

# **Ultimate Studies of Environmental Effects in Cosmic Webs in the Distant Universe**



**Can we use Subaru  
prime-focus?**



**Yes (which means  
“pending”...)**

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# Report by the international review committee of the Subaru Telescope (28-29 Feb 2008)

“To use the same field of view as supported by Hyper Suprime-Cam for high and medium resolution multi-object spectroscopy with a multiplex capability of 4000, as suggested for **WF MOS**, **would be next consequent bold step** into the same direction... **The committee urges the Subaru Telescope to enter into a dialogue with the Japanese astronomy community about WF MOS.**”

“It is important that Subaru after its excellent start keeps up the momentum it had gained. **This might be a challenge for the Japanese community, as simultaneously with the development for the next generation of instruments, the plans for a participation in a next generation Extremely Large Telescope have also become very concrete.** Careful planning will be needed to find the right balance of investment, to use the synergies between the two projects, and to identify new financial and human resources.”

# Subaru Future Instrumentation WG (galaxy, AGN and cosmology)

The WG has reached to the conclusion that the most wanted Subaru next instruments are the following three:

- (1) Wide-field multi-object optical spectrograph on the prime focus (WFMOS)
- (2) Wide-field NIR imager on the prime focus (30')
- (3) Multi-object Integral Field Unit

of which WFMOS will be the most competitive instrument in the era of ELT and JWST.

**Issues:**      **Are stars /ism/planets people happy as well?**  
**Can we still do individual small projects in the era of HSC and WFMOS?**

# Outline

WFEMOS will be a powerful explorer of cosmic webs to  $z < 1.4$ .

➤ **Panoramic mapping of cosmic webs with “ordinary” galaxies (nearly stellar-mass selected galaxies).**

1.5 deg = 50Mpc@ $z=0.5$ , 86Mpc@ $z=1$

2 Abell clusters / FoV / ( $z=0.1$ )

➤ **Resolving SFH / CE depending on environment**

e.g., OII/Ha emission, Balmer absorption lines

$\sim 10^7$  yrs

$\sim 10^{8-9}$  yrs

# Panoramic Imaging and Spectroscopy of Cluster Evolution with Subaru

Class	Cluster	RA (J2000)	Dec (J2000)	$z$	$L_X$ $10^{44}$	Bands	Coordination	
$z \sim 0.4$	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	
$z \sim 0.55$	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 <sup>†</sup>	$BVRi'z'$	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	
$z \sim 0.85$	RX J1716.4+6708	17 16 49.6	+67 08 30	0.813	2.7 <sup>‡</sup>	$VRi'z'$	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	Spitzer
	RX J0152.7-1357	01 52 42.0	-13 57 52.9	0.831	16.0	$VRi'z'$	ACS (6'), XMM, Chandra, S-Z	Spitzer
	RX J1226.9+3332	12 26 58.2	+33 32 49	0.9	53.0	$VRi'z'$	XMM, Chandra, S-Z	Spitzer
	CL 1604+43	16 04 28.3	+43 16 24.0	0.9	2.0	$VRi'z'$	ACS (6'), XMM	Spitzer
$z \sim 1.2$	RD0910+5422	09 10 44.9	+54 22 08.9	1.11	2.1	$VRi'z'$	Chandra ACS(3.5')	Spitzer
	CL 1252-2927	12 52 54.4	-29 27 17.0	1.23	6.6	$VRi'z'$	ACS (6'), XMM, Chandra	Spitzer
	RX J1053.7+5735	10 53 43.4	+57 35 21	1.14	2.0 <sup>†</sup>	$VRi'z'$	ACS (6') XMM	Spitzer
	RX J0848.9+4452	08 48 46.9	+44 56 22	1.26	2.8	$BVRi'z'$	ACS (6'), XMM, Chandra	Spitzer

<sup>†</sup> 0.4-10 keV, <sup>‡</sup> 0.5-2 keV, others are bolometric X-ray luminosity ( $H_0=70$ ).

Imaging : Suprime-Cam-BB

CL0024, CL0939, CL0016, CL0451, RX1716, RXJ0153, CL1604, RD0910, CL1252, RXJ0849, MS2054, MS1054

Suprime-Cam-NB (H $\alpha$ )

CL0024 ( $z=0.39$ ), CL0939 ( $z=0.41$ )

WFCAM (NIR)

RXJ0153, CL1604, CL1252, RXJ0848

MOIRCS (NIR)

RXJ1716, RD0910

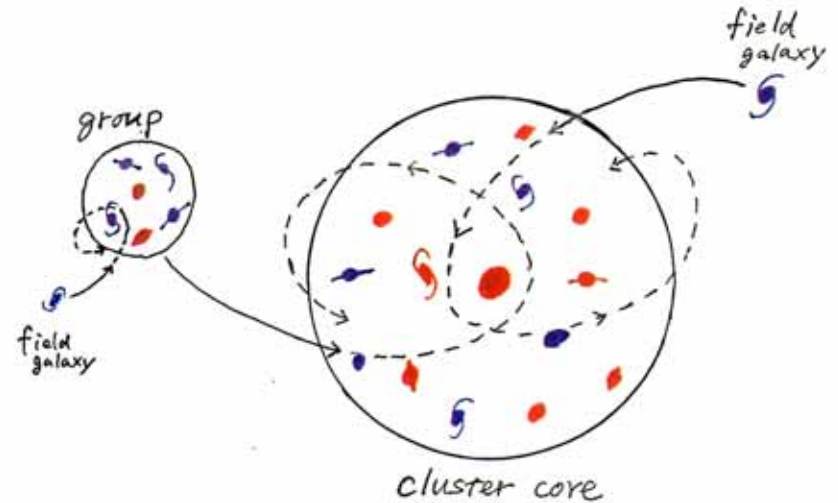
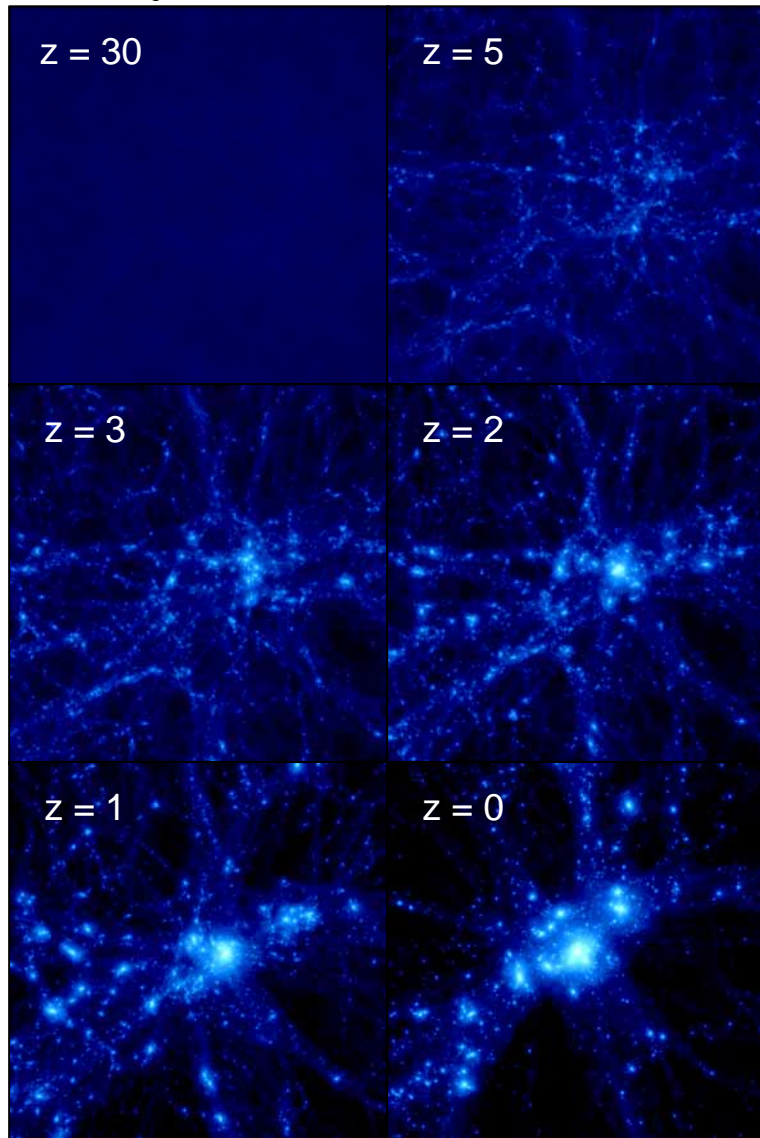
Spectroscopy : FOCAS

CL0939, CL0016, RXJ0153, CL1252, RXJ0848



# Origin of Environmental Dependence

N-body simulation (Dark matter)

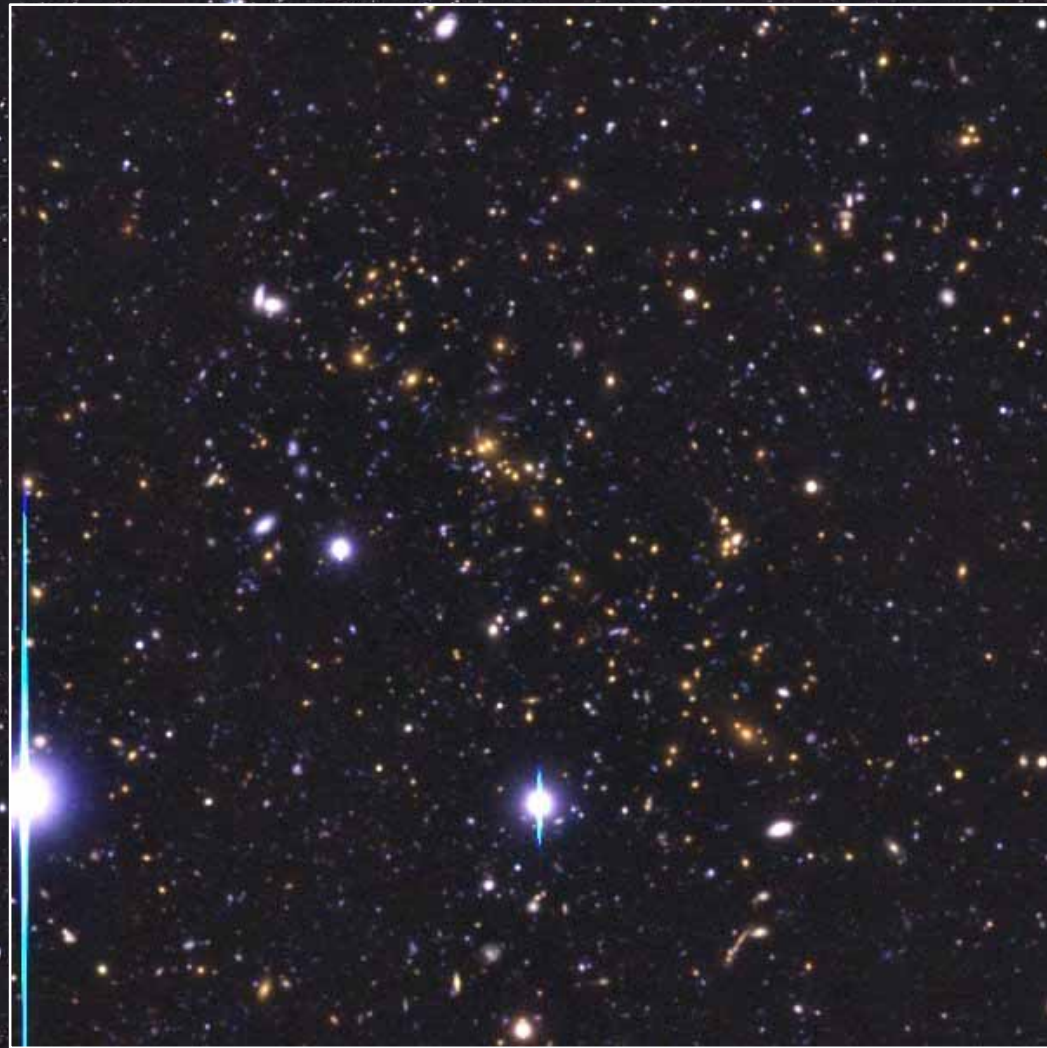


***Nature?***

**Ellipticals form early in the highest density peaks while Spirals form later in lower density regions.**

***Nurture?***

**Transformation of Spirals to E/S0s as they assemble to denser regions.**



*RXJ0152-13 at  $z=0.83$*

*VRizK photometry + 200 spec. objects*

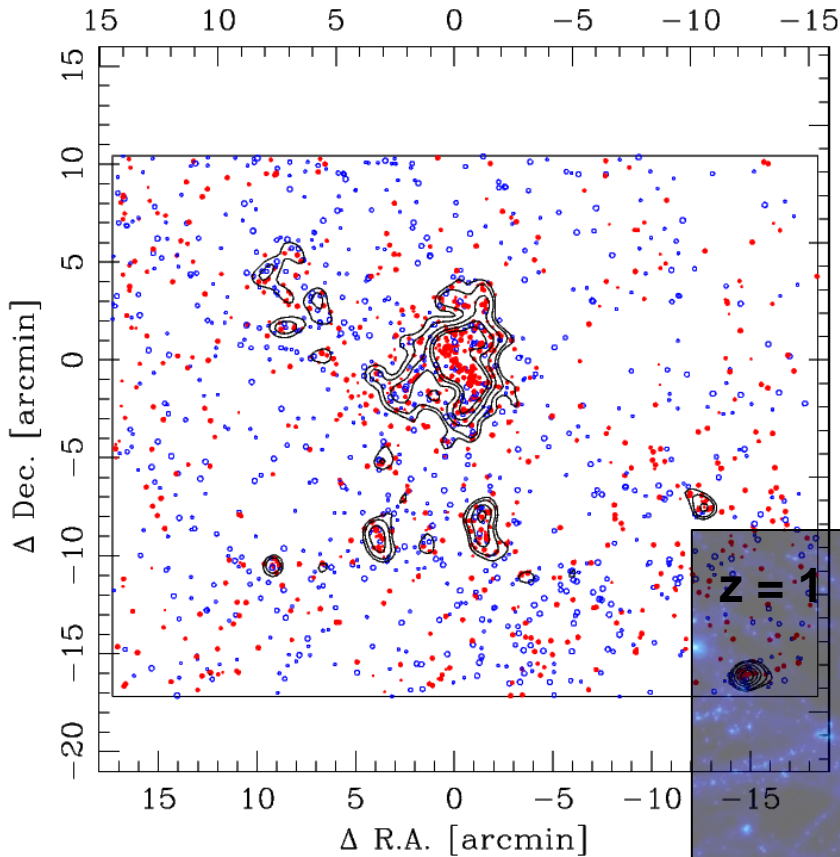


# Panoramic Views of Cluster Assembly

Spatial distribution of phot-z members (  $z = -0.05 \sim +0.03$  )

RXJ 0152.7-1357 (VRi'z')

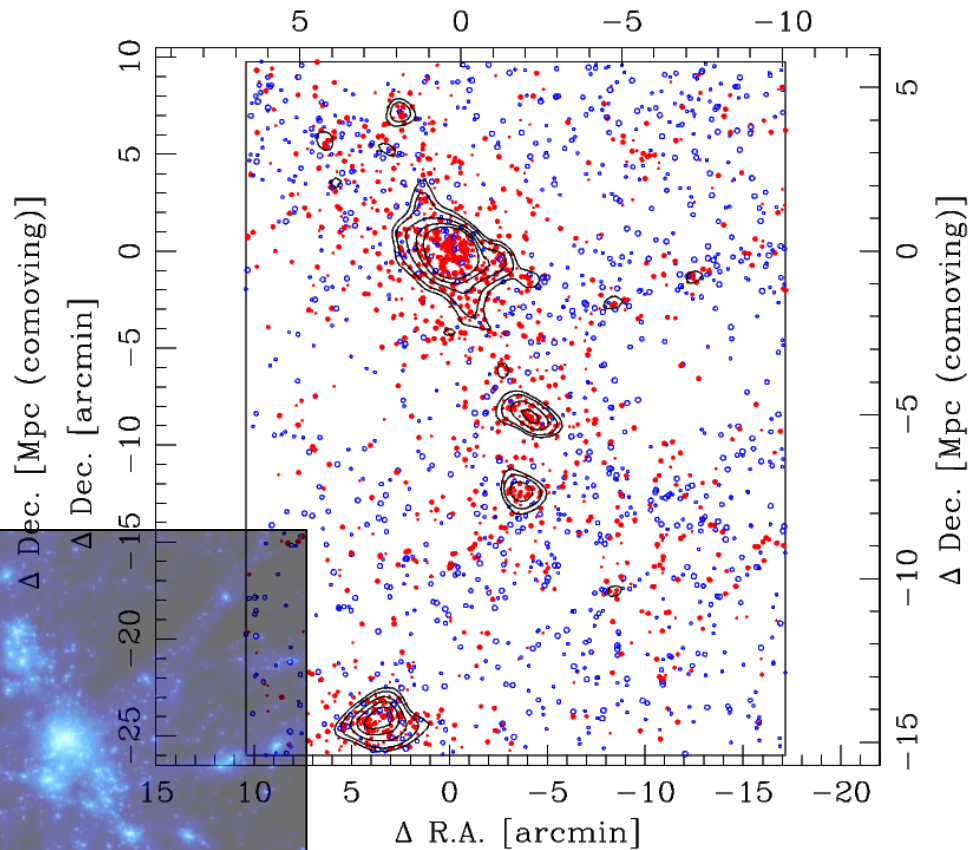
$\Delta$  R.A. [Mpc (comoving)]



$z=0.83$  (7Gyr ago)

CL 0016+16 (BVRi'z')

$\Delta$  R.A. [Mpc (comoving)]



$z=0.55$  (5.4Gyr ago)

Kodama, et al. (2005)

simulation

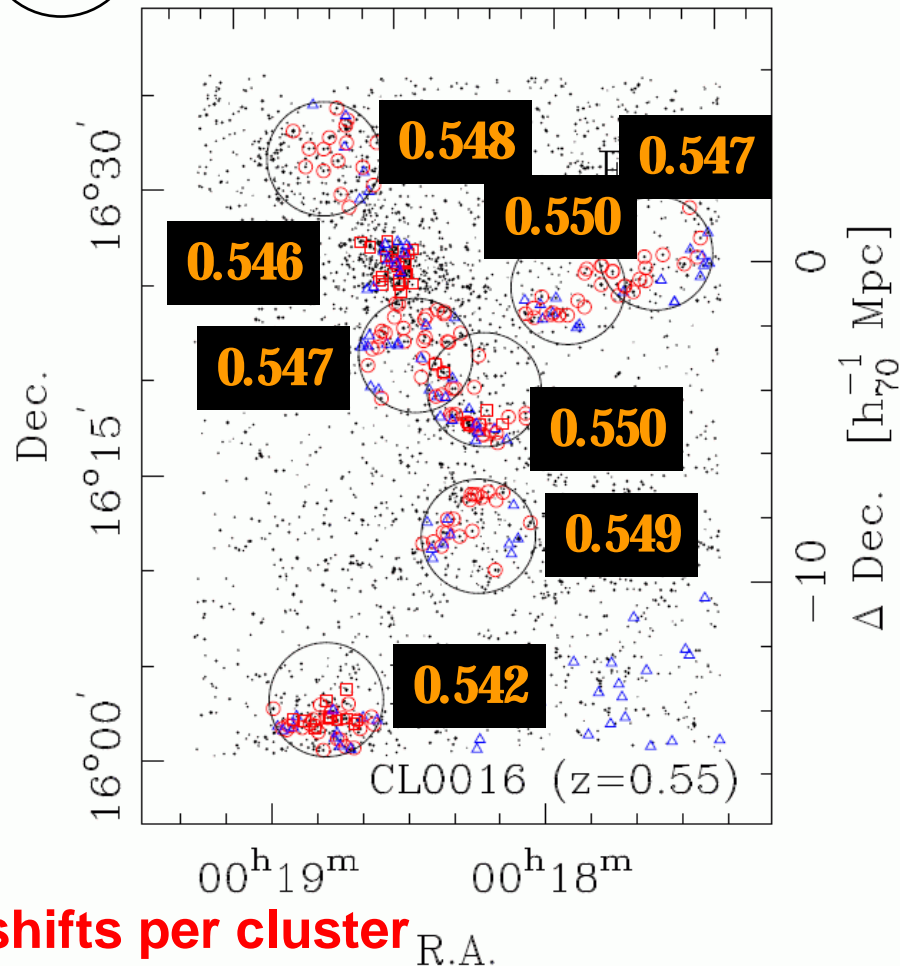
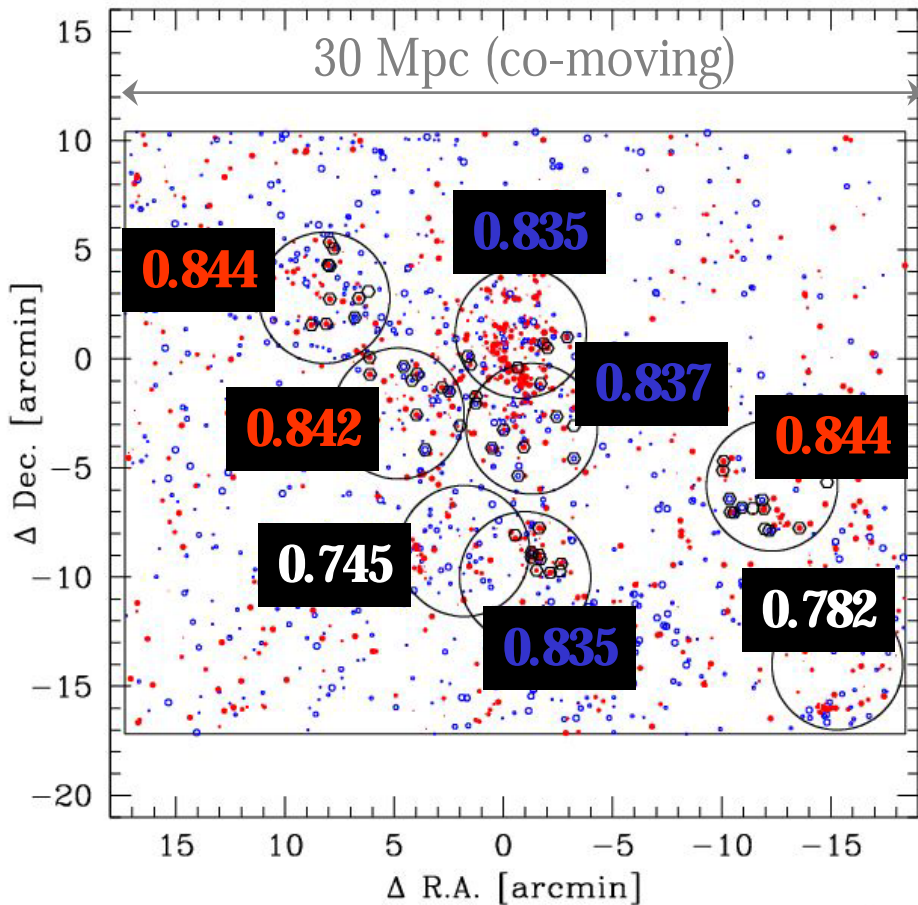
# Spectroscopic Confirmation of LSS

RXJ 0152.7-1357 (BVRI)

FOCAS

CL 0016+16 (BVRi'z')

5 0 -5 -10



**~200-300 redshifts per cluster** R.A.

**Physical association of most of the structures have been confirmed!**

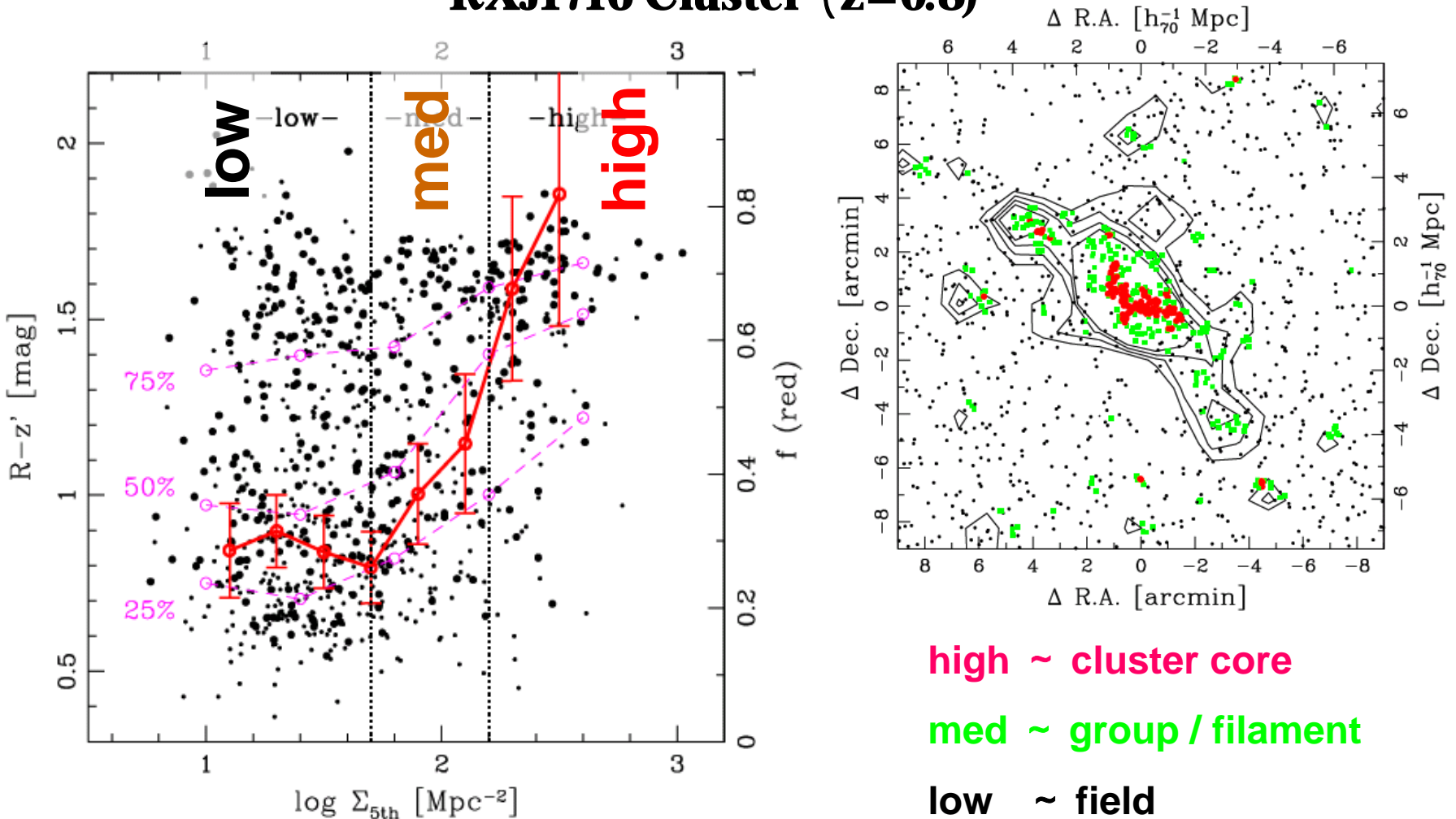
Tanaka, TK, et al. (2005b; 2007)



**PISCES**

# Sharp Colour Transition in Groups/Filaments

## RXJ1716 Cluster ( $z=0.8$ )



Koyama's talk

# Dusty star-bursting galaxies in groups/filaments at $z \sim 0.8$ (Subaru + AKARI)

$z'$   $\sim$  Stellar Mass

L15  $\sim$  Star Formation Rate



$z' - L15$

$$= -2.5 \log [ f(z') / f(15) ]$$

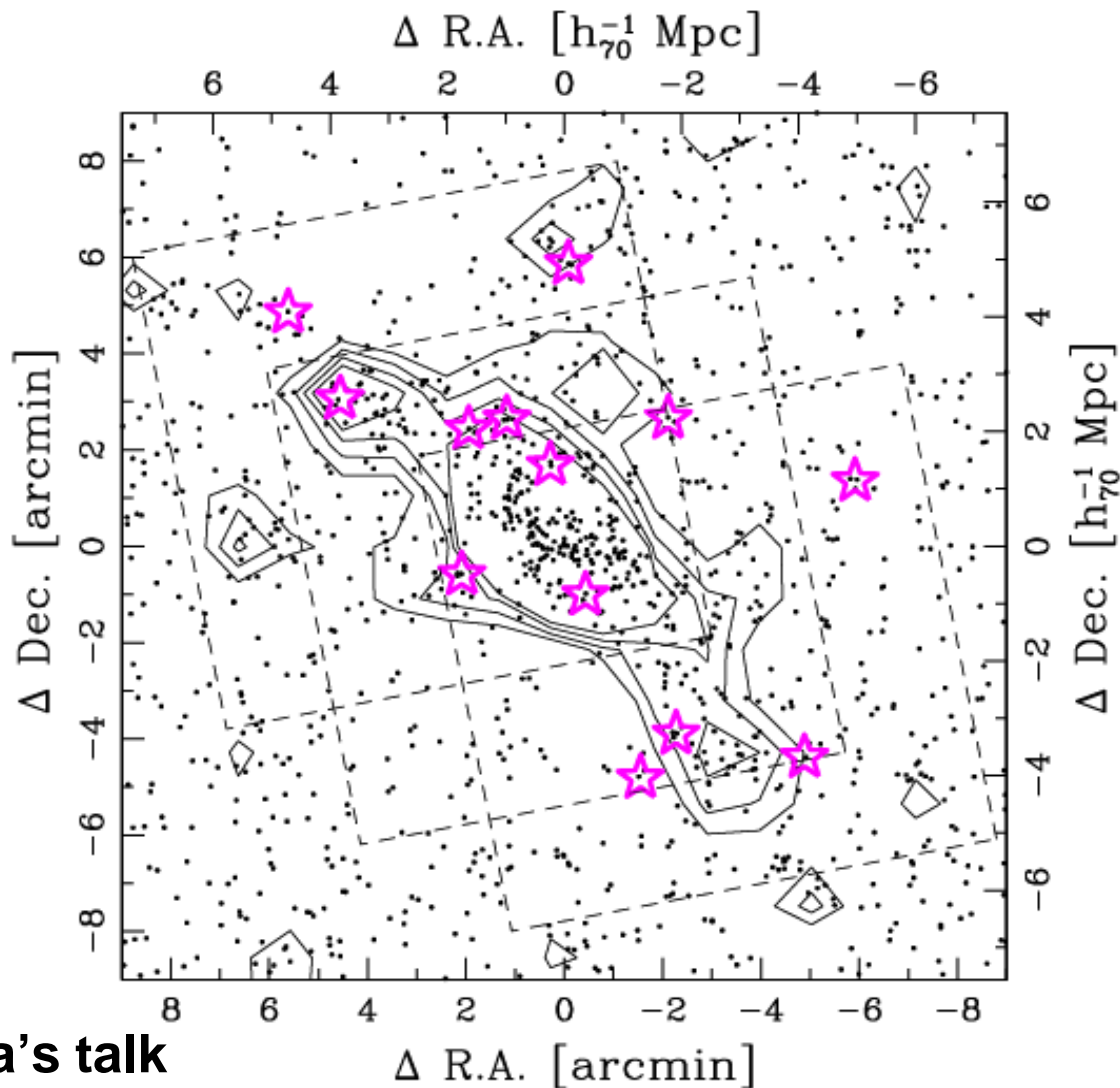
$$\sim \frac{\text{SFR}}{M(\text{star})}$$

“specific star formation rate”



large  $z' - L15$

large SF efficiency

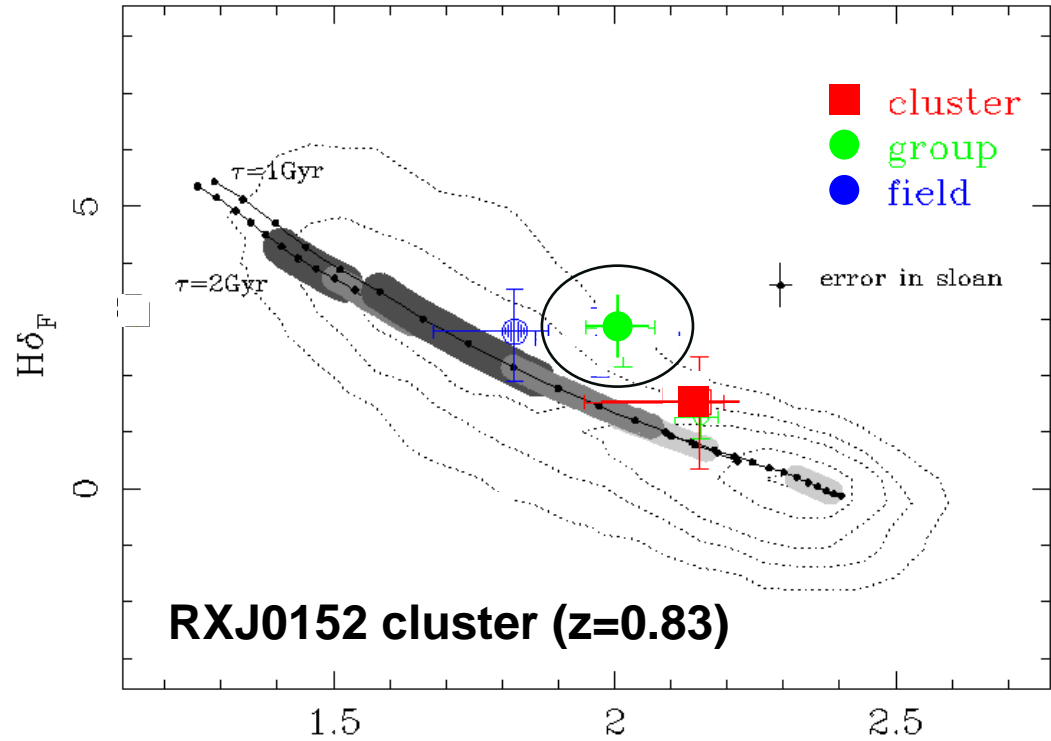
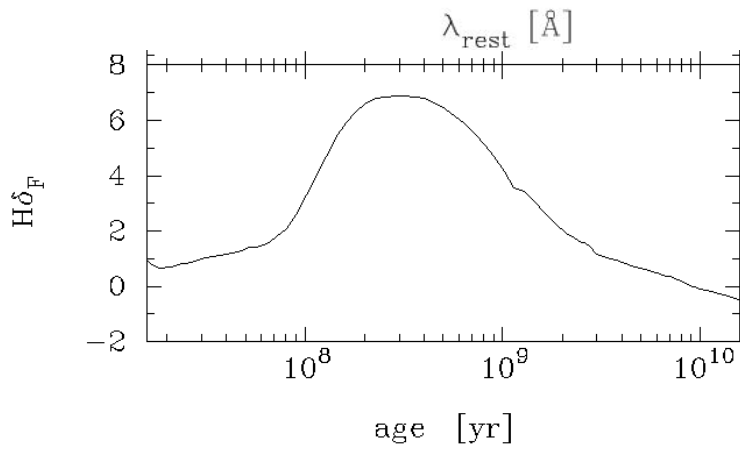
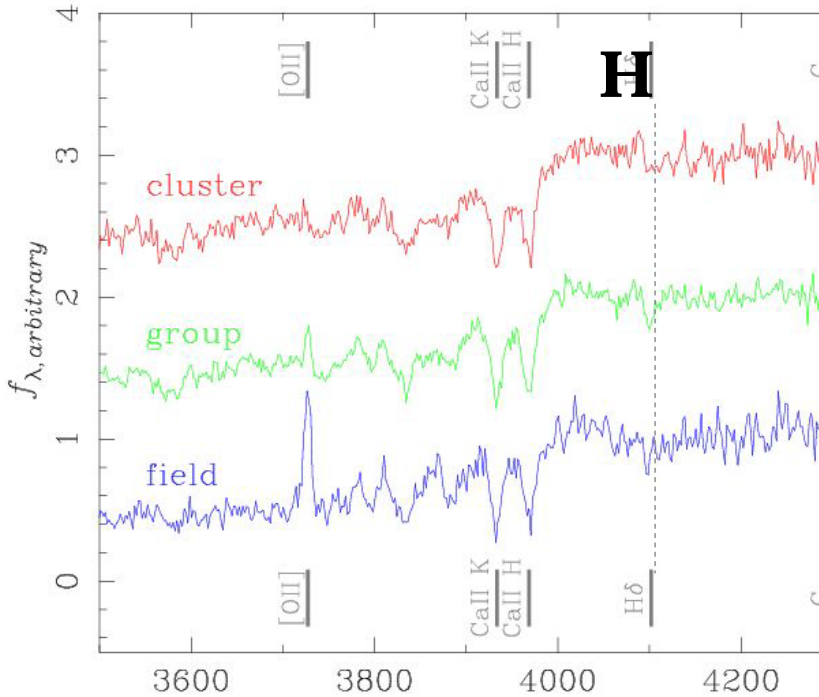


Koyama's talk

# Post star-burst galaxies in groups?

“Composite” spectra of red galaxies for Cluster/Group/Field

~2hrs integration with FOCAS  
~10 galaxies combined



Strong Balmer absorption lines (eg. H $\delta$ ) indicate “recent starburst activity”.

Tanaka, TK, et al. (2005b)

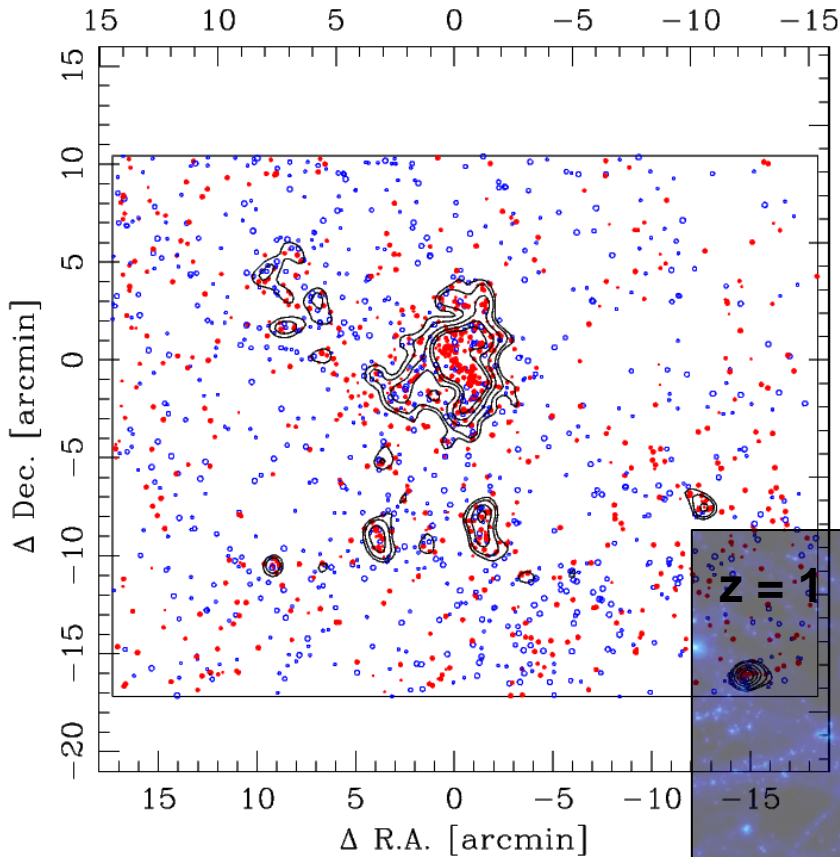


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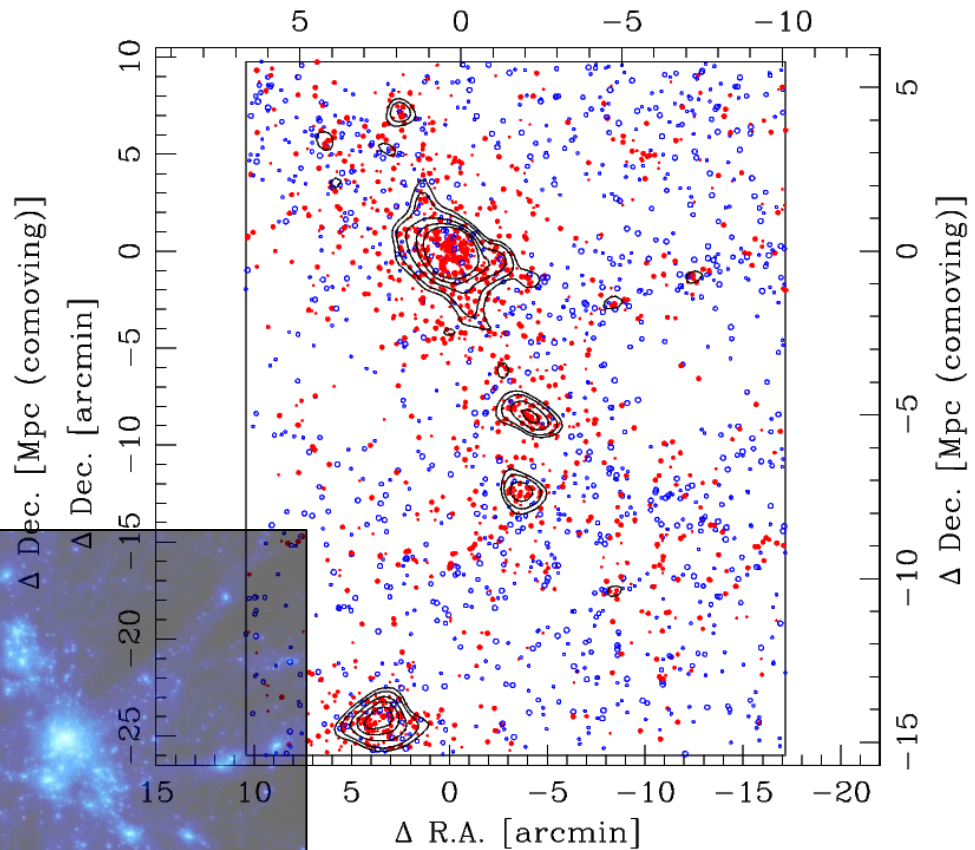
RXJ 0152.7-1357 (VRi'z')

$\Delta$  R.A. [Mpc (comoving)]



CL 0016+16 (BVRi'z')

$\Delta$  R.A. [Mpc (comoving)]



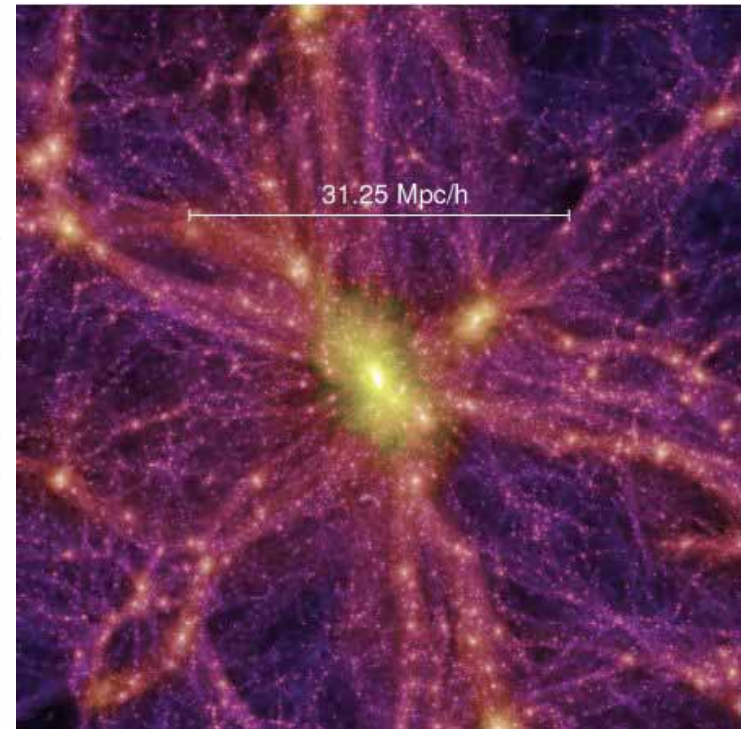
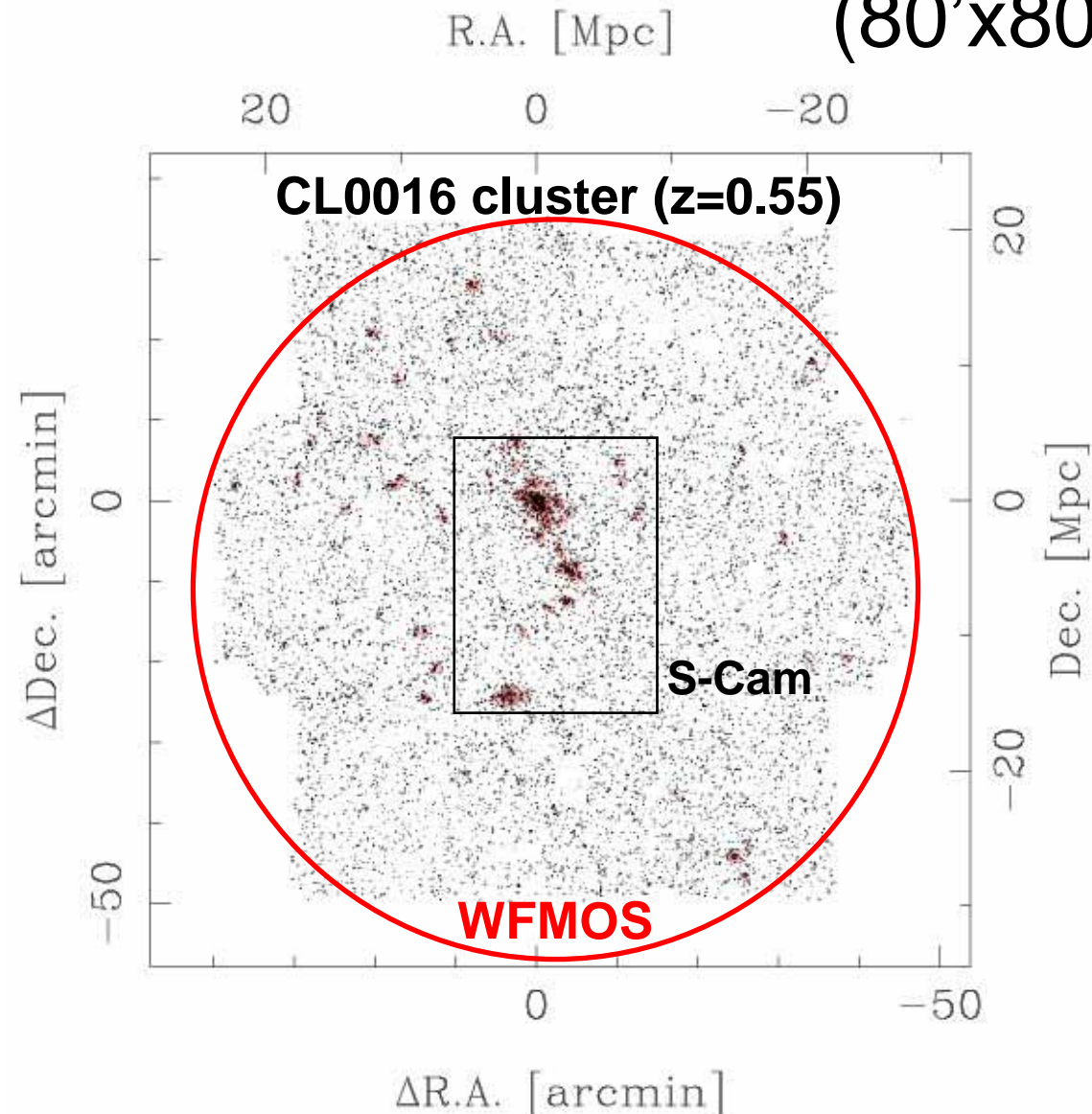
$z=0.83$  (7Gyr ago)

$z=0.55$  (5.4Gyr ago)

simulation

Kodama, et al. (2005)

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

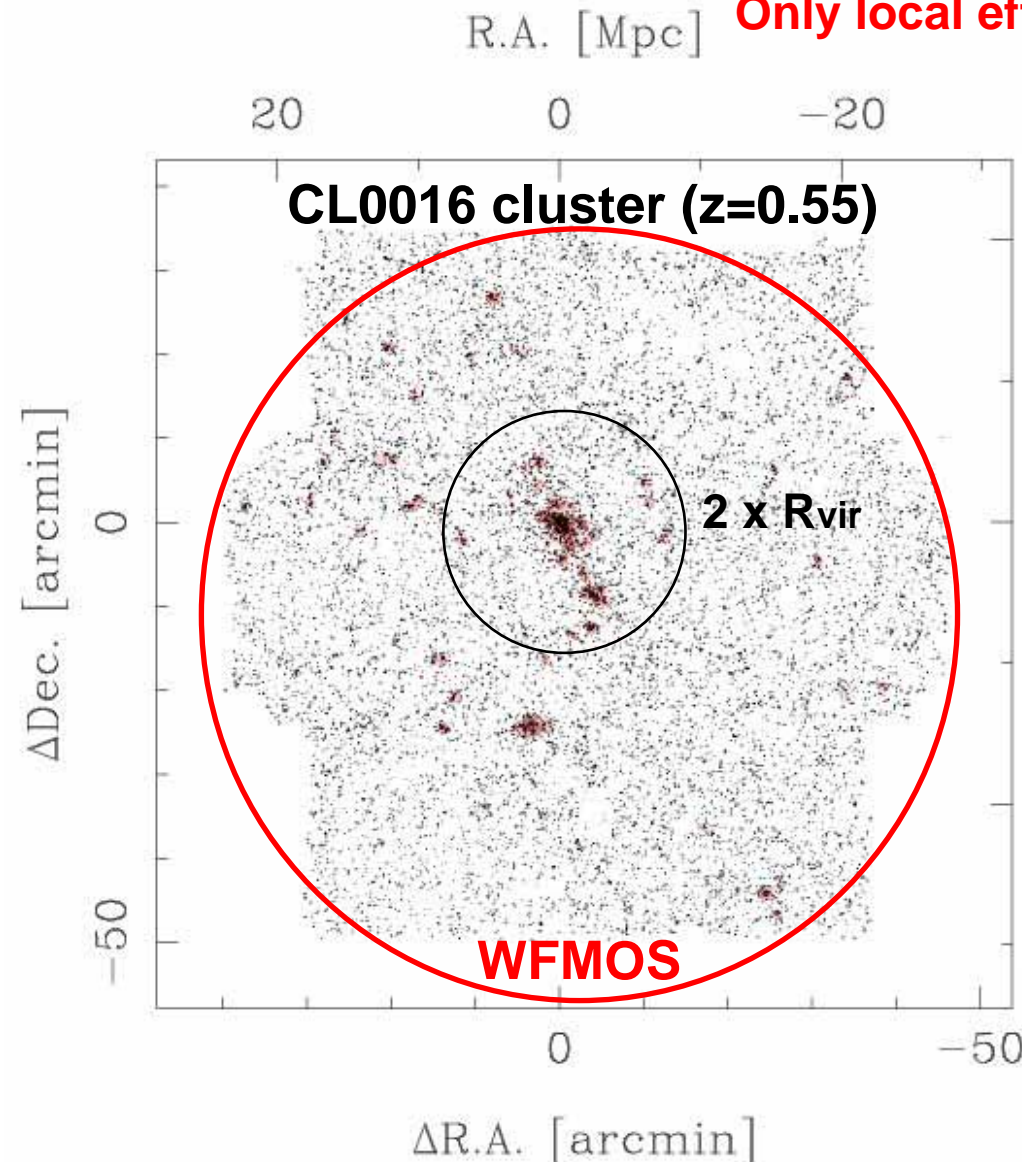


**Millennium Simulation  
(Springel et al. 2005)**

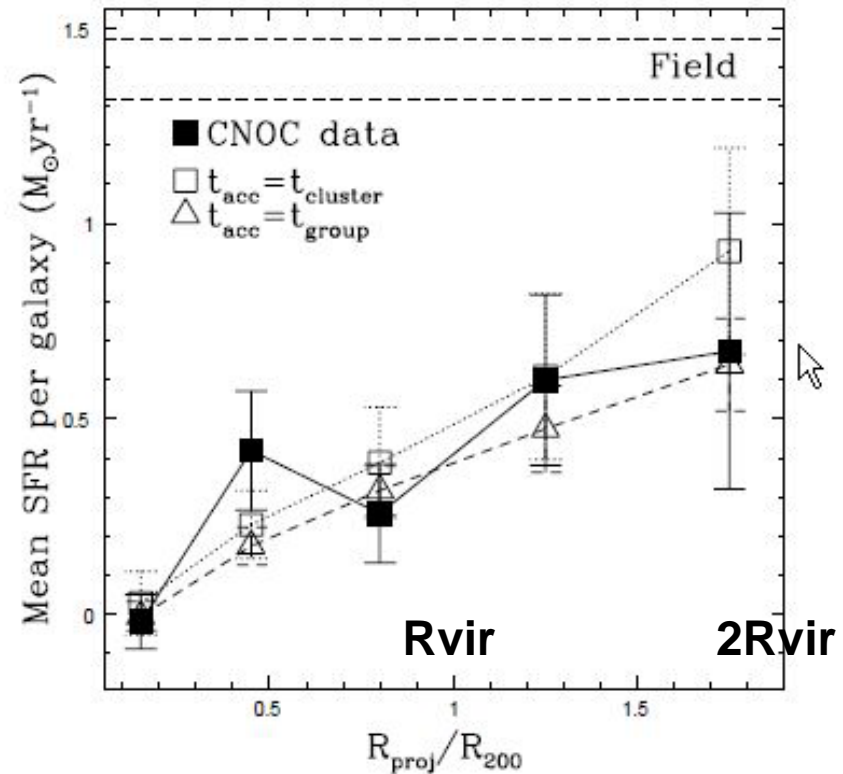
**Traced by red-sequence galaxies in V-I colours (Tanaka, et al., in prep.)**

# “Groups Near and Far”

Only local effects? or some global effect as well?



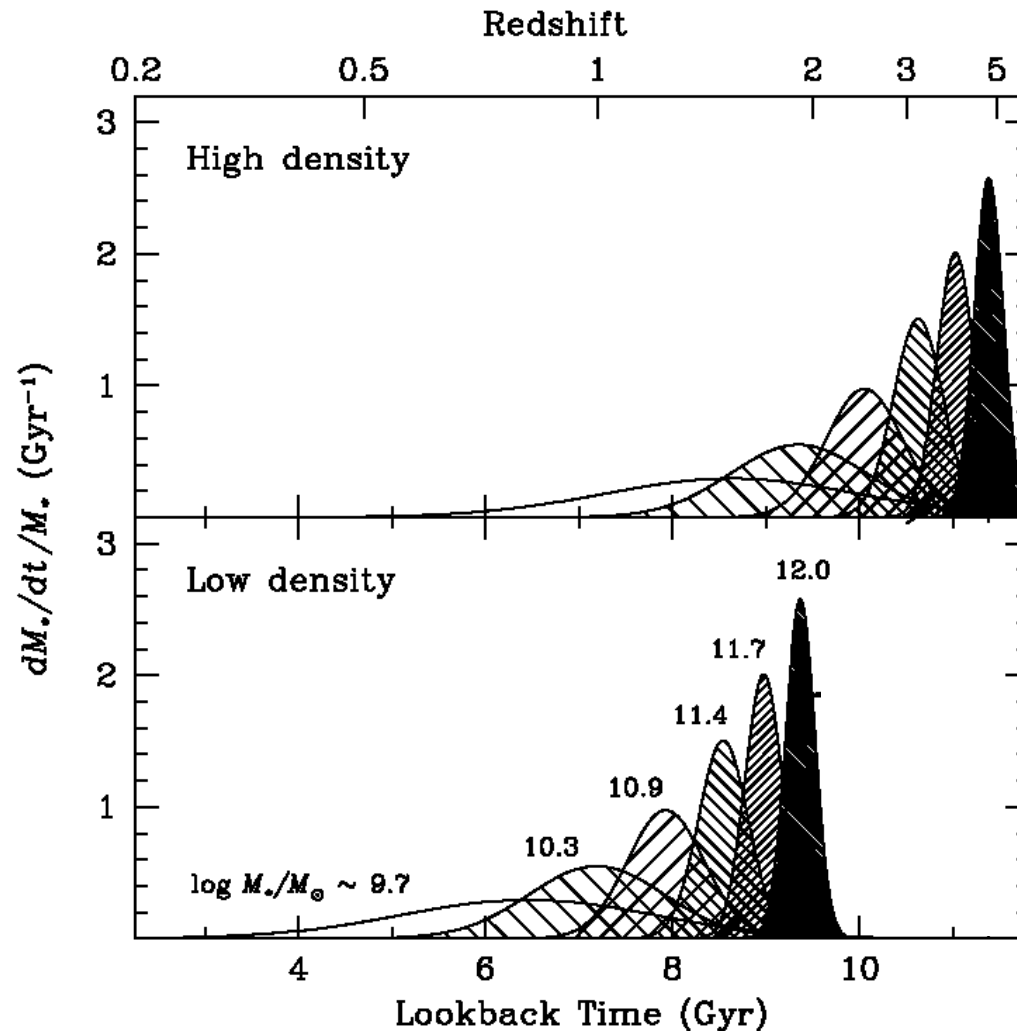
N-body simulation + truncation  
by Balogh et al. (2000)



“backsplash”

Many galaxies up to 2 x R<sub>vir</sub> have already passed the cluster center (<R<sub>vir</sub>) and may have been “processed”.

# Star Formation Histories (Down-Sizing) as functions of Mass and Environment



Thomas et al.  
(2005)

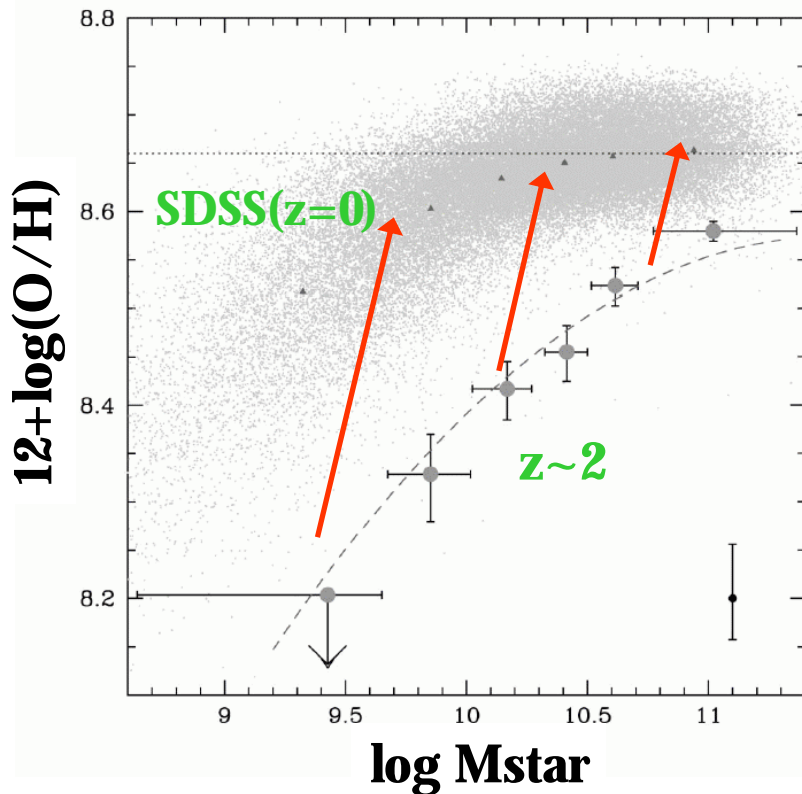
*high-mass/high-density  $\rightarrow$  low-mass/low-density*

# Chemical Evolution Traced by Line Emitters

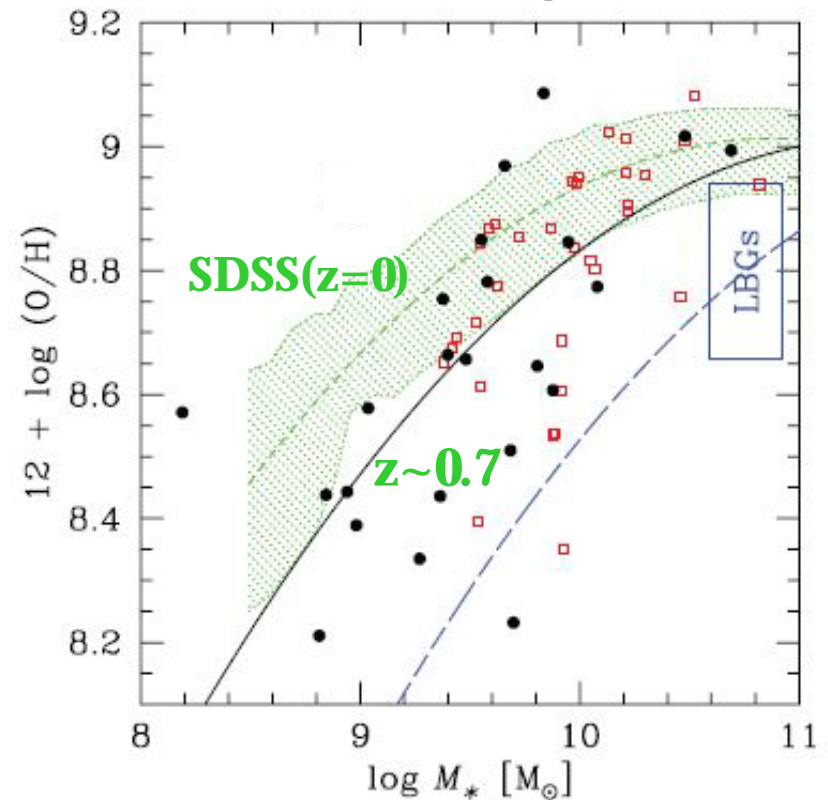
$\text{NII}/\text{H}$  ,  $(\text{OII}+\text{OIII})/\text{H}$  → gaseous metallicity

Synergy with  
BAO survey!

$z \sim 2$ , Erb et al. (2006)



GDDS+VFRS, Savaglio et al. (2005)



Chemical Evolution



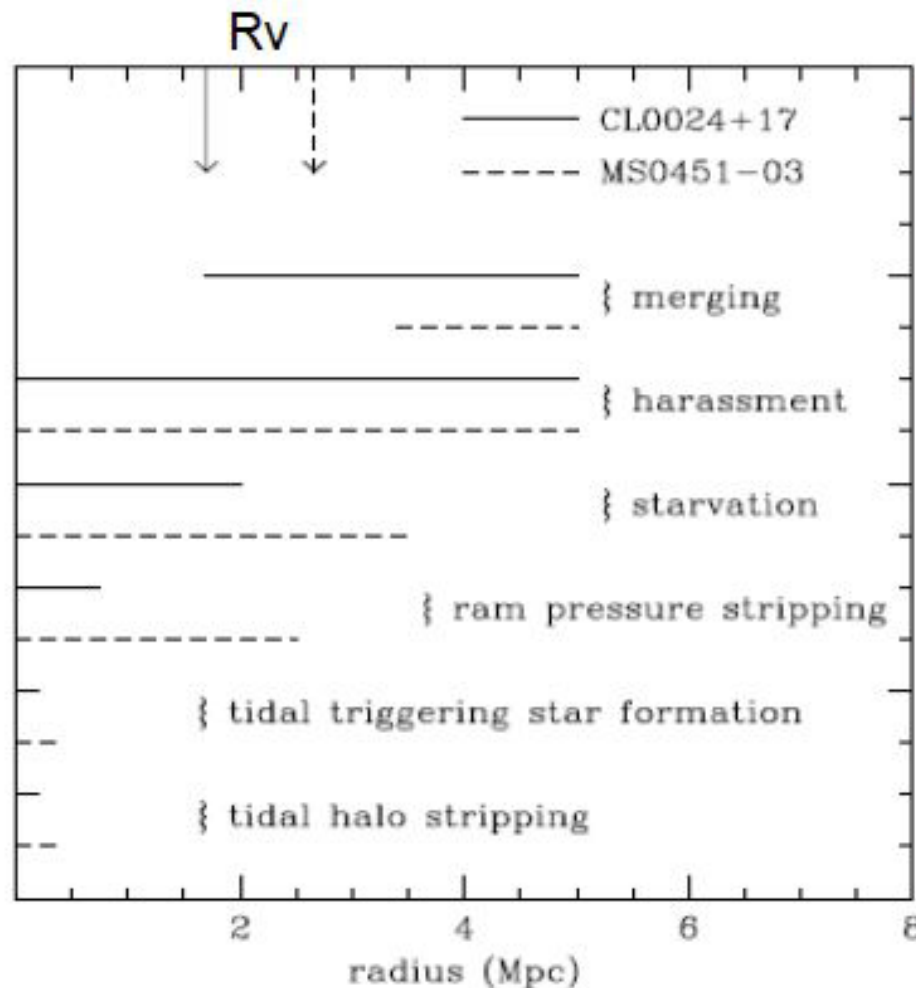
Feedback (outflow) as a func of mass !

Star Formation History

# Summary: Advantages of WFMOS survey of clusters

- Unbiased sample of clusters/groups to  $z \sim 1.4$   
10-100 deg<sup>2</sup> → 10-100 progenitors of present-day Abell clusters per  $z=0.1$ . (Direct, statistical evolutionary link!)
- No projection effect with secure redshifts  
2-D → 3-D structures like SDSS. (“Real” galaxy groups)
- Cosmic webs as ideal sites for ultimate studies of environmental effects.  
e.g. Can we see short-lived starbursts/post-starbursts in groups?  
e.g. Do groups within  $2xR_{\text{vir}}$  (processed) and those outside (pristine) have systematic difference? (“Groups Near and Far”)
- Cosmic chemical evolution to  $z \sim 1$  (by-product of BAO)  
Comparison with SFH → Feedback (e.g. outflow) as a function of galaxy mass.

# Physical Processes of Environmental Effects



Passive spirals are also preferentially seen in group environments.

**Moran et al. (2007)**

In group (medium-density) environments, ram-pressure stripping of cold gas cannot be a dominant process and galaxy-galaxy interactions (mergers/harassment) and starvation/suffocation (halo gas stripping) are more likely to be playing major roles.