SWIMS Workshop (IoA, Univ. of Tokyo; Sep 17-18)

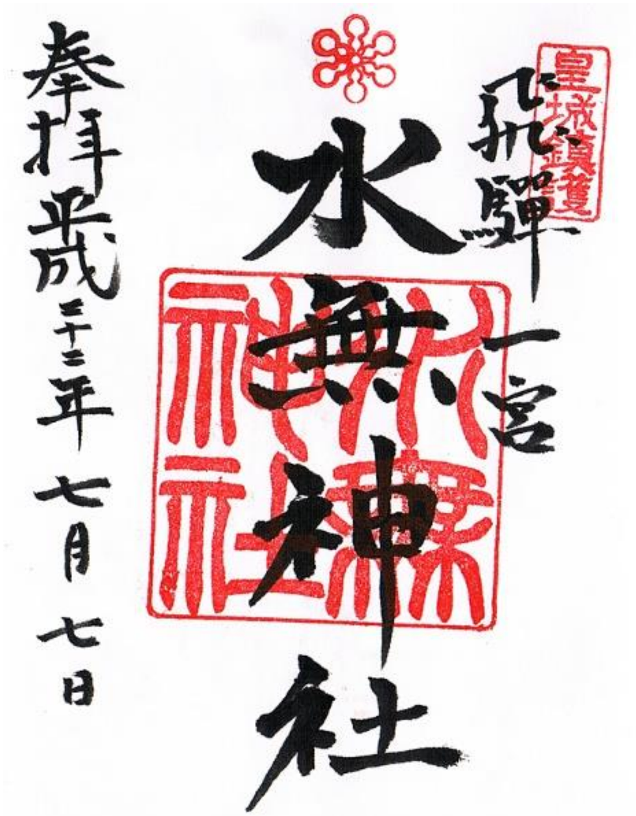
Superb, Wide-field, Imaging, Multi-colour Survey, with 18 Filters

SWIMS-18

Taddy Kodama (NAOJ) on behalf of the SWIMS-18 team

A galaxy cluster RXJ0152 at z=0.83 (Subaru/Suprime-Cam)

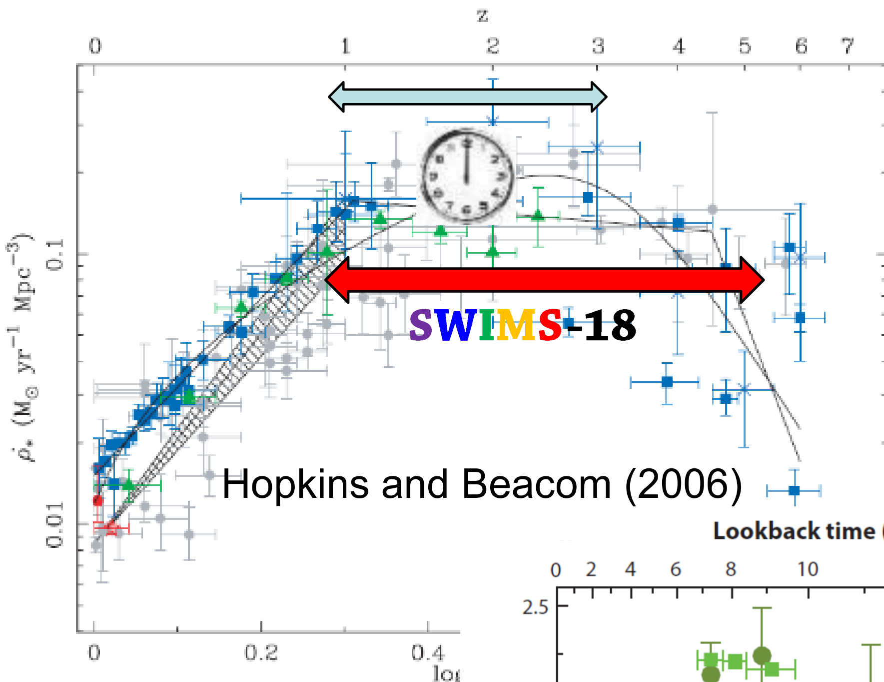
SWIMSrine



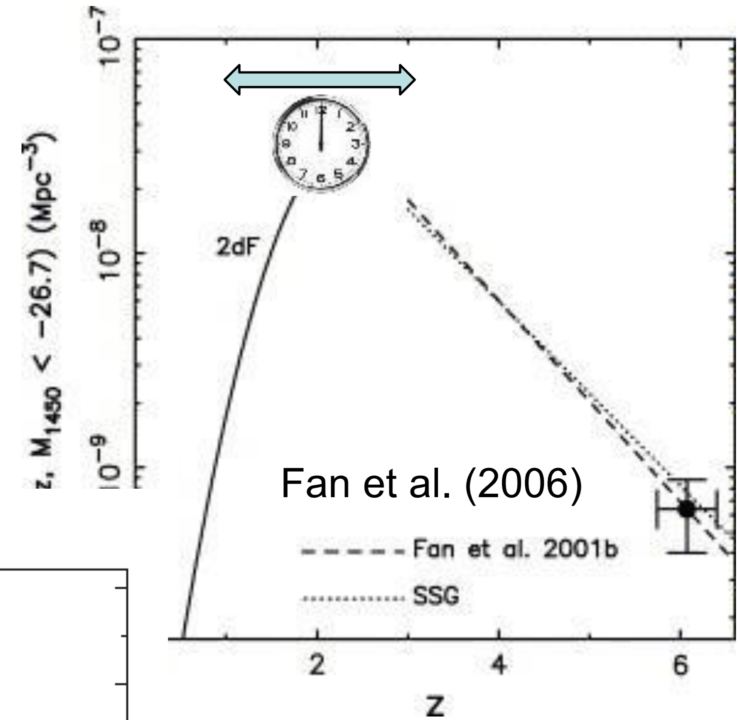
No Water!

"COSMIC HIGH NOON"

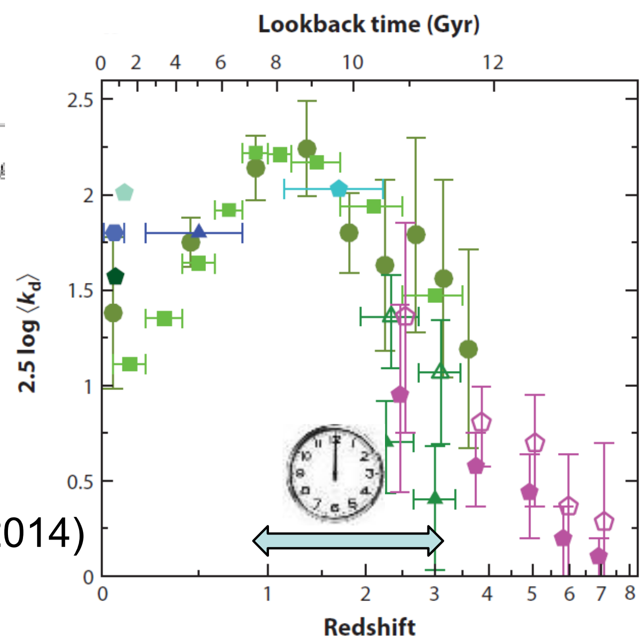
The peak epoch of galaxy/SMBH formation/dust extinction: 1<z<3 (6>T_{cos}(Gyr)>2)



Star formation



BH accretion (AGN/QSO)



Madau & Dickinson (2014)

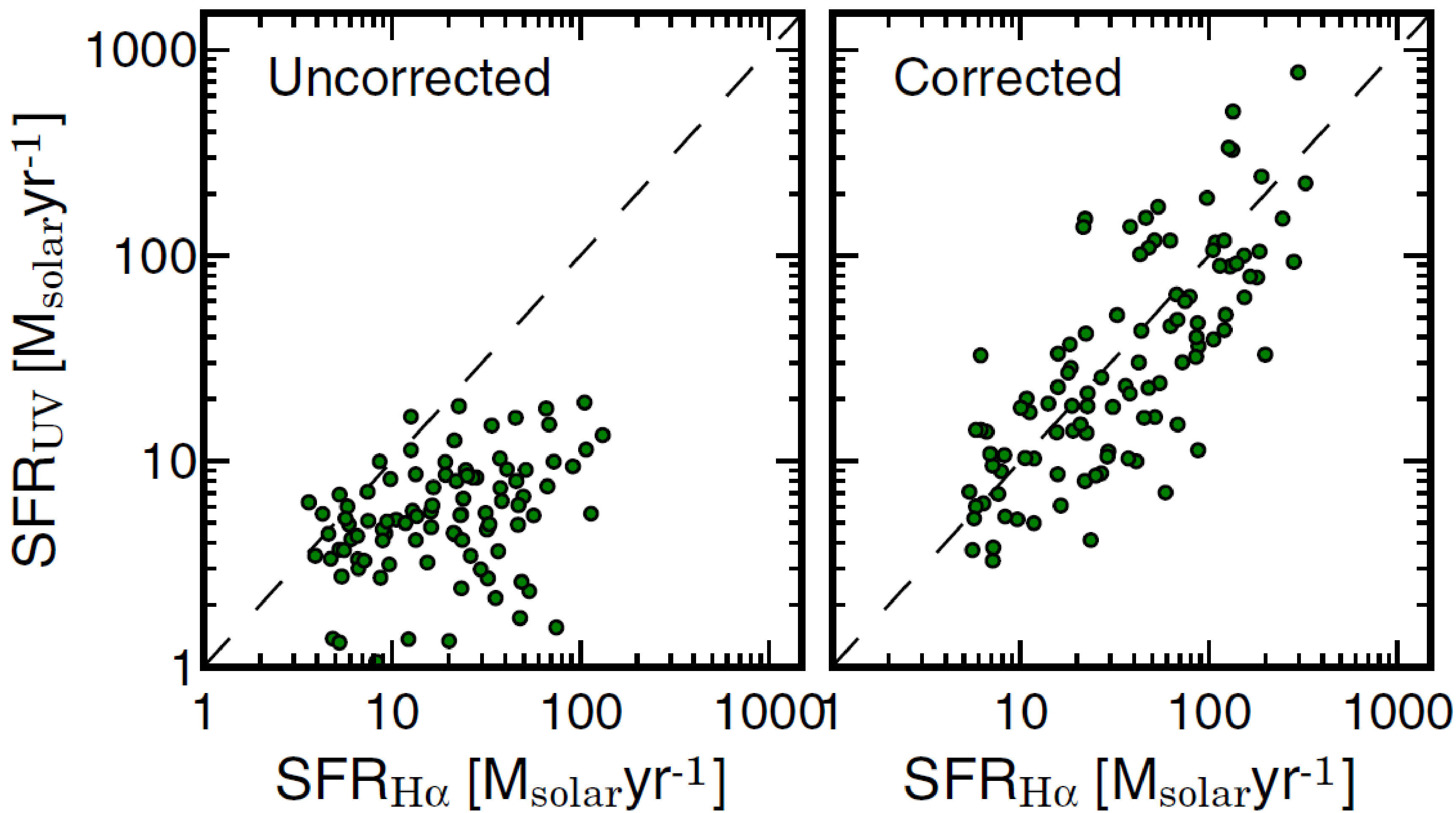
Dust extinction

The Cosmic High Noon tends to be hidden by dust!

Comparison of dust extinction between UV and Hα

SFGs at z~2.2-2.5 (NB-selected Hα emitters)

Tadaki et al. (2013)



Rest-UV is NOT a good tracer of SF in this critical era → Go for Hα and [OIII] at NIR!

MAHALO-Subaru

MApping HAlpha and Lines of Oxygen with Subaru

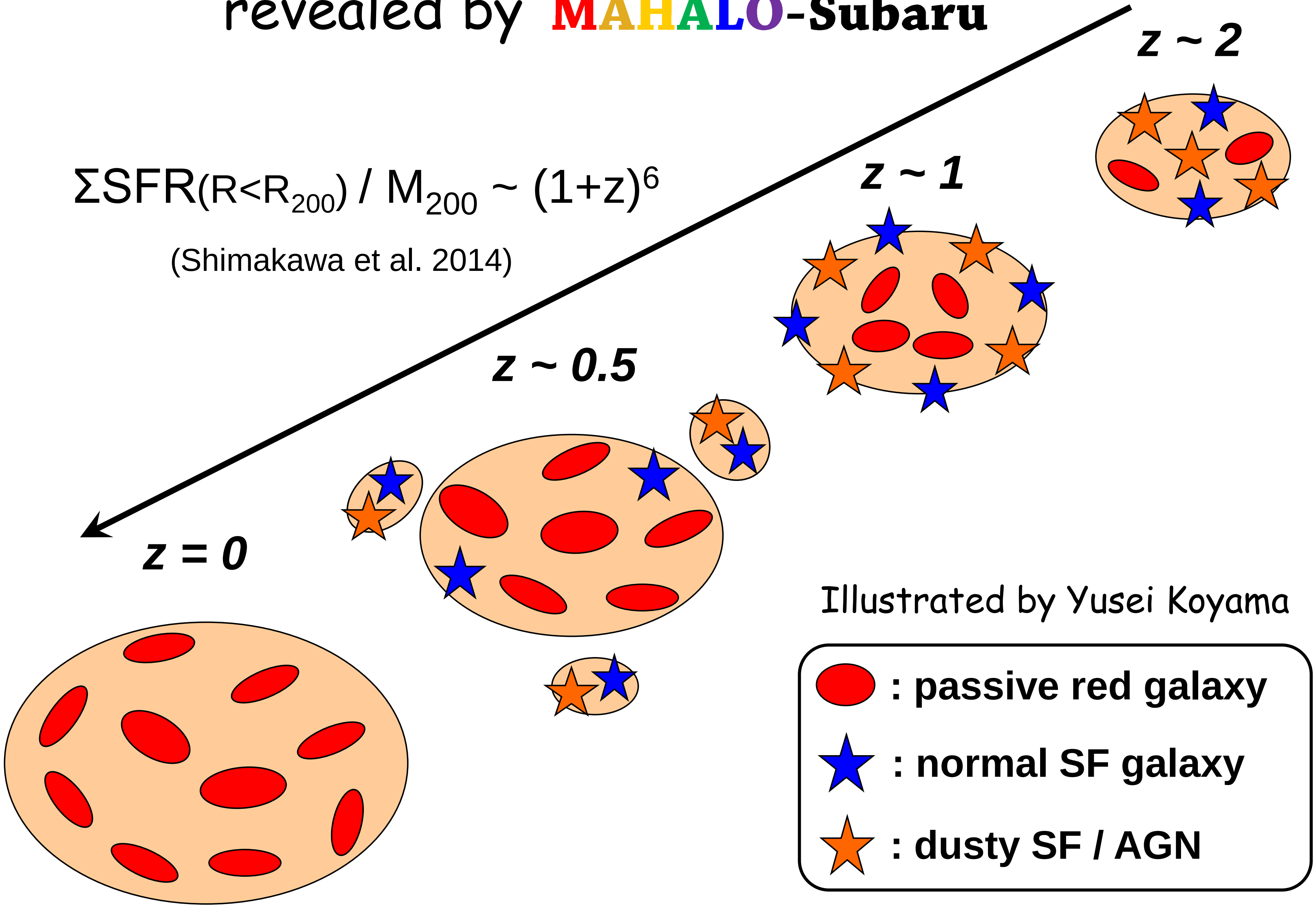
(PI: T. Kodama)

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

	environ-ment	target	z	line	λ (μm)	camera	NB-filter	conti-nuum	status (as of Oct 2014)
z<1 clusters	Low-z clusters	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
		CL0016+1609	0.541	Hα	1.011	Suprime-Cam	NB1006	z'	not yet
		RXJ1716.4+6708	0.813	Hα	1.190	MOIRCS	NB1190	J	Koyama+'10
				[OII]	0.676	Suprime-Cam	NA671	R	observed
z~1.5 clusters	High-z clusters	XCSJ2215–1738	1.457	[OII]	0.916	Suprime-Cam	NB912, NB921	z'	Hayashi+'10, '12
		4C65.22	1.516	Hα	1.651	MOIRCS	NB1657	H	Koyama+'14
		CL0332–2742	1.61	[OII]	0.973	Suprime-Cam	NB973	y	observed
		ClGJ0218.3–0510	1.62	[OII]	0.977	Suprime-Cam	NB973	y	Tadaki+'12
z>2 clusters	Proto-clusters	PKS1138–262	2.156	Hα	2.071	MOIRCS	NB2071	K_s	Koyama+'12
		HS1700+64	2.30	Hα	2.156	MOIRCS	BrG	K_s	observed
				[OIII]	1.652	MOIRCS	[Fe II]	H	not yet
		4C23.56	2.483	Hα	2.286	MOIRCS	CO	K_s	Tanaka+'11
		USS1558–003	2.527	Hα	2.315	MOIRCS	NB2315	K_s	Hayashi+'12
		MRC0316–257	3.130	[OII]	2.539	MOIRCS	NB1550	H	not yet
				[OIII]	2.068	MOIRCS	NB2071	K_s	observed
z>2 field	General	GOODS-N	2.19	Hα	2.094	MOIRCS	NB2095	K_s	Tadaki+'11
		(70 arcmin^2)		[OII]	1.189	MOIRCS	NB1190	J	observed
		SXDF-CANDELS	2.19	Hα	2.094	MOIRCS	NB2095	K	Tadaki+'13
		(92 arcmin^2)	2.53	Hα	2.315	MOIRCS	NB2315	K_s	Tadaki+'13
			3.17	[OIII]	2.093	MOIRCS	NB2095	K_s	Suzuki+'14
			3.63	[OIII]	2.317	MOIRCS	NB2315	K_s	Suzuki+'14

20 nights for imaging, >15 nights for spectroscopy

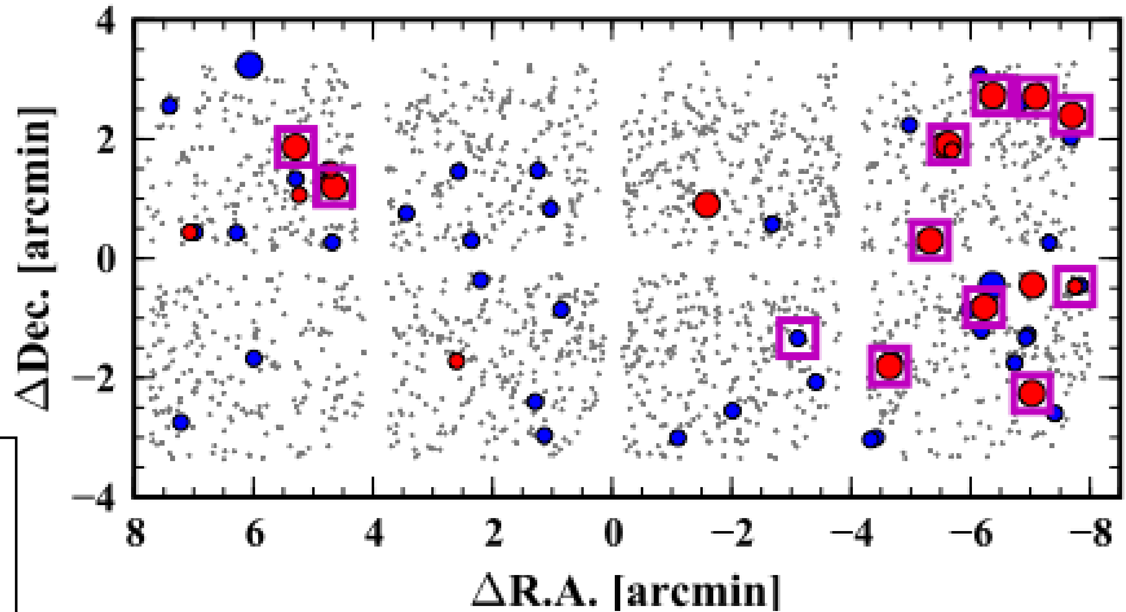
Inside-out growth of galaxy clusters revealed by MAHALO-Subaru



Star forming galaxies at the peak epoch @SXDF-UDS-CANDELS

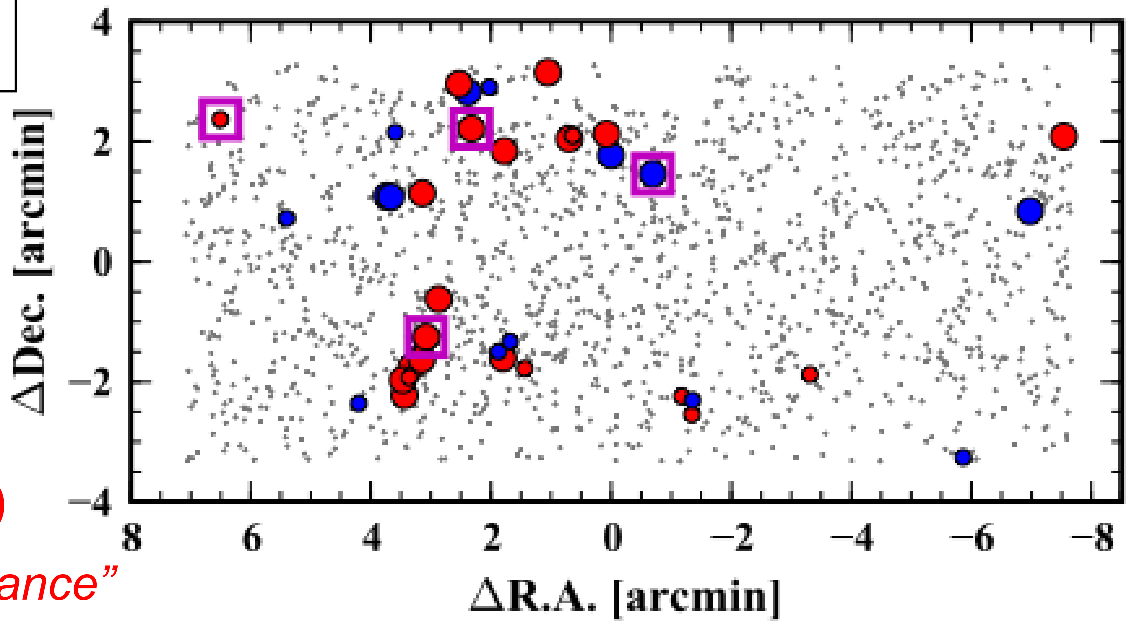
Tadaki et al. (2013a)

z=2.2 Hα emitters
(NB2095)



● : blue HAE (J-K<1)
● : red HAE (J-K>1)
□ : MIPS sources
(dusty star-bursting galaxies)

z=2.5 Hα emitters
(NB2315)



Limited to ~200 $arcmin^2$
(SXDF-UDS and COSMOS)

Strong clustering → *"cosmic variance"*

SWIMS-18

"NIR version of COMBO-17"

Super multi-λ (NIR) imaging survey of the "Cosmic High Noon" over a 1-deg^2 unbiased field + some high density regions

- 6 Narrow-Band Filters (NBF)
  SFR limited sample and AGNs at z=0.9, 1.5, 2.3, 3.3.
  Hα & [OIII] dual emitters with pair NBFs.

- 9 Medium-Band Filters (MBF)
  Stellar mass limited sample at $1<z<5$ with improved phot-z ($\Delta z/(1+z) \sim 0.01$).

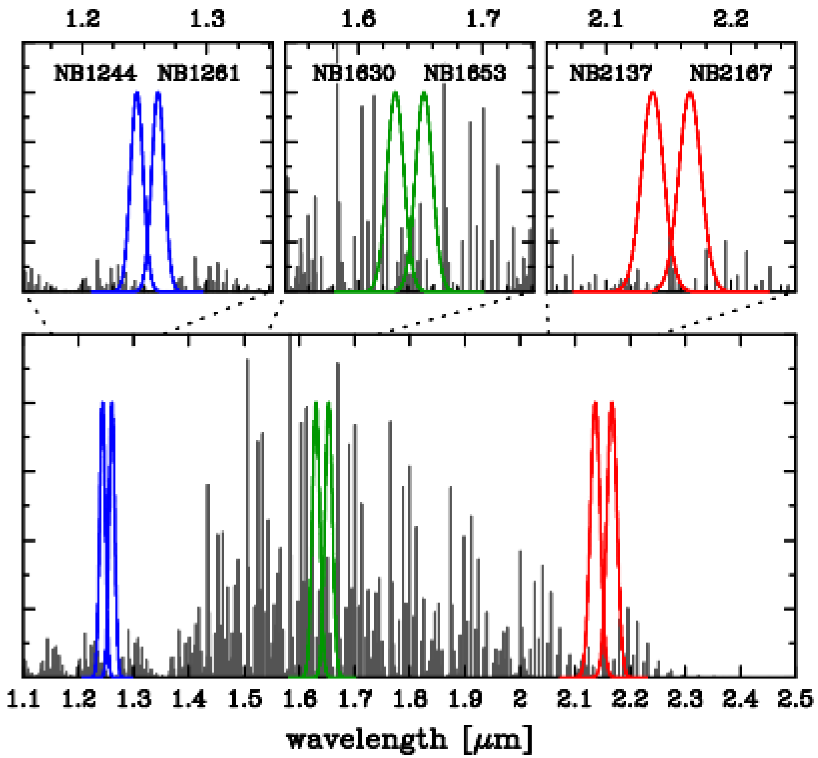
- 3 Broad-Band Filters (BBF)

→ Tracking the cosmic histories of "mass assembly" and "star formation/AGN activities" back to z~3-5.

Six Narrow-band filters (NBF)

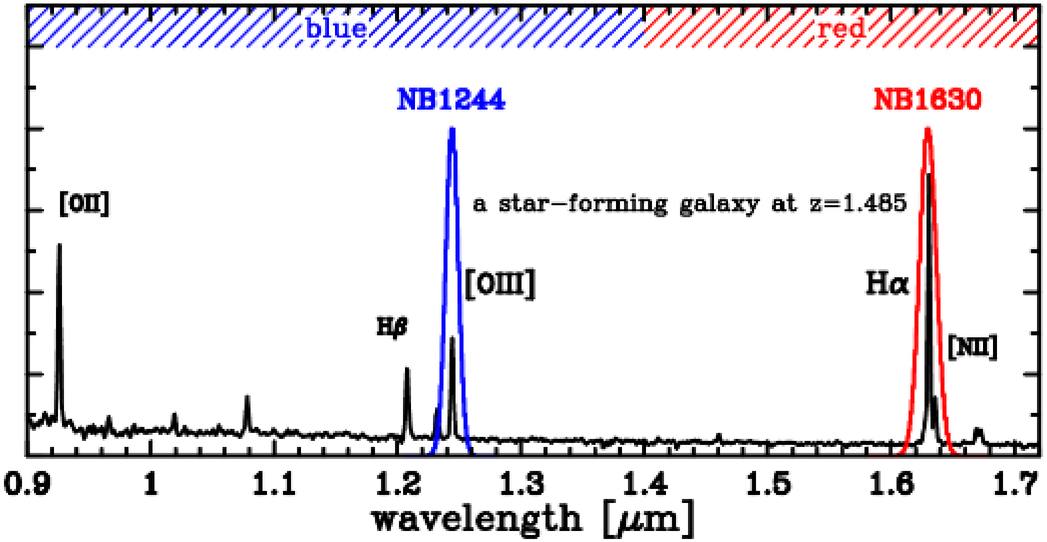
SFR-limited sample at z=0.9, 1.5, 2.3, and 3.3

NB filters	λ_c (μm)	FWHM (μm)	z(Hα) 6563Å	z([OIII]) 5007Å	z(Hβ) 4861Å	z([OII]) 3727Å	HSC filter pairs	Cluster targets
NB1244	1.244	0.012	0.895	*1.484*	1.559	2.337	NB926 ([OII]@z=1.485)	CL1604+4304(z=0.895)
NB1261	1.261	0.012	0.922	*1.519*	1.595	2.384	NB718 ([OII]@z=0.926)	CL1604+4321(z=0.920)
NB1630	1.630	0.016	*1.484*	*2.256*	2.354	3.374	NB926 ([OII]@z=1.485)	
NB1653	1.653	0.016	*1.519*	*2.302*	2.401	3.436		HS1700+64 (z=2.30)
NB2137	2.137	0.021	*2.256*	3.268	3.396	4.734		
NB2167	2.167	0.021	*2.302*	3.328	3.458	4.814		HS1700+64 (z=2.30)



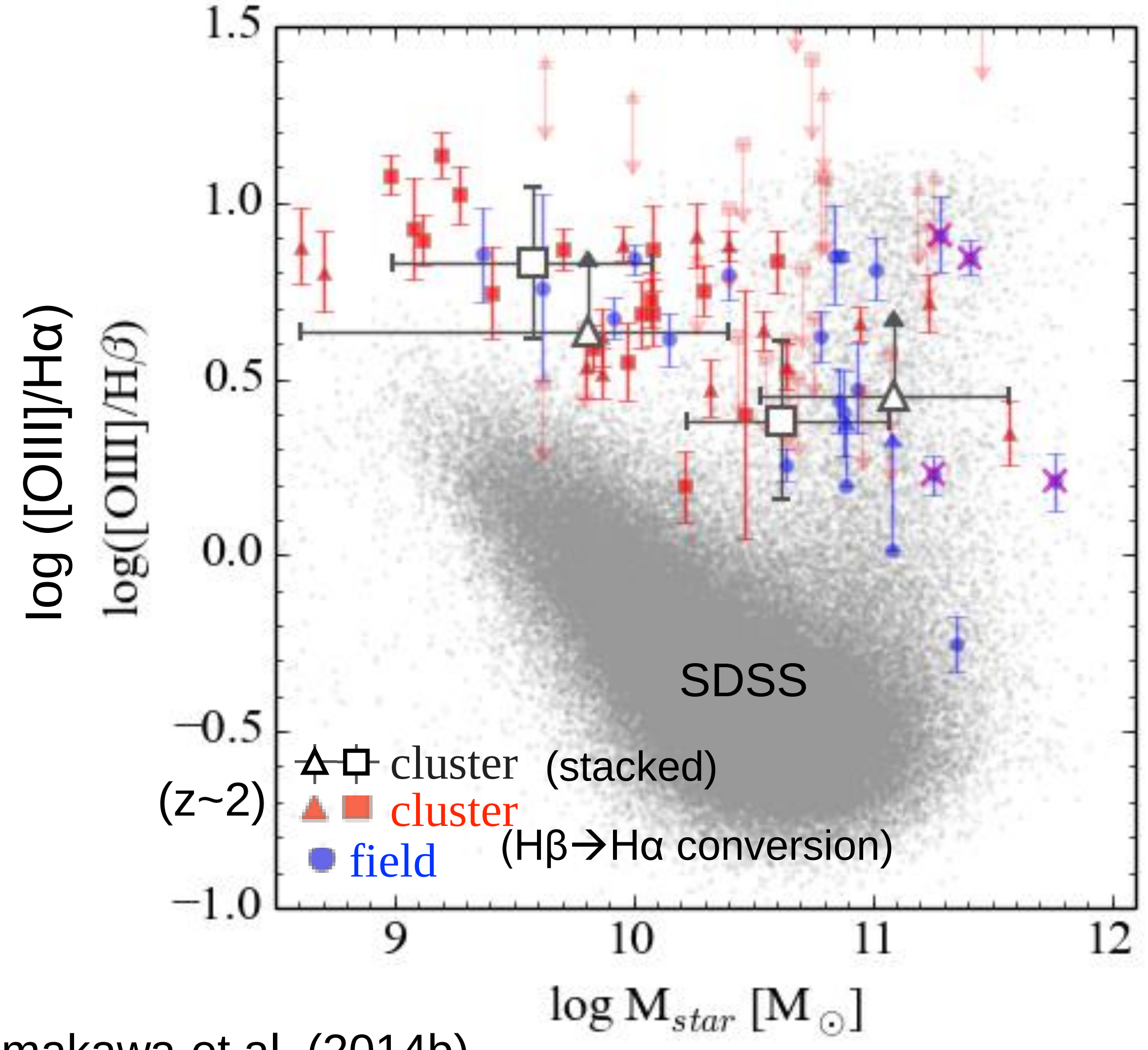
Dual emitters ([OIII] & Hα) with 4 pair NBFs

→ Redshift identification & Ionization states (ratio)



[OIII]/Hα ratio → Ionization/Excitation State

SWIMS-18 can do this only by imaging !



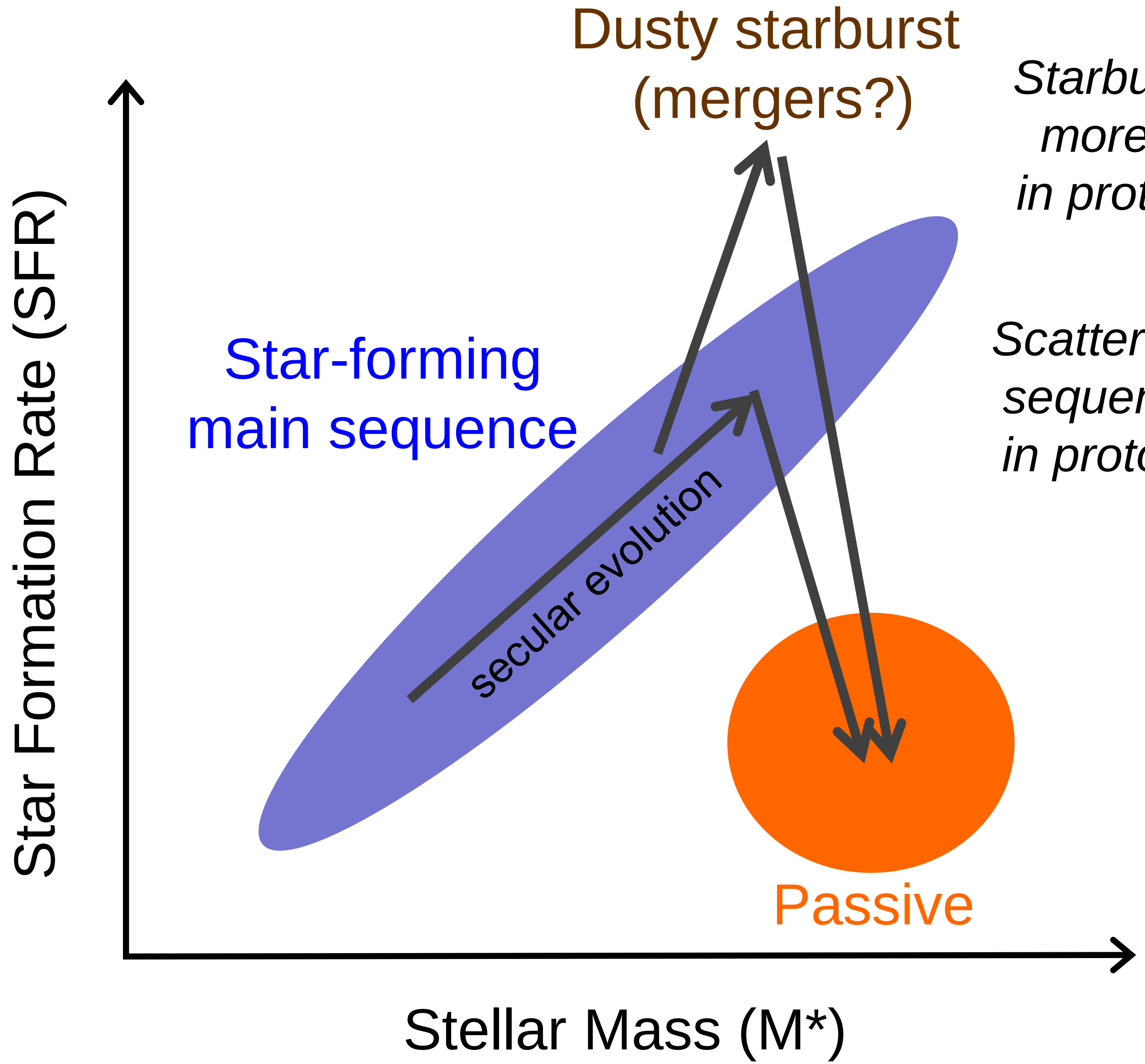
Shimakawa et al. (2014b)

High-z > Low-z

Both higher sSFR and lower metallicity are contributing to much higher ionization states of high-z SF galaxies. (Kewley et al. 2013)

See Shimakawa's talk and Silverman's talk

Hypothetical galaxy evolution on the SFR vs. M* diagram

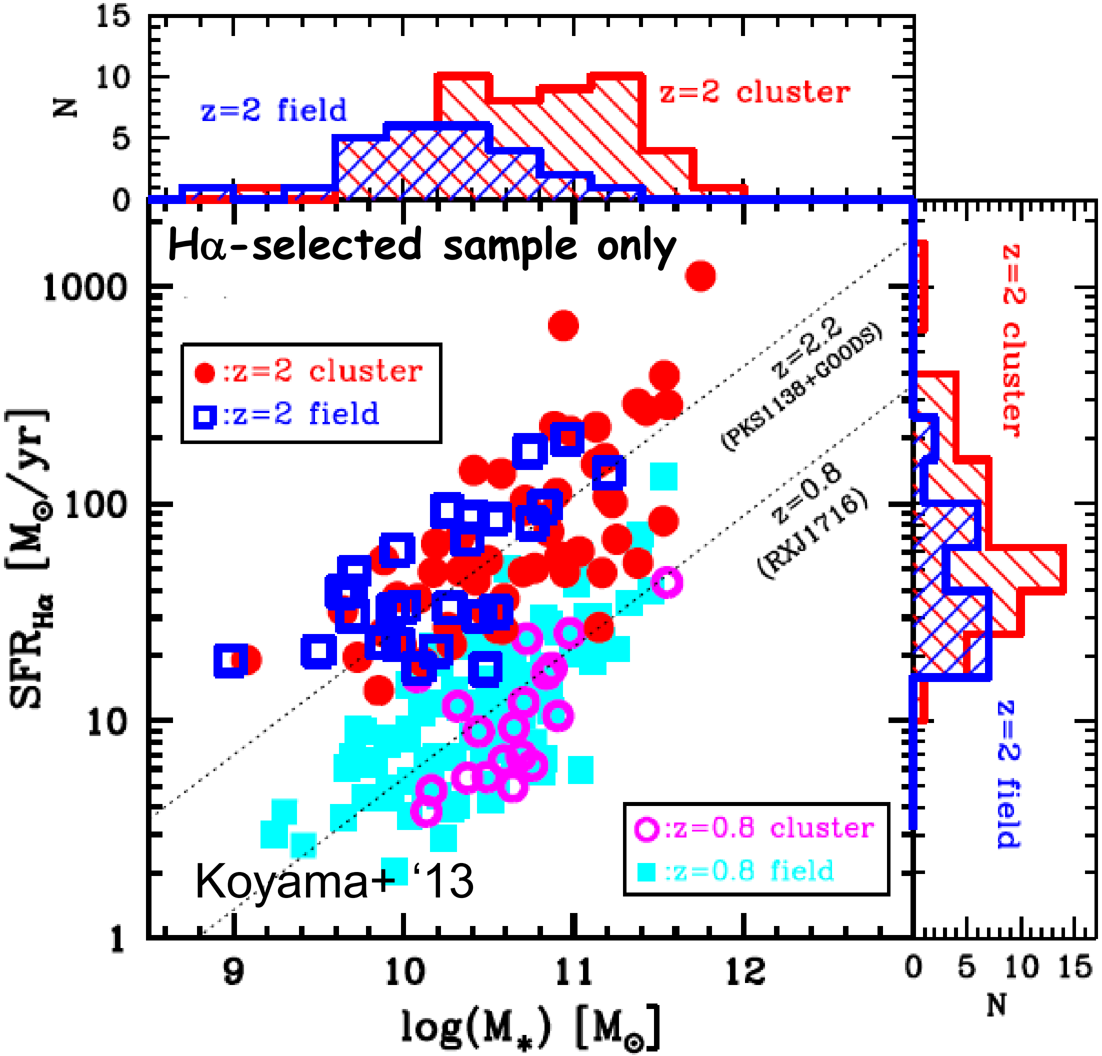


Starburst mode is more prevalent in proto-clusters?

↓

Scatter of the main sequence is larger in proto-clusters?

Environmental (In-)dependence of the Star-Forming Main-Sequence at z~2 ?



M*-scaled dust correction for Ha is applied.
(Garn & Best 2010)

SF galaxies in the proto-cluster at z~2 follow the same main sequence as the field one, although the galaxy distributions on the sequence are different due probably to accelerated galaxy formation in the proto-cluster.

Two difficulties in making the critical test on MS scatter:

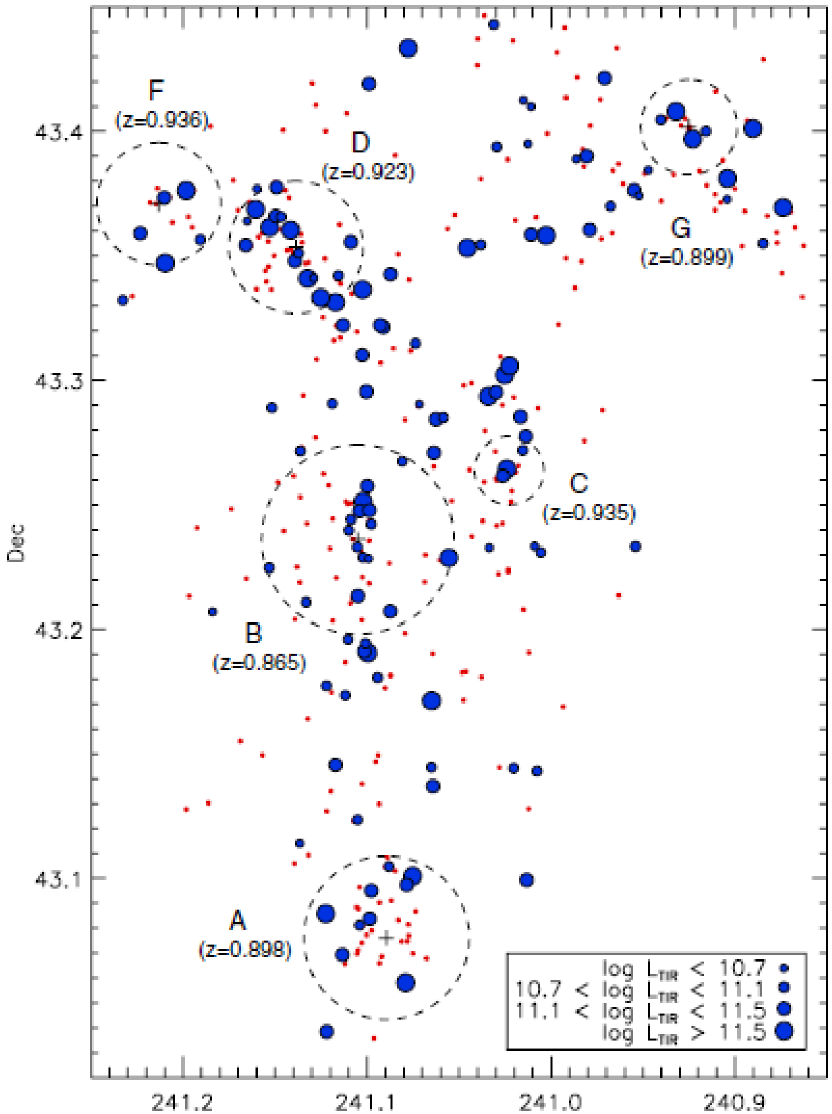
(1) Too small statistics.

(2) M*-scaled dust correction cannot be applied.

See Koyama's talk

Ha mapping of a known super-cluster at z=0.9

CL1604+43 (z=0.895, 0.922)



Kocevski et al. (2011)   • MIPS sources

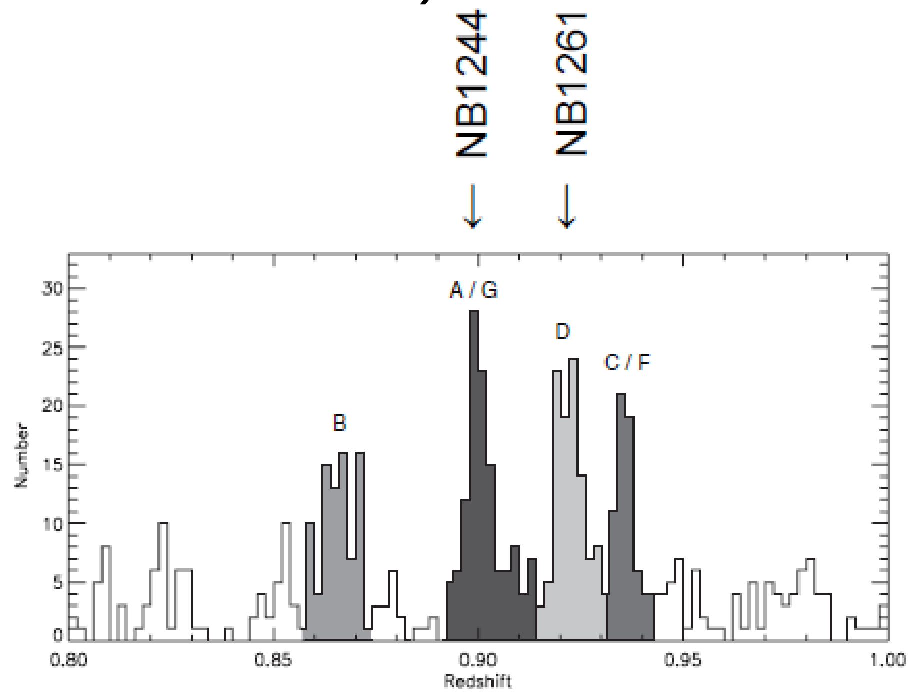


Figure 2. Redshift distribution of the Cl1604 supercluster.

Table 1
Properties of Galaxy Clusters and Groups in the Cl1604 Supercluster

ID	Name	R.A. (J2000)	Decl. (J2000)	z	σ_v (km s^{-1})	R_{vir} arcmin/(h_{70}^{-1} Mpc)	N_{gal} ($R < 2R_{vir}$)
A	Cl1604+4304	241.097473	43.081150	0.898	703 ± 110	1.969/0.92	40
B	Cl1604+4314	241.105050	43.239611	0.865	783 ± 74	2.261/1.05	62
C	Cl1604+4316	241.031623	43.263130	0.935	304 ± 36	0.824/0.39	13
D	Cl1604+4321	241.138651	43.353430	0.923	582 ± 167	1.594/0.75	60
F	Cl1605+4322	241.213137	43.370908	0.936	543 ± 220	1.470/0.70	16
G	Cl1604+4324	240.925080	43.401718	0.901	409 ± 86	1.143/0.53	15

This northern target can be observed only while SWIMS is on Subaru.

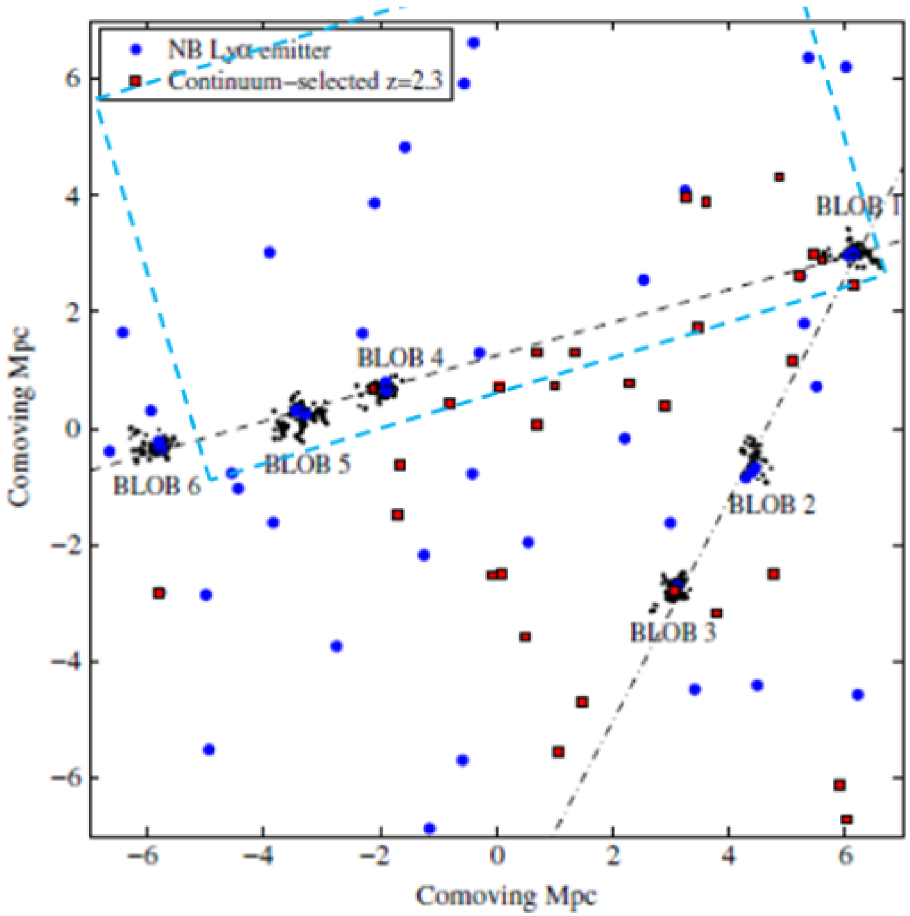
Hα and [OIII] mapping of a proto-cluster at z=2.3

HS1700+64 proto-cluser (z=2.30)

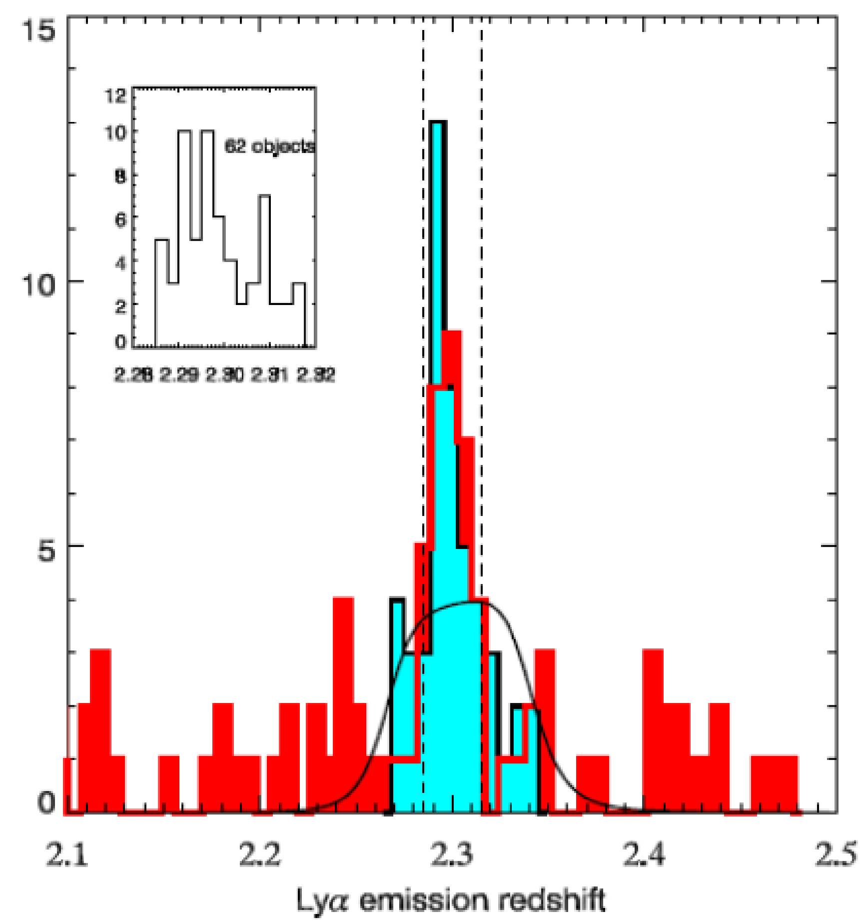
This northern target can be observed only while SWIMS is on Subaru.

SWIMS-18 NB filters

NB1653: [OIII] emitters
NB2167: Hα emitters

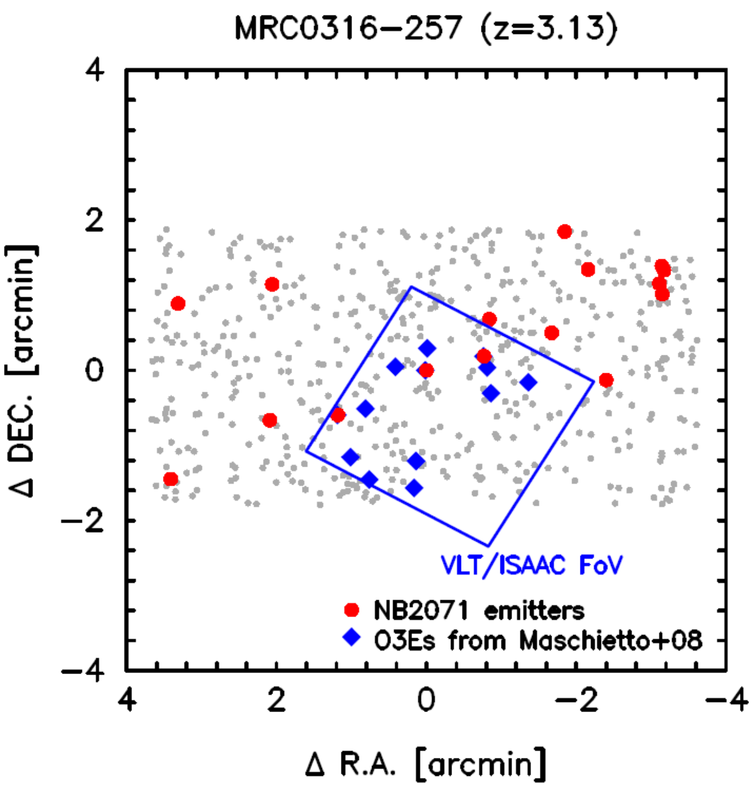


Steidel (2005)



Bogosavljevic (2010)

Towards higher redshifts (z>3) with [OIII] emitters

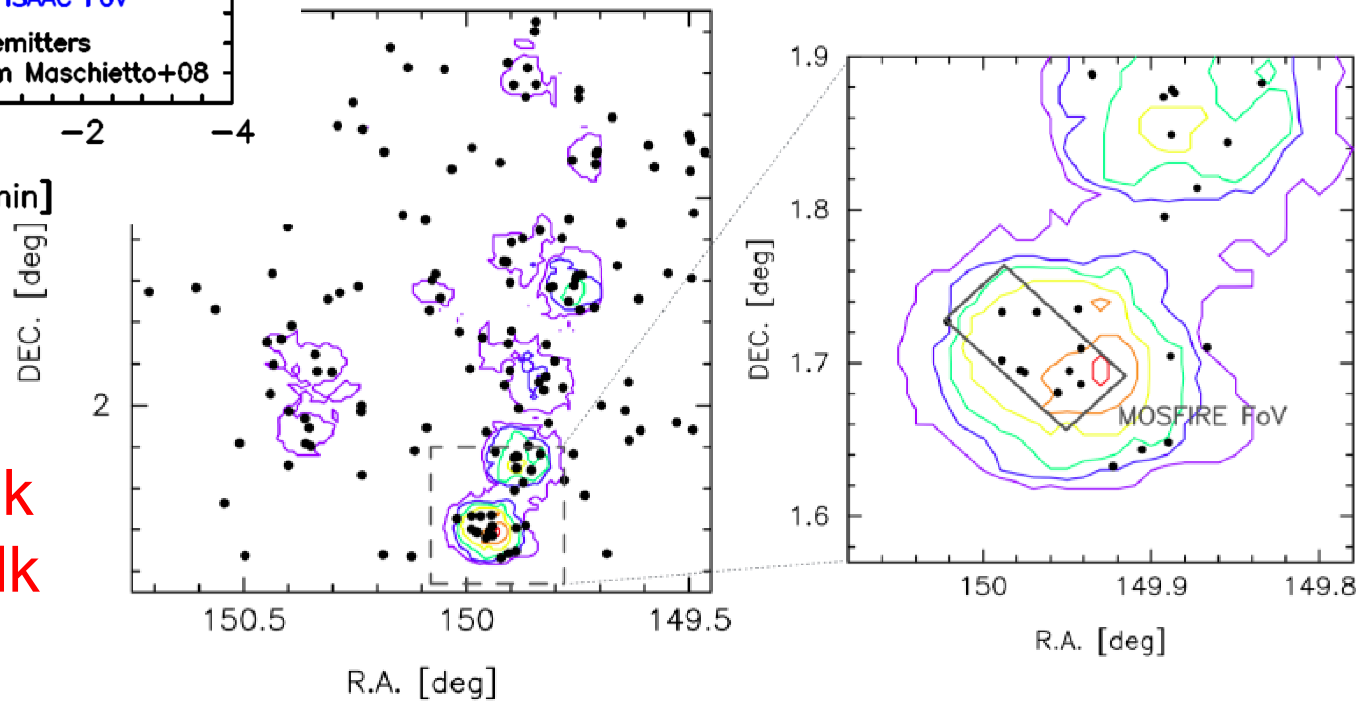


z=3.27, 3.33

Proto-cluster at z=3.13 traced by [OIII] emitters with NB207 (HzRG, MAHALO)

Courtesy: T. Suzuki

High density regions of [OIII] emitters at z=3.24 (HiZELS)



See Suzuki's talk and Tanaka's talk

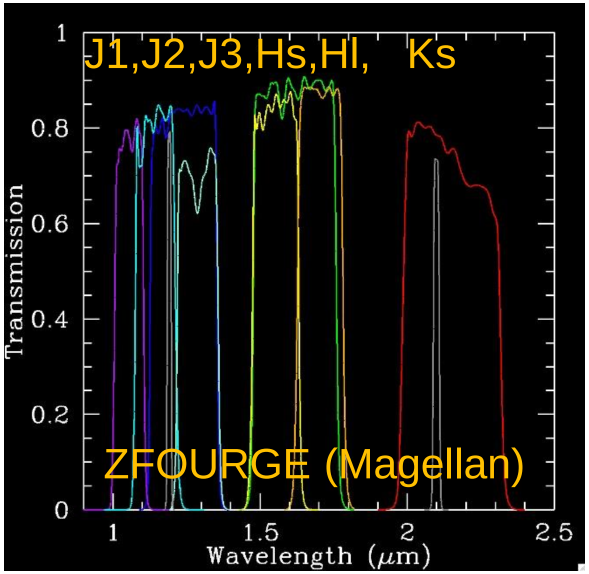
Nine Medium-band filters (MBF)

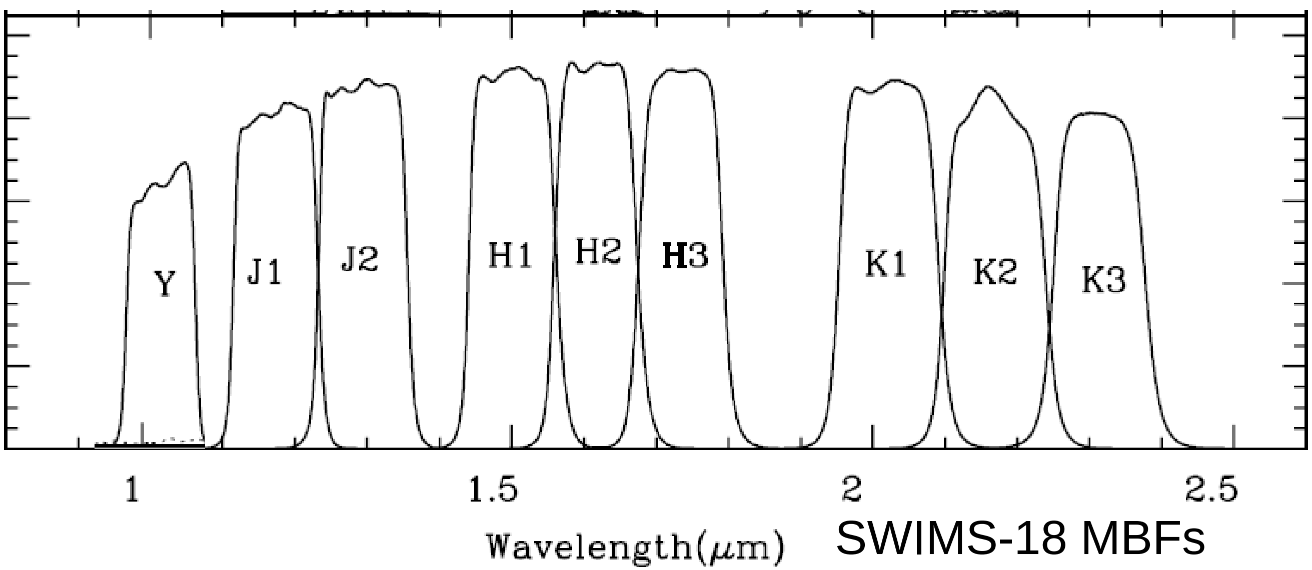
M*-limited sample of galaxies up to z~5

MB filters	λ_c (μm)	FWHM (μm)	z_s(Bal.Lim.) 3645Å	z_s(D4000) 4000Å
Y	1.05	0.10	1.74	1.50
J1	1.17	0.12	2.05	1.78
J2	1.29	0.12	2.37	2.08
H1	1.50	0.12	2.95	2.60
H2	1.62	0.12	3.28	2.90
H3	1.74	0.12	3.61	3.20
K1	2.03	0.14	4.38	3.90
K2	2.17	0.14	4.76	4.25
K3	2.31	0.14	5.14	4.60

BB filters	λ (μm)	λ_c (μm)	FWHM (μm)
J	1.17–1.33	1.25	0.16
H	1.48–1.78	1.63	0.30
K_s	1.99–2.30	2.15	0.30

Will open a new window to 4<z<5 with K1,K2,K3 !

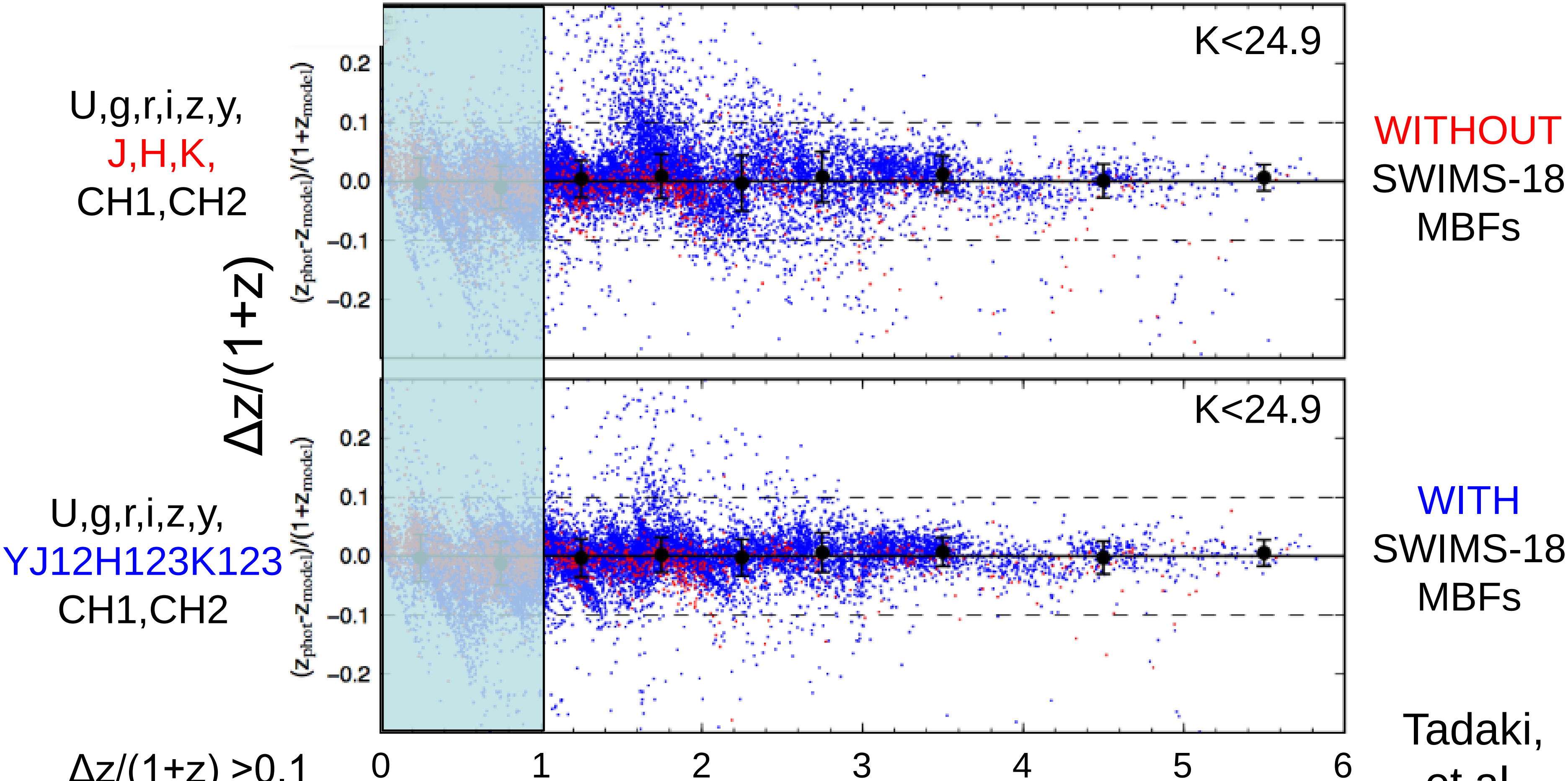




SWIMS-18 MBFs

Improvements of Photometric Redshifts @1<z<5.5

We should also have better estimates of dust extinction.



Tadaki, et al.

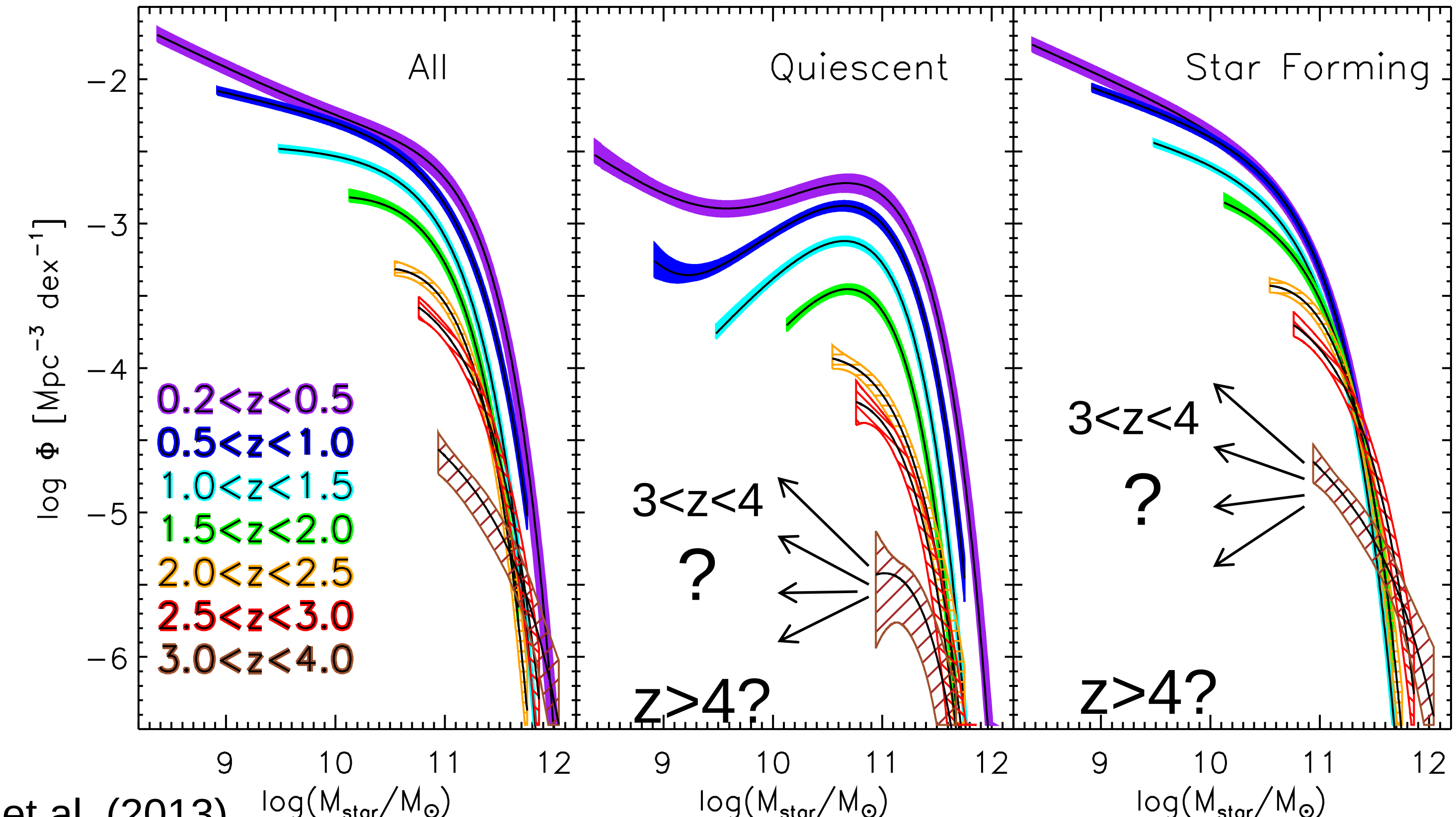
Δz/(1+z) >0.1
Outlier fraction (%)

z range	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-4.0	4.0-5.0	5.0-6.0
w/o SWIMS18	22.7	9.9	7.8	13.0	14.8	11.4	7.2	12.4	26.6
w/ SWIMS18 (Deep)	15.5	7.9	4.1	6.5	6.0	6.9	4.5	8.2	6.3

Mass assembly history of galaxies: stellar mass functions to z~5

ULTRA-VISTA (COSMOS)

100K galaxies over a 1.62 deg^2 field down to Ks=23.4 (AB)

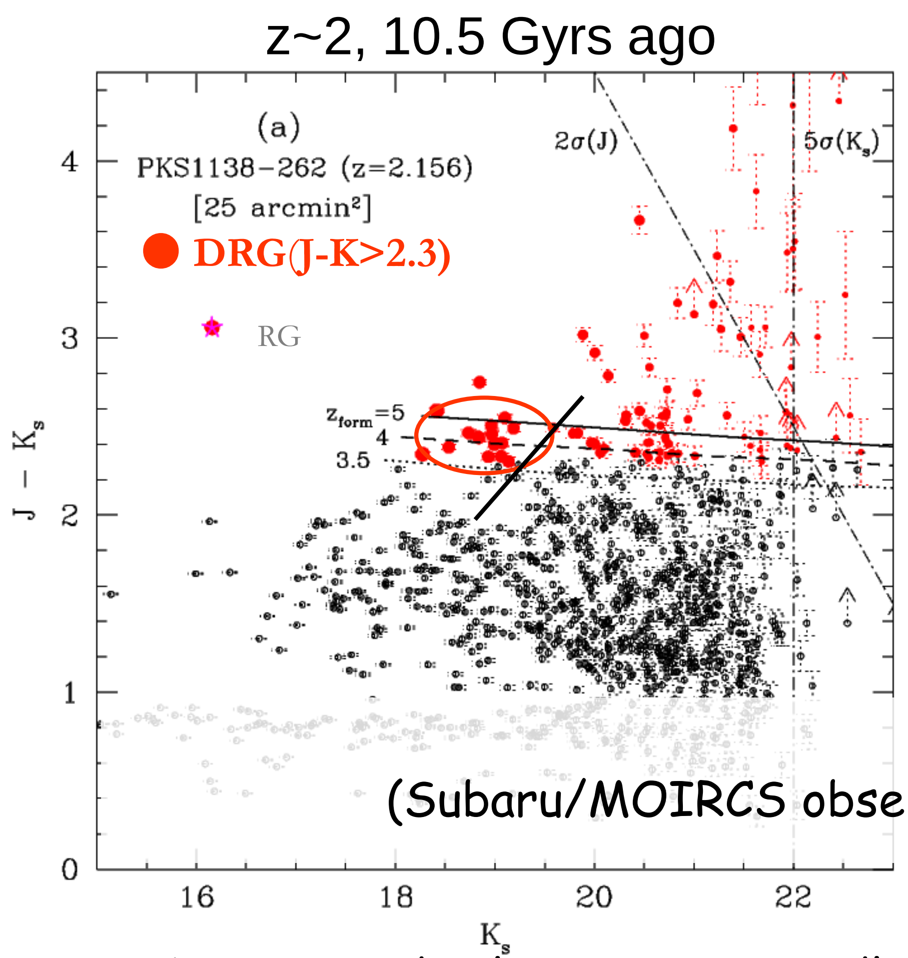


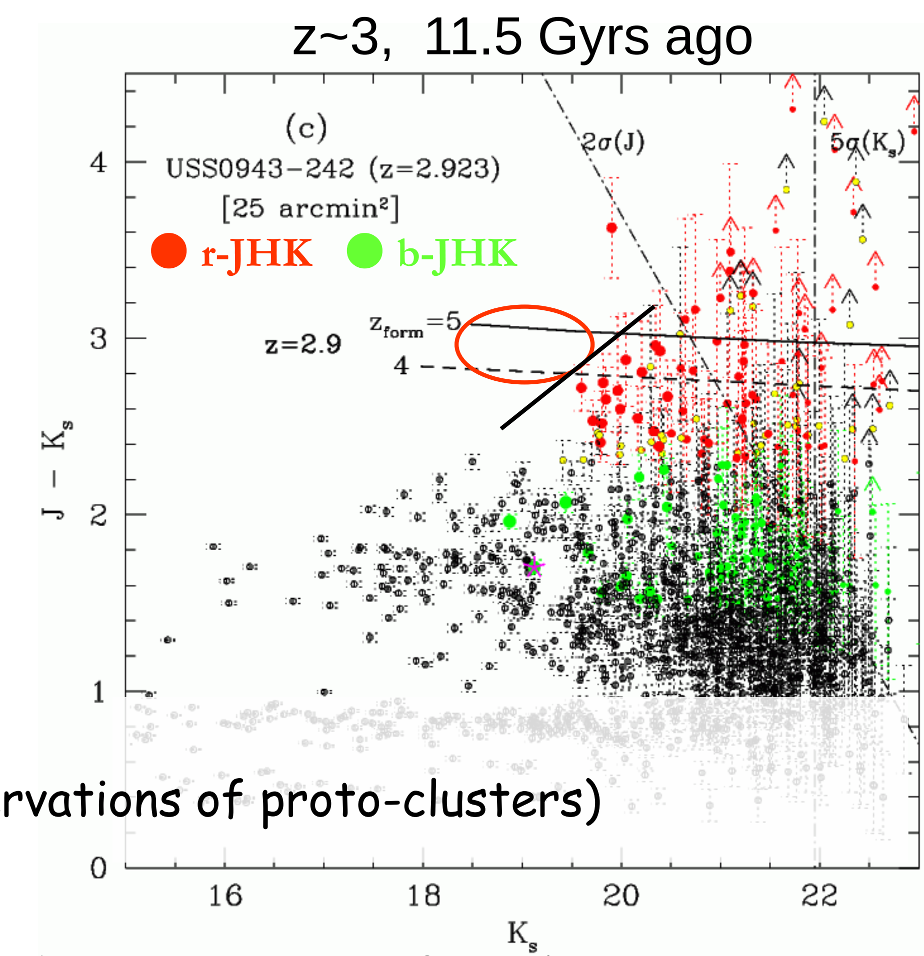
Muzzin et al. (2013)

Faint end at z<4? What about z>4???

Growth/quenching history of (massive) galaxies: LFs along the red sequence at 2<z<5

Medium band filters → Much less contamination at 2<z<5 (<1/3) !





(Subaru/MOIRCS observations of proto-clusters)

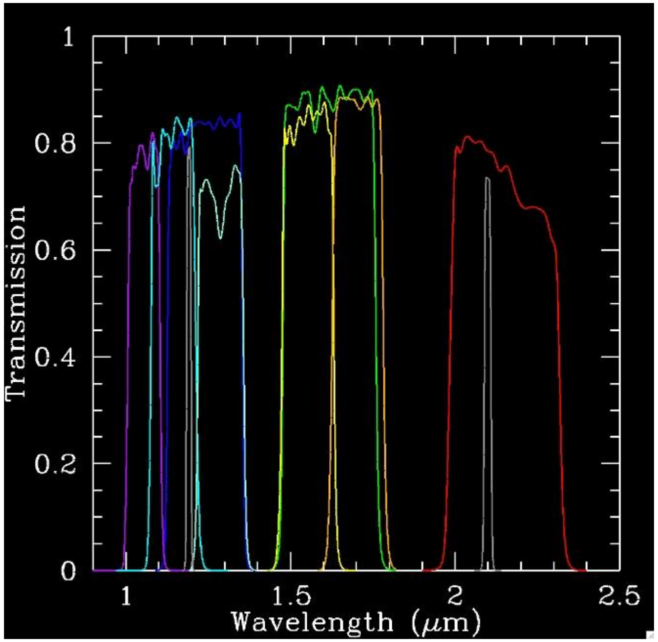
Massive, red galaxies grow rapidly during 2-3 Gyrs after the Big-Bang.

Kodama et al. (2007)

ZFOURGE @Magellan 6.5m (El. 2400m)

(FourStar Galaxy Evolution Study)

- Four Star Infrared Camera; Hawaii-2RG x 4
- One deep 10.9'x10.9' field each in COSMOS, CDFS and UDS FourStar; Hawaii-2RG x 4) – 0.1 sq. deg.
- 30,000 galaxies at $1<z<3$
- J1,J2,J3 ≈ 25.5, Hl, Hs ≈ 25, and Ks ≈ 24.5 (AB, 5σ, total mag for compact sources)
- $\Delta z/(1+z) \sim 0.02$



Why SWIMS-18 > ZFOURGE ?

(TAO 6.5m) (Magellan 6.5m)

- More medium-band filters (from 5 to 9)
  J1(Y),J2,J3,Hs,Hl → Y,J1,J2,H1,H2,H3,K1,K2,K3
  → Improvement of phot-z accuracy (in particular at z>3), Balmer break up to z~5
- Existence of narrow-band filters
  6 narrow-band filters, 4 pairs (Hα and [OIII]), adjacent on/off bands
  → optimized to strong [OIII] emitters at high-z, no contamination
- Simultaneous observations of two passbands
  $\lambda<1.4\mu m$ (blue channel) and $\lambda>1.4\mu m$ (red channel) with a dichroic mirror
  → Survey efficiency is doubled
- Large amount of time allocation to some dedicated programs
  → 1.5 yrs of observing time for 1 sq. deg. (10 × ZFOURGE),
  optimal for environmental studies with clusters of $>10^{14}M_\odot$

Survey Design for SWIMS-18

survey layer	area (sq. deg.)	# of pointings	observing time (Subaru)	observing time (TAO)	total time for TAO
SWIMS-18-Wide	1	100	25hrs/FoV	40hrs/FoV	4,000 hrs
SWIMS-18-Deep	0.1	10	125hrs/FoV	200hrs/FoV	2,000 hrs

SWIMS-18-Wide (1 sq. deg.)

SFR-limited sample (HAEs) : 7.5 × 10^5 Mpc^3 at each redshift

SFR-limit ($M_\odot$/yr)	expected # of HAEs
10(z=1.5), 30(z=2.5)	8000(z=1.5), 4000(z=2.5)

M*-limited sample: 1.2 × 10^7 Mpc^3 (Δz=1)

M_*-limit ($M_\odot$)	expected # /(Δz=1)
10^{10}(z=1.5), 10^{11}(z=3)	3000(z=3), 300(z=4)

→ Requires ~500 nights of observing time at TAO

A few % of the survey will be conducted on Subaru as a pilot study when SWIMS is mounted on Subaru for 3 yrs (2016-2018)

SWIMS-18 Pilot Survey @ Subaru

~24 nights (?) over 2017B/2018A

(1) General Fields (120hrs=12 nights)

A part (80arcmin^2) of ZFOURGE fields (UDS, COSMOS) where deep Y, J1, J2, Hs, Hl, Ks already exist.

MB: H3, K1, K2, K3: 3hrs exposure each (or more?)

Balmer break galaxies@3.5<z<5: ~10 galaxies in 80arcmin^2

NB: 1244/1261/1630/1653/2137/2167: 3hrs exposure each.

~50 HAEs & ~20 O3Es in 80arcmin^2/NB (100@z=1.5 & 2, 40@z=3).

(2) Clusters (120hrs=12 nights)

A super-cluster CL1604+43 (z=0.9) with NB1244/NB1261 (Hα)

A proto-cluster HS1700+64 (z=2.3) with NB1653 ([OIII])/NB2167 (Hα) + MBFs (phot-z, red sequence galaxies)

SW/MS Spectroscopy

- Large spectroscopic survey at the cosmic noon

Lots of spectroscopic follow-up needs for SWIMS-18 galaxies and HSC selected galaxies/clusters at $0.7<z<3.7$ (with Hα or [OIII]).

c.f.) PFS to z~0.9-1.5 → SWIMS to z~2.5-3.7

- Accurate line ratios with simultaneous observations of blue and red channels

e.g.) J ([OII]), H ([OIII], Hβ) and K (Hα, [NII], [SII]) at z~2-2.5, so we can get "accurate" line ratios (O32, R23, Hα/Hβ, etc…), free from a slit-loss problem.

See Shimakawa's talk

Summary

- **SWIMS-18** is a super multi-λ (NIR) imaging survey of the "Cosmic High Noon" over a 1-deg^2 unbiased field + some high density regions.
- Stellar mass-limited sample at $1<z<5$ with MB filters. SFR-limited sample of star-forming galaxies (and AGNs) at $0.9<z<3.3$ with NB filters.
- Balmer-break galaxies at $3.5<z<5$, and Dual (Hα and [OIII]) emitters at $z=1.5$ and 2.3 are unique samples!
- The project will track the histories of mass assembly and star formation (and AGN activity) over the cosmic high noon and beyond with great statistics!