JCMT JCMT & HSC : JCMT Deep submm imaging of dusty starbursts in protoclusters at 2<z<6</td>

-Project summary and current status report-

On behalf of MAHALO-JCMT (PI: T. Kodama) and HSC-protocluster team



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Galaxy evolution on the main seq. and its environ. dependence



Boylan-Kolchin+09

MAHALO-Subaru

MApping HAlpha and Lines of Oxygen with Subaru

Unique sample of NB-selected SF galaxies across environments and cosmic times

	environ-	target	z	line	λ	camera	NB-filter	conti-	status
	ment				(μm)			nuum	(as of Apr 2015)
	Low-z	CL0024+1652	0.395	$H\alpha$	0.916	Suprime-Cam	NB912	z'	Kodama+'04
7<1	clusters	CL0939+4713	0.407	$H\alpha$	0.923	Suprime-Cam	NB921	z'	Koyama+'11
271		CL0016+1609	0.541	$H\alpha$	1.011	Suprime-Cam	NB1006	z'	not yet
clusters		RXJ1716.4+6708	0.813	$H\alpha$	1.190	MOIRCS	NB1190	J	Koyama+'10
				[O11]	0.676	Suprime-Cam	NA671	R	observed
		RXJ0152.7–1357	0.837	[O111]	0.920	Suprime-Cam	NB921	z'	not yet
-~15	High-z	XCSJ2215–1738	1.457	[OII]	0.916	Suprime-Cam	NB912, NB921	z'	Hayashi+'10, '12
2~1.5	clusters	4C65.22	1.516	$H\alpha$	1.651	MOIRCS	NB1657	H	Koyama+'14
clusters		CL0332-2742	1.61	[O11]	0.973	Suprime-Cam	NB973	\boldsymbol{y}	observed
		ClGJ0218.3-0510	1.62	[O11]	0.977	Suprime-Cam	NB973	\boldsymbol{y}	Tadaki+'12
	Proto-	PKS1138-262	2.156	$H\alpha$	2.071	MOIRCS	NB2071	$K_{\rm s}$	Koyama+'12
	clusters	HS1700+64	2.30	$_{ m Hlpha}$	2.156	MOIRCS	\mathbf{BrG}	$K_{\rm s}$	observed
-> 0				[O111]	1.652	MOIRCS	[Fe 11]	H	not yet
Z>2		4C23.56	2.483	$_{ m Hlpha}$	2.286	MOIRCS	CO	$K_{\rm s}$	Tanaka+'11
clustors		USS1558-003	2.527	$_{ m Hlpha}$	2.315	MOIRCS	NB2315	$K_{\rm s}$	Hayashi+'12
ciusters		MRC0316-257	3.130	[O11]	2.539	MOIRCS	NB1550	H	not yet
				[O111]	2.068	MOIRCS	NB2071	$K_{ m s}$	observed
	General	SXDF-CANDELS	2.16	$H\alpha$	2.071	MOIRCS	NB2071	$K_{\rm s}$	observed
	fields	(90 arcmin ²)	2.19	$H\alpha$	2.094	MOIRCS	NB2095	$K_{ m s}$	Tadaki+'13
			2.53	$H\alpha$	2.315	MOIRCS	NB2315	$K_{\rm s}$	Tadaki+'13
-> 0			3.17	[O111]	2.093	MOIRCS	NB2095	$K_{\rm s}$	Suzuki+'14
Z>Z			3.63	[O111]	2.317	MOIRCS	NB2315	$K_{\rm s}$	Suzuki+'14
field		COSMOS-CANDELS	2.16	$H\alpha$	2.071	MOIRCS	NB2071	$K_{ m s}$	partly observed
		(90 arcmin ²)	2.19	$H\alpha$	2.094	MOIRCS	NB2095	$K_{ m s}$	partly observed
		GOODS-N	2.19	$H\alpha$	2.094	MOIRCS	NB2095	$K_{ m s}$	Tadaki+'11
		(70 arcmin ²)		[O11]	1.189	MOIRCS	NB1190	J	observed

~20 nights for imaging, >15 nights for spectroscopy

Kodama et al. (2013)

Spatial distributions of Ha emitters in two proto-clusters at z>2

Lots of HAEs live in proto-cluster cores, indicating strong SF activities there. Red HAEs (J-Ks >1.38; dusty starbursts) tend to favor dense cores/clumps!

Massive + dusty galaxies in the proto-cluster core

Red Ha emitters are very massive ($M \star > 10^{11} M_{\odot}$) and dusty star-forming galaxies. Many are detected at 24µm with MIPS.

 \rightarrow Cluster specific/preferred phenomena at high-z, holding a key to understanding the early environmental effects.

MAHALO-JCMT

USS1558-003 (z=2.53)

A coordinated program with JCMT (~100hrs) to map dusty starbursts in proto-clusters.

(15AB; Kodama et al.)

as of 2016/01/31

Cluster	Redshift	Integrat	tion
PKS1138-262	2.16	7.5 h	
2QZ10hr	2.23	10.0 h	
4C23.56	2.48	1.0 h	
USS1558-003	2.53	15.0 h	
USS0943-242	2.92	10.0 h	
MRC0316-257	3.13	13.0 h	
TNJ1338-1942	4.11	8.0 h	
SDF-z6cluster	6.00	15.0 h	

14hrs on-source integration with SCUBA-2 in DAISY mode (FoV~6') \rightarrow 1.26mJy (3 σ)=220M•/yr at center, 1.7mJy=300M•/yr at edge (@850µm)

MAHALO-JCMT

Enhanced dusty starbursts (Twelve 850µm sources within the MOIRCS deep image). Spatial distributions are similar (NNE-SSW filament) between 850µm sources and HAEs.

Subaru-HSC Legacy Surveys

Science goals

layer	area (deg ²)	filters	depth (mag)
Wide	1400 (700 deg ² × 2 fields)	grizy	<i>i</i> ~25.9
Deep	27 (7 deg ² × 4 fields)	grizy + 3NB	<i>i</i> ~26.8
Ultradeep	3.5 (1.8 deg ² × 2 fields)	grizy + 3NB	<i>i</i> ~27.4

- 1. Ultradeep/Deep layer (~27 deg2) ~10-20 protoclusters will be found at each redshift → redshift evolution of protoclusters
- 2. Wide layer (~1400 deg2)
 ~1000 protoclusters will be found at z~4 (g-dropout)
 → variety of protoclusters

Expectation

survey	area	cluster number (dn/dz)
HSC-Deep	27 deg ²	200 (>10 ¹⁴ M_{\odot}) at z=1
		6 (>10 ^{14.5} M _•) at z=1
HSC-Wide	1400 deg ²	10,000 (>10 ¹⁴ M_{\odot}) at z=1
		300 (>10 ^{14.5} M _☉) at z=1

Our recent JCMT program as **DDT pilot** (HSC protocluster followup) (PI : M. Yuichi)

SCUBA-2 mapping of HSC-selected galaxy clusters at 1 < z < 7

- 5-6 targets will be observed as DDT pilot program
- We are currently carefully brushing-up our final target source for the classical observation on July

Summary

- The successful JCMT follow-up of galaxies detected with MAHALO-Subaru program
 - We are currently working on the *data reduction* (~80 % completion of the requested time)
 - for USS1558 : potential detection that are associated to colorselected (DRG) galaxies are to be followed-up by ALMA
 - other 5 protocluster : several detection above > 5σ
 - analysis is, and will be undertaken in detail
 - number density, SFRD etc.

• JCMT-HSC synergy :

- HSC protocluster survey is NOW dramatically increasing the number of protoclusters z>1 up to z=7
- 5-6 sources through the approved DDT program would open a new potential between JCMT and HSC synergy, in terms of starburst phase occurrence in over dense region and thus the galaxy evolution