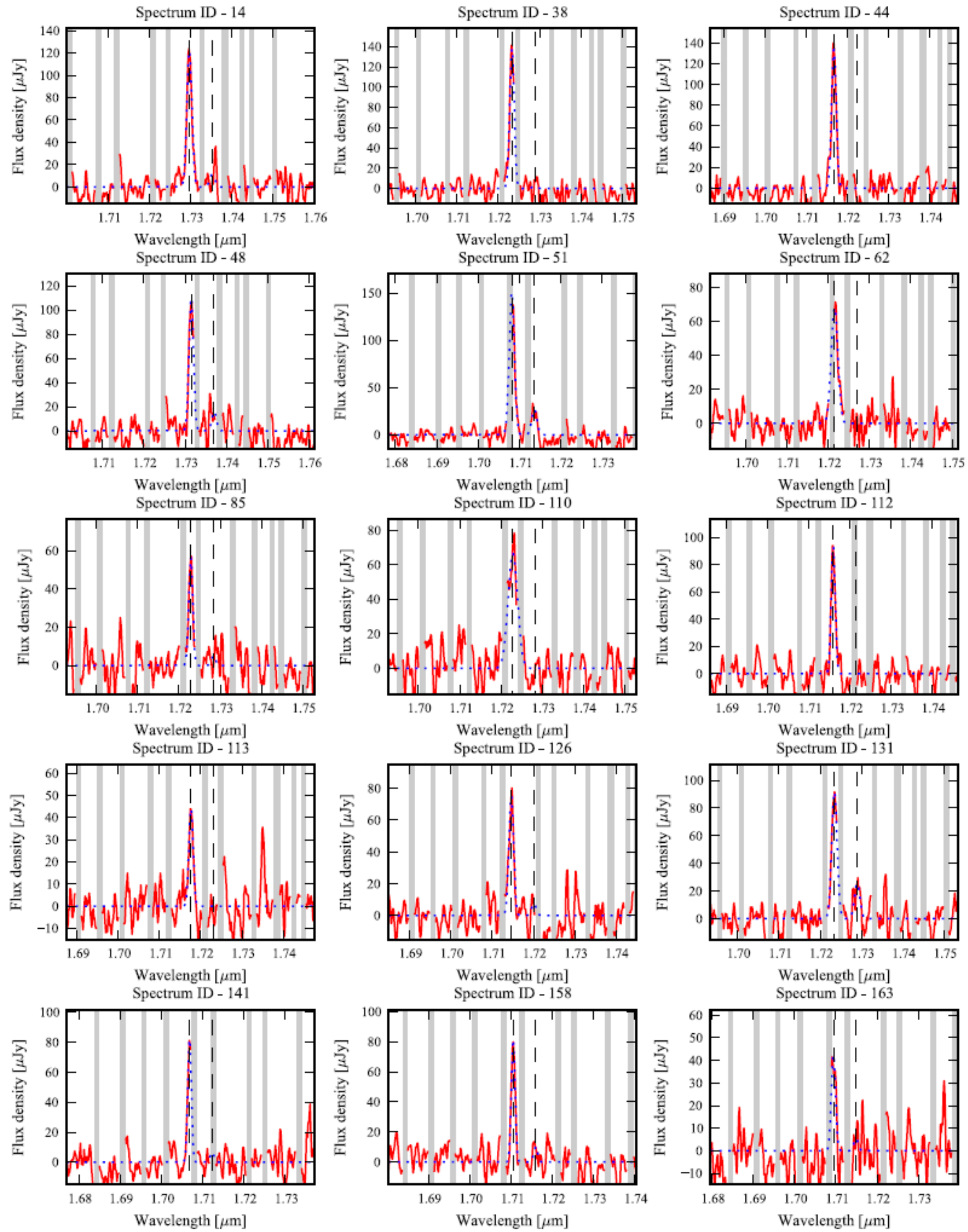
- ● [OII] emitters
- ● Red [OII] emitters
- □□□ spectroscopically confirmed members

No environmental dependence is seen at z~1.6.

The cluster is embedded in LSS of a scale of ~20Mpc.

Tadaki et al. (2011b), submitted

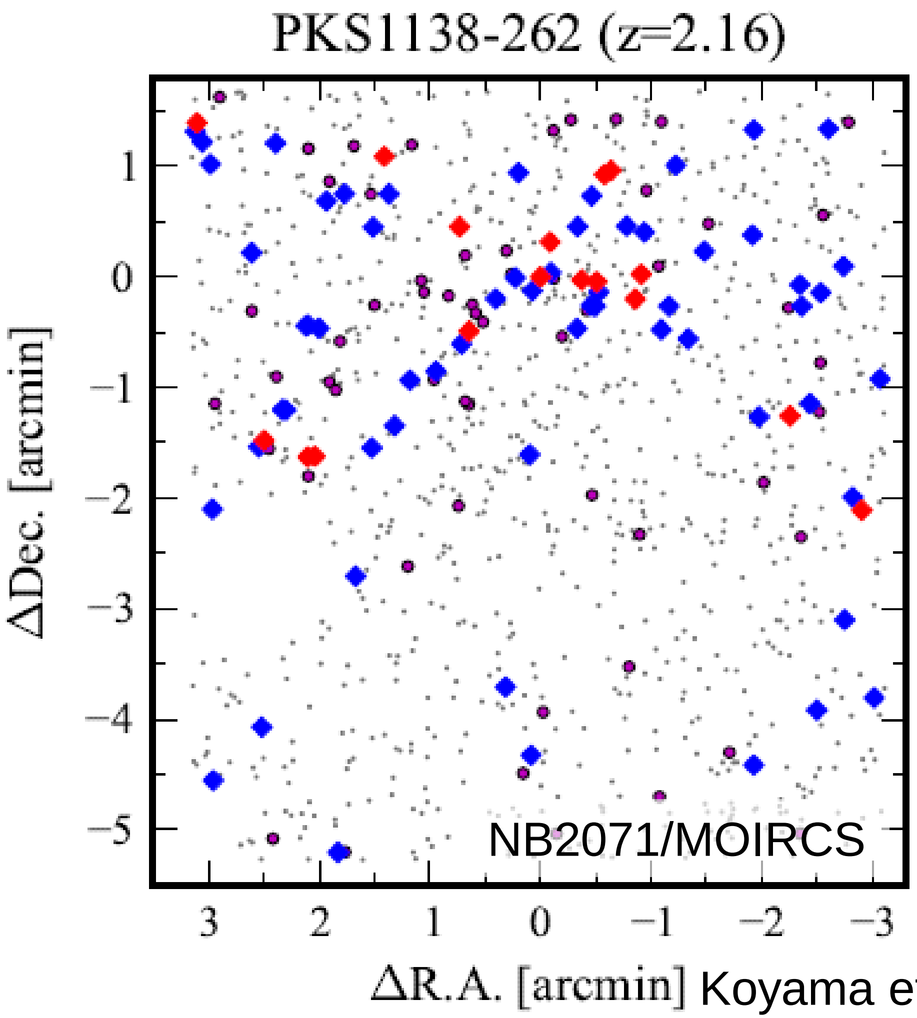
Examples of FMOS spectra of the [OII] NB emitters with the presence of Hα emission lines, which confirm their membership of the large scale structure in and around the cluster at z~1.6.



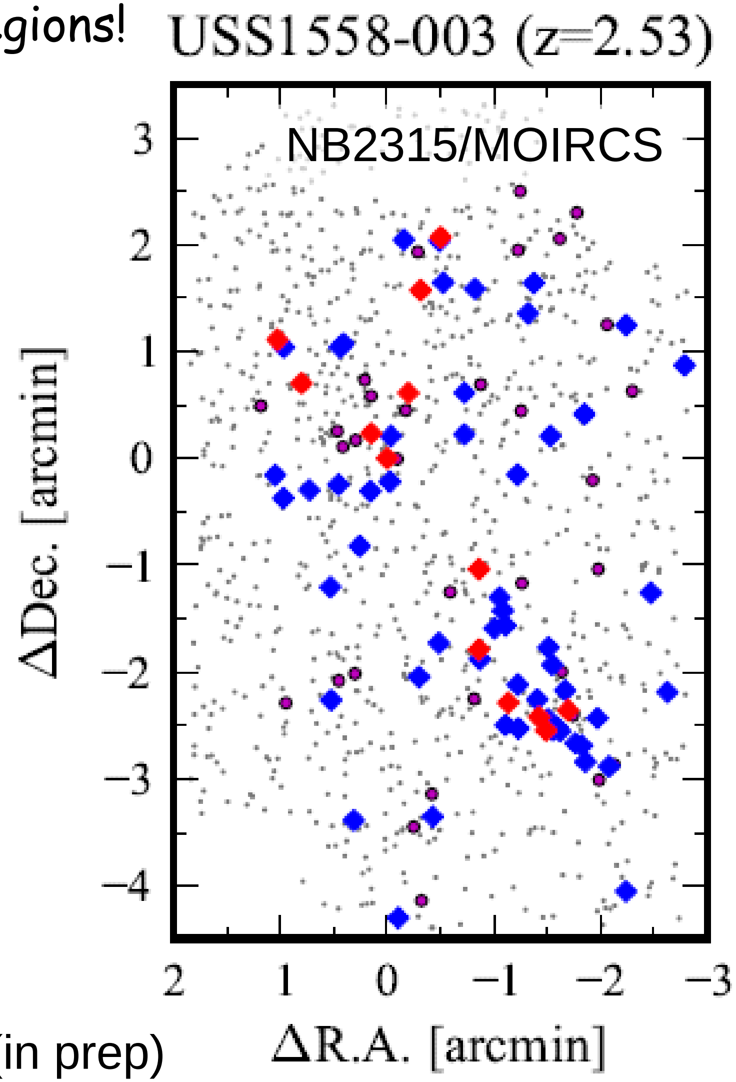
New data just taken in Jan 2012 by Hayashi, Tadaki et al.

Hα emitters in two high-z proto-clusters at z>2

"Red emitters" tend to favor high density regions!



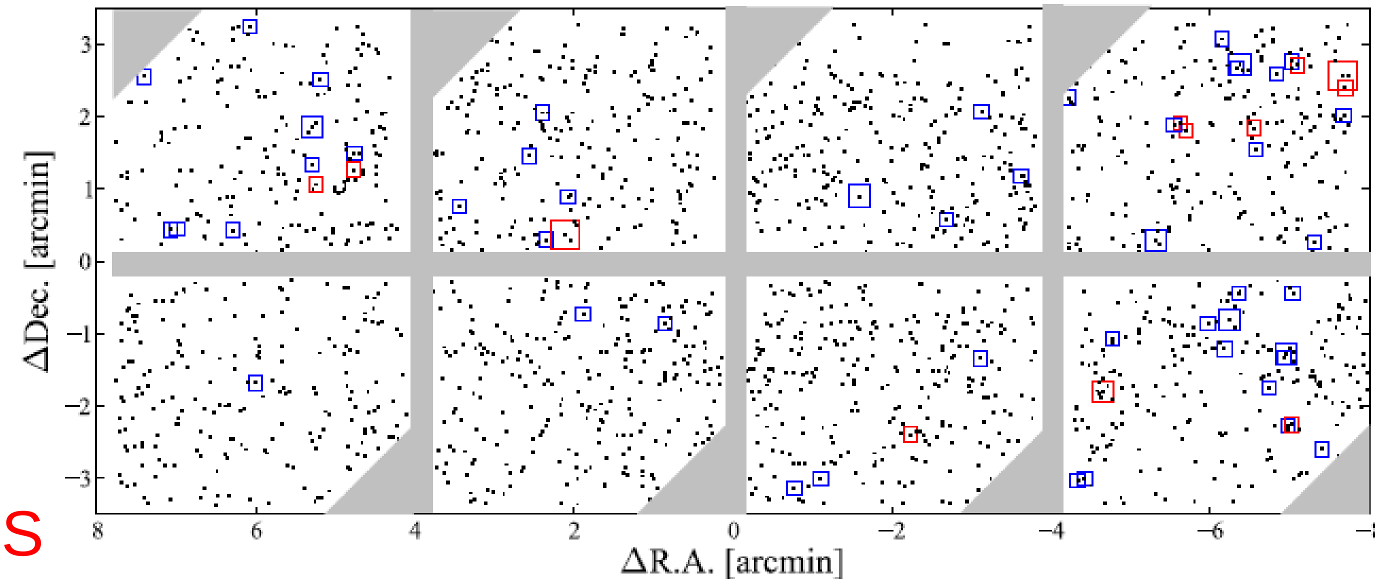
Koyama et al. (in prep)



Hayashi et al. (2012),
See Hayashi's talk

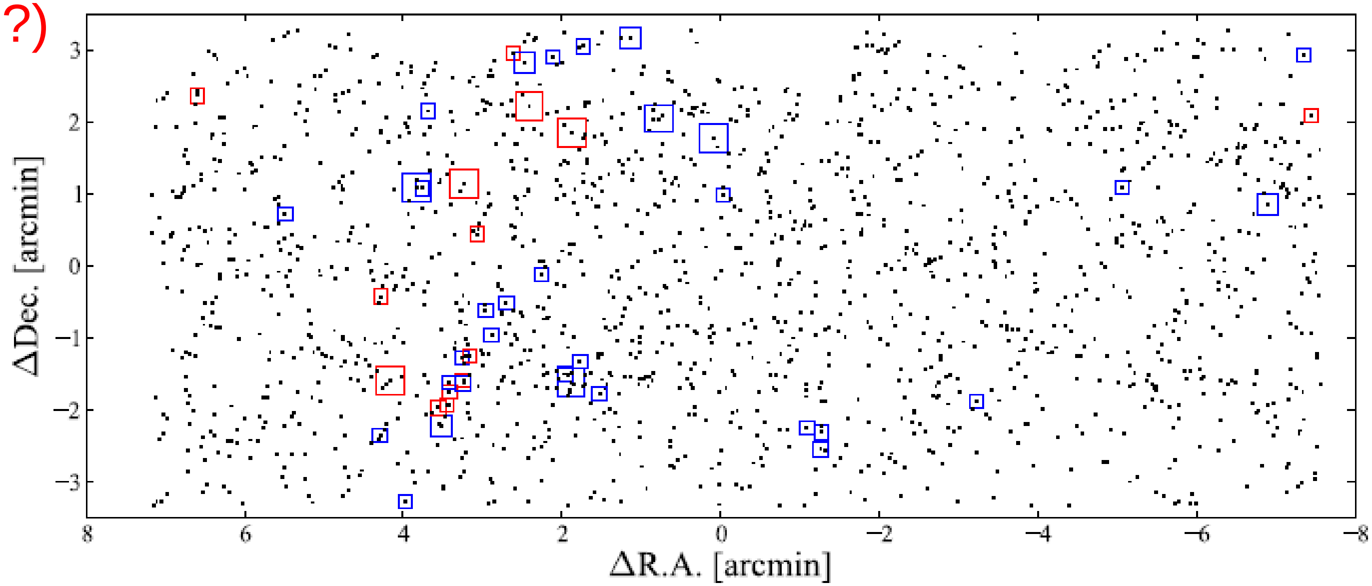
What's the nature of "red" Hα emitters?
Dusty+SF (SF mode)? or Passive+AGN (AGN activity)?

Hα emitters
at z=2.19
(NB2095)



SXDF/CANDELS
(J-ALMA Deep Field?)

Hα emitters
at z=2.53
(NB2315)

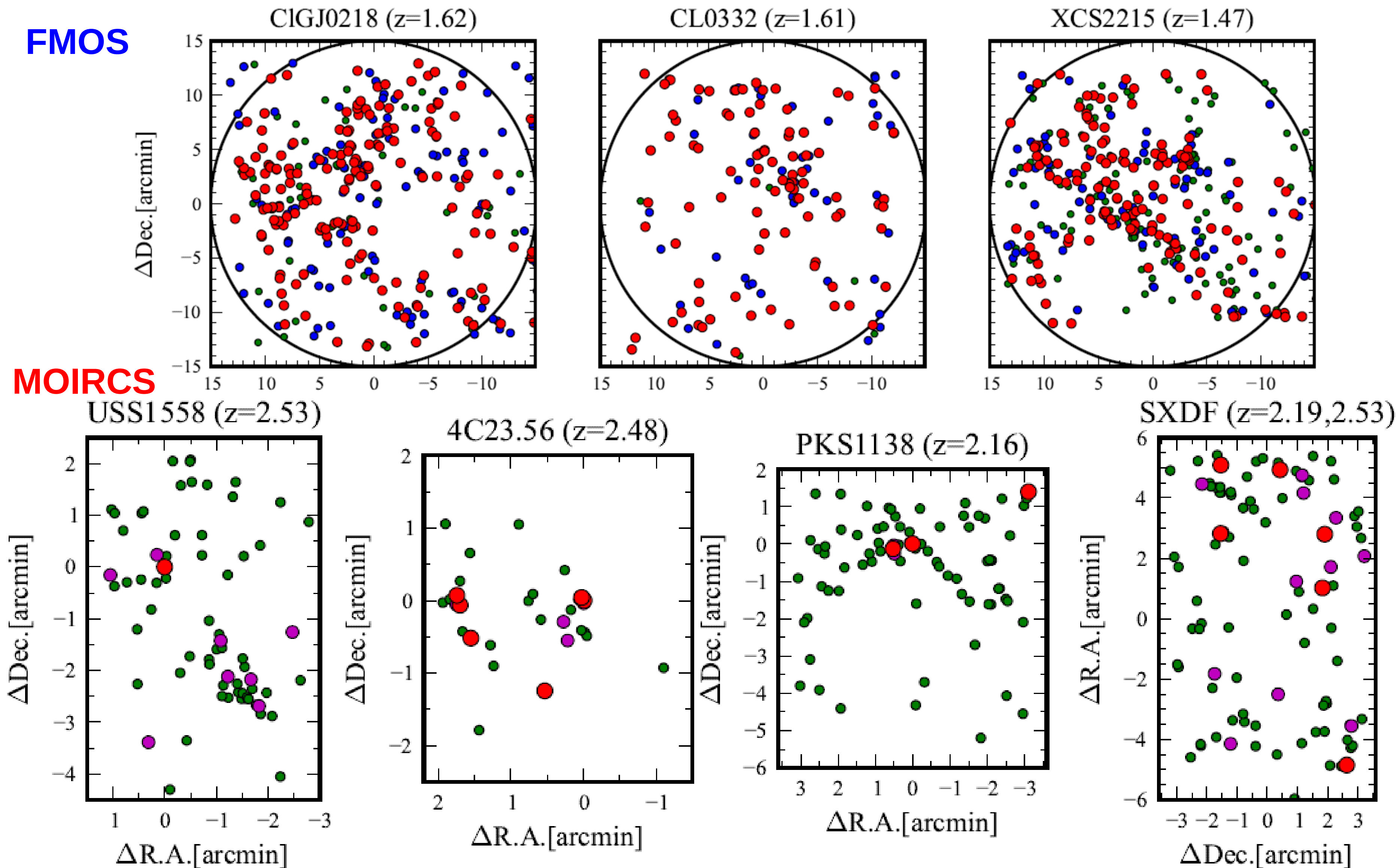


□ : Hα emitter
□ : red Hα emitter ($[J-K]_{vega}$ > 2.3)
● : Galaxy with NB2315 > 5σ

large : SFR>150
medium : 100<SFR<150
small : SFR<100

Subaru is best suited for NIR spectroscopic follow-up!

redshifts, velocity dispersion, dust extinction (Hβ/Hα), AGN contribution (BPT diagram), and gaseous metallicity (N2, O3N2).



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↓

"Gracias-ALMA"

GRAphing CO Intensity And Submm with ALMA

CO(3→2) @ z~2.5 @100GHz → M_{gas}

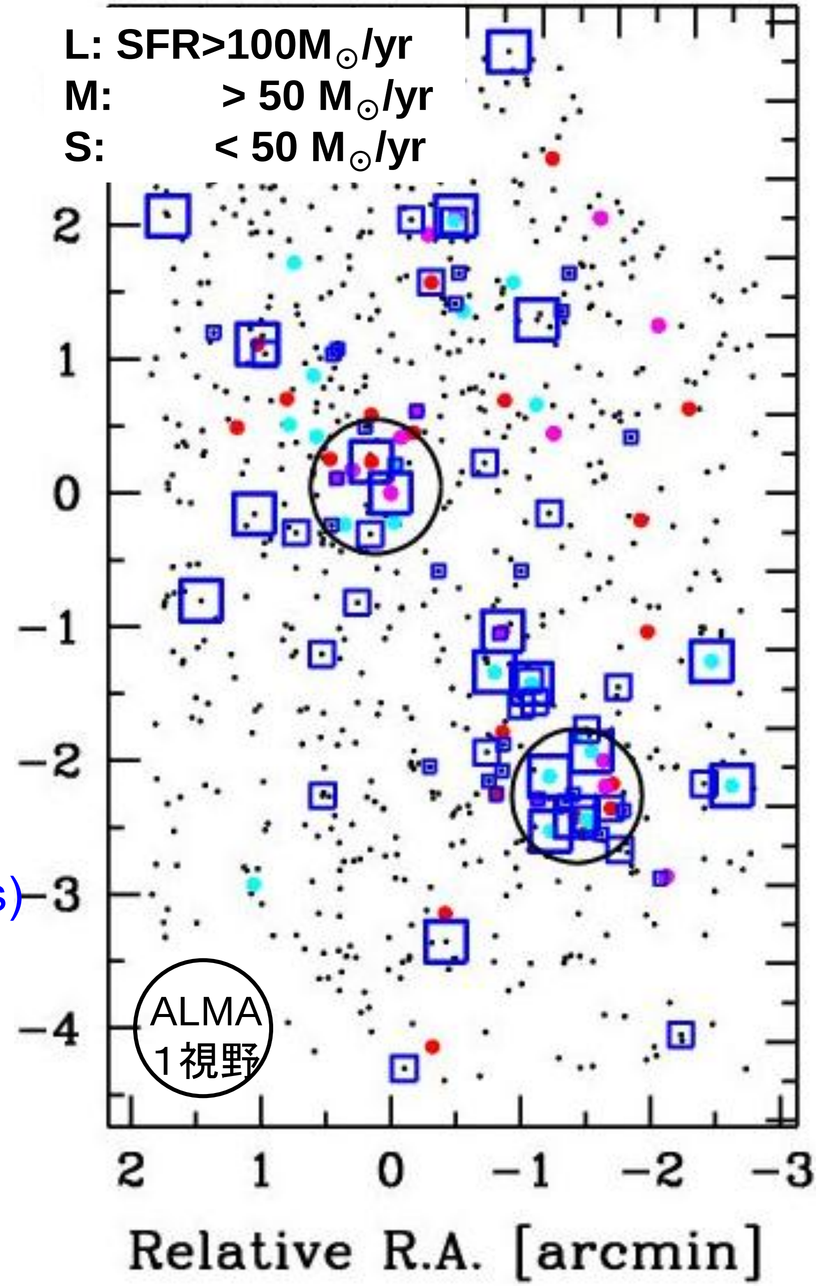
Dust conti. @450 μm–1.1 mm → Dusty SFR

resolving spatially (<0.1"), kinematically (~50km/s)

- SFE (SFR / M_{gas})
- f(gas) ($M_{gas} / M_{gas}+M_{star}$)
- Distribution and motion of gas

→ Merger induced starburst at the center?
or Extended star formation over the disk?

USS1558 proto-cluster (z=2.53)



Summary

- Mahalo-Subaru is mapping out star formation activities across time and environment at the peak epoch of galaxy formation and evolution.
- Red emitters are the key populations under the influence of environmental effects.
- Inside-out propagation of SF activities in clusters since z~2.5.
- Need NIR spectroscopy to know why.
- Gracias-ALMA will reveal the mode of SF and evolutionary states of galaxies at the peak epoch of galaxy formation.

The End