Evolving galaxies in evolving environment (2014/9/15)

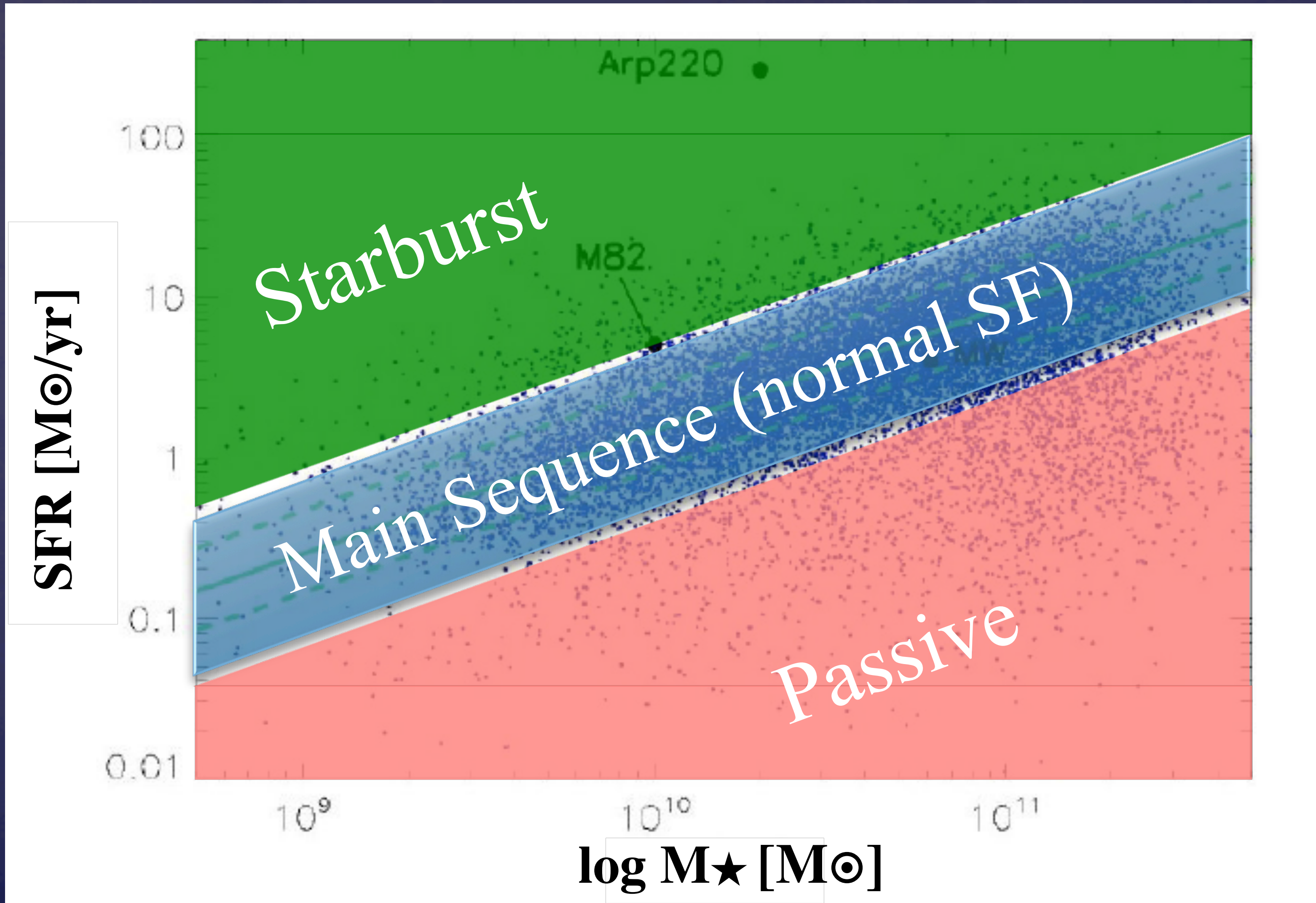
The environmental impacts on the star formation main sequence out to z~2

Yusei Koyama (ISAS/JAXA)

MAHALO-Subaru collaboration

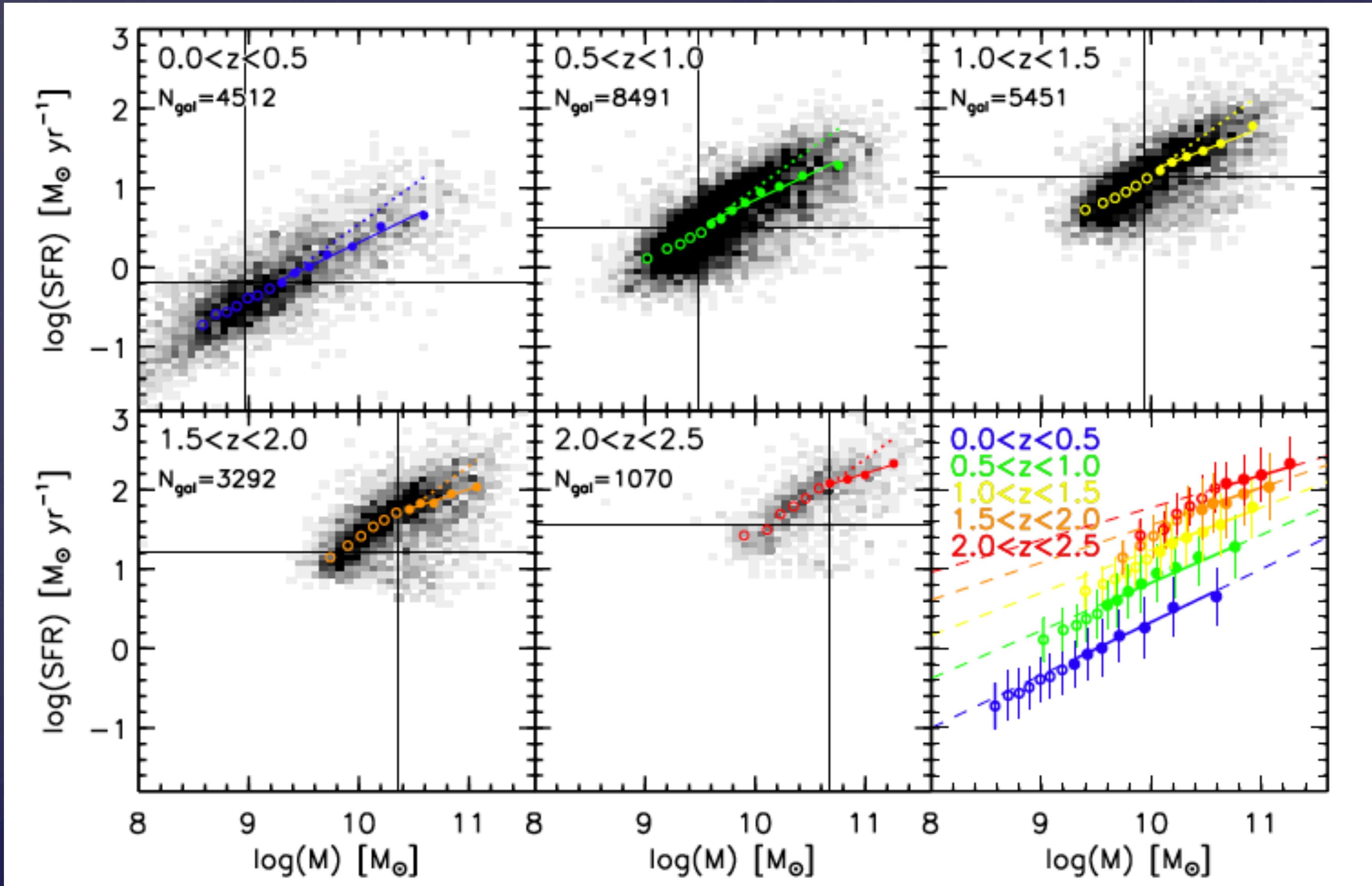
Star Formation "Main Sequence"

= SFR-M⋆ relation for star-forming galaxies



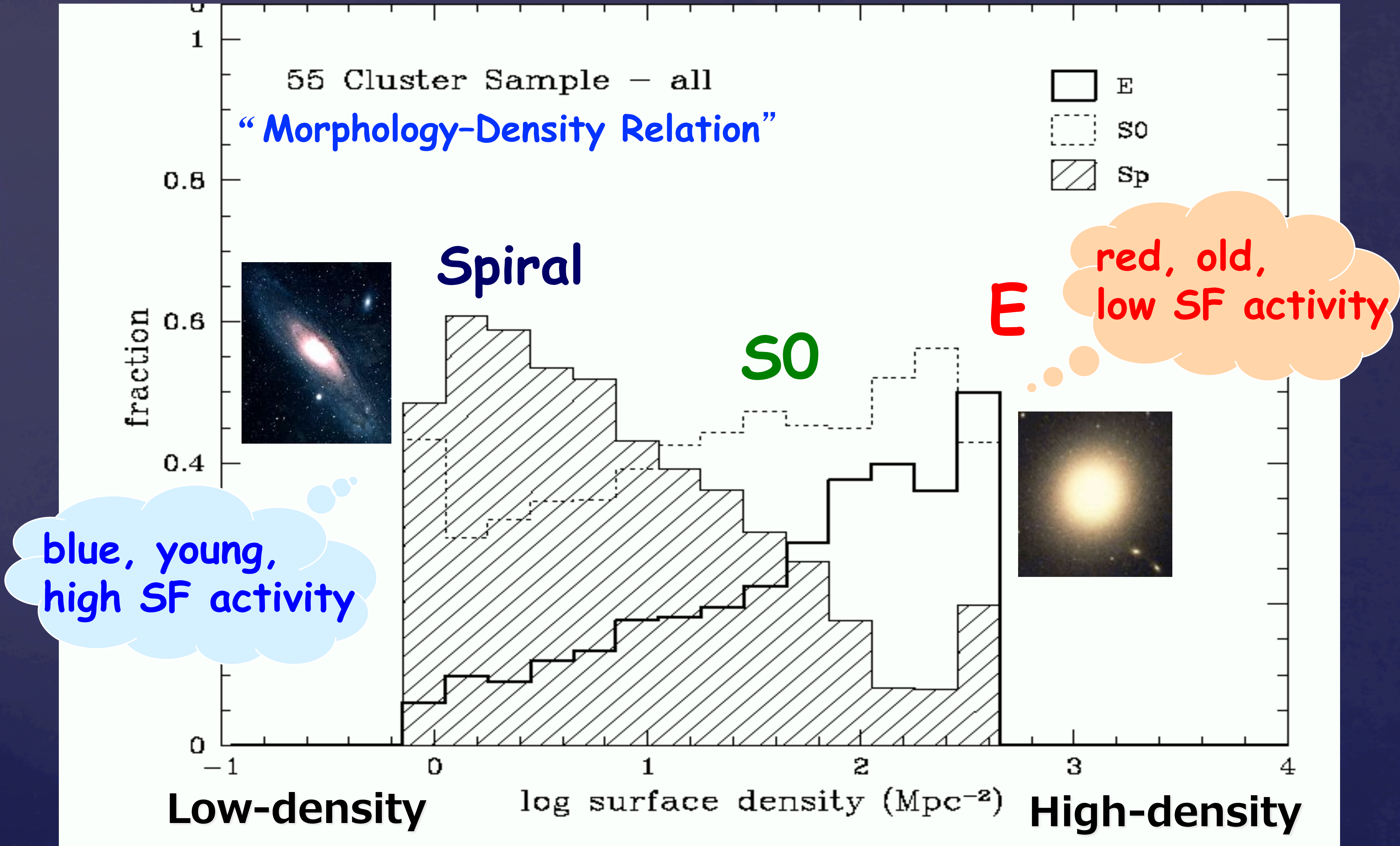
Elbaz et al. (2007)

SF main sequence out to z>2



From NEWFIRM medium-band survey (Whitaker et al. 2012)

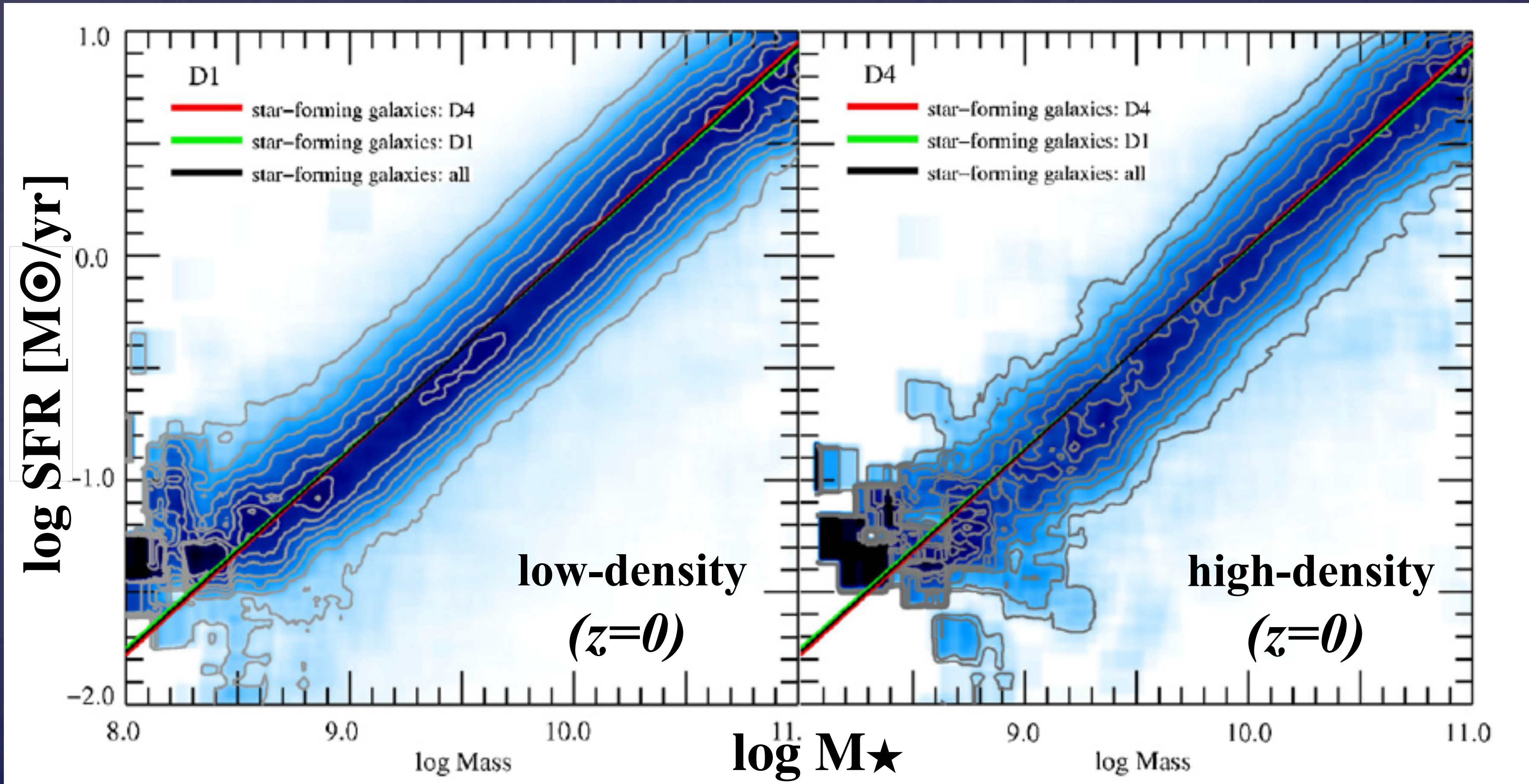
Galaxy evolution & environment



(Dressler 1980)

Main sequence vs. environment (*z=0*)

SF main sequence is "independent" of environment at z=0



Local star-forming galaxies from SDSS (Peng et al. 2010)

Q: How about in distant universe?

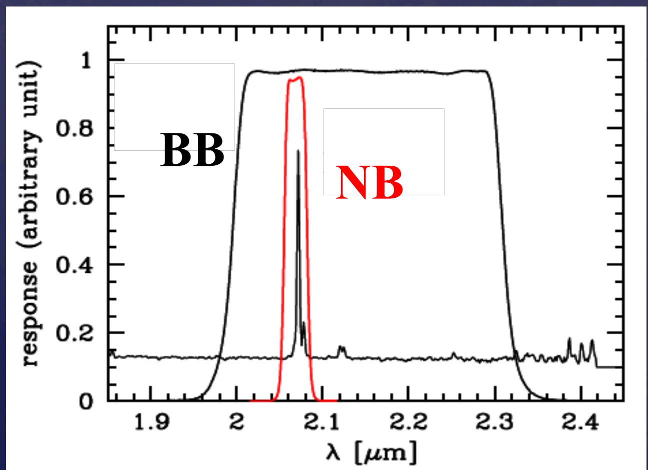
Two big challenges

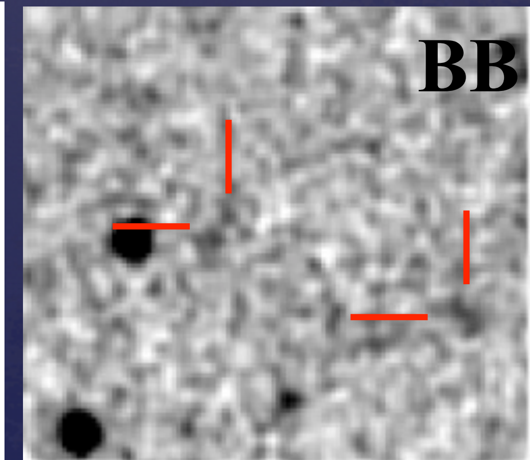
(1) Distant clusters (z>>1) are very rare.

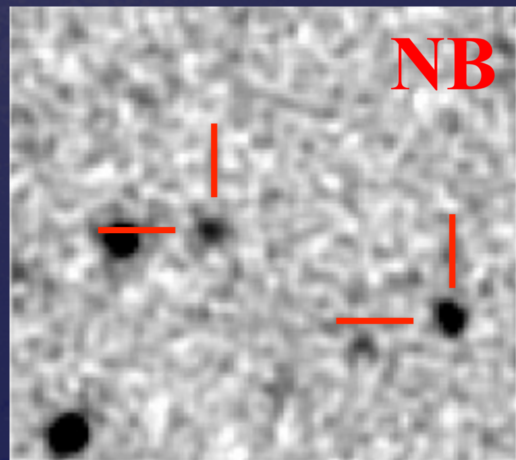
→ Known (proto-)clusters are now increasing.

(2) Large uniform sample of SF galaxies is required.

→ NB emission-line survey is an ideal solution.







MAHALO-Subaru project

Collaborator: T. Kodama (PI), M. Hayashi, K. Tadaki, I. Tanaka, R. Shimakawa, T. Suzuki, M. Yamamoto

MApping H-Alpha and Lines of Oxygen with Subaru

Narrow-band Hα(λ=6563A)/[OII](λ=3727A) survey for 0.4<z<2.6

environment	target	z	line	λ (μm)	camera	NB-filter	continuum	status (as of Jul. 2014)
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+'10,11,14
	4C65.22	1.516	Hα	1.651	MOIRCS	NB1657	H	Koyama+ '14
	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+'12
Proto-cluster	PKS1138–262	2.156	Hα	2.071	MOIRCS	NB2071	K_s	Koyama+'13a
	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	2.19	Hα	2.094	MOIRCS	NB2095	K_s	Tadaki+'11a
	(62 arcmin^2)		[O II]	1.189	MOIRCS	NB1190	J	observed
	SXDF	2.19	Hα	2.094	MOIRCS	NB2095	K	Tadaki+'13,14
	(110 arcmin^2)		Hβ	1.551	MOIRCS	NB1550	H	not yet
			[O II]	1.189	MOIRCS	NB1190	J	not yet

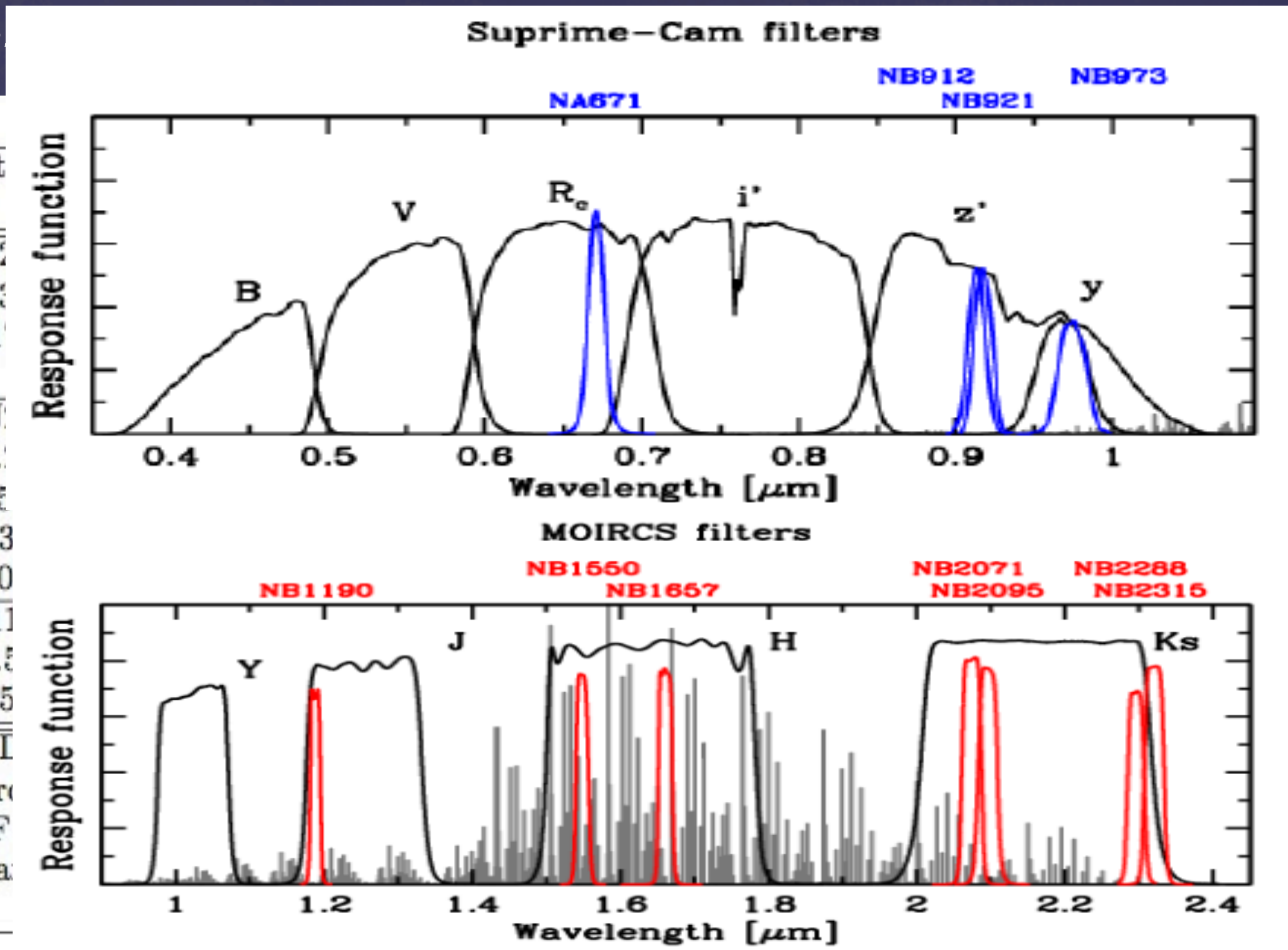
MAHALO-Subaru project

Collaborator: T. Kodama (PI), M. Hayashi, K. Tadaki, I. Tanaka, R. Shimakawa, T. Suzuki, M. Yamamoto

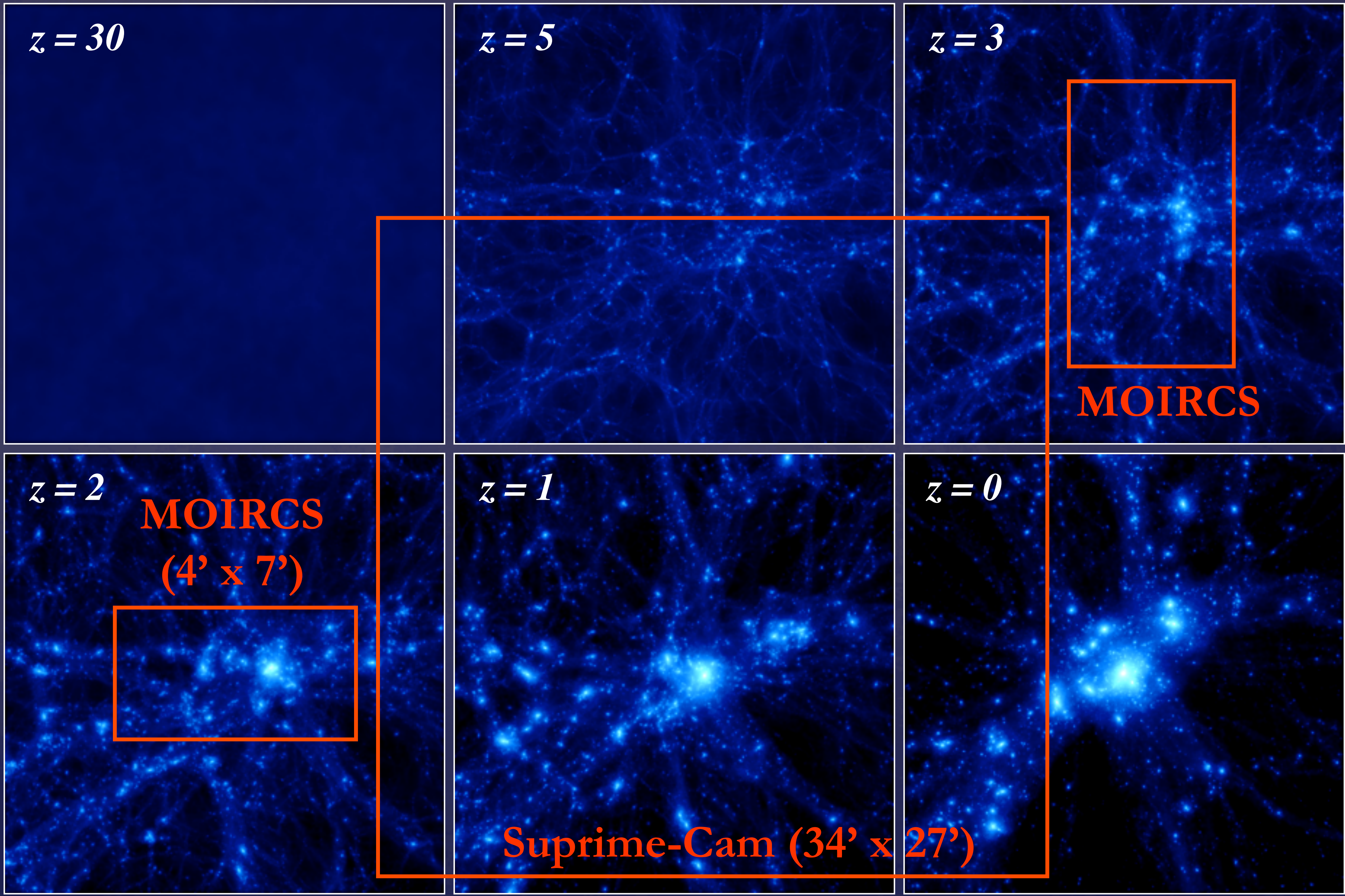
MApping H-Alpha and Lines of Oxygen with Subaru

Narrow ... 4<z<2.6

environ-ment	target	status (as of Jul. 2014)
Low-z cluster	CL00	dama+'04
	CL09	yama+'11
	RXJ1	yama+'10
		erved
High-z cluster	XCSJ	yashi+'10,11,14
	4C65.	yama+ '14
	Q0835	erved
	CL033	erved
	ClGJ0	aki+'12
Proto-cluster	PKS11	ama+'13a
	4C23.5	aka+'11
	USS15	ashi+'12
General field	GOOD	aki+'11a
	(62 ar	erved
	SXDF	aki+'13,14
	(110 a	yet
		yet



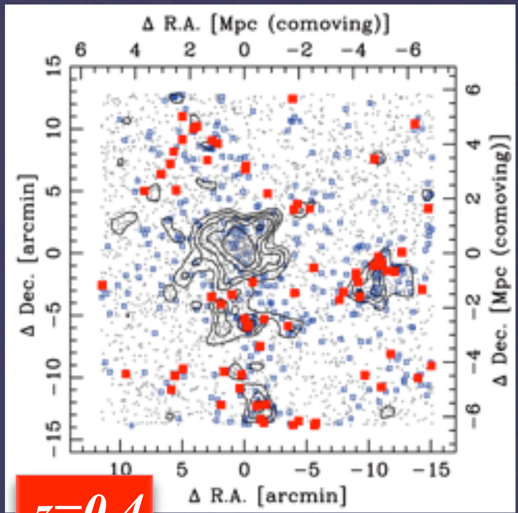
Big advantage of Subaru



M=6×10^14 Msun, 20Mpc×20Mpc (co-moving)

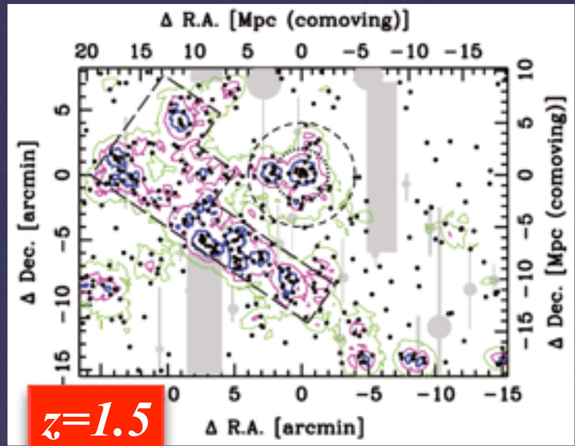
Yahagi et al. (2005)

High-z structures revealed by *MAHALO*



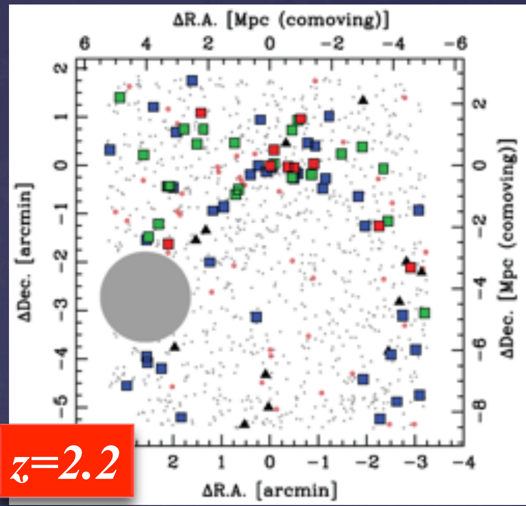
z=0.4

(Koyama+11)



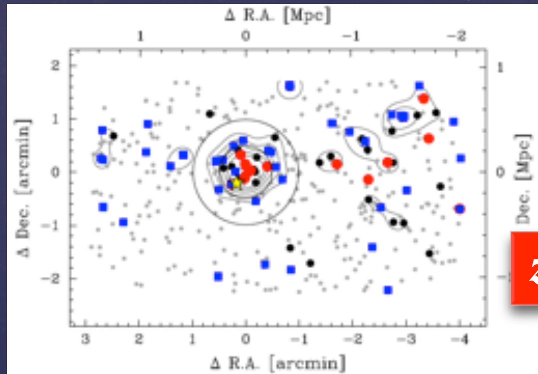
z=1.5

(Hayashi+10, 11)



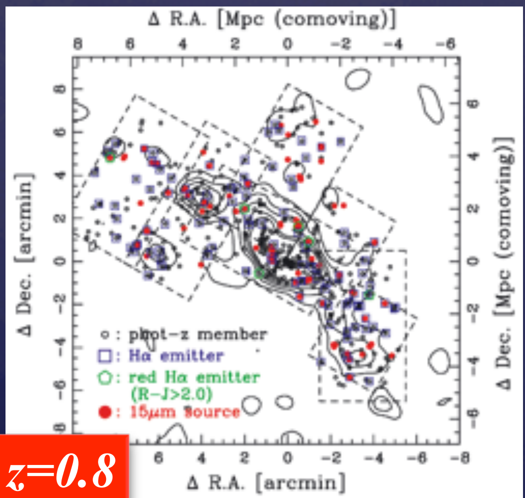
z=2.2

(Koyama+13)



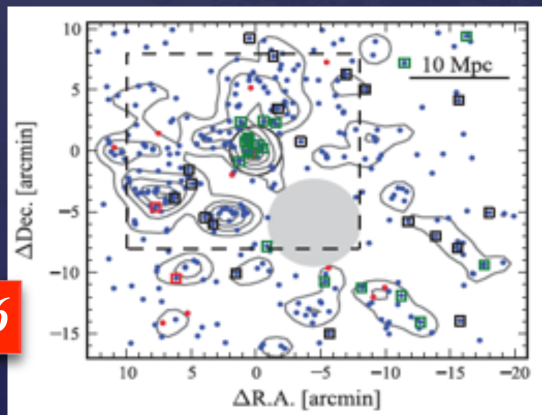
z=1.5

(Koyama+14)



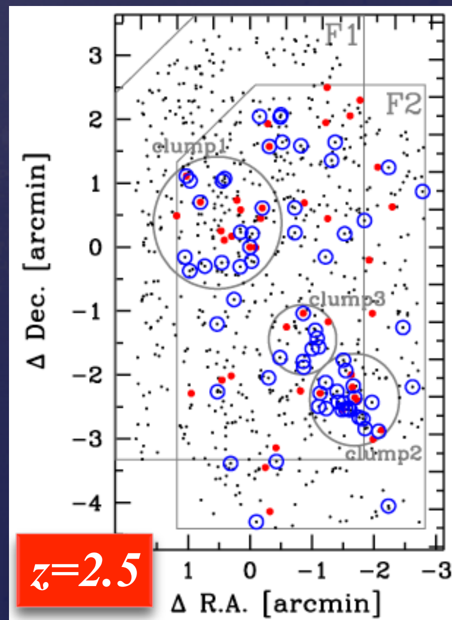
z=0.8

(Koyama+10)



z=1.6

(Tadaki+12)

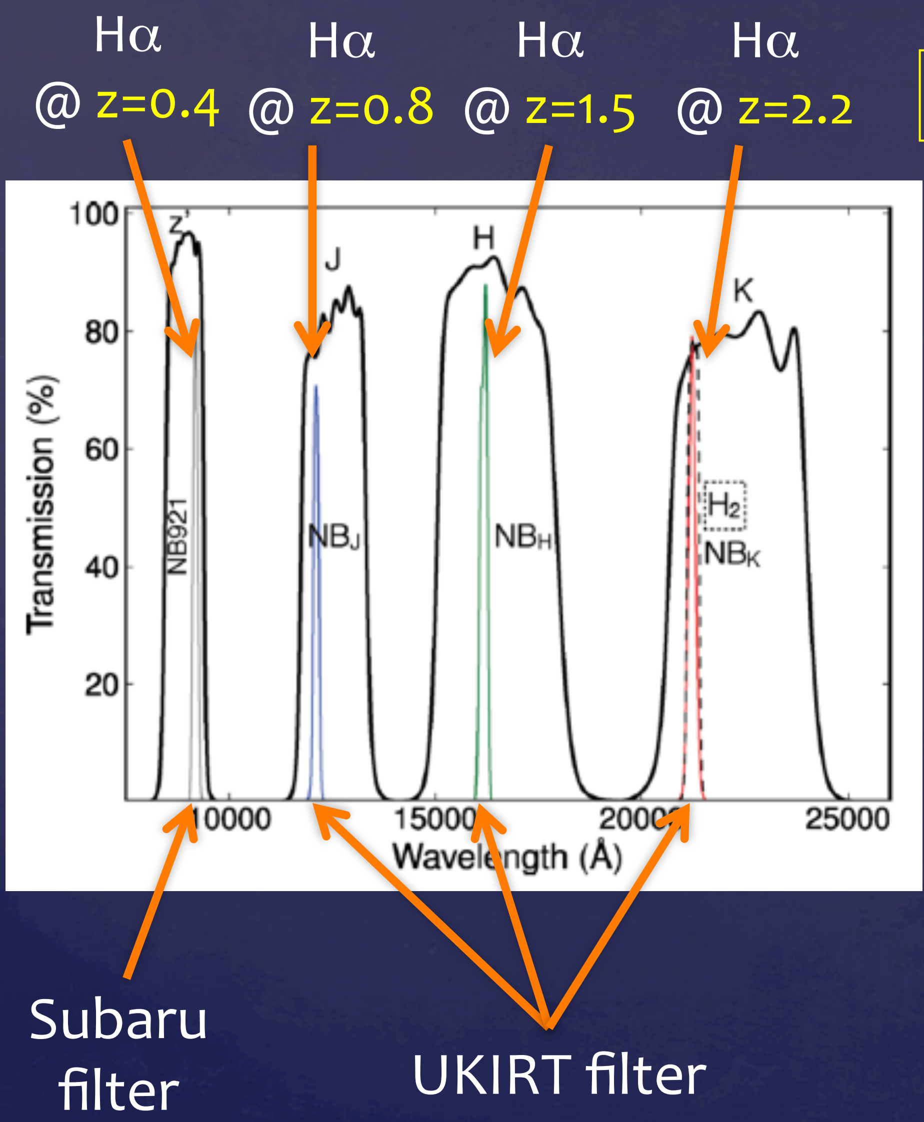


z=2.5

(Hayashi+12)

HiZELS: *High-Z Emission-Line Survey*

Collaborator: I. Smail (Durham), D. Sobral (Lisbon), J. Geach (Herts), M. Swinbank (Durham), P. Best (Edinburgh)



Total ~2 deg² survey in COSMOS & UDS

 # now further extending the survey area.

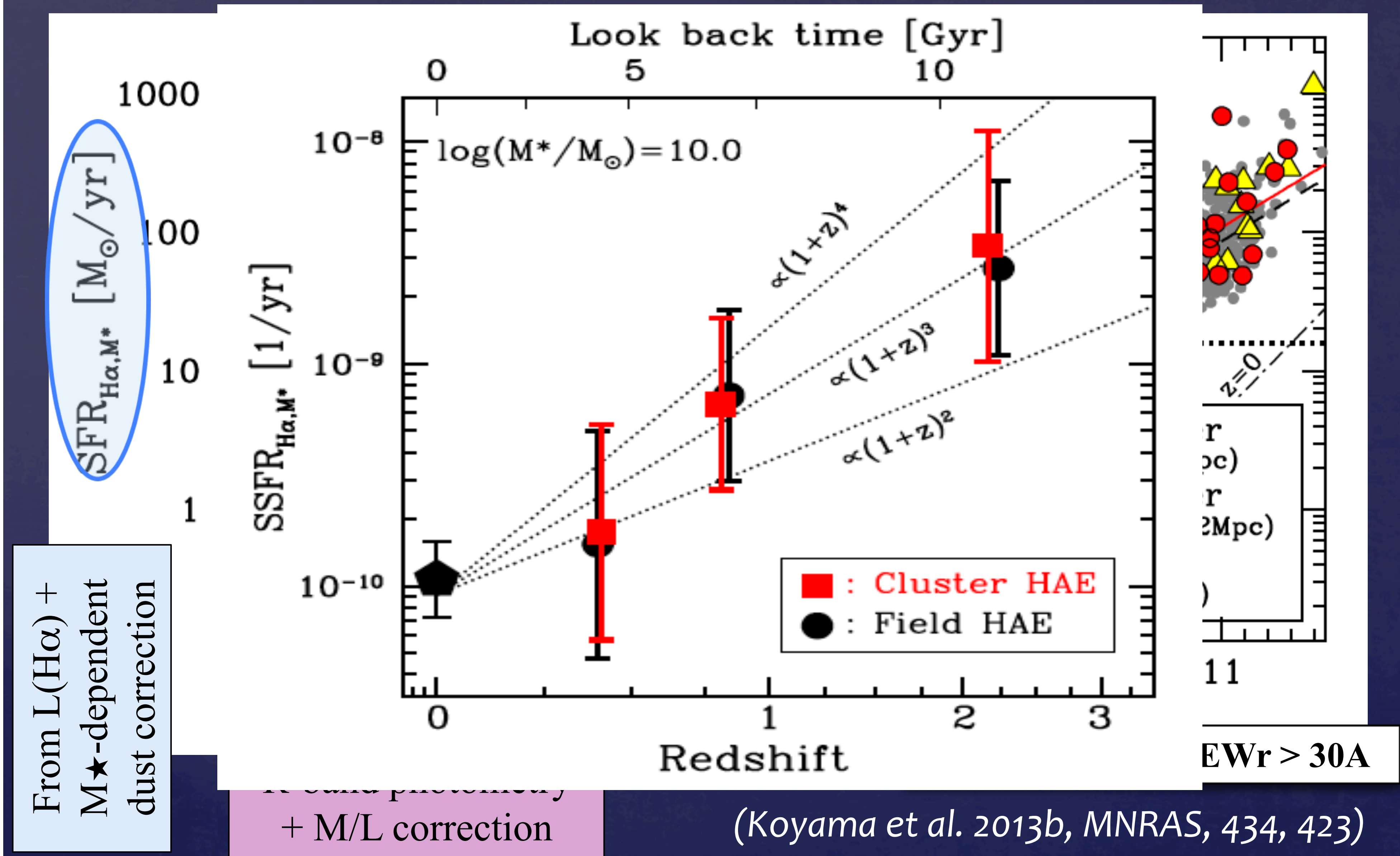
Filter NB	Field C/U	Detect (3σ)	W/colours #	Emitters (3Σ)	Stars #	Artefacts #	Hα #
NB921	C	155 542	148 702	2819	247	–	521
NB921	U	236 718	198 256	6957	775	–	1221
NB_J	C	32 345	31 661	700	40	46	425
NB_J	U	21 233	19 916	551	49	30	212
NB_H	C	65 912	64 453	723	60	63	327
NB_H	U	26 084	23 503	418	23	5	188
NB_K	C	99 395	98 085	1359	78	56	588
NB_K	U	28 276	26 062	399	28	10	184
H_2	C	1054	940	52	3	2	31
H_2	U	1193	1059	33	7	1	14

~500-2000 Ha emitters at each redshift, providing excellent comparison sample for our MAHALO cluster samples.

Sobral et al. (2013)

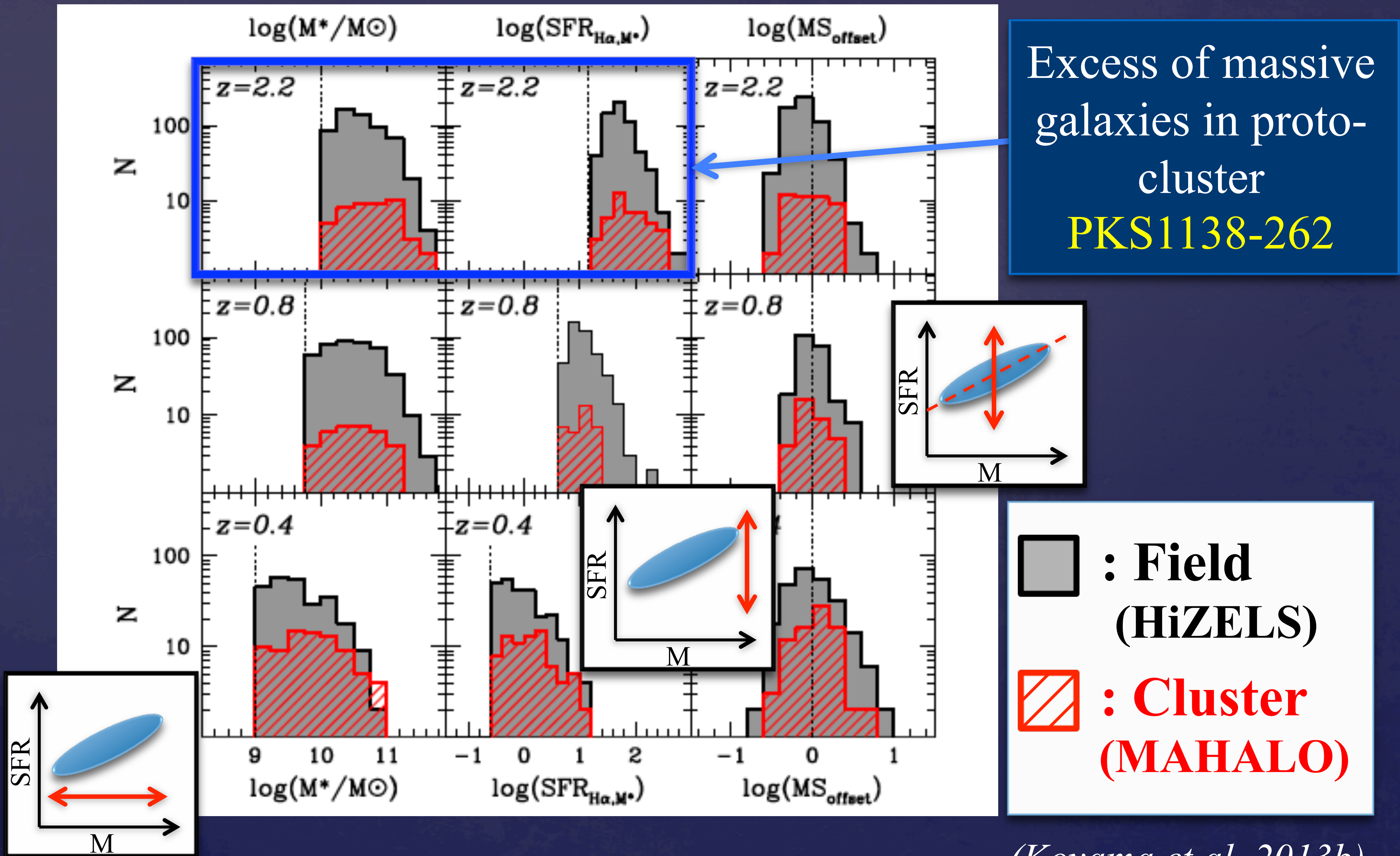
Cluster vs. Field comparison out to z~2

The MS location is always independent of environment since z~2 !



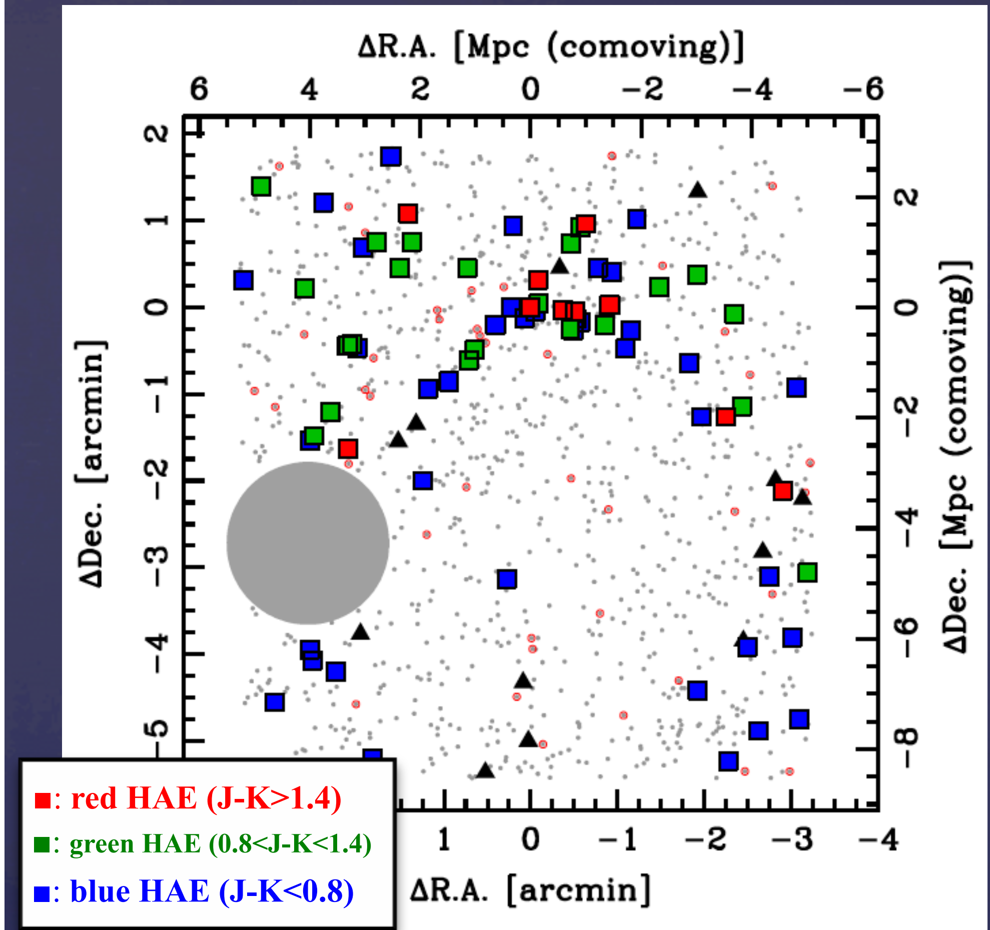
(*Koyama et al. 2013b, MNRAS, 434, 423*)

M★, SFR, ΔMS distribution

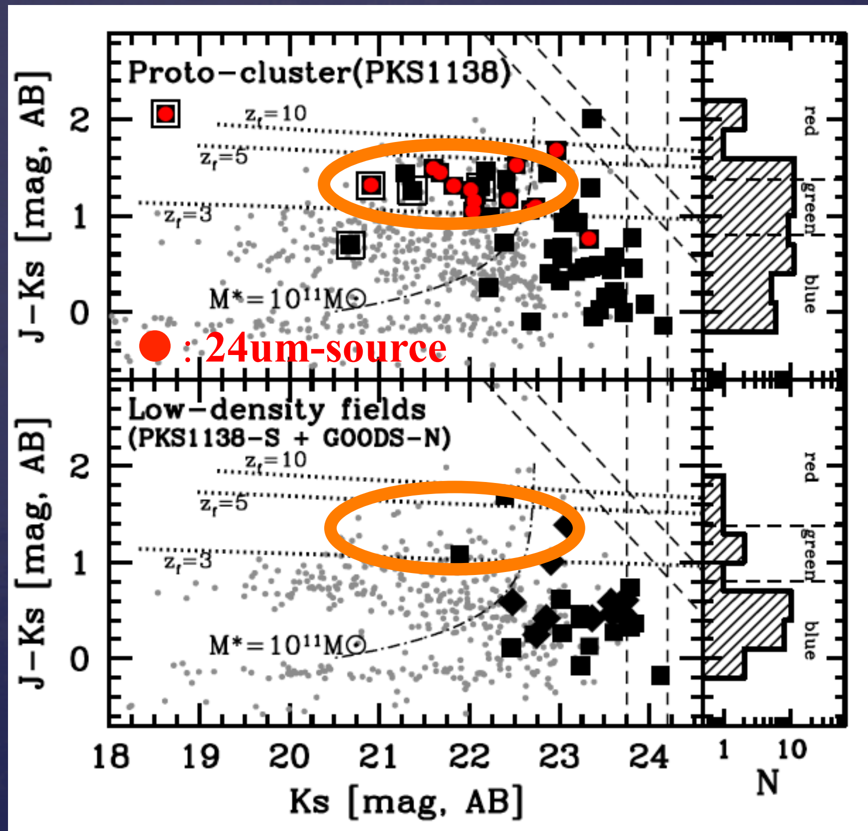


(Koyama et al. 2013b)

Massive SF galaxies in z>2 proto-cluster



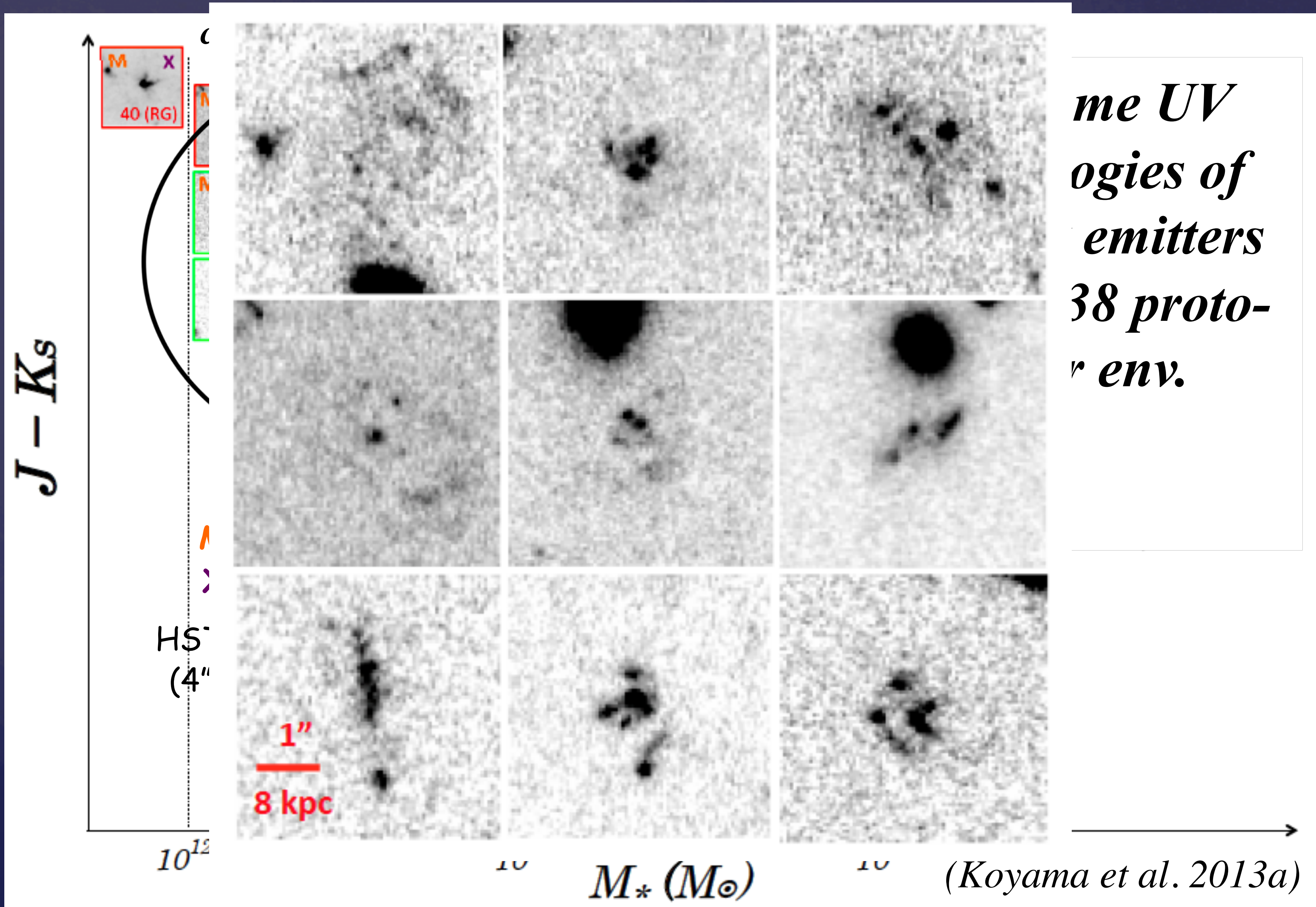
Our MOIRCS+NB(Hα) survey revealed red Hα emitters dominate the core of z=2.16 proto-cluster (PKS1138-262).



Red emitters are massive (M★ >10^{11}M⊙), and clearly dominate dense environment at z~2.

(Koyama et al. 2013a)

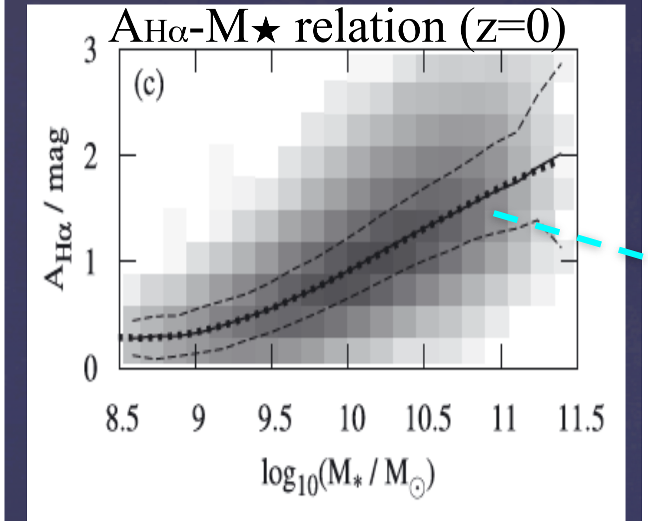
Clumpy galaxies in z>2 proto-clusters



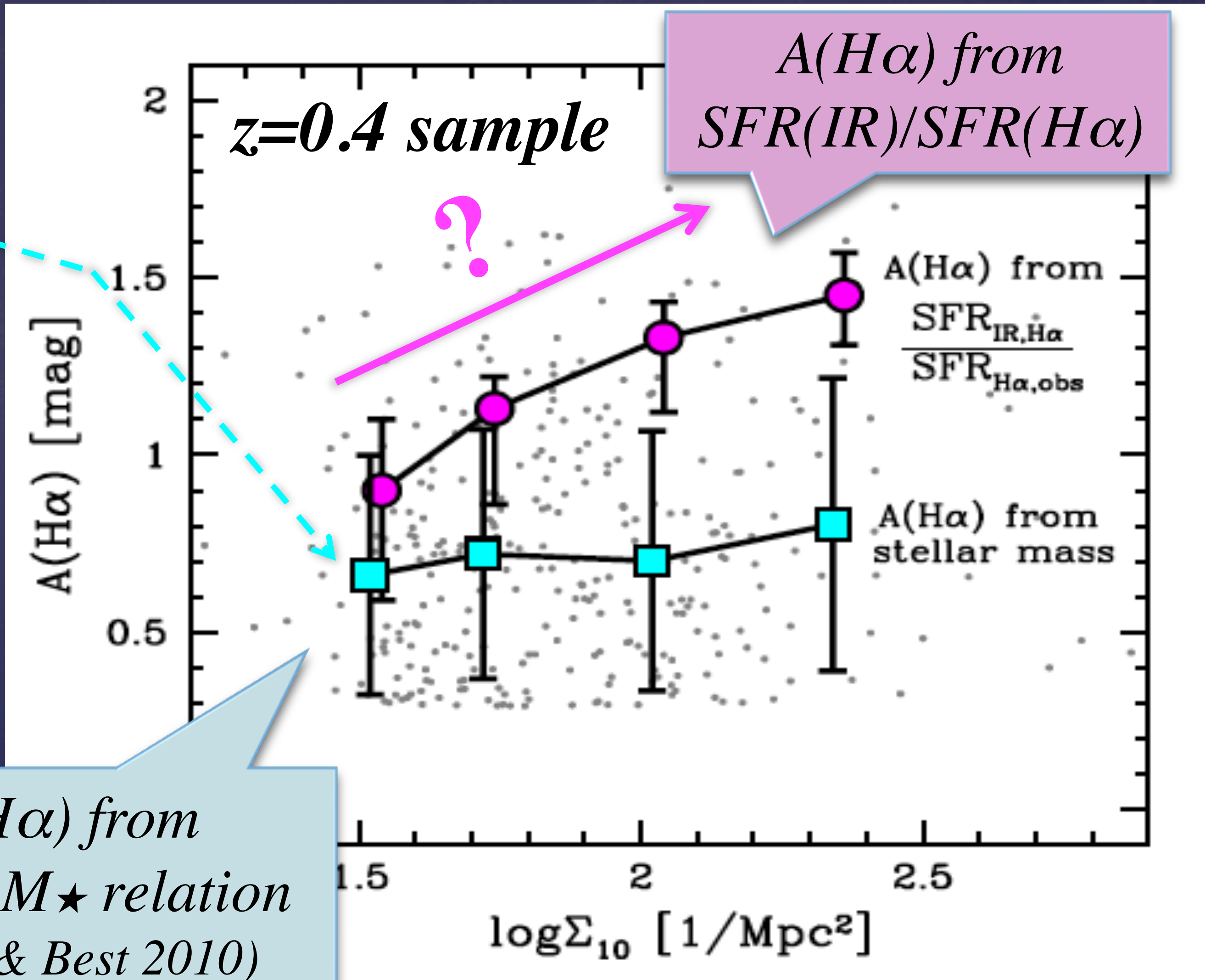
(Koyama et al. 2013a)

Dust extinction vs. environment (*z=0.4*)

Higher dust extinction (different SF mode?) in high-density env.



(Garn & Best 2010)



(Koyama et al. 2013b)

Conclusions

(1) With MAHALO+HiZELS collaboration, we find that SF main sequence is independent of environment at any time in the history of universe since z~2, suggesting rapid SF quenching.

→ Cluster vs. field difference is always small (~0.1-0.2 dex level)

(2) SF galaxies in z=2.2 proto-cluster environments tend to be more massive (and showing redder J-K colours) than the field counterparts at the same redshift.

→ M★ distribution "along" the MS does depend on environment.

(3) SF galaxies "surviving" in high-density environments tend to be more highly obscured by dust, suggesting a different mode of SF activity in clusters/groups.

→ Environment may affect dust properties (SF geometry or mode).