FMOS Science Workshop (Oxford, 22-23/06/2009)

Star Formation History in Biased Regions at $0.4<z<3$

“to extend the parameter space to higher density environment which would be missed by non-biased (blank-field) surveys!”

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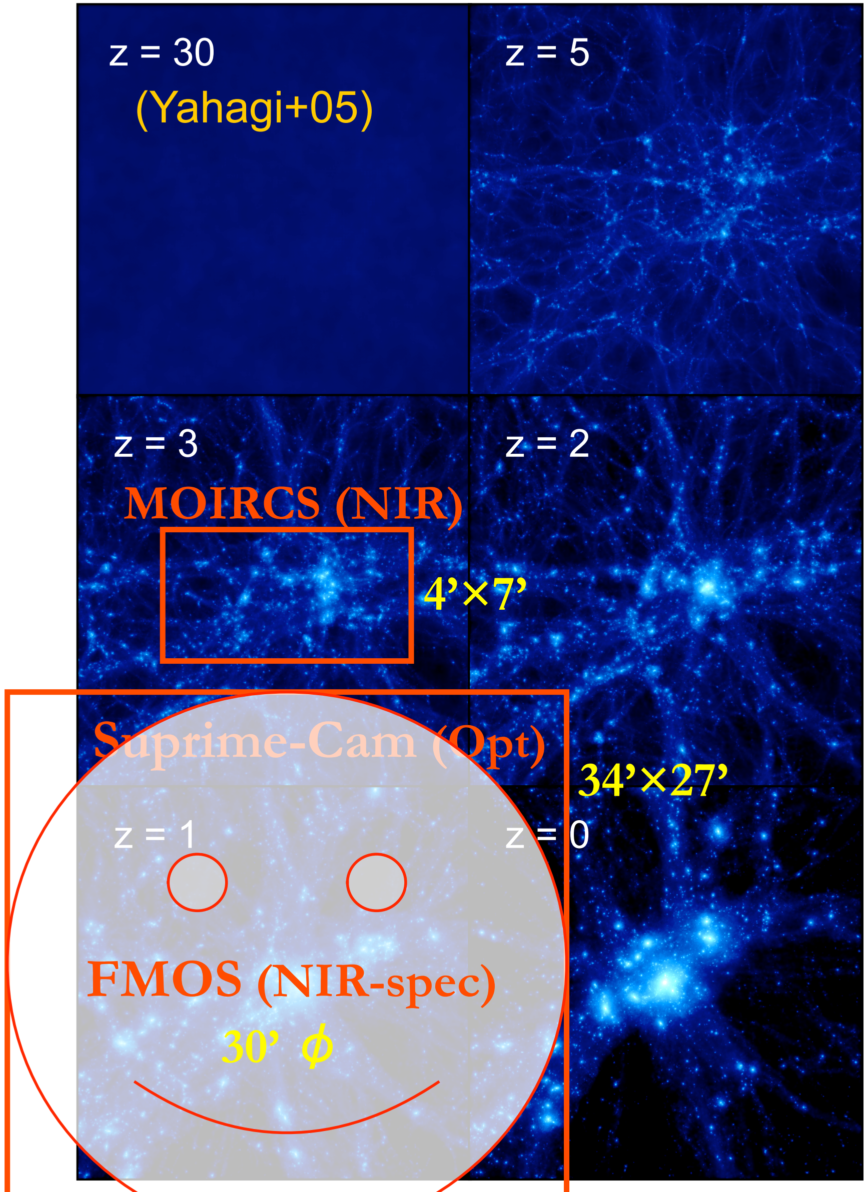
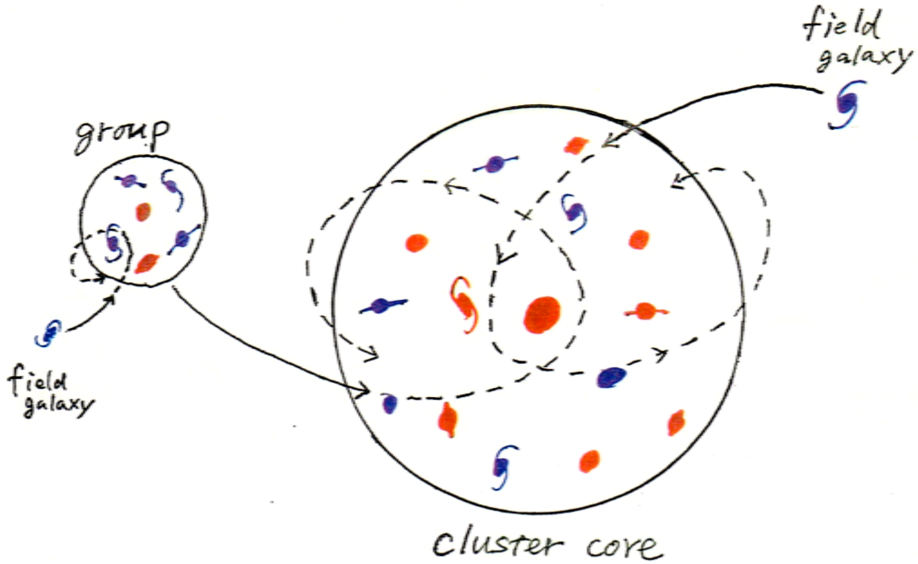
Masao Hayashi (Tokyo), Yuichi Matsuda (Durham),
Ichi Tanaka (Subaru), Masaru Kajisawa (Tohoku), et al.

Origin of Environmental Dependence

N-body simulation of a massive cluster



M=6×10^{14} $M_{\odot}$ 20×20Mpc^2 (co-moving)



Nature? (intrinsic)

Need to go higher redshifts because it becomes more evident.

Nurture? (external)

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

Panoramic Imaging and Spectroscopy of Cluster Evolution with Subaru

PISCES

~10 X-ray detected clusters at 0.4 < z < 1.45

Class	Cluster	RA (J2000)	Dec (J2000)	z	L_X 10^{44}	Bands	Coordination
z~0.4	CL 0024+1654	00 26 35.7	+17 09 43.1	0.39	3.2	BRz',NB	ACS, XMM, Chandra
	CL 0939+4713	09 42 56.2	+46 59 12	0.41	9.2	$BVRI$,NB	XMM
	(RX J2228+2037)	22 28 36	+20 37 12	0.42	16.5	$BVRi'$	Chandra, S-Z
z~0.55	MS 0451.6−0305	04 54 10.9	−02 58 07	0.54	12.0	$BVRI$	ACS (3.5′), Chandra, S-Z
	CL 0016+1609	00 18 33.5	+16 26 13.4	0.546	26.0†	$BVRi'z'$	ACS (3.5′), XMM, Chandra, S-Z
	(MS 2053.7−0449)	20 56 21.8	−04 37 51.4	0.583	5.0	$BVRi'z'$	ACS (3.5′), XMM, Chandra, S-Z
z~0.85	RX J1716.4+6708	17 16 49.6	+67 08 30	0.813	2.7‡	$VRi'z'$,NB	Chandra, Astro-F target
	(MS 1054.4−0321)	10 56 59.5	−03 37 28.4	0.83	20.0	$VRi'z'$	ACS (6′), XMM, Chandra, S-Z
	RX J0152.7−1357	01 52 42.0	−13 57 52.9	0.831	16.0	$VRi'z'$	ACS (6′), XMM, Chandra, S-Z
	(RX J1226.9+3332)	12 26 58.2	+33 32 49	0.9	53.0	$VRi'z'$	XMM, Chandra, S-Z
	(CL 1604+43)	16 04 28.3	+43 16 24.0	0.9	2.0	$VRi'z'$	ACS (6′), XMM
z~1.2	RDCS J0910+5422	09 10 44.9	+54 22 08.9	1.11	2.1	$VRi'z'$	Chandra ACS(3.5')
	CL 1252−2927	12 52 54.4	−29 27 17.0	1.23	6.6	$VRi'z'$	ACS (6′), XMM, Chandra
	(RX J1053.7+5735)	10 53 43.4	+57 35 21	1.14	2.0‡	$VRi'z'$	ACS (6′) XMM
	RX J0848.9+4452	08 48 46.9	+44 56 22	1.26	2.8	$BVRi'z'$	ACS (6′), XMM, Chandra
z~1.4	(XMMU2235.3-2557)	22 35 20.6	-25 57 42.0	1.39	3.0	$VRi'z'$	XMM
	XMMJ2215.9-1738	22 15 58.5	-17 38 02.5	1.45	4.4	$VRi'z'$,NB	XMM

Kodama et al. (2005)

High redshift(z) Radio Galaxies [HzRG] with Subaru, VLT, and Spitzer

7 confirmed proto-clusters at $2 < z < 5.2$ associated to radio galaxies

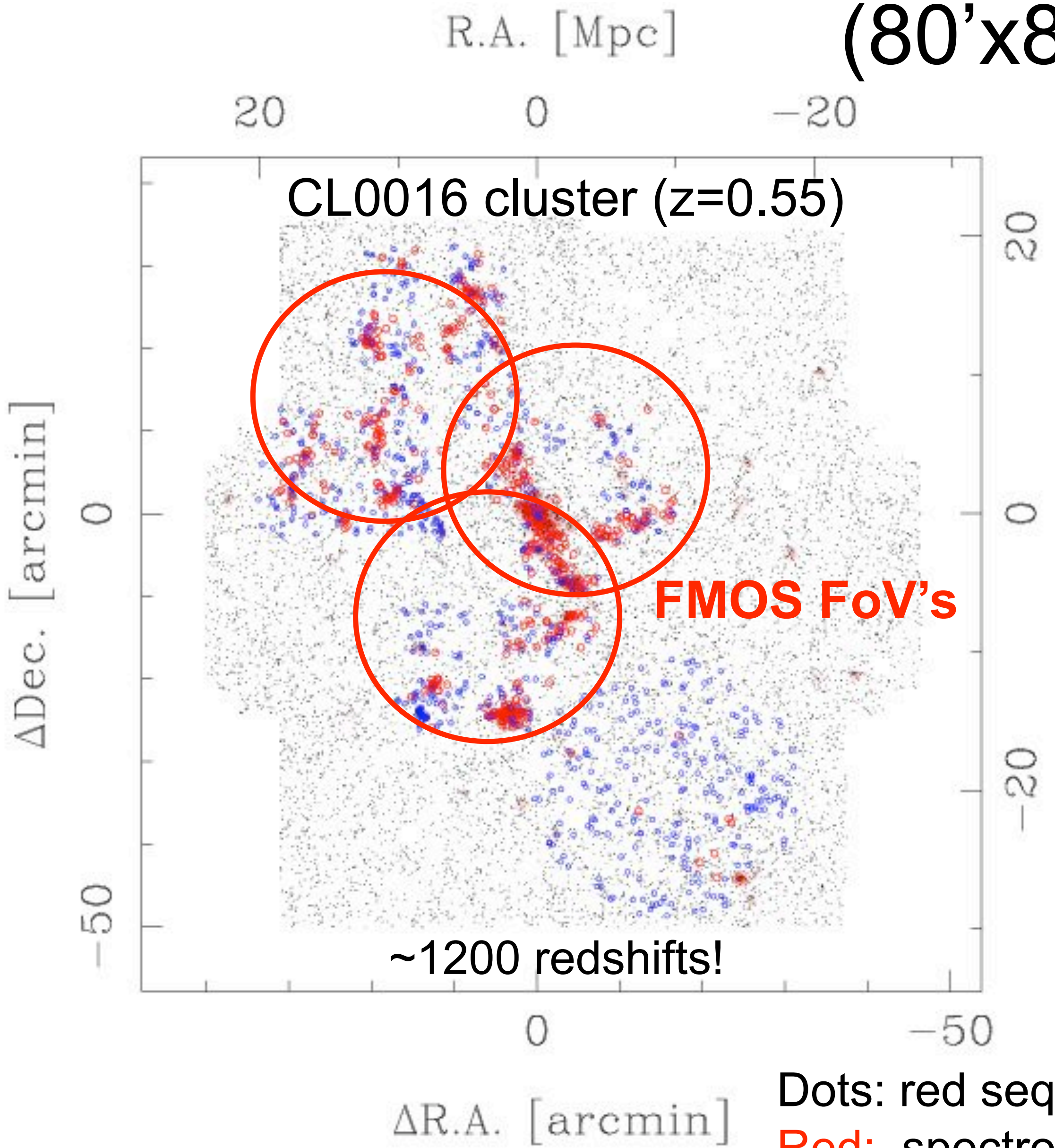
Overdense regions in Lyman-α emitters by a factor of 3—5.

Name	redshift	NIR	Spitzer	Lya	spectra	others
PKS 1138-262	2.16	JHKs	3.6--8.0	16	NIR/Opt	Ha, VLA, Chandra, SCUBA
4C 23.56	2.48	JHKs	3.6--8.0		NIR	Ha
USS 1558-003	2.53	JHKs	3.6--8.0			
USS 0943-242	2.92	JHKs	3.6--24.0	29	NIR/Opt	
MRC 0316-257	3.13	JHKs	3.6--8.0	32	NIR	
TNJ 1338-1942	4.11	JHKs	3.6--8.0	37		Suprime-Cam, VLA, MAMBO
TNJ 0924-2201	5.19	JHKs	3.6--24.0	6		Suprime-Cam/ACS (LBGs)

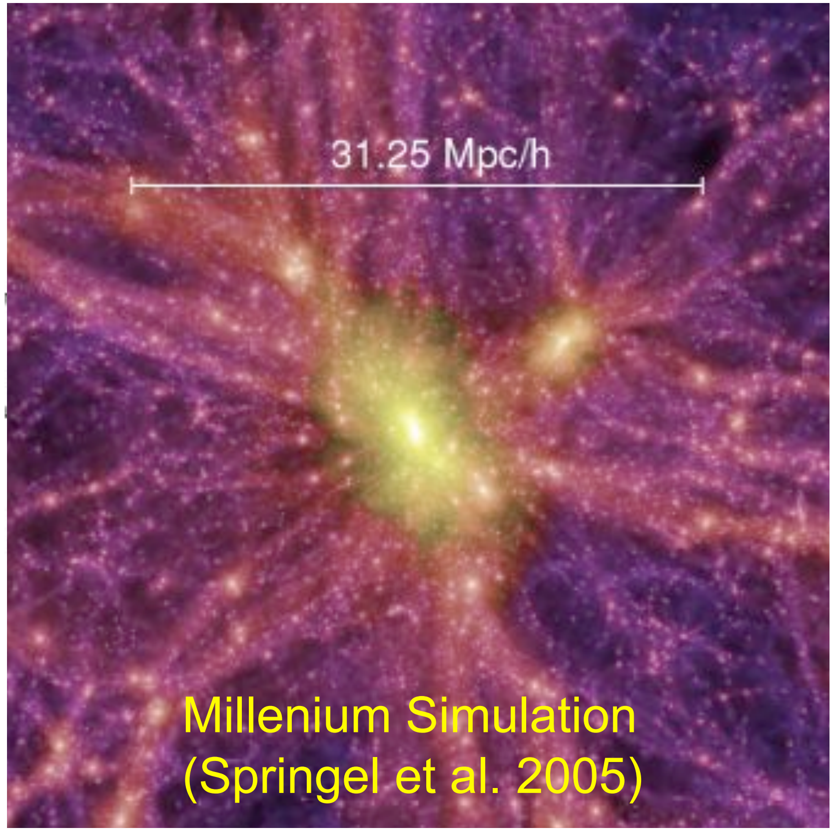
Primarily using MOIRCS/Subaru and Hawk-I/VLT

Kodama et al. (2007), De Breuck et al. (Spitzer HzRGs)

A Huge Cosmic Web at z=0.5 over 50 Mpc (80'x80' by 7 S-Cam ptgs.)



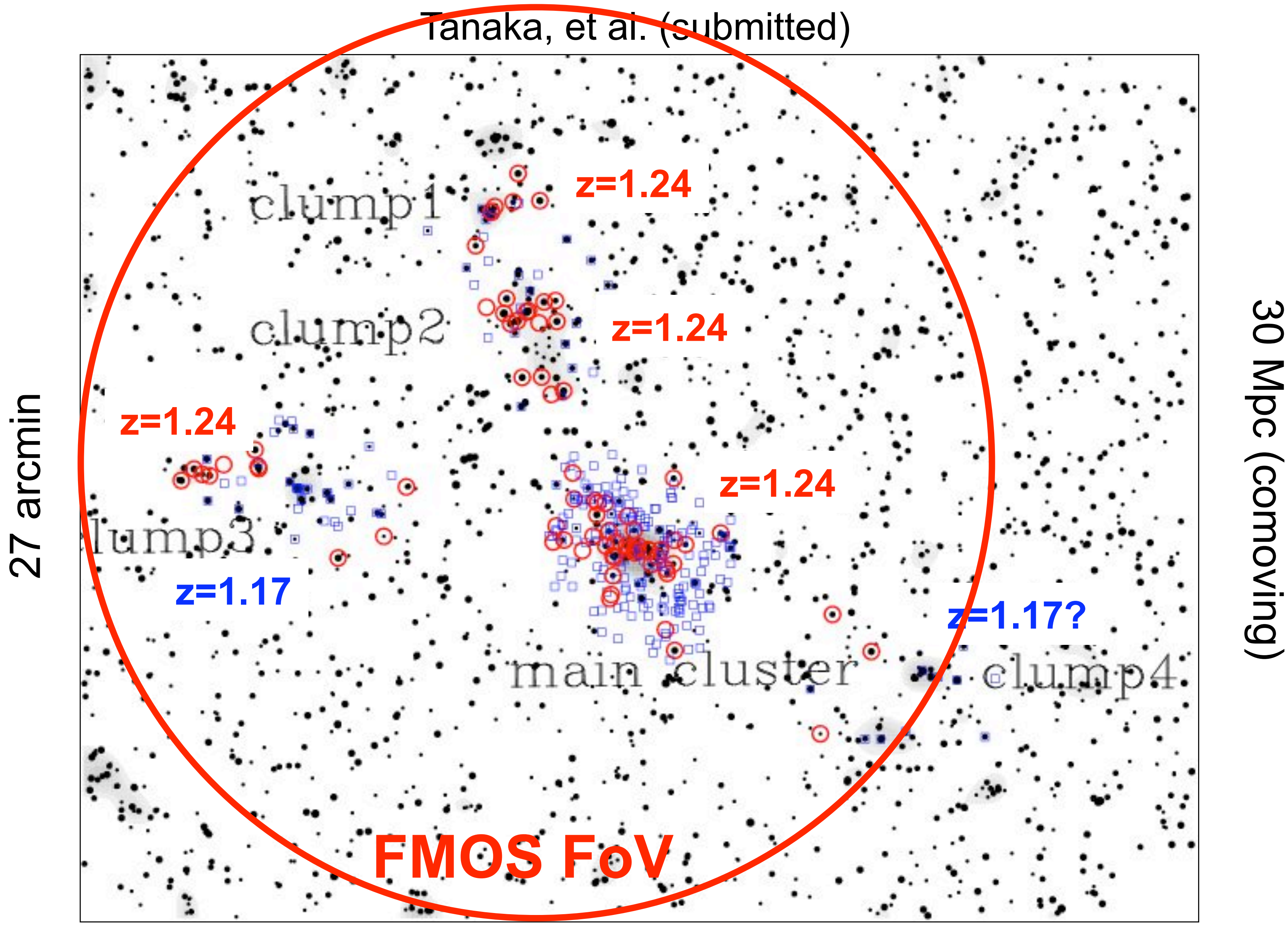
(Tanaka, et al., in prep.)



Dots: red sequence galaxies in V-I
Red: spectroscopically confirmed members
Blue: spectroscopically confirmed non-members

LSS around CL 1252-2927 (z=1.24)

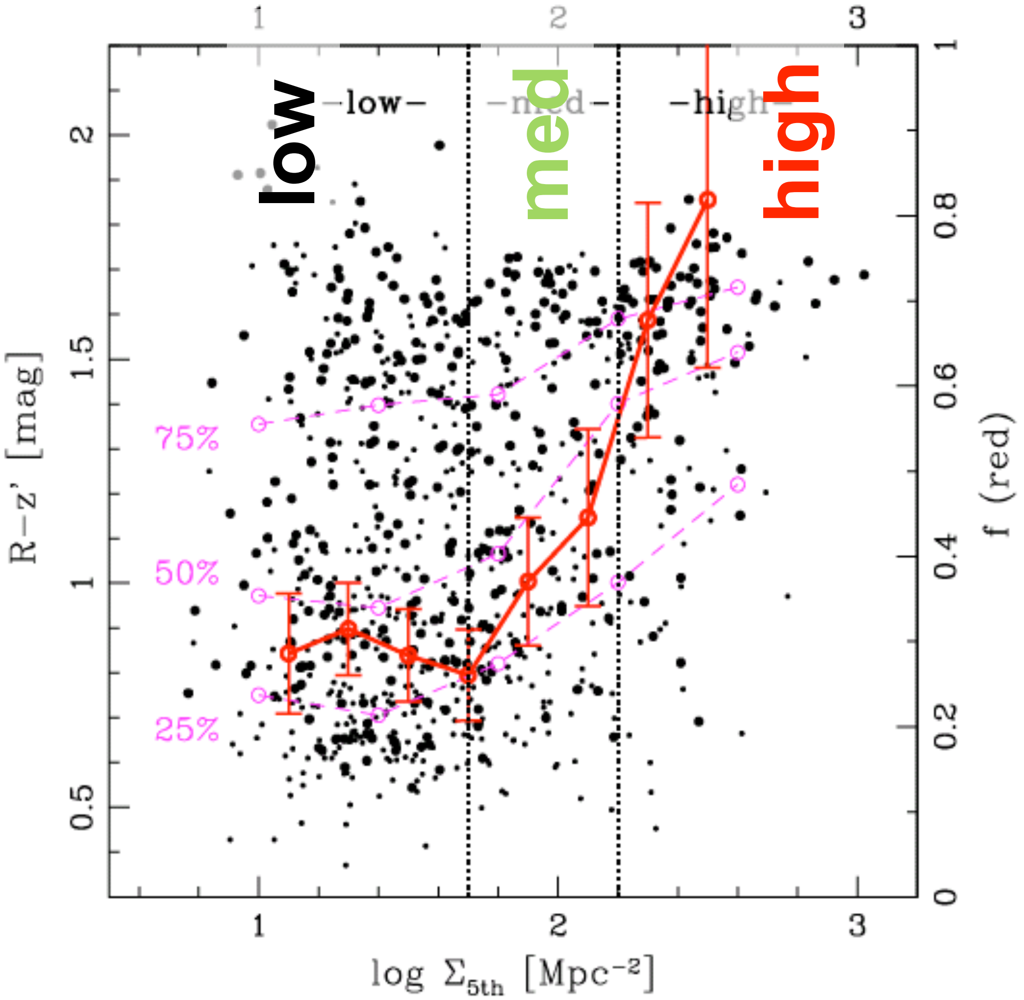
Tanaka, et al. (submitted)

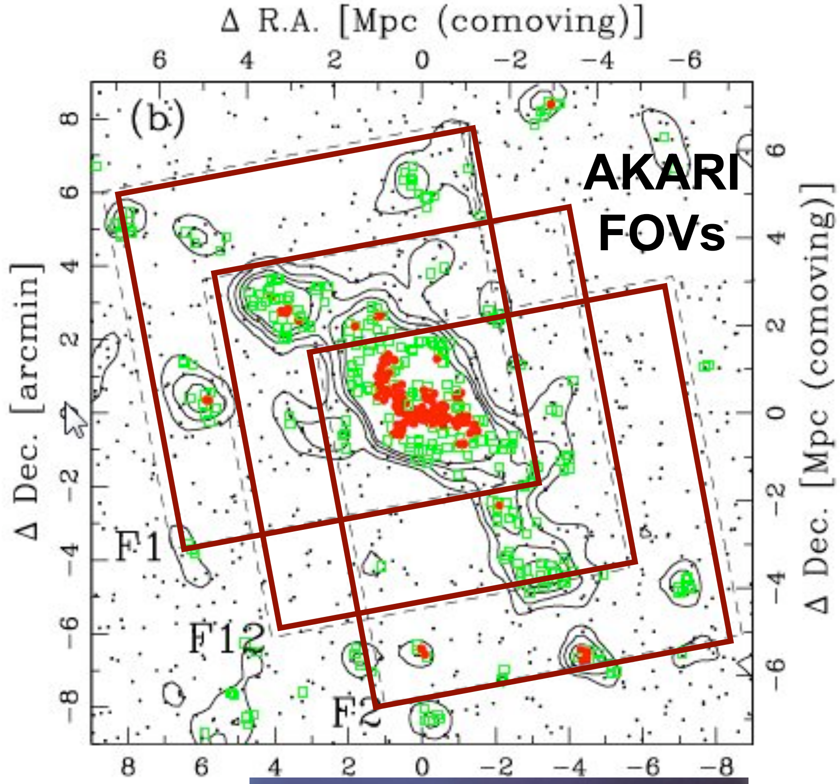


Subaru/Suprime-Cam (V,R,I',z') + UKIRT/WFCAM (K') + VLT/FORS2 (spectroscopy)

Sharp colour transition in groups/outskirts

RXJ1716 cluster (z=0.81)





high

med

low

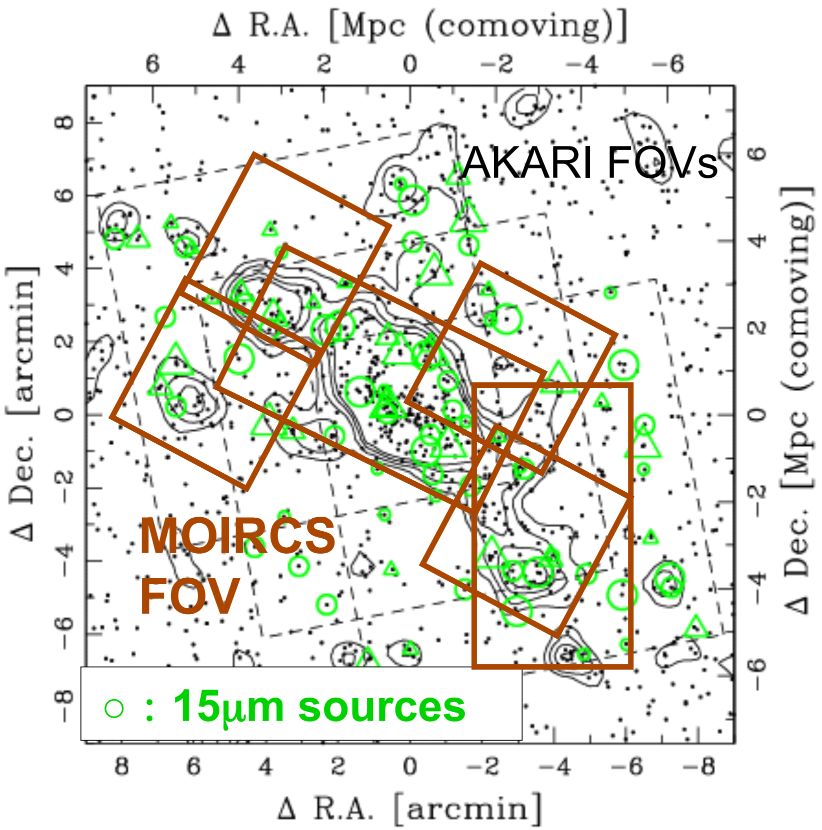
Koyama, TK, et al. (2008)

A narrow-band Hα imaging with MOIRCS/Subaru

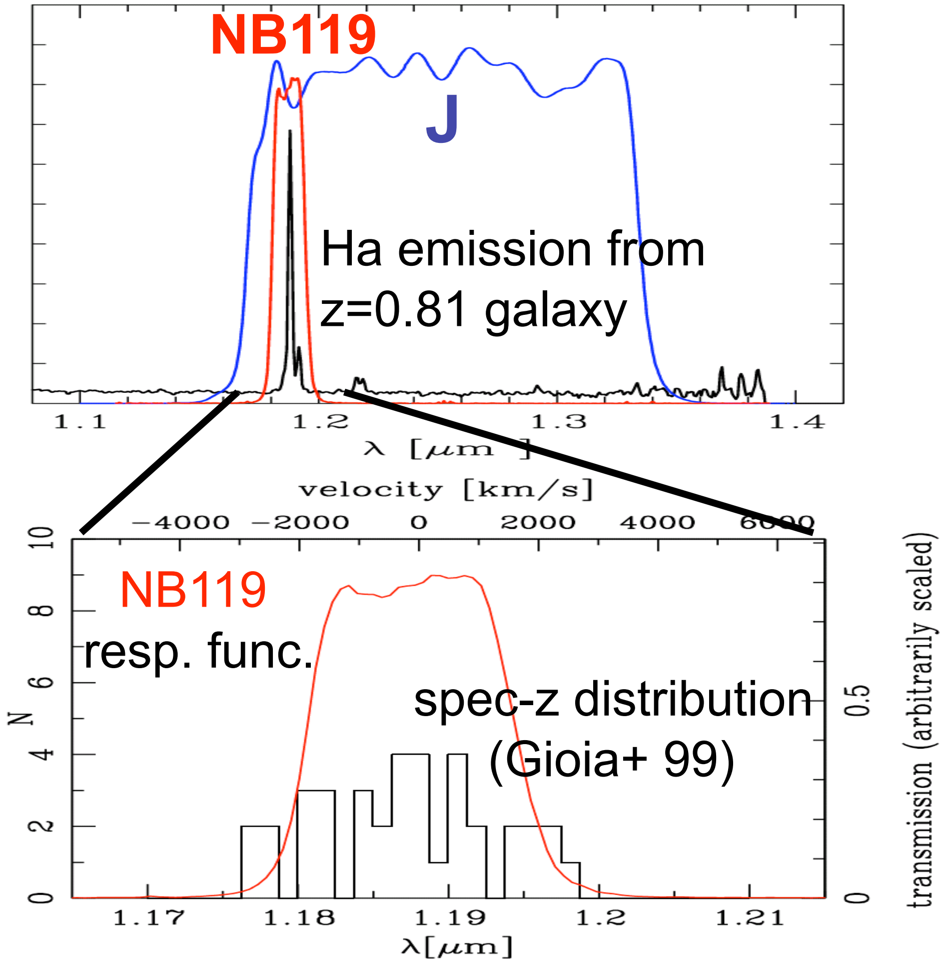
RXJ1716 cluster (z=0.813)

J ～ 30min (23.1 mag, AB, 5σ) → continuum

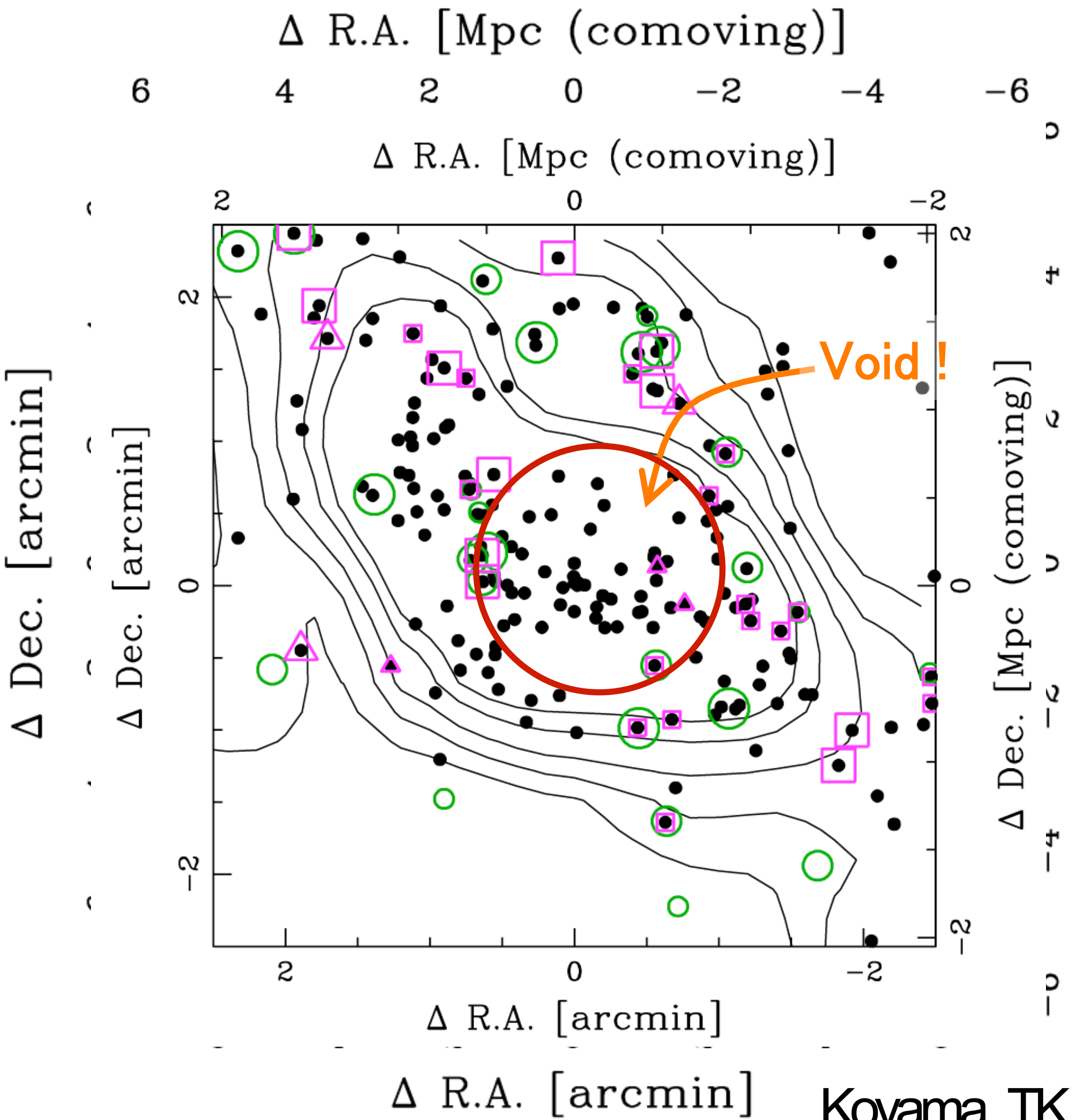
NB119 ～ 100min (22.7 mag, AB, 5σ) → Hα emission

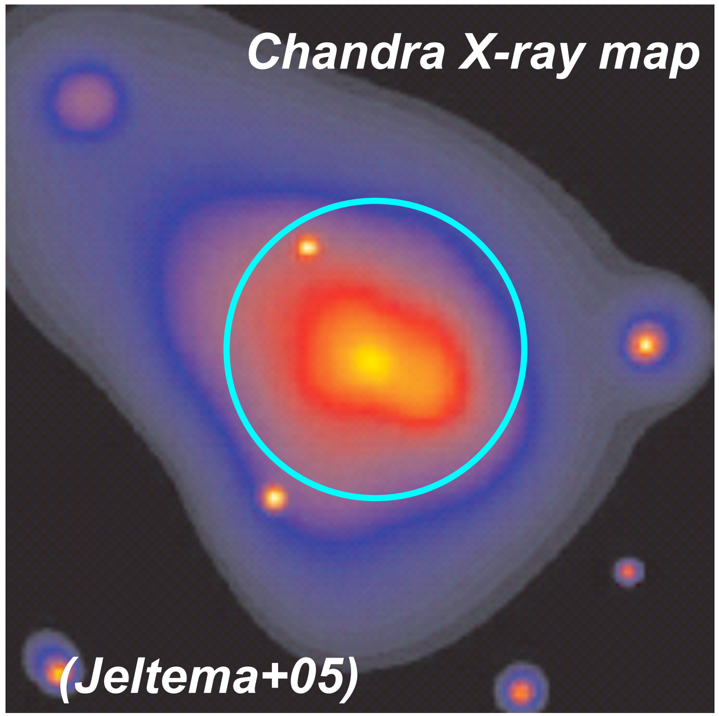


Koyama, TK, et al. (2009)



Spatial Distribution of the 15μm sources and Hα emitters

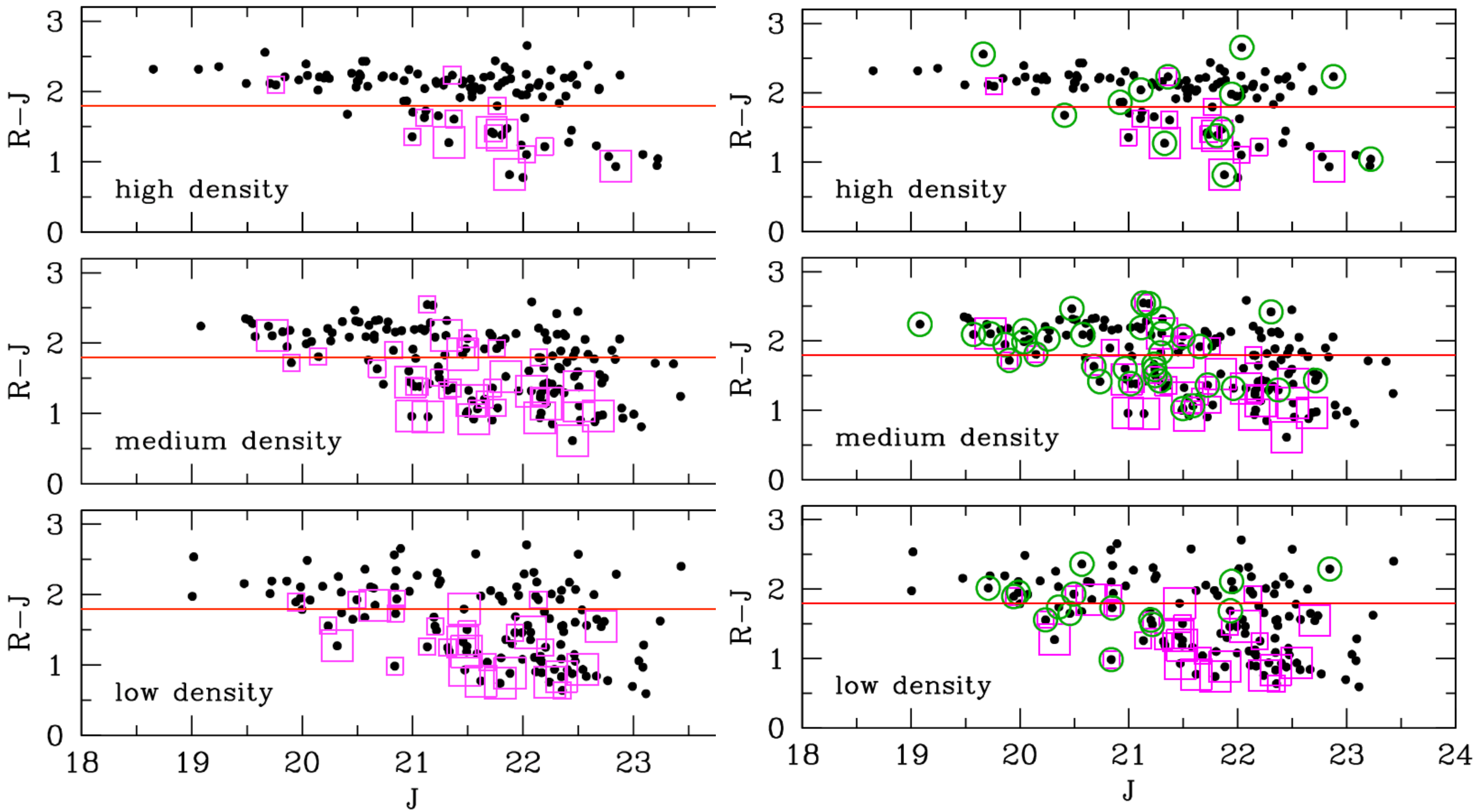




Koyama, TK, et al. (2009)

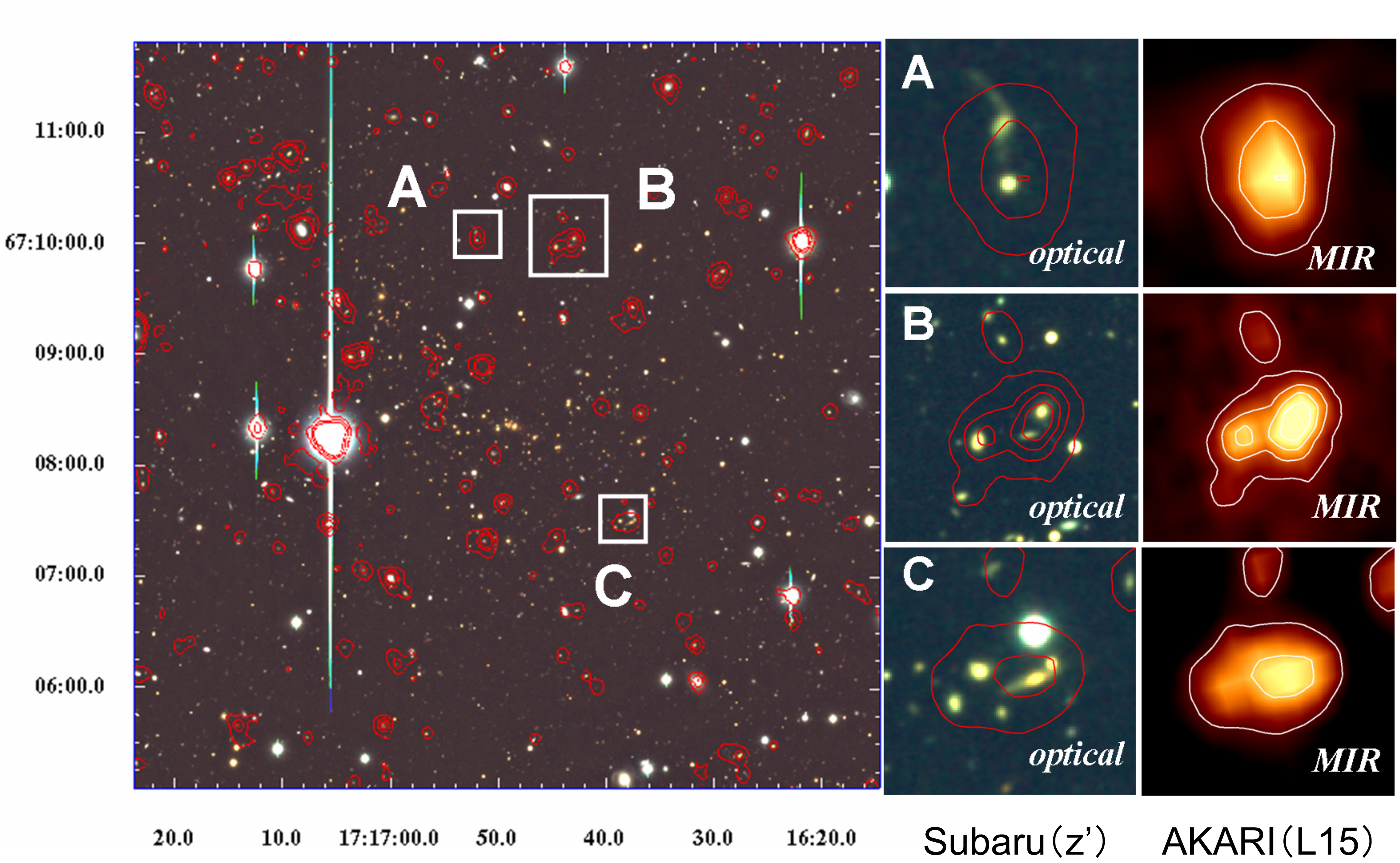
Some Hα emitters on/near the RS   Many 15μm sources on/near the RS

Especially in the medium density regions!



Lots of SF is hidden in the red sequence, especially in the medium density regions!

Interacting galaxies in the 15μm sources

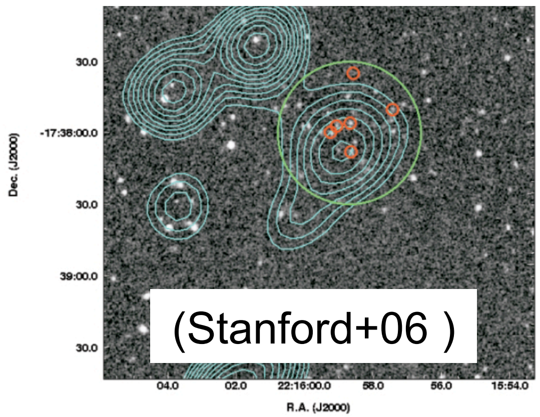


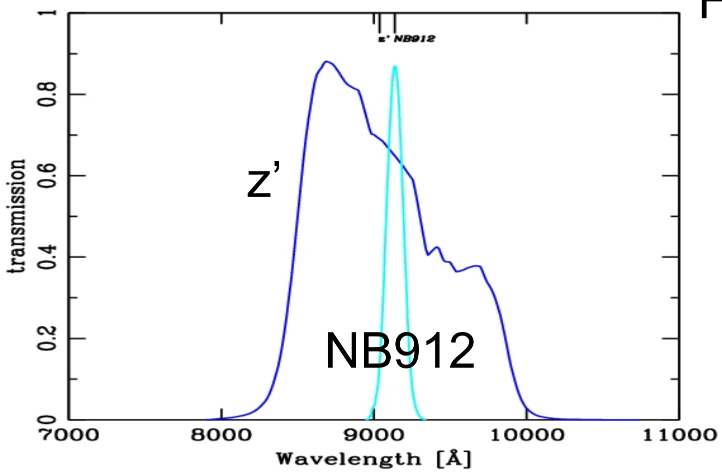
Koyama, TK, et al. (2008)

A narrow-band [OII] imaging with Suprime-Cam/Subaru (XCS2215@z=1.457)

Hayashi et al. (2009), in prep.

XMMXCS J2215.9-1738





[OII] @ z=1.46

↓

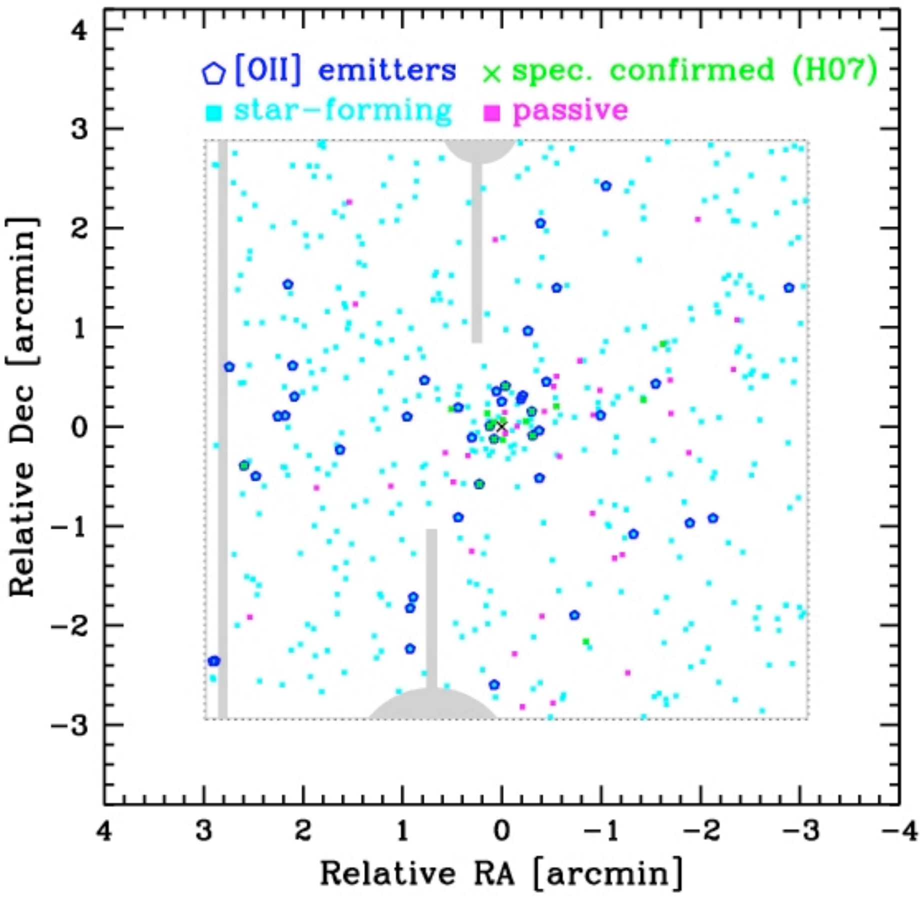
NB912 filter

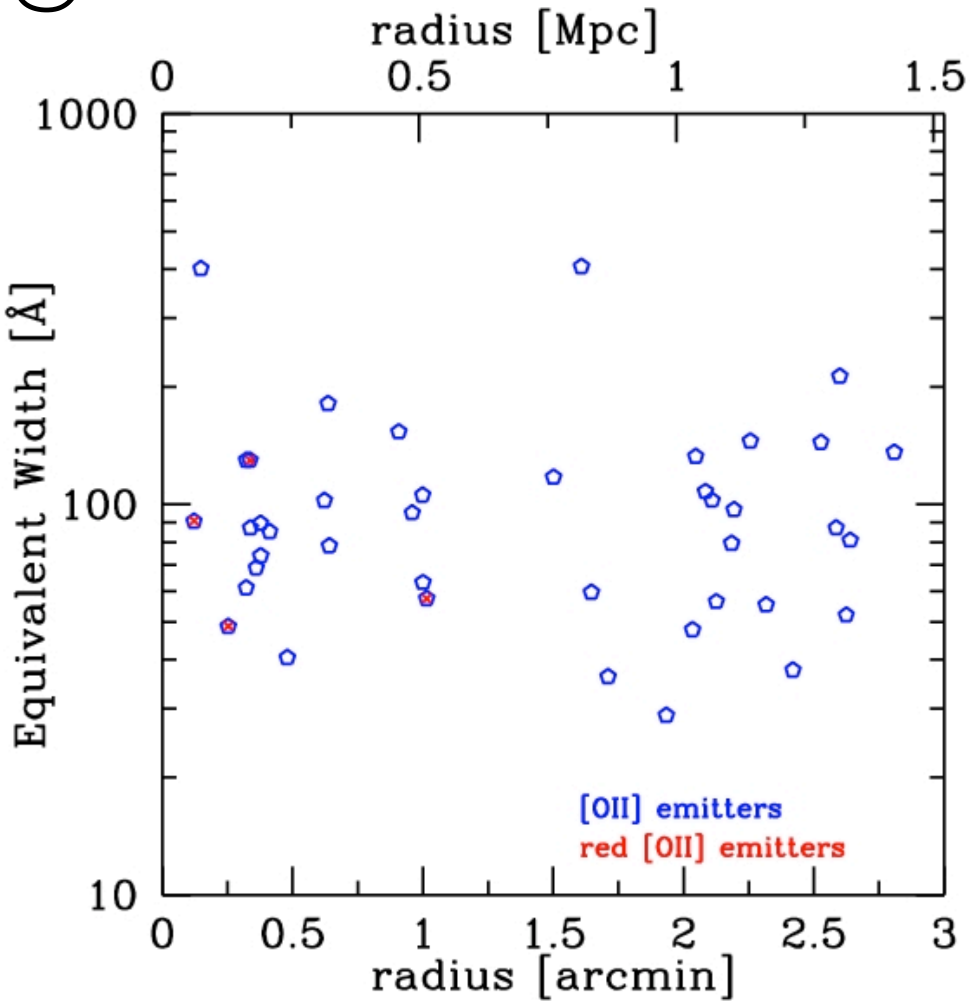
(λ_c=9139A, $\Delta\lambda$=134A)

instruments	**Suprime-Cam**			**MOIRCS**	
passbands	**B**	**z'**	**NB912**	**J**	**Ks**
dates	2008. 07.30-31			2008. 06.30-07.01	
pointings	1			4	
FoV	32' x 23'			6.1' x 5.8'	
3σ mags	27.59	25.81	25.75	23.84-24.57	23.07-23.65
seeing	1.09"			1.09"	

Spatial Distribution of the [OII] emitters

XCS2215@z=1.457



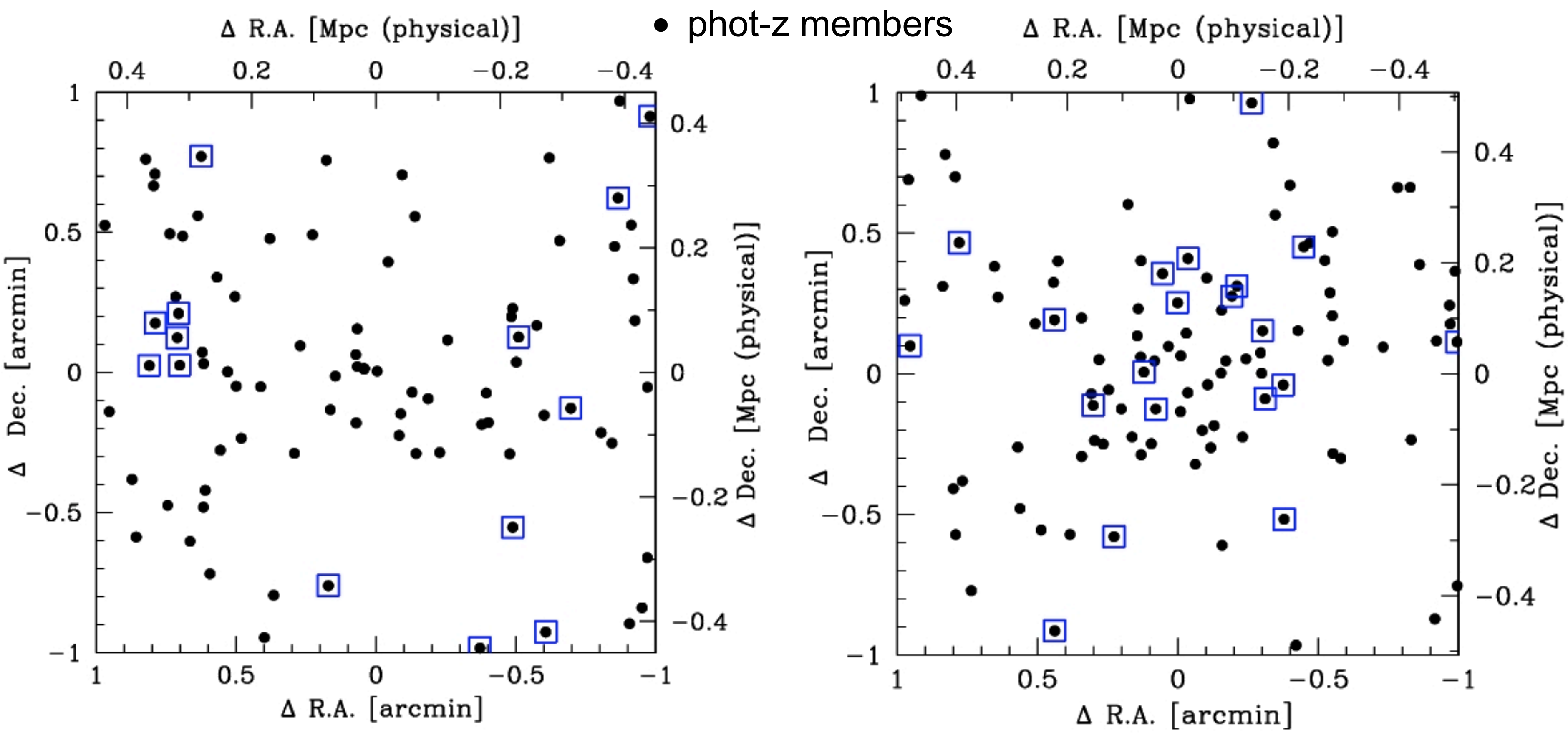


High star formation activity to the very centre of the cluster!

Hayashi et al. (2009), in prep.

Star forming activity in the cluster cores

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

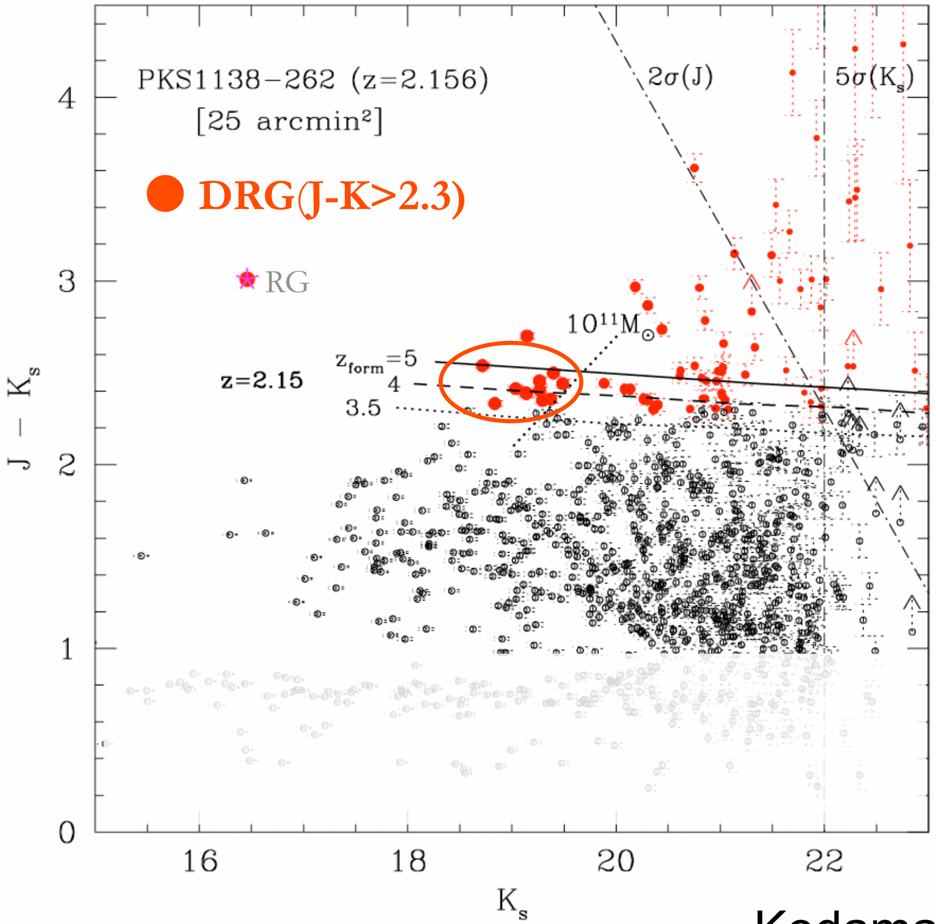


Koyama, TK, et al. (2009) Hayashi, TK, et al. (2009)

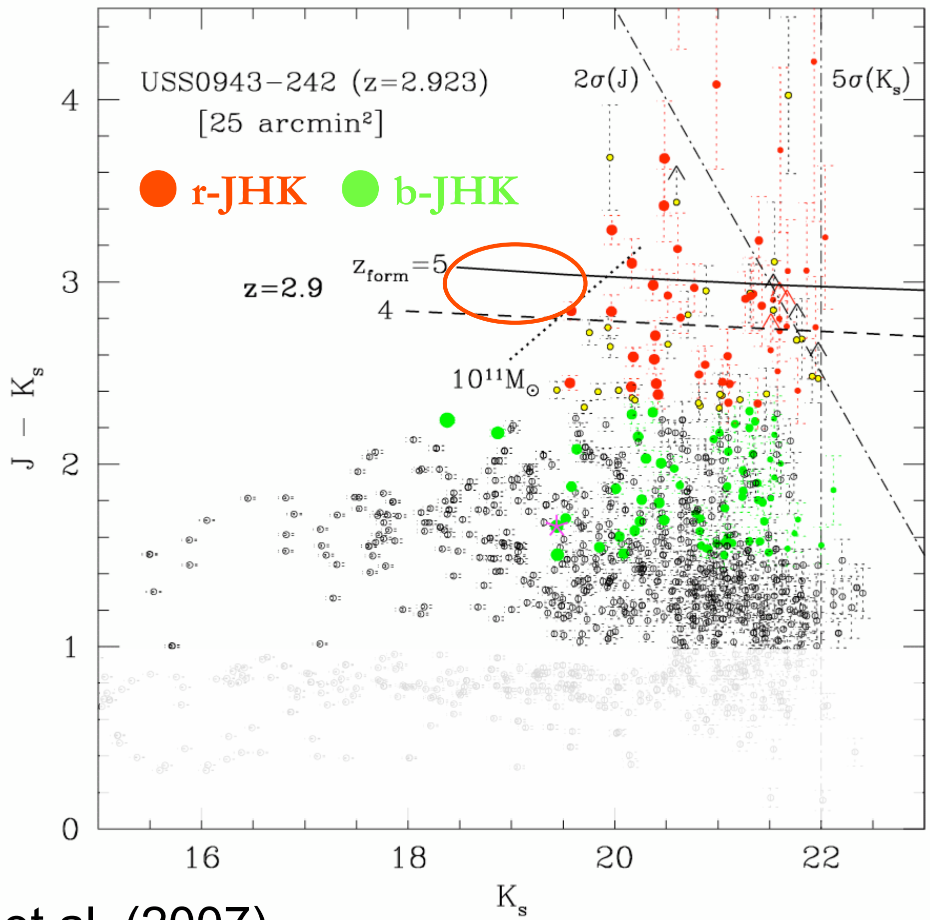
Inside-out propagation of star forming activity in cluster cores !?

Emergence of the red-sequence at z~2 in proto-clusters?

z~2 (PKS1138)



z~3 (USS0943)



Kodama et al. (2007)

The red sequence seems to be emerging between z=3 and 2 (2 < Tuniv[Gyr] < 3).

Working hypotheses

- Starbursts/truncation of galaxies in groups/ outskirts of clusters at z<1

  → *External effects ("Nurture")*

  (galaxy-galaxy interaction?)

- Formation of massive galaxies in cluster cores at z>1.5-2

  → *Intrinsic effects ("Nature")*

  (galaxy formation bias?)

"Inside-out propagation/truncation of star formation in clusters?"

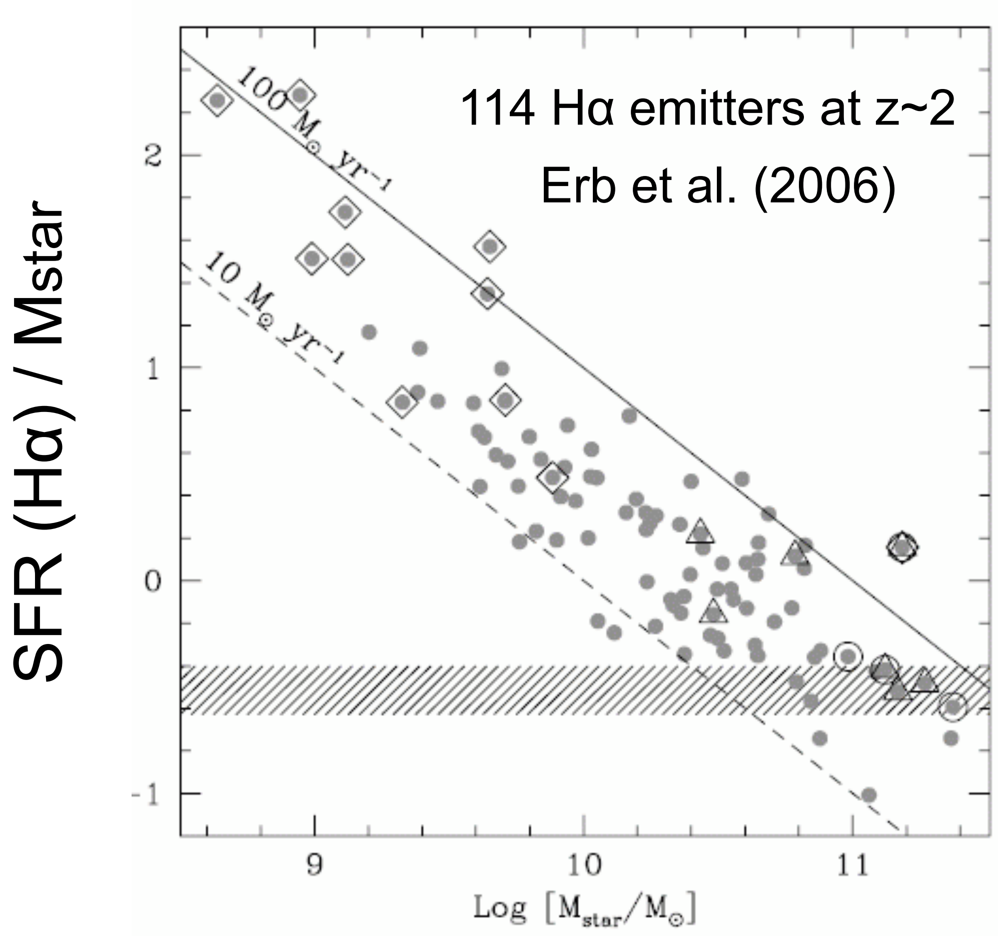
FMOS Windows（0.9＜λ[μm]＜1.8）

- Hα（6563Å）：0.4 <z< 1.7 （excl. 1.05 ～1.2）
- [OII]（3727Å）：1.4 <z< 3.8 （excl. 2.6 ～ 2.9）
- [OIII]（5007Å）：0.8 <z< 2.6 （excl. 1.7 ～ 1.9）
- Hβ（4861Å）：0.85<z< 2.7 （excl. 1.77 ～ 2）

30’ = 30Mpc (z=1), 50Mpc (z=2)

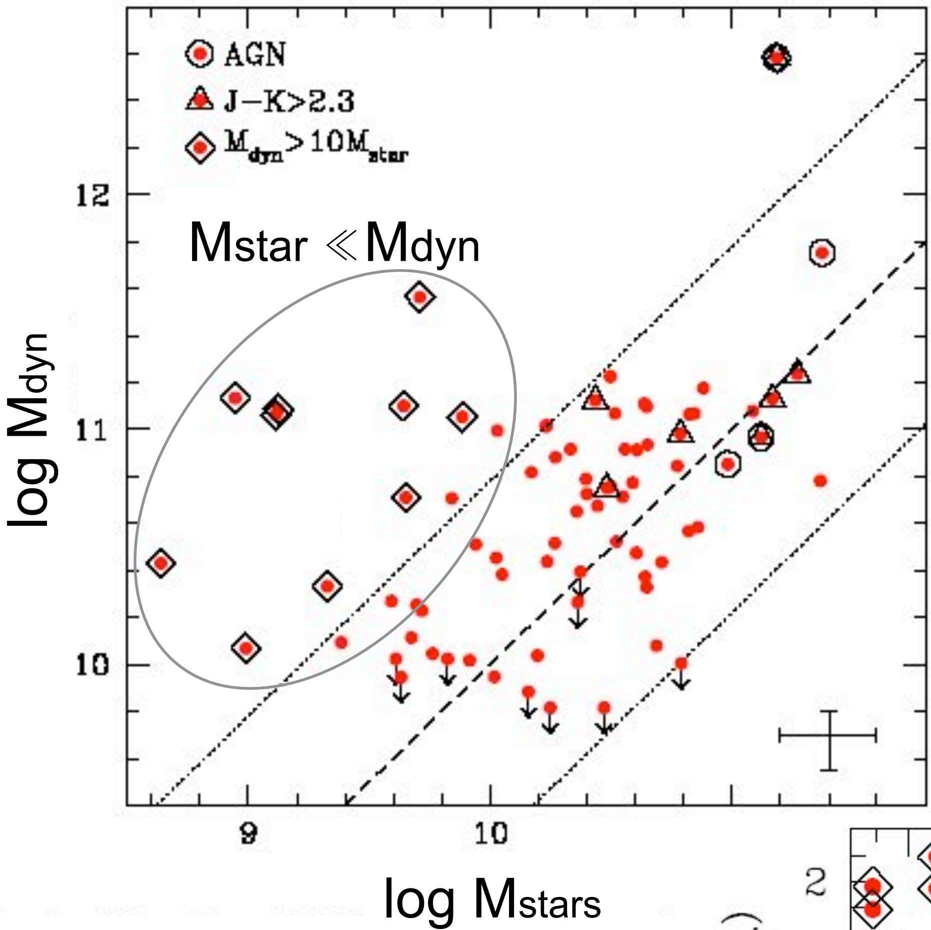
SFR, chemical abundance, dynamical mass of SF galaxies at 0.4<z<3.8 and their environmental dependence

<SFR>=SFR/M* versus M*
as functions of Redshift and Environment



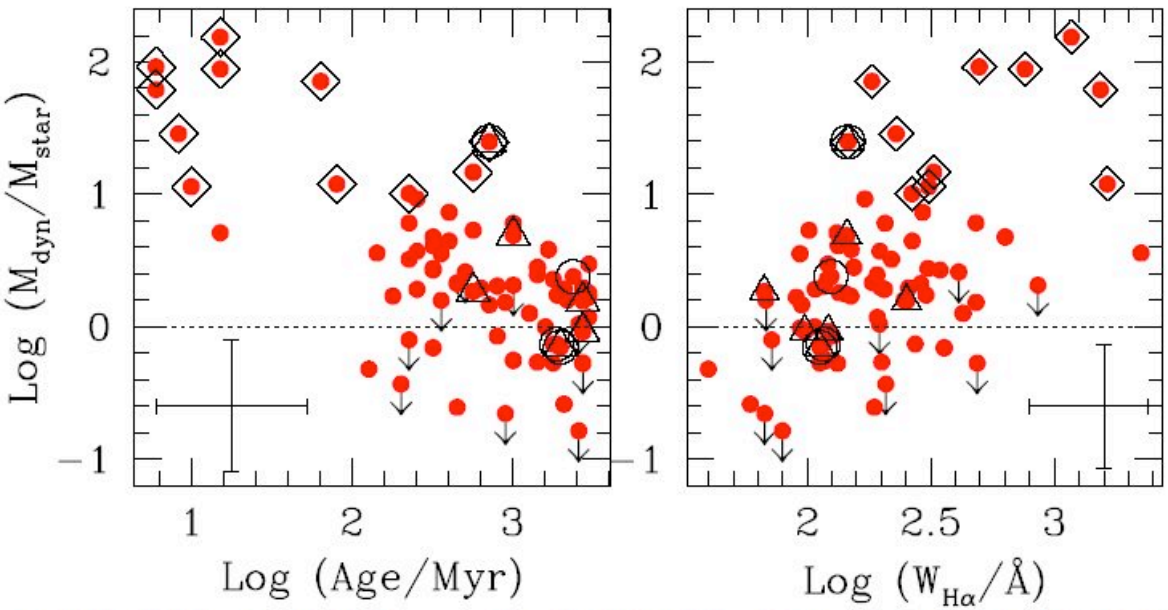
With FMOS, we can correct for dust extinction with Hβ/Hα for 0.85<z<1.7

Mdyn vs. Mstars



Mstars / Mdyn ratios indicate evolutionary stages of galaxies!

Galaxies with Mstars ≪ Mdyn tend to have younger ages and stronger Hα emission.



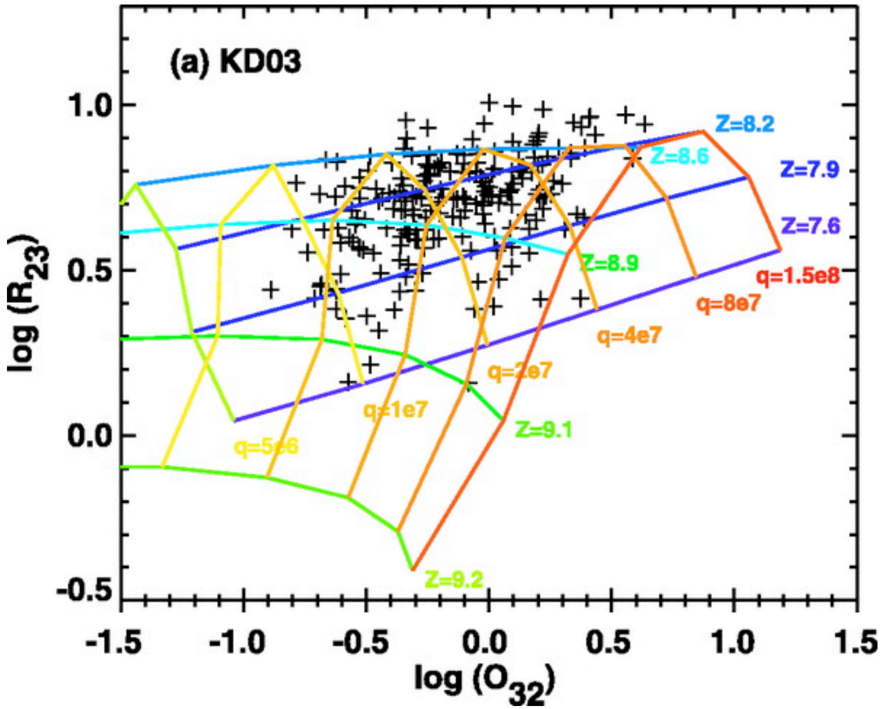
Erb et al. (2006)

Gaseous Metallicity of Distant Galaxies

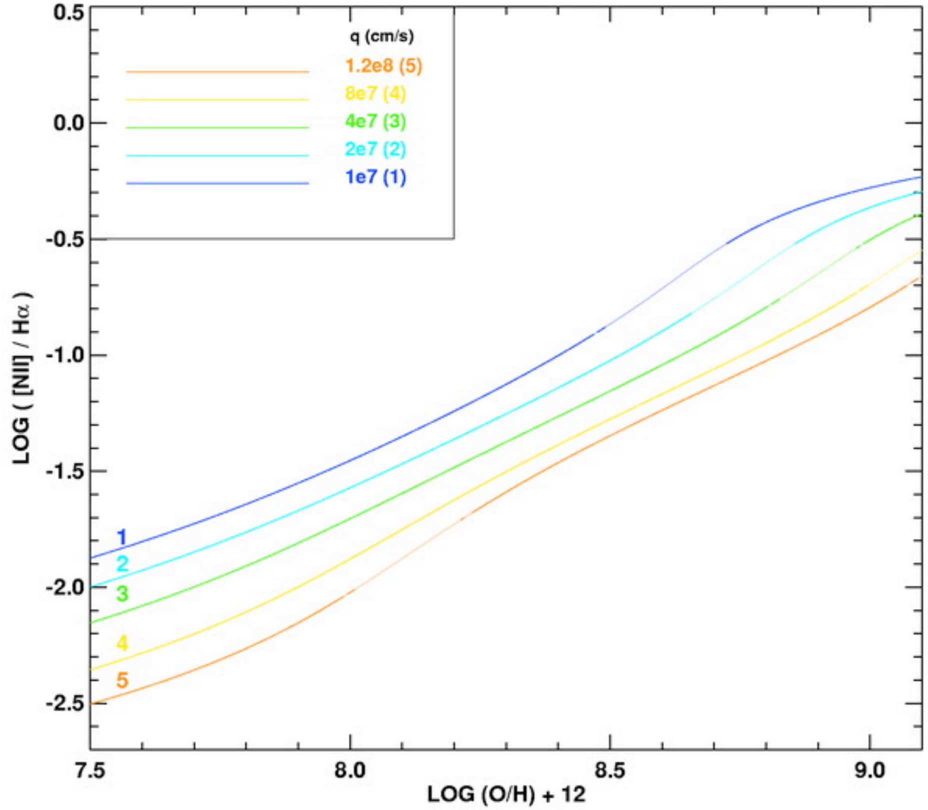
$$\log R_{23} \equiv \frac{I_{[\mathrm{O\,II}]\lambda3727} + I_{[\mathrm{O\,III}]\lambda4959} + I_{[\mathrm{O\,III}]\lambda5007}}{I_{\mathrm{H}\beta}}$$

$$\log O_{32} \equiv \log\left(\frac{I_{[\mathrm{O\,III}]\lambda4959} + I_{[\mathrm{O\,III}]\lambda5007}}{I_{[\mathrm{O\,II}]\lambda3727}}\right)$$

Kobulnicky & Kewley (2004)



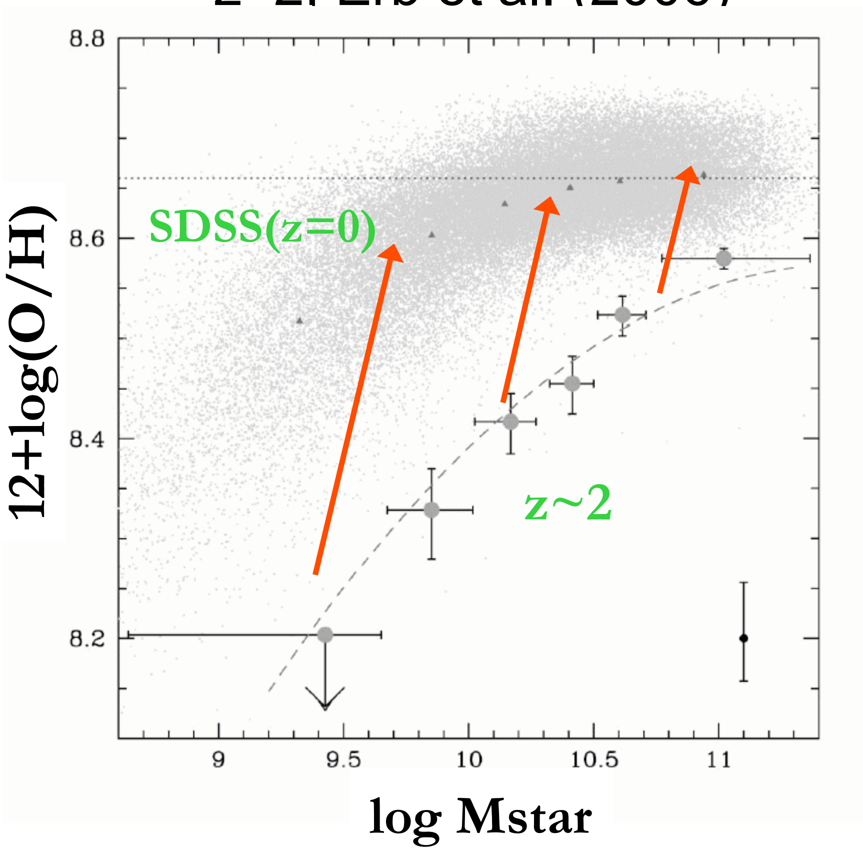
[NII] / Hα vs. [O/H]



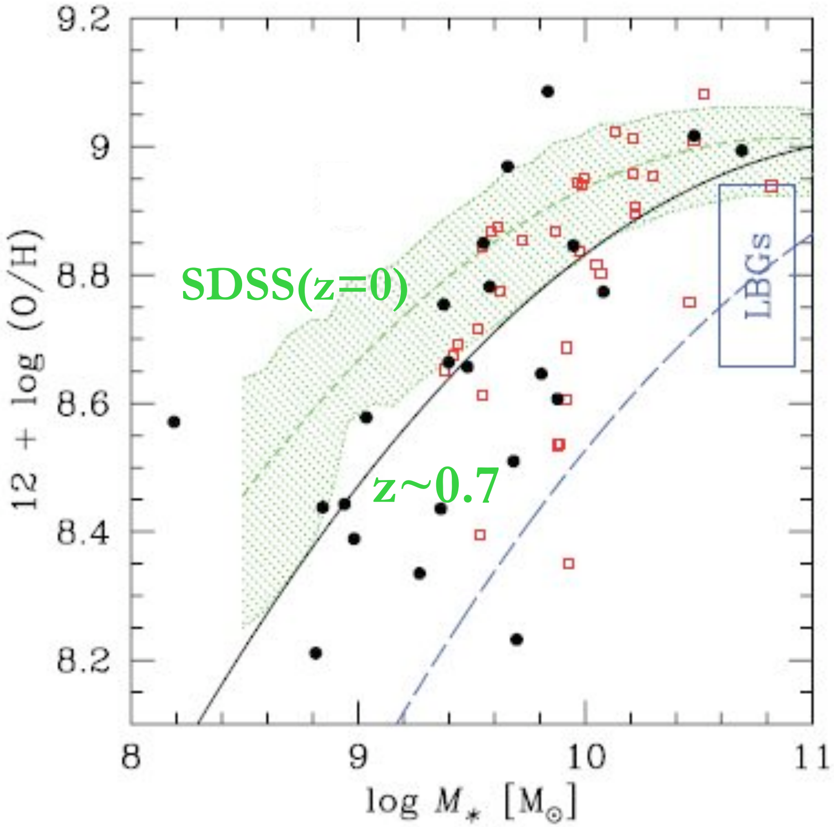
We can apply both techniques at 1.4<z<1.7 with FMOS
and break the degeneracy between Z (metallicity) and q (ionization parameter)

Chemical Evolution vs. Star Formation History

z~2. Erb et al. (2006)



GDDS+VFRS, Savaglio et al. (2005)



$Zg = -y(1-R_{eject})\ \ln(fg)$

Chemical Evolution

↕ Feedback (outflow) as a func of mass !

Star Formation History

Target List and Requested Time

5 (~10) mid-z clusters at 0.4<z<1.5, and 3 (~6) proto-clusters at 2<z<3

Cluster	z	t (Gyr)	RA(J000)	Dec(J2000)	$M_\odot$/yr (5σ)	ptgs.	available lines
CL 0024+1652	0.39	3.2	00 26 35.7	+17 09 43	1.0 (0.5hr)	2	$H\alpha$,[NII]
CL 0939+4713	0.41	9.2	09 42 56.6	+46 59 22	1.0 (0.5hr)	2	$H\alpha$,[NII]
CL 0016+1609	**0.55**	8.1	00 18 33.3	+16 26 36	**1.0 (2hr)**	**6**	$H\alpha$,[NII]
MS 0451.6−0305	0.55	12.0	04 54 10.9	−03 01 07	1.0 (2hr)	2	$H\alpha$,[NII]
RX J1716.4+6708	**0.81**	6.6	17 16 49.6	+67 08 30	**1.5 (2hr)**	**2**	$H\alpha$,[NII],[OIII]
RX J0152.7−1357	**0.84**	6.5	01 52 41.0	−13 57 45	**1.5 (2hr)**	**2**	$H\alpha$,[NII],[OIII],Mg
RDCS J0910+5422	1.11	2.1	09 10 00.0	+54 22 00	1.5 (4hr)	2	$H\alpha$,[NII],[OIII],Mg
RDCS J1252−2927	**1.24**	4.9	12 52 54.4	−29 27 17	**1.5 (5hr)**	**2**	$H\alpha$,[NII],[OIII],Mg
RX J0848.9+4452	1.26	4.8	08 48 56.3	+44 52 16	1.5 (5hr)	2	$H\alpha$,[NII],[OIII],Mg
XCS2215.9−1738	**1.46**	4.3	22 15 58.5	−17 38 03	**2.3 (5hr)**	**2**	$H\alpha$,[NII],[OIII],Mg
PKS 1138−262	**2.16**	3.0	11 40 48.4	−26 29 11	**11 (10hr)**	**1**	[OII],[OIII],Mgb,H
4C 23.56	**2.48**	2.6	21 07 14.8	+23 31 45	**17 (10hr)**	**1**	[OII],[OIII],Mgb,H
USS 1558−003	2.53	2.5	16 01 17.3	−00 28 48	17 (10hr)	1	[OII],[OIII],Mgb,H
USS 0943−242	2.92	2.2	09 45 32.8	−24 28 50	27 (10hr)	1	[OII],$H\delta$,$H\gamma$
SSA22	**3.09**	2.1	22 17 34.0	+00 17 00	**30 (10hr)**	**1**	[OII],$H\delta$,$H\gamma$
MRC 0316−257	3.13	2.0	03 18 12.0	−25 35 11	30 (10hr)	1	[OII],$H\delta$,$H\gamma$

Including overheads (30%?), we request 103hrs (=10nights) for the primary targets and 82.2 hrs (=8nights) for the secondary targets.

FIT-PISCES (*FMOS InTensive PISCES*)

FMOS will nicely FIT in our on-going PISCES project!

＊Mapping 3-D large scale structures (~４００/FoV)

＊Environmental dependence of SFH

(Hα ~ 1-2 M⊙/yr @z<1.5, [OII] ~ 10-30 M⊙/yr @z>2)

Star formation rate (Hα, [OII] emission lines)

Dust extinction (Hα/Hβ)

Post-starburst (composite Balmer absorption lines)

Dynamical mass (line width)

Metallicity, AGN separation ([OII], [OIII], Hα/β, [NII])

"When and Where do we see (post-)starbursts and truncation?"

"How much star formation is hidden in the optical (rest-UV) surveys?"