(Subaru Seminar @Subaru-Hilo, 2015/4/28)

Mahalo Subaru, Ohako SWIMS, and Aloha TMT!

18

Taddy Kodama (NAOJ)

Masao Hayashi, Yusei Koyama (NAOJ), Ken-ichi Tadaki (MPE),
Ichi Tanaka, Yosuke Minowa (Subaru),
Rhythm Shimakawa, Tomoko Suzuki, Moegi Yamamoto
(NAOJ/SOKENDAI), et al.

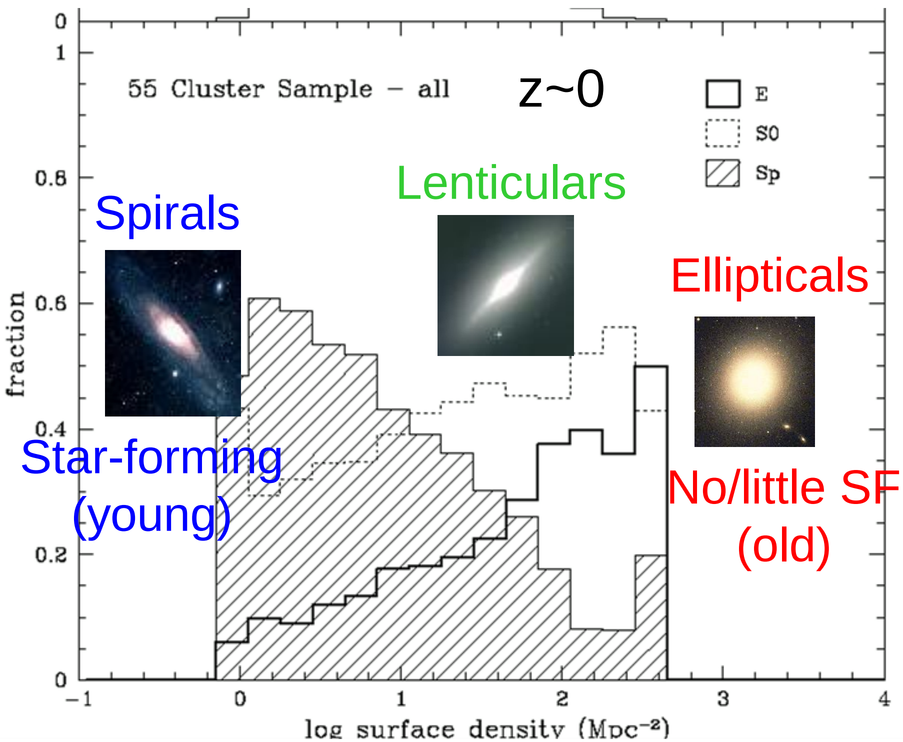
A galaxy cluster RXJ0152 at z=0.83 (Subaru/Suprime-Cam)

Line-up of our on-going/future projects

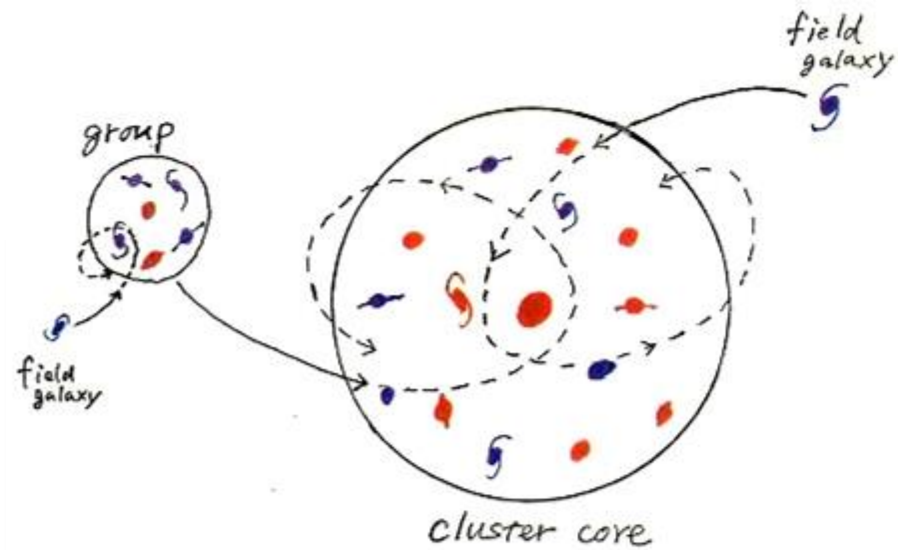
1. MAHALO-Subaru ⇐ Today's talk
2. GANBA-Subaru
3. ULTIMATE-Subaru
4. SWIMS-18 ⇐
5. WISH-7
6. HSC-HSC
7. MAHALO2-SCUBA2
8. GRACIAS-ALMA
9. Aloha-TMT ⇐

What is the origin of the cosmic habitat segregation?

Morphology- (SFR-) density relation
(Dressler 1980)



log surface density (Mpc^{-2})



Nature? (intrinsic)

Biased, earlier galaxy formation
in high density regions

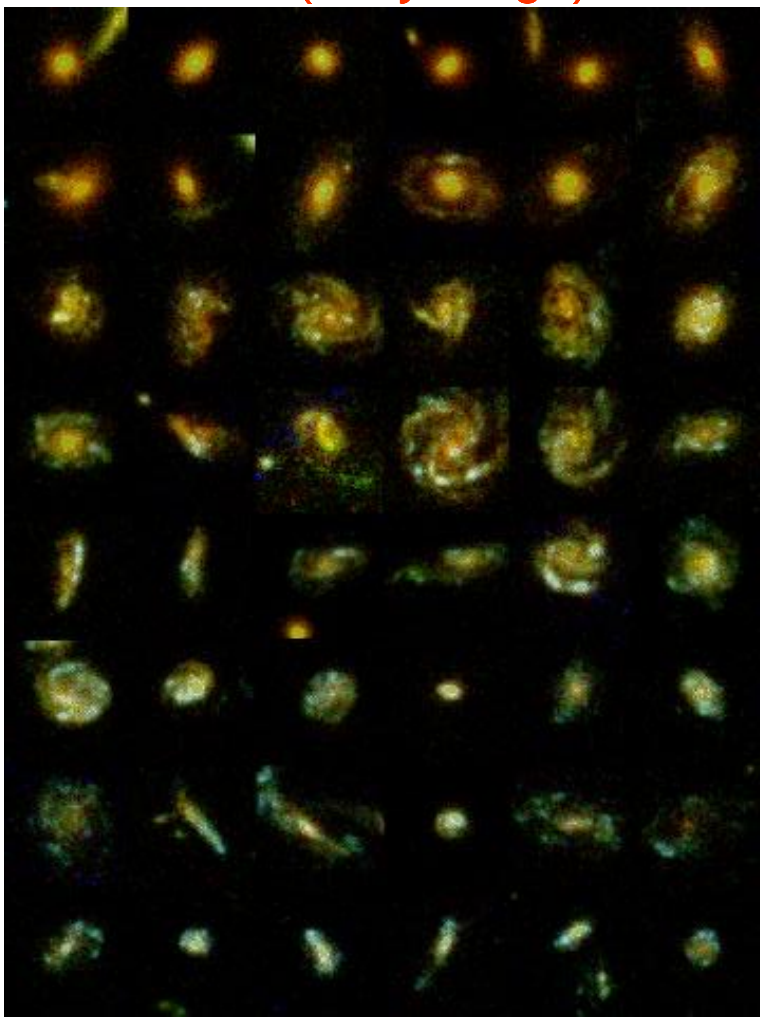
Nurture? (external)

Galaxy-galaxy interaction/mergers,
gas-stripping

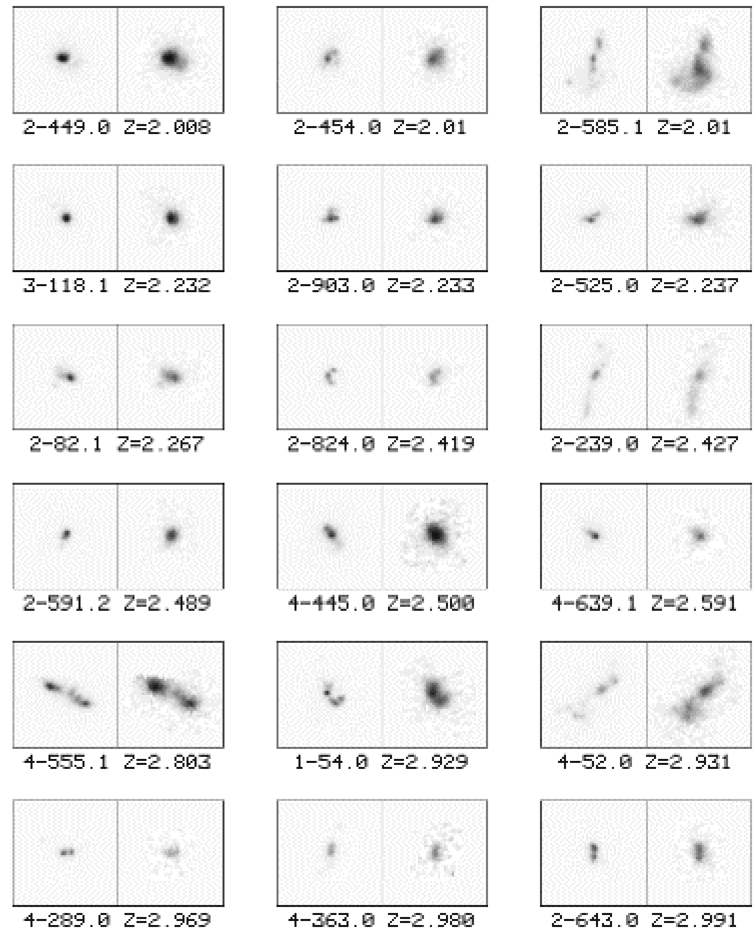
Emergence of the Hubble sequence between z=3 and 1

z~1 (8 Gyrs ago)

z~2-3 (10-11 Gyrs ago)



λ_{rest}=1700 Å, 4300 Å LBGs

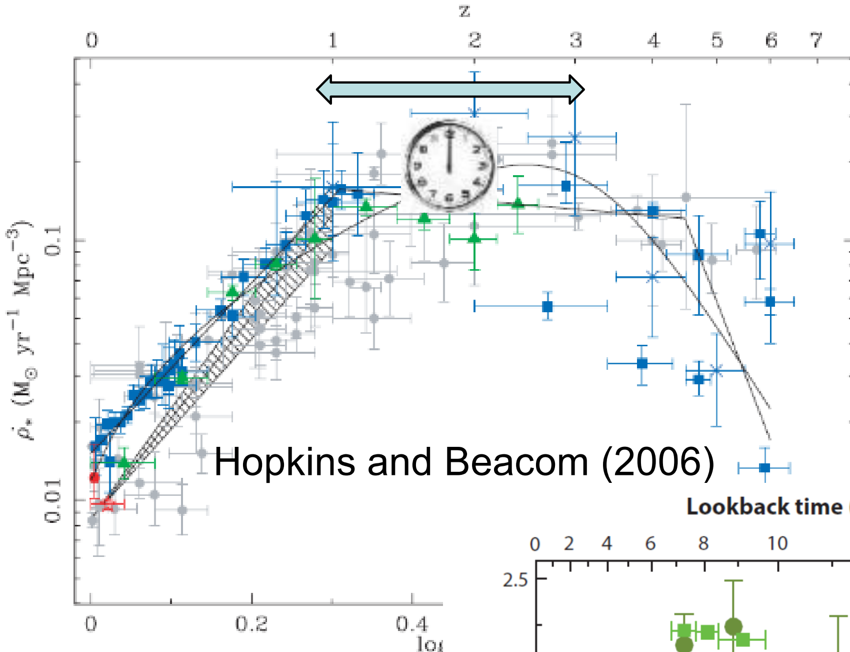


Hubble Space Telescope

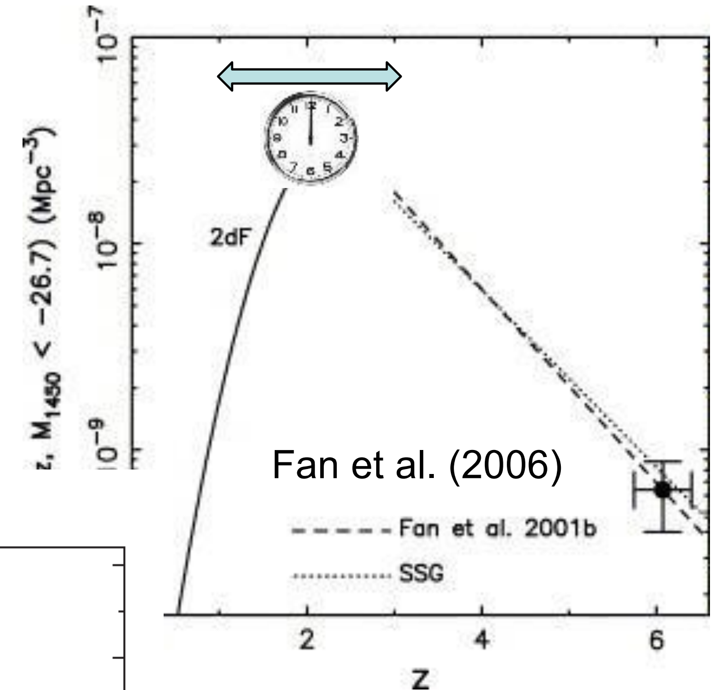
Dickinson (2000), ….many!

"COSMIC HIGH NOON"

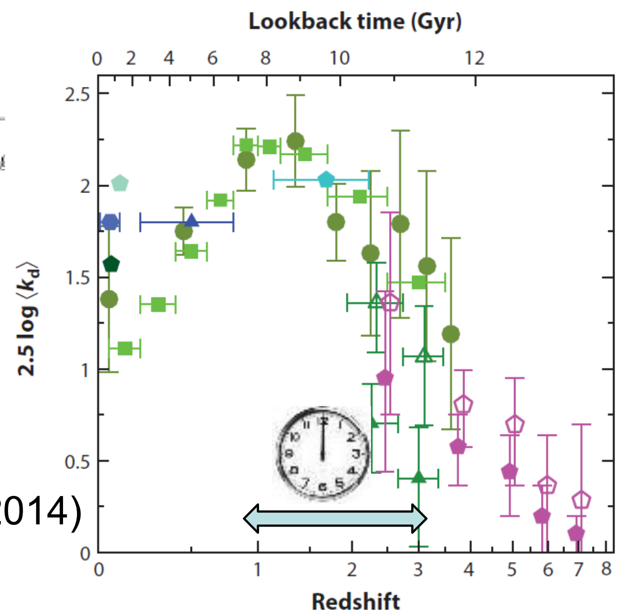
The peak epoch of galaxy/SMBH formation/dust extinction: 1<z<3 (6>T_{cos}(Gyr)>2)



Star formation



BH accretion (AGN/QSO)



Madau & Dickinson (2014)

Dust extinction

Hα and [OIII] are better tracers of SF activities than the UV-light at this epoch, because they are less affected by dust extinction.

MAHALO-Subaru

MApping HAlpha and Lines of Oxygen with Subaru

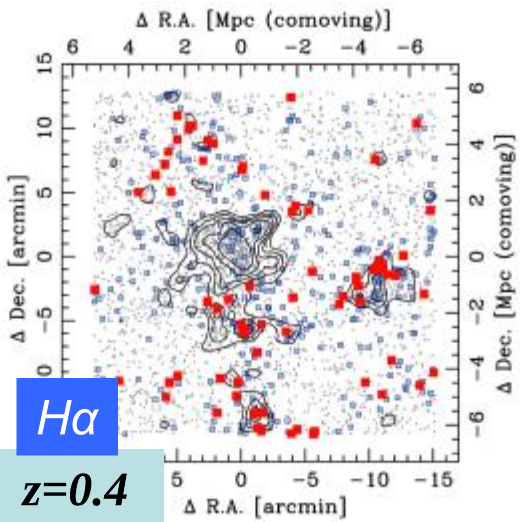
Unique sample of NB-selected SF galaxies across environments and cosmic times

	environ-ment	target	z	line	λ (μm)	camera	NB-filter	conti-nuum	status (as of Apr 2015)
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
		RXJ0152.7–1357	0.837	[OIII]	0.920	Suprime-Cam	NB921	z'	not yet
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 fields	SXDF-CANDELS	2.16	Hα	2.071	MOIRCS	NB2071	K_s	observed
		(90 arcmin^2)	2.19	Hα	2.094	MOIRCS	NB2095	K_s	Tadaki+'13
			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
		COSMOS-CANDELS	2.16	Hα	2.071	MOIRCS	NB2071	K_s	partly observed
		(90 arcmin^2)	2.19	Hα	2.094	MOIRCS	NB2095	K_s	partly observed
		GOODS-N	2.19	Hα	2.094	MOIRCS	NB2095	K_s	Tadaki+'11
		(70 arcmin^2)		[OII]	1.189	MOIRCS	NB1190	J	observed

~20 nights for imaging, >15 nights for spectroscopy

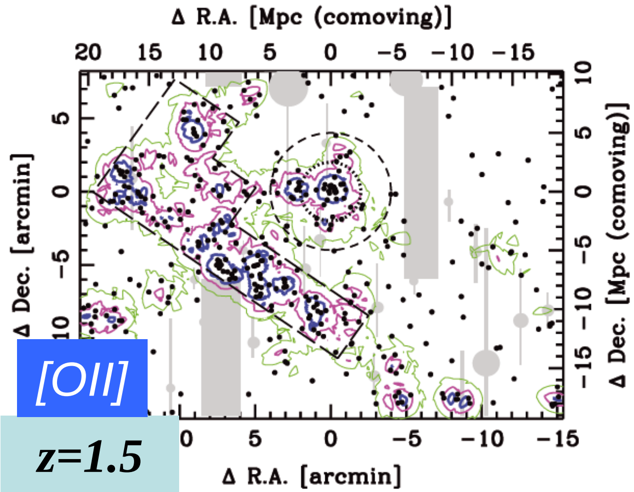
Kodama et al. (2013)

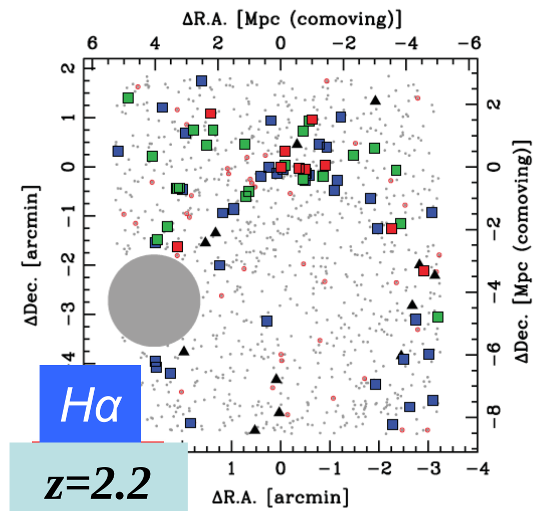
High-z structures revealed by MAHALO



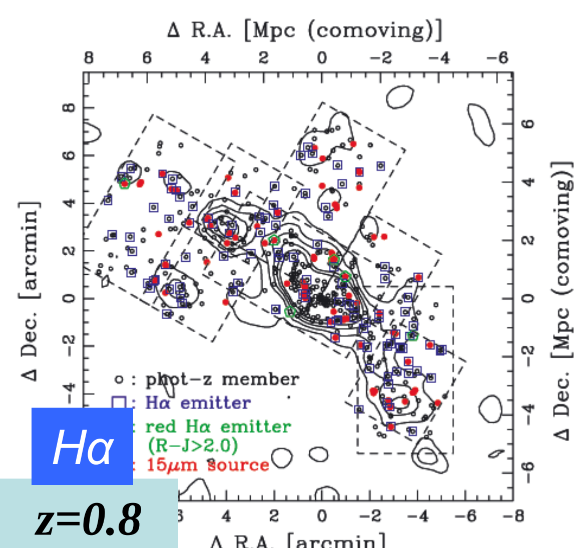
(Koyama+11)

(Hayashi+10, 11)



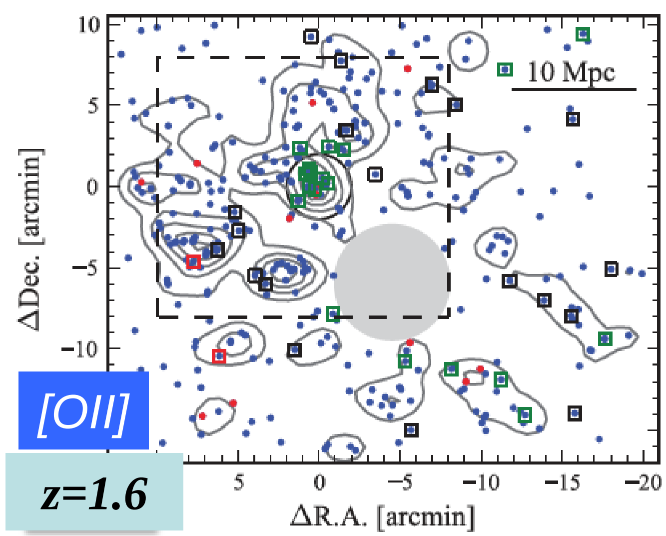


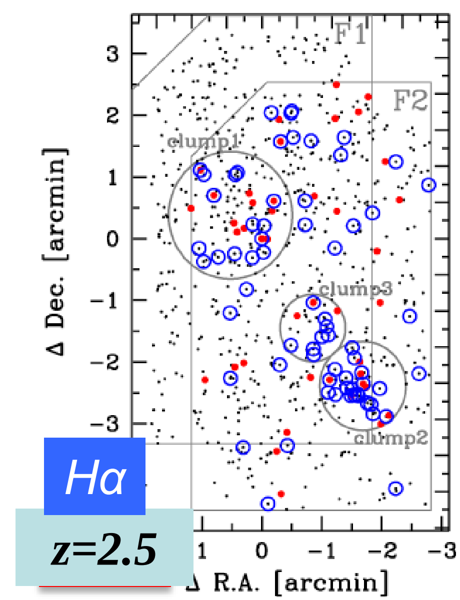
(Koyama+13)



(Koyama+10)

(Tadaki+12)

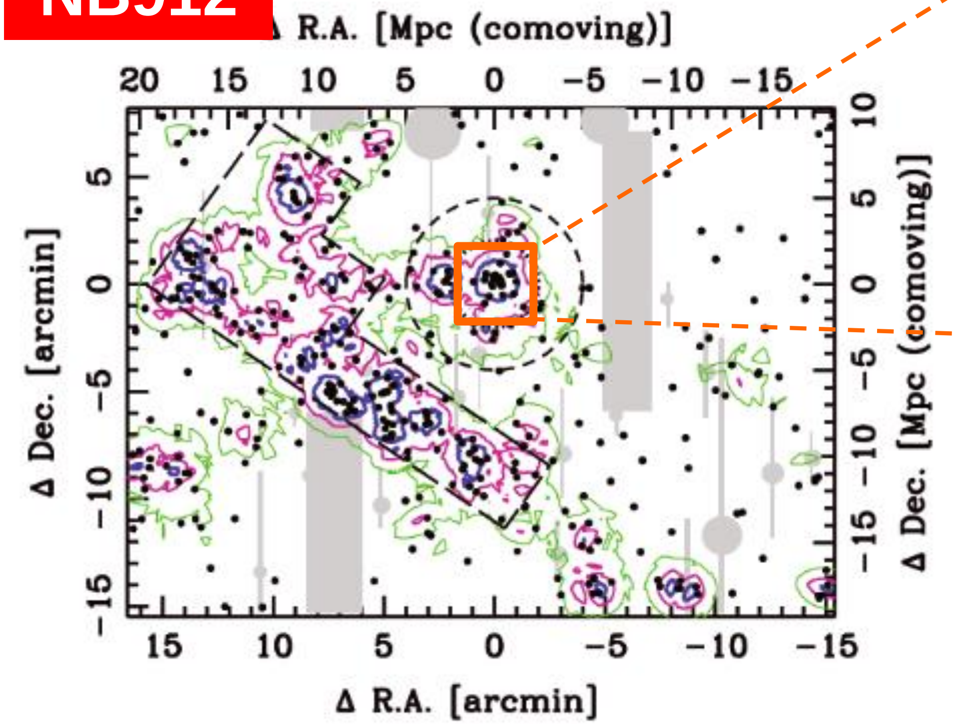




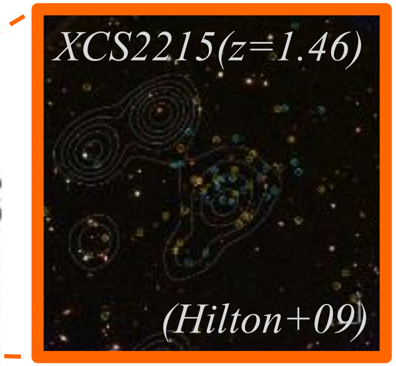
(Hayashi+12)

LSSs (~20Mpc) around two x-ray clusters at z~1.5 traced with [OII] emitters

NB912

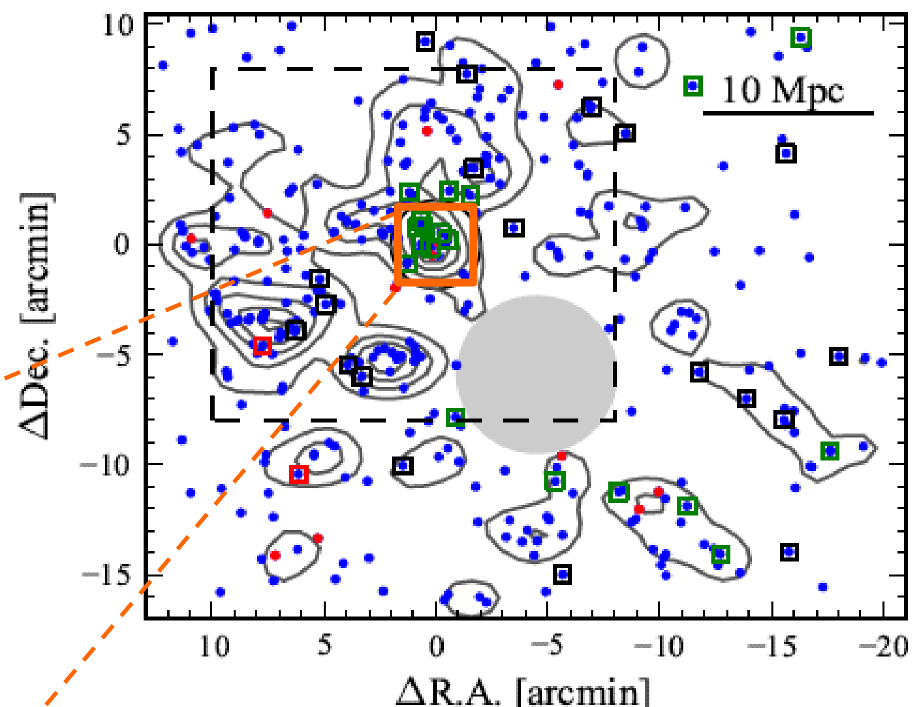


Hayashi et al. (2011)



Suprime-Cam/Subaru
30' ~ 30-40 Mpc
(co-moving) on a side

NB973



Tadaki et al. (2012)

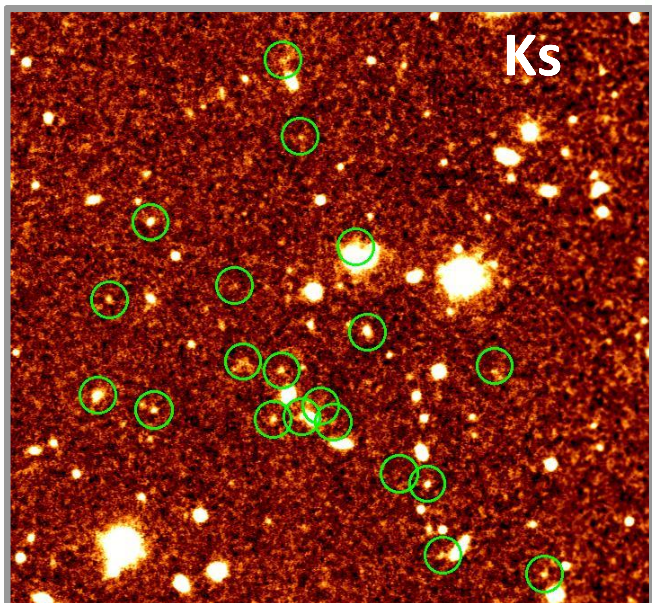
The most prominent star-bursting proto-cluster at z~2.5

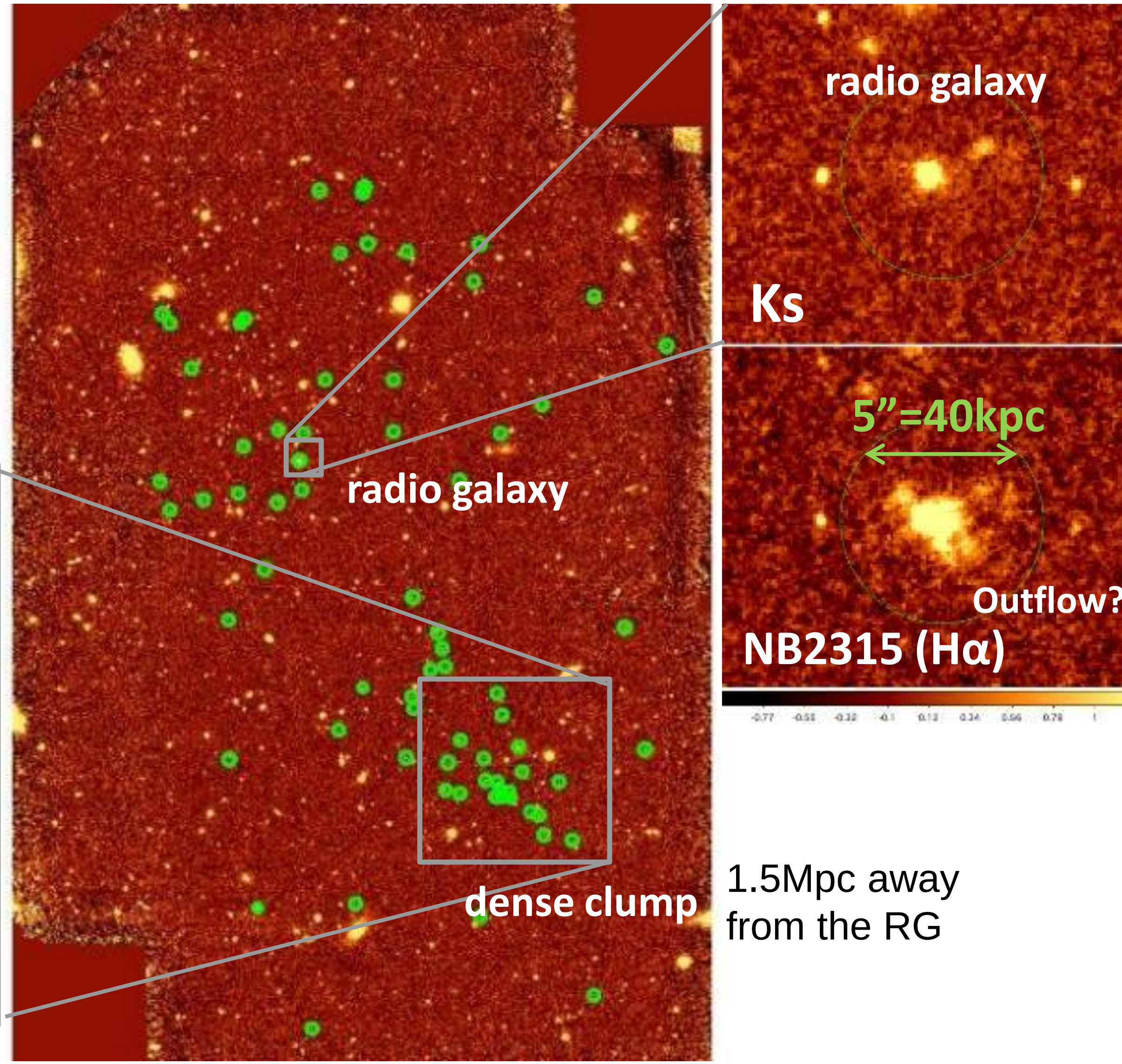
USS1558-003 (z=2.53)

Ha imaging
with MOIRCS/NB2315

FoV=4’ x 7’

68 Ha emitters detected.
~40 are spec. confirmed.

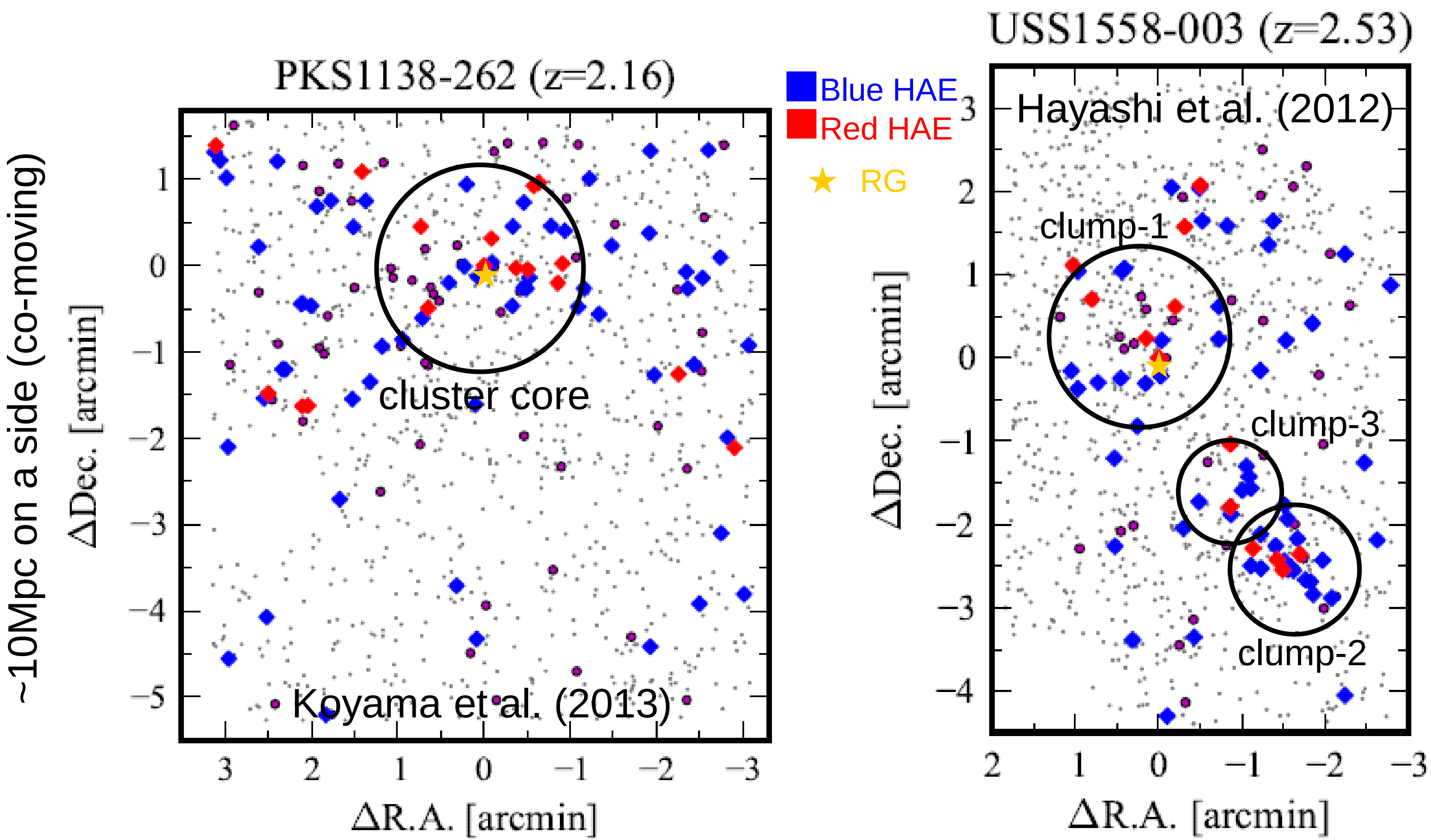




~20x denser than the general field.
Mean separation between galaxies is ~150kpc in 3D.

Hayashi et al. (2012)

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

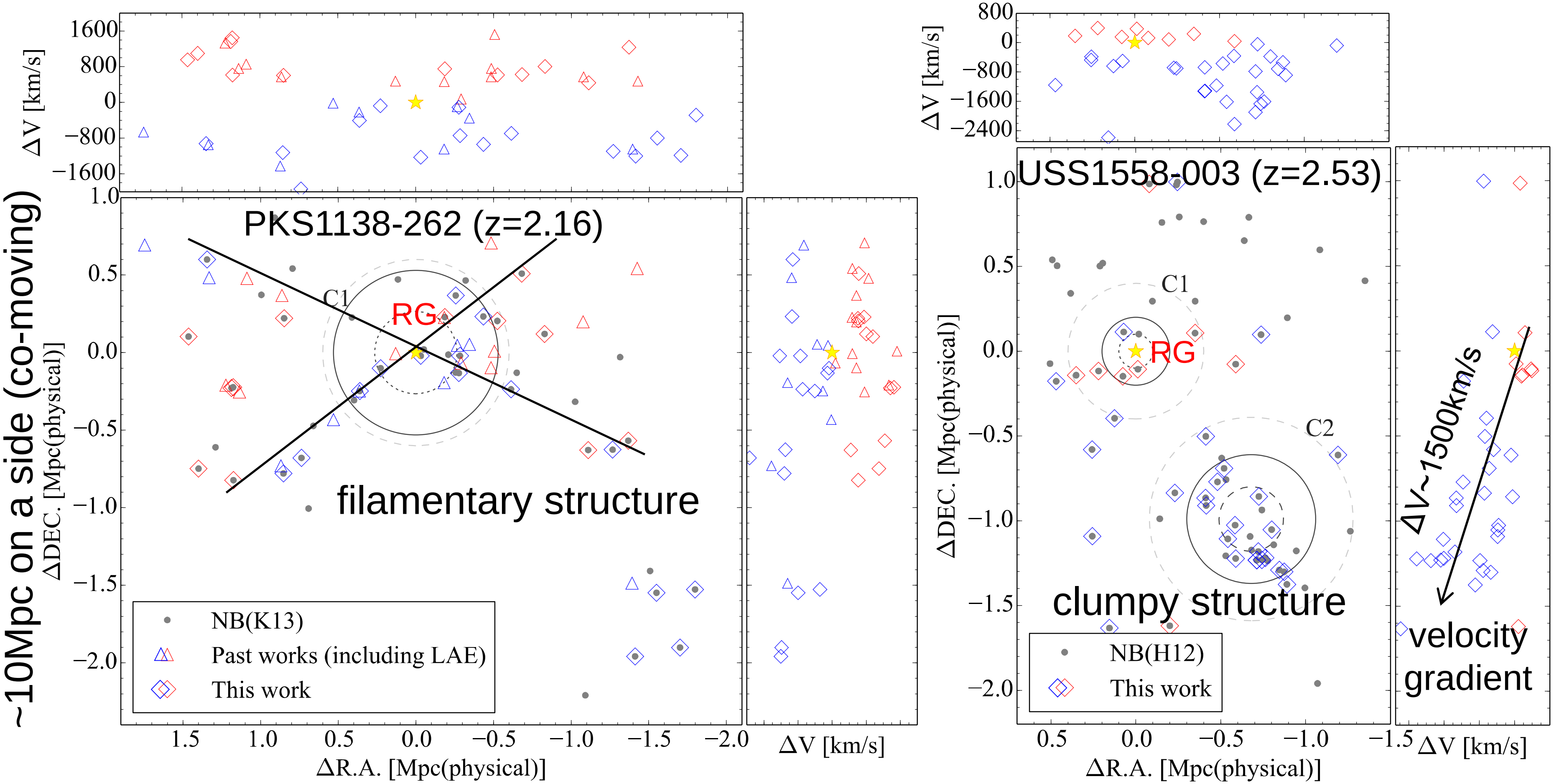


Lots of HAEs live in proto-cluster cores, indicating strong SF activities there.

Red HAEs (dusty starbursts) tend to favor even denser cores/clumps!

2D/3D Views of Proto-Clusters at z>2

They are a mid of vigorous assembly!
HzRGs are not always located at the centers (densest regions).



Spectroscopic confirmation of 40-50 members in each cluster
with Subaru/MOIRCS

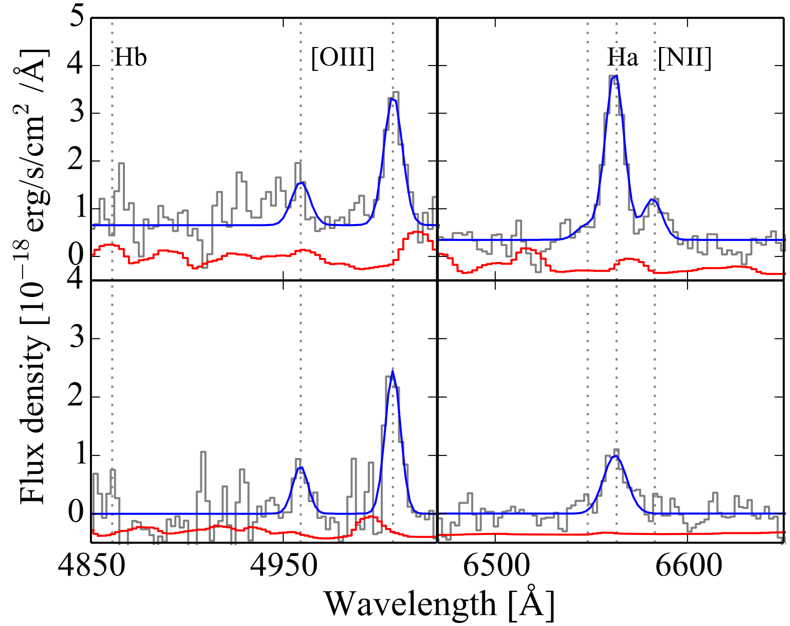
Shimakawa et al. (2014)

[OIII] strong galaxies in proto-clusters at z>2

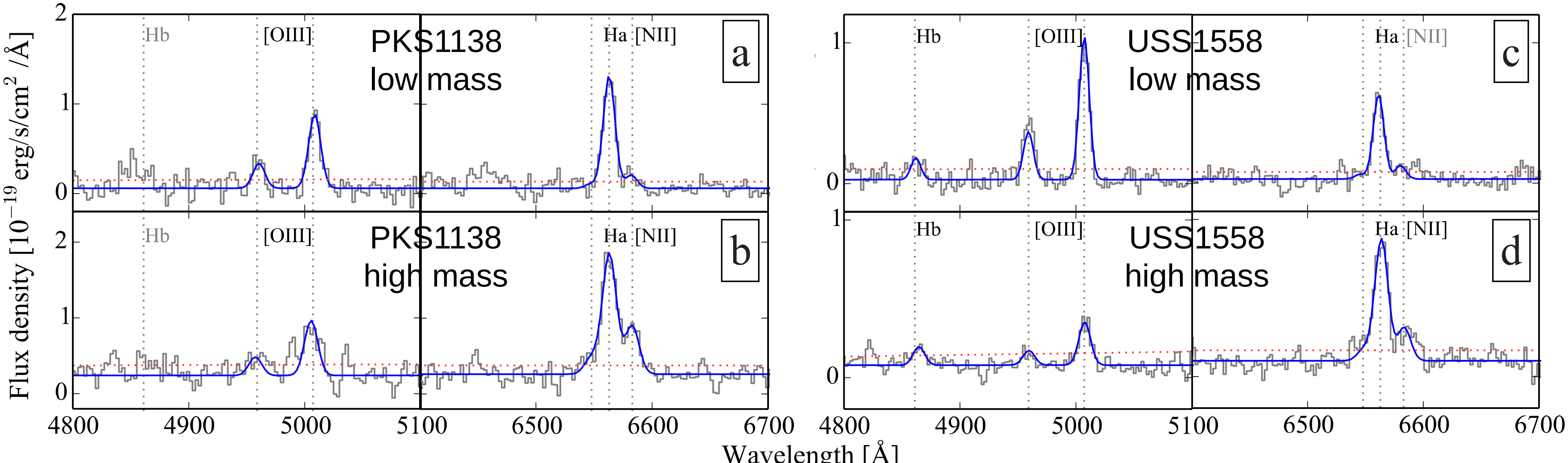
Kewley's model (2013) suggests:

low metallicity and/or large sSFR and/or large density?

Individual MOIRCS spectra (best examples)

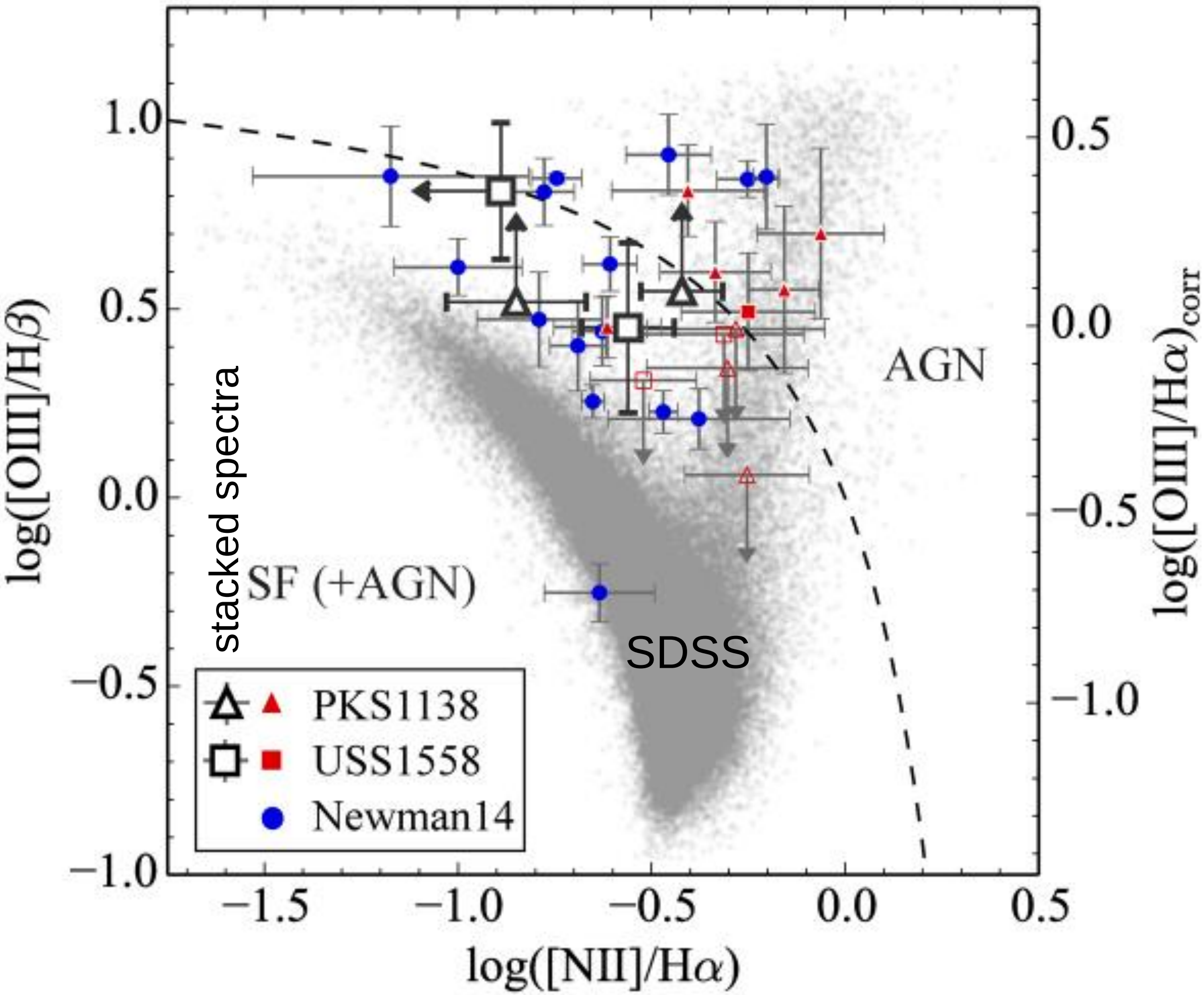


Stacked MOIRCS spectra



Shimakawa et al. (2015a)

Ionization/Excitation States



(individual Hβ are estimated
from Hα with dust correction)

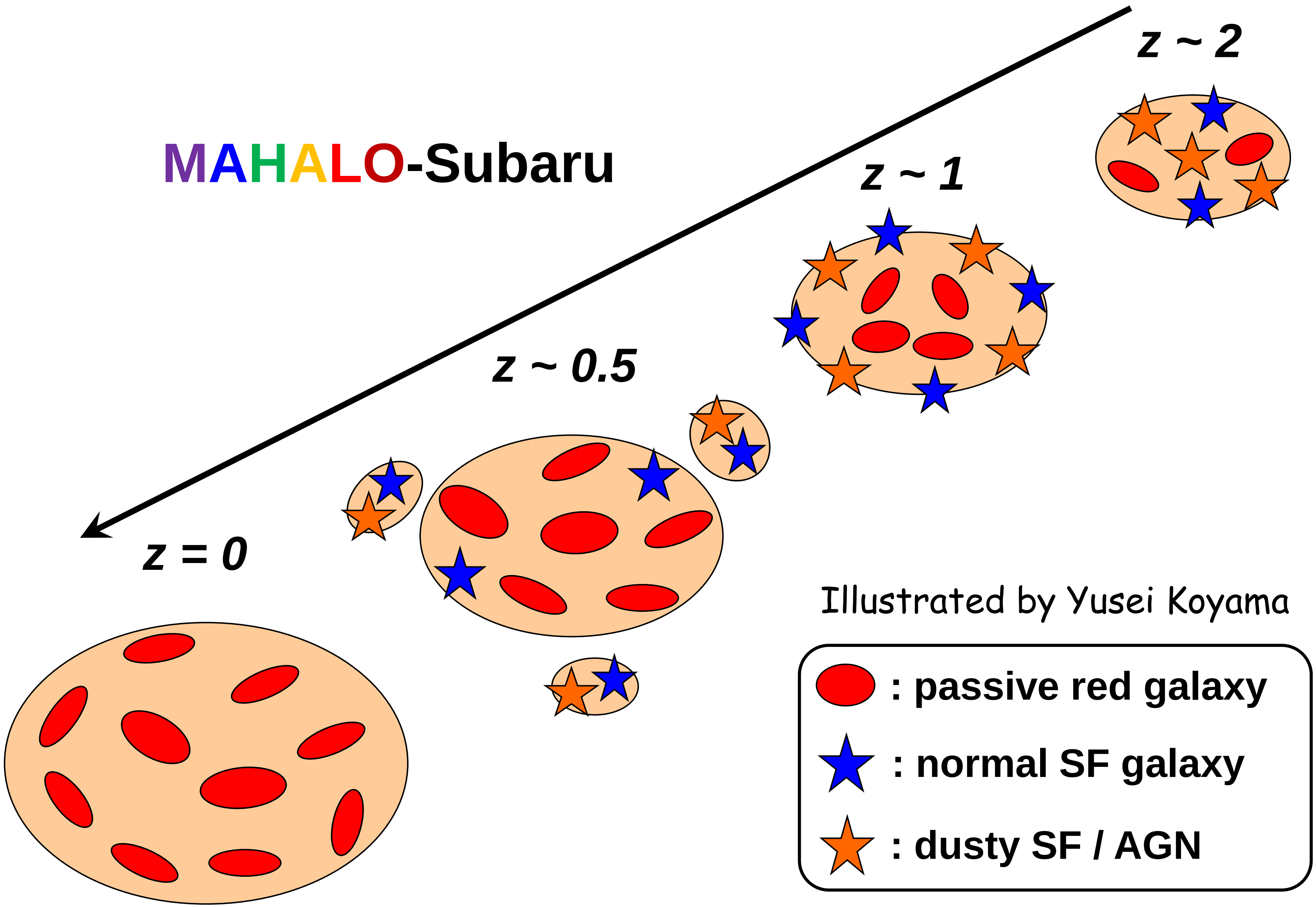
High-z ≫ Low-z

Higher sSFR
Lower metallicity
Larger e-density

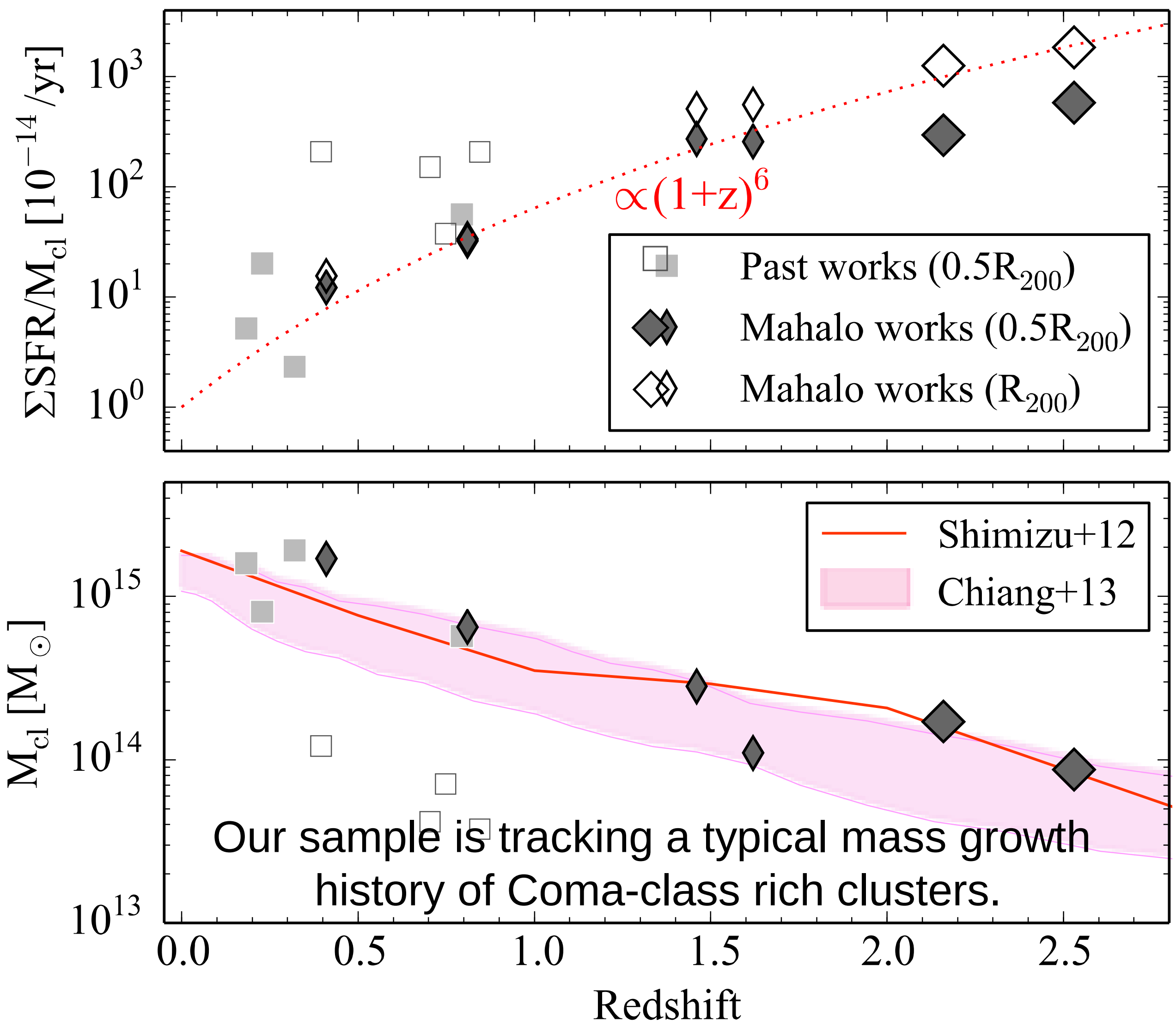
in high-z SFGs.

Shimakawa et al. (2015a)

Inside-out growth of galaxy clusters



Evolution of integrated SFRs and growth of dynamical mass in cluster cores



Rapid increase of integrated SFR per unit cluster mass with increasing z

Numerical simulations suggest that these proto-clusters will grow to ~$10^{15}M_\odot$ clusters by the present-day

Shimakawa et al. (2014)

Environmental effects at high-z

(Physical Processes)

- Merger, Interaction

  Frequency, Mode of SF (starburst)

- Gas inflow

  Filamentary cold streams vs. spherical accretion

- Gas outflow, stripping

  IGM pressure confinement, R-P/Tidal Stripping

(Consequences)

- Star formation activity

  Scatter of the SF main sequence (boost/truncation)

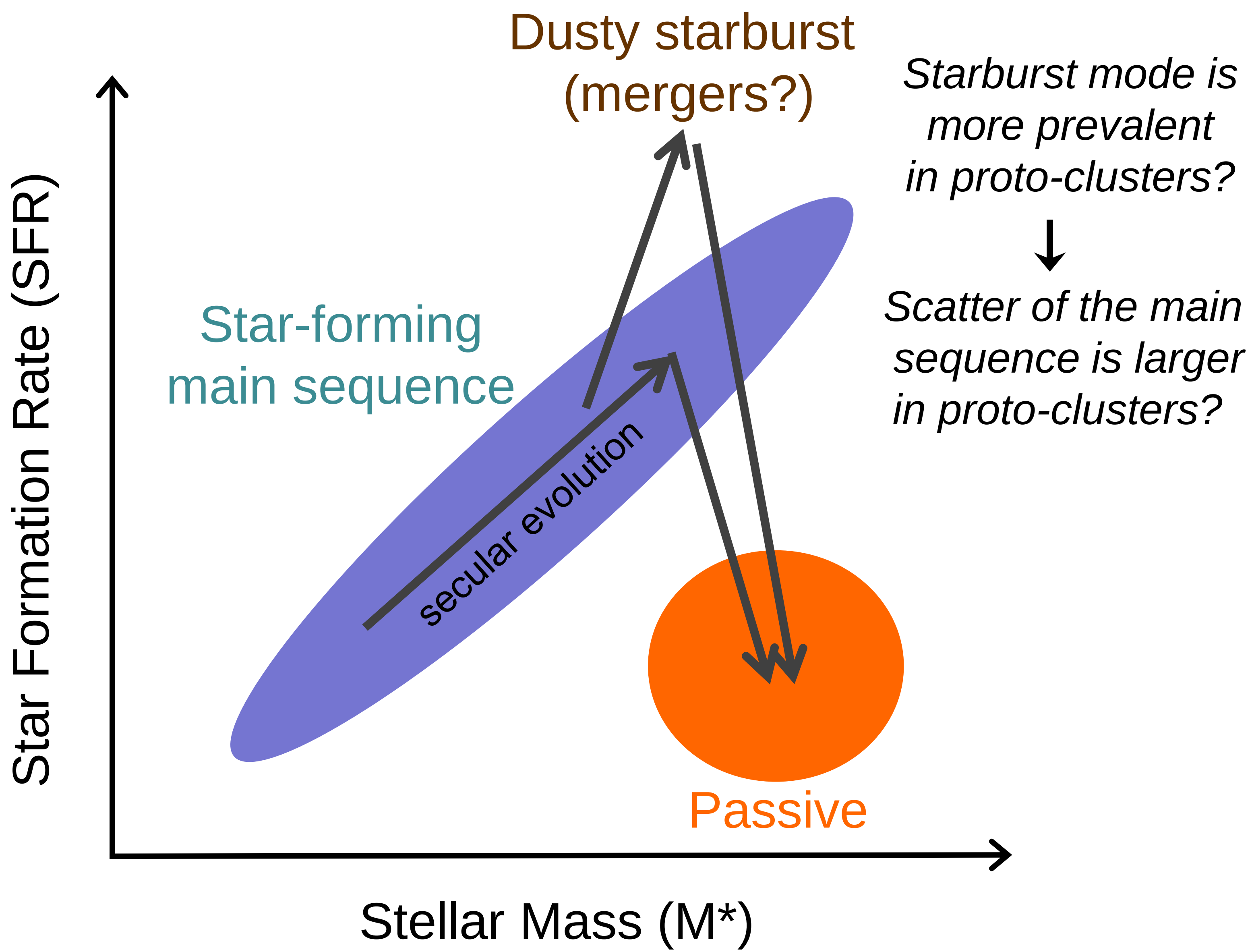
- AGN activity

  Frequency, Co-activation with star formation

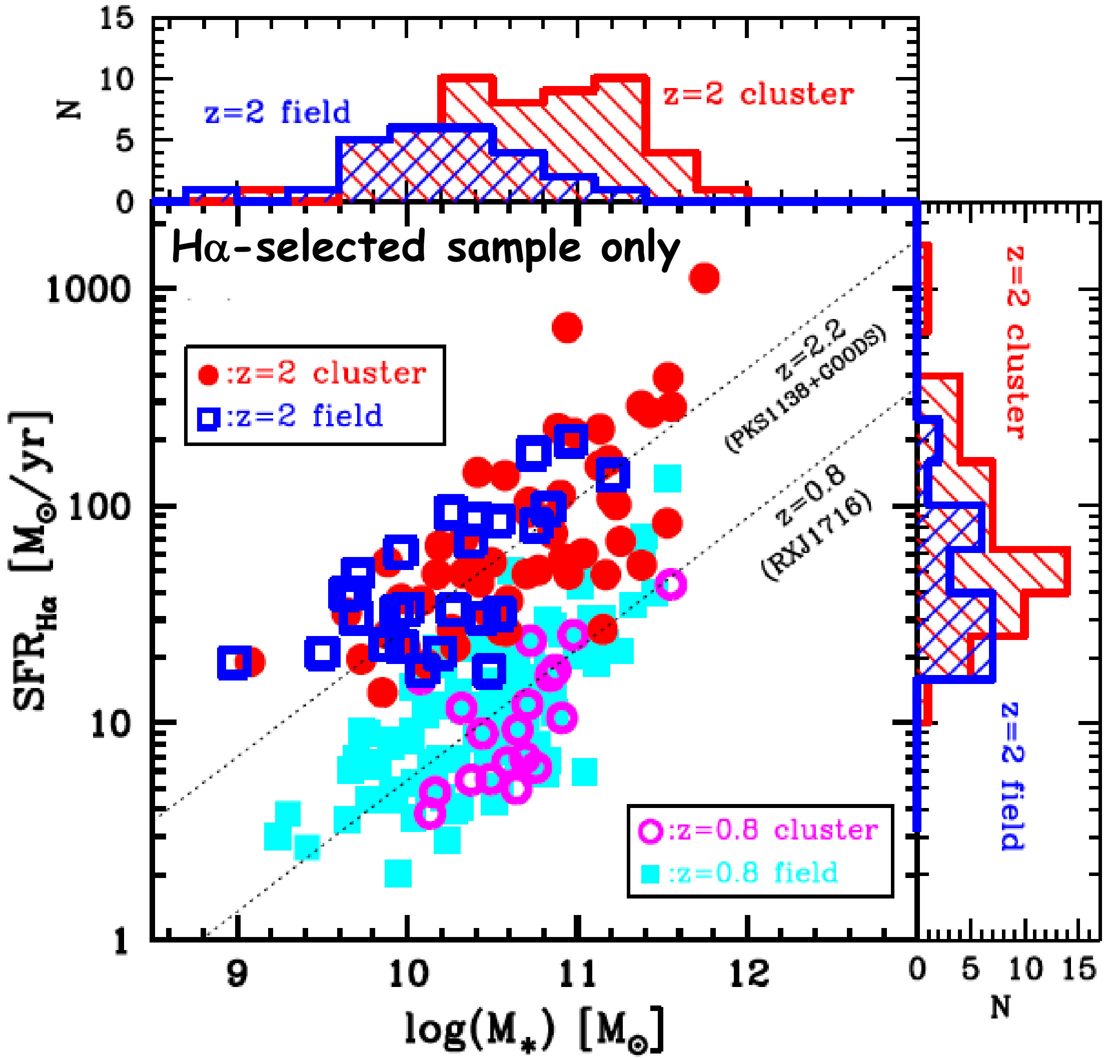
- Internal structure

  Disturbance, Location/Compactness/Dustiness of SF, Clumpiness

Hypothetical galaxy evolution on the SFR vs. M* diagram



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



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

SF galaxies in the proto-cluster at z~2 follow the same "main sequence" as the field one.

However, the galaxy distributions on the sequence are different in the sense that the proto-cluster contains more massive, higher-SFR, and probably dustier galaxies.

Also, a caveat is that the M* -scaled dust correction may not be applied for cluster galaxies.

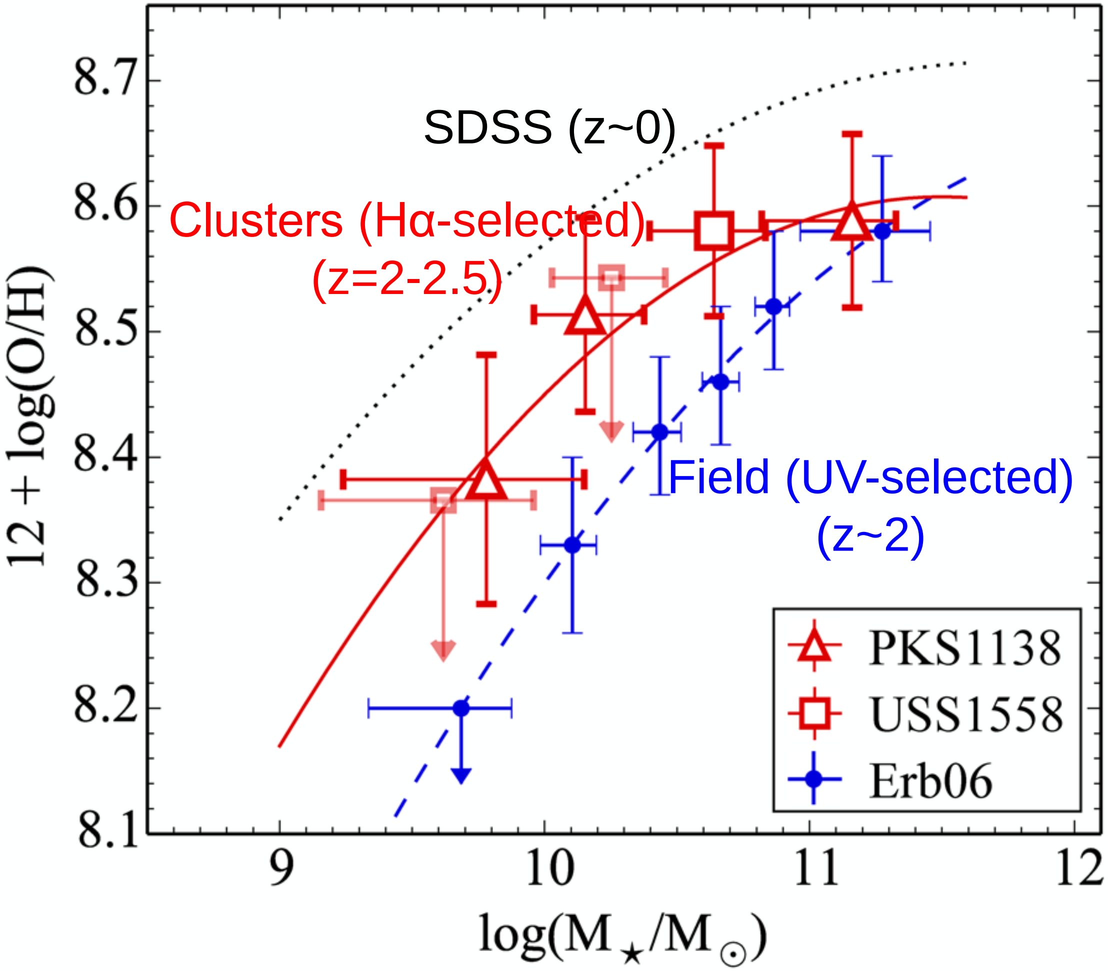
Koyama et al. (2013a)

see also Hatch et al. (2011) and Cooke et al. (2014)

MAHALO-Spec

Environmental dependence of gaseous metallicity at z>2

Based on stacking analysis of N2=[NII]/Hα with Subaru/MOIRCS



Shimakawa et al. (2015a)

High-z < Low-z

Cluster > Field
at low-mid mass

① Sample selections? HAEs in clusters tend to be more evolved than LBGs in the field.

② Accelerated, hence more advanced chemical evolution in clusters, and smaller f(gas)?

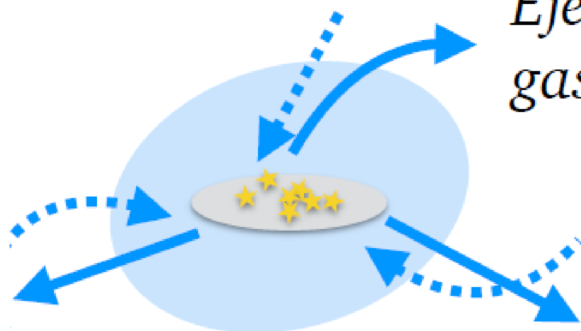
③ Stripping of metal poor gas from the reservoir, and stopping dilution of metals.

④ Recycling of enriched and once ejected gas? (Dave+ '11; Kulas+ '13)

Inflow and outflow processes may well depend on environment !

General field

Stochastic, rapid, cold gas accretion through filaments



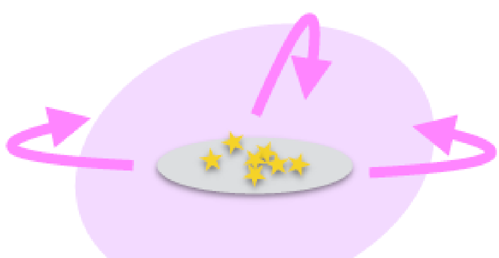
Ejecting enriched gas selectively

Metal dilution by primordial gas inflow

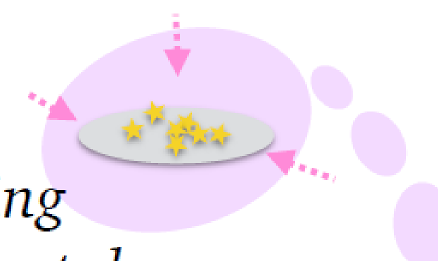
(Proto)cluster

Recycling of metal enriched gas

Stripping of metal poor gas from the reservoir



Steady but slow(?) gas accretion from a common halo



enriched gas falls back

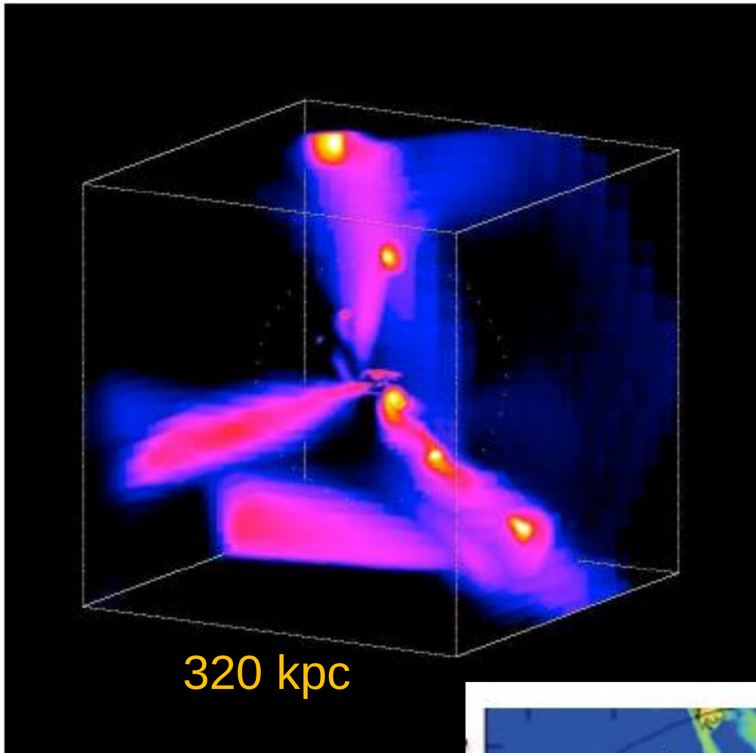
Stripping outer metal-poor gas

(Dave+ ’11; Kulas+ ’13)

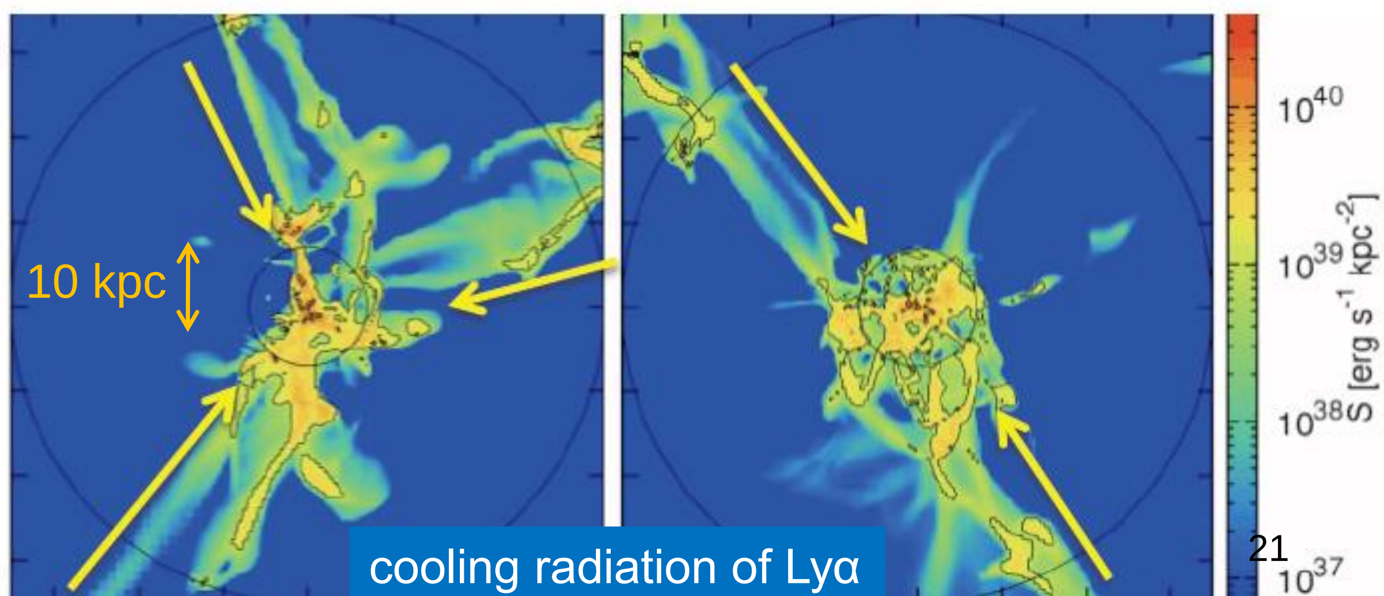
“Cold Streams” along filaments (Inflow)

Efficient gas supply to form a massive galaxy on a short time scale at high-z.

Rapid gas accretion forms a gas rich disk which becomes gravitationally unstable and fragmented.



Dekel et al. (2009, Nature)



Goerdt et al. (2010)

Environmental dependence of gas in-/out-flow processes is expected and should be explored!

→ another key aspect of the environmental effects on top of merger?

Inflow (cold streams):

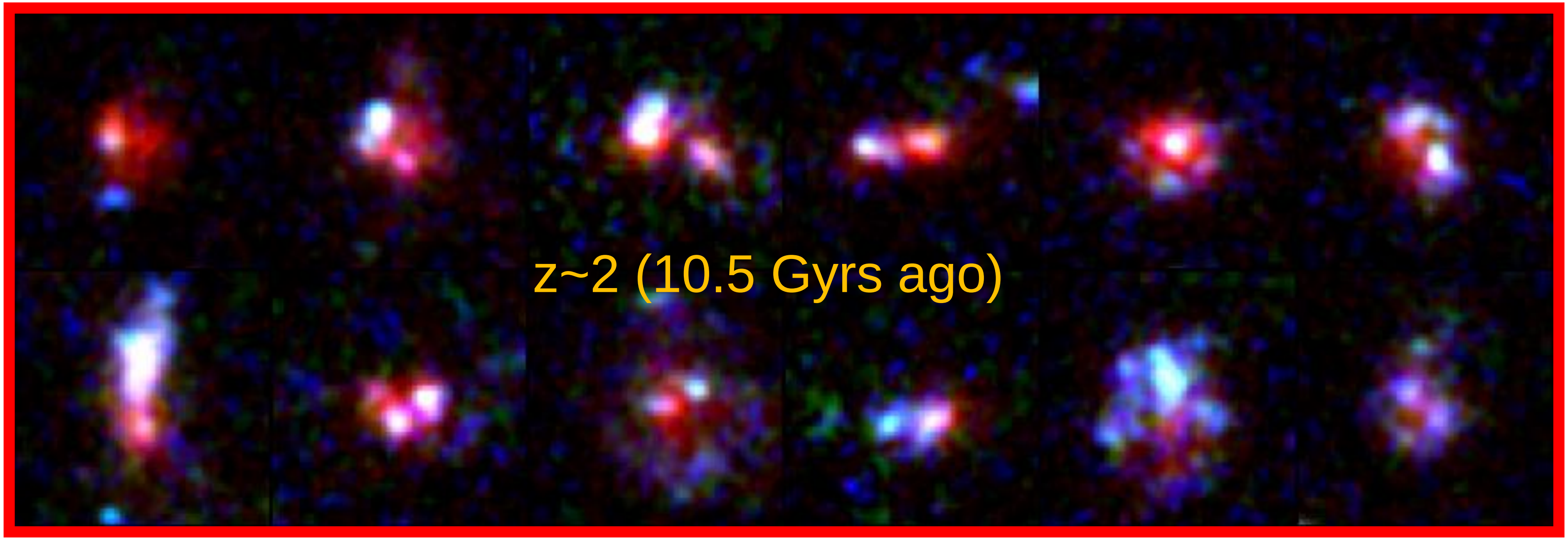
- can be different between common haloes in clusters and isolated haloes in the field?
- may affect internal structures (clumpiness)?

Outflow:

- suppressed by IGM pressure?
- selective stripping of outer metal poor gas?

→ Gaseous metallicity (MOSFIRE spectroscopy),
Gas fraction and effective chemical yield (ALMA), and
Galaxy anatomy (AO+NB imaging, IFU) will tell us more.

“Clumpy” SFGs at the cosmic noon



Clumpy structure is common (~40%)   Mergers or Fragmentation?

Massive clumpy galaxies tend to have a ***red*** clump, and be detected at 24μm.

Numerical simulation

→ The red clumps may be the site of nucleated dusty starburst to form a bulge?

→ Environmental dependence?

Tadaki, TK, et al. (2012)

Numerical simulations (N-body+SPH) reproduce the clumpy nature of star forming galaxies and the bulge formation

Bournaud et al. (2013)

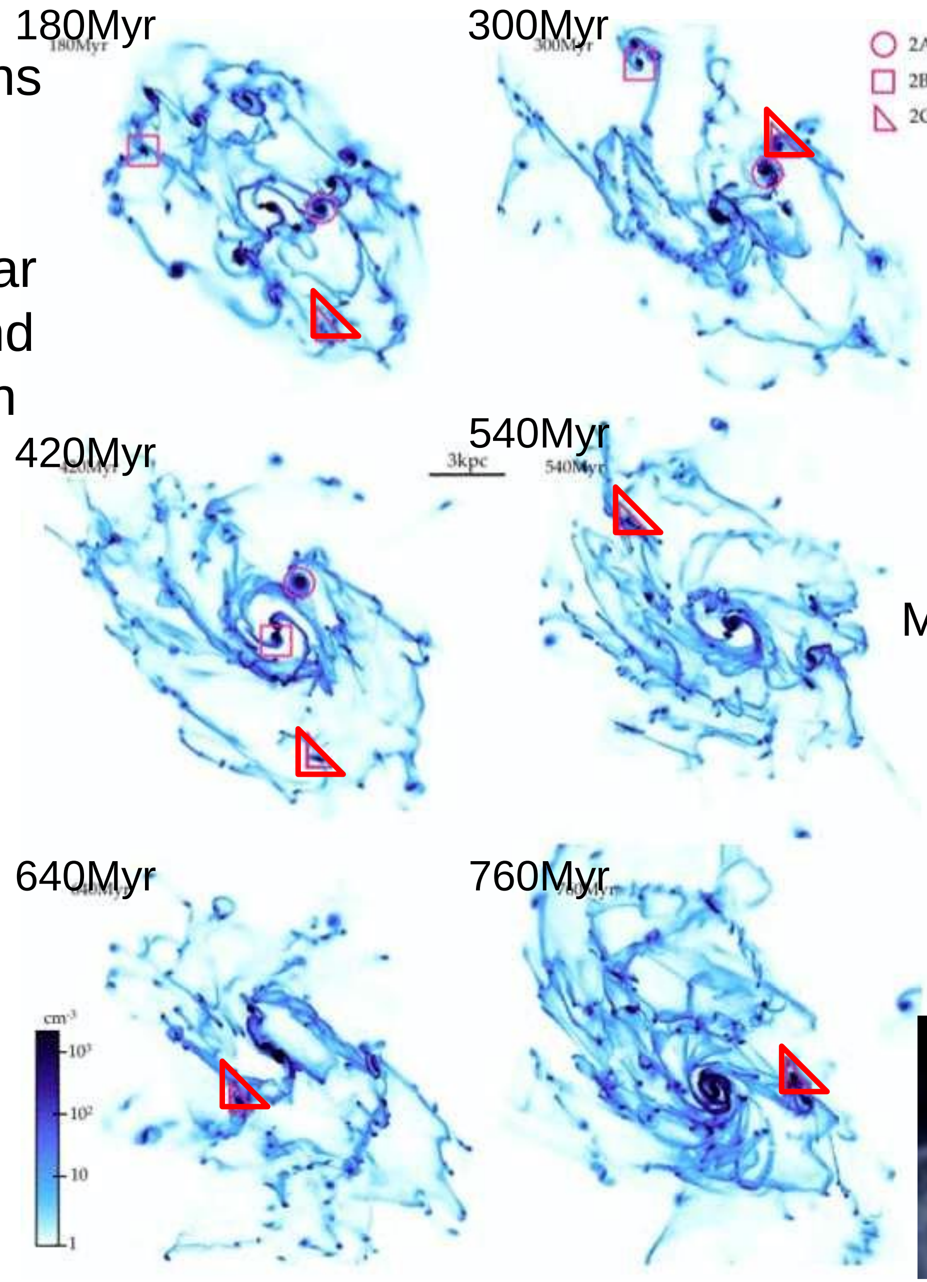


FIG. 2.— Same as Figure 1 for galaxy G2 (medium mass). Detailed sequences and movies of our fiducial models are available in Perret et al. (2013a).

$M_{dyn} = 3.5 \times 10^{10} M_\odot$

Hypothesis

Massive gas infall

↓

Gas rich disk

↓

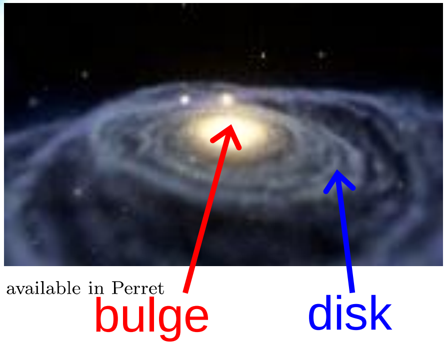
Fragment to clumps

↓

Migrate towards center

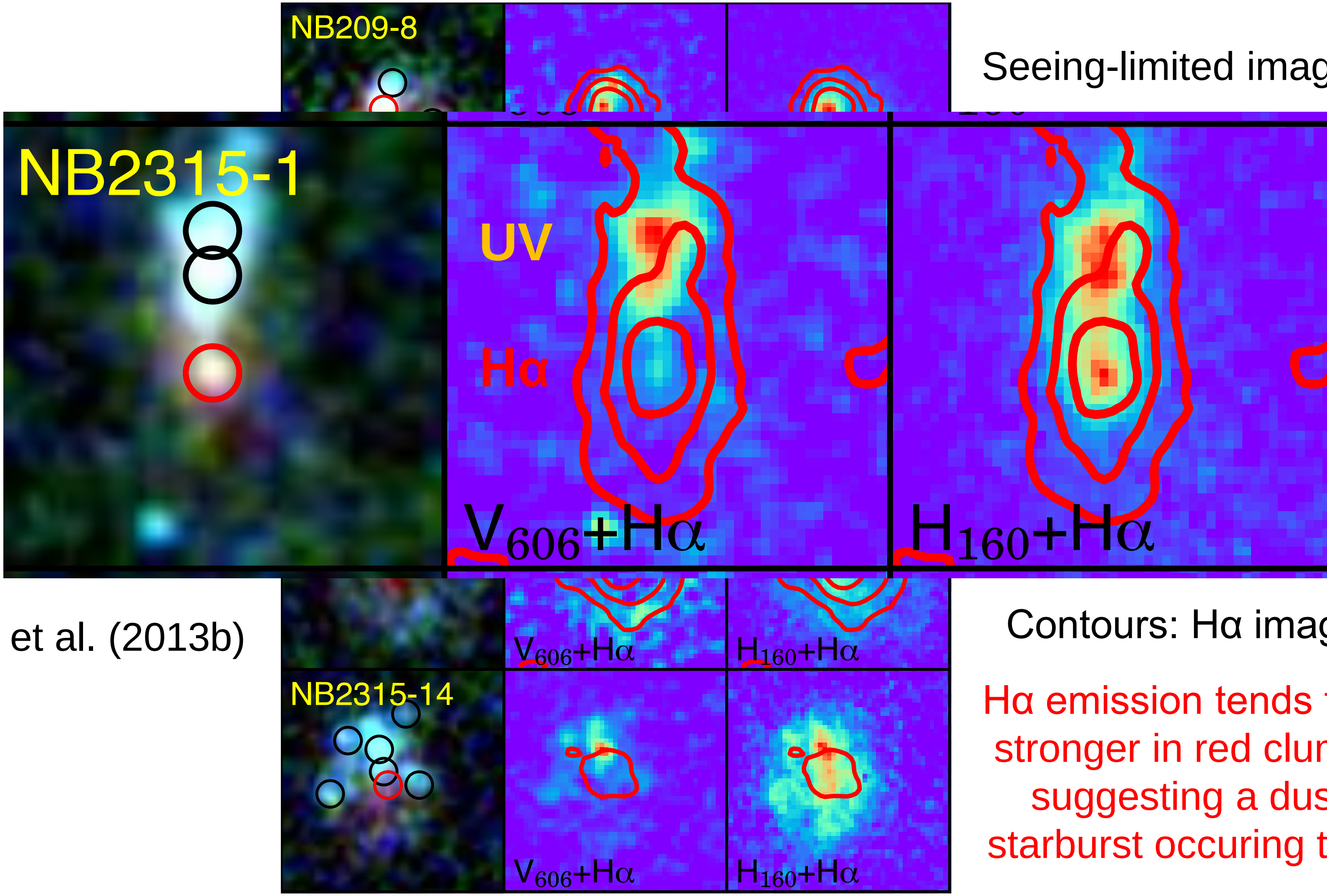
↓

Formation of a bulge



Spatially resolved Hα line emission in clumpy galaxies

Seeing-limited images



Tadaki et al. (2013b)

Contours: Hα images

Hα emission tends to be stronger in red clumps, suggesting a dusty starburst occuring there

Some extended HAEs are resolved with natural seeing, but for the majority, we require better resolutions with AO+NB imaging, IFU and ALMA.

GANBA-Subaru

(our on-going project; but we're really struggling with terrible weathers ☹)

Galaxy Anatomy with Narrow-Band AO imaging with Subaru

AO-assisted narrow-band Hα, [OIII] imaging with IRCS/Subaru

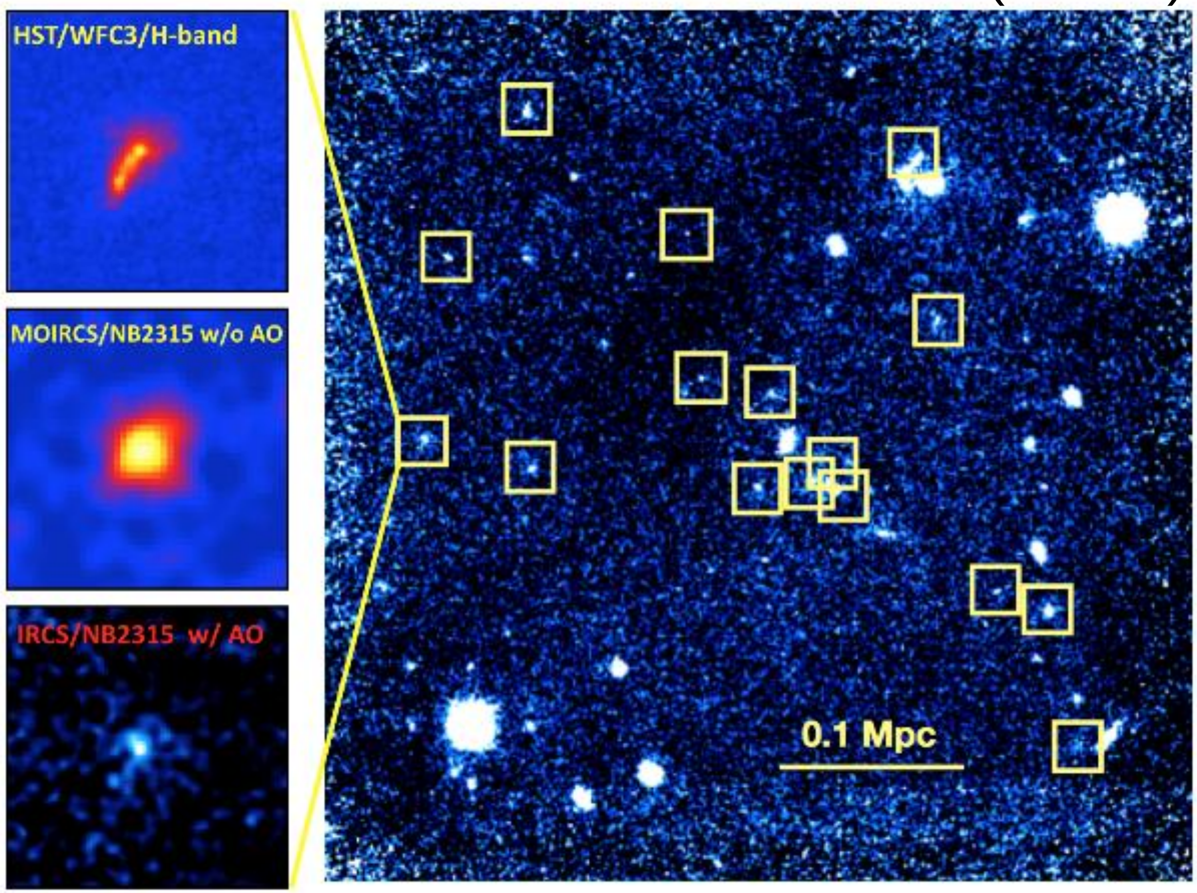
Any environmental dependence in internal structures?

Proto-cluster USS1558-003 (z=2.53)

HST/H-band (0.16") (Hayashi et al. in prep)

MOIRCS + NB (Hα) (seeing~0.5")

IRCS + AO188 +NB (Hα) (0.16" ~ 1.3 kpc)



IRCS 1' x 1'

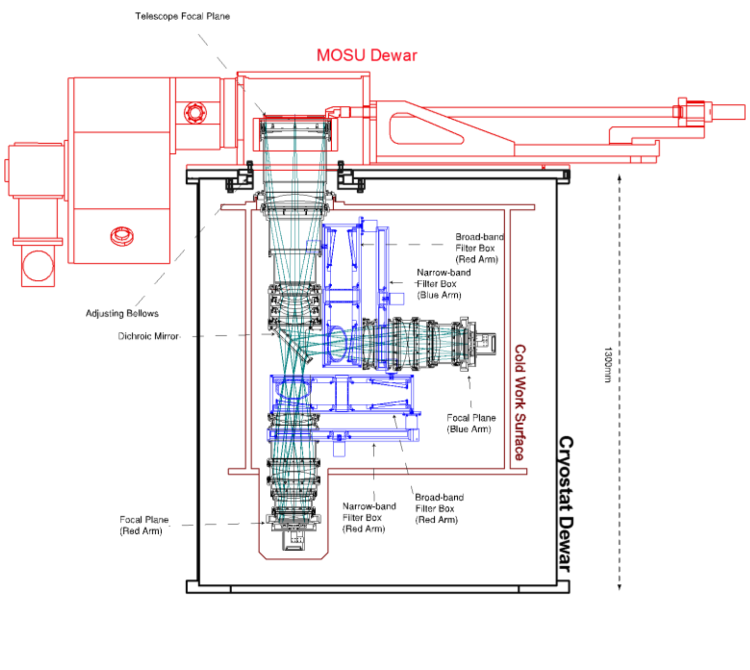
Resolved star-forming clumps!

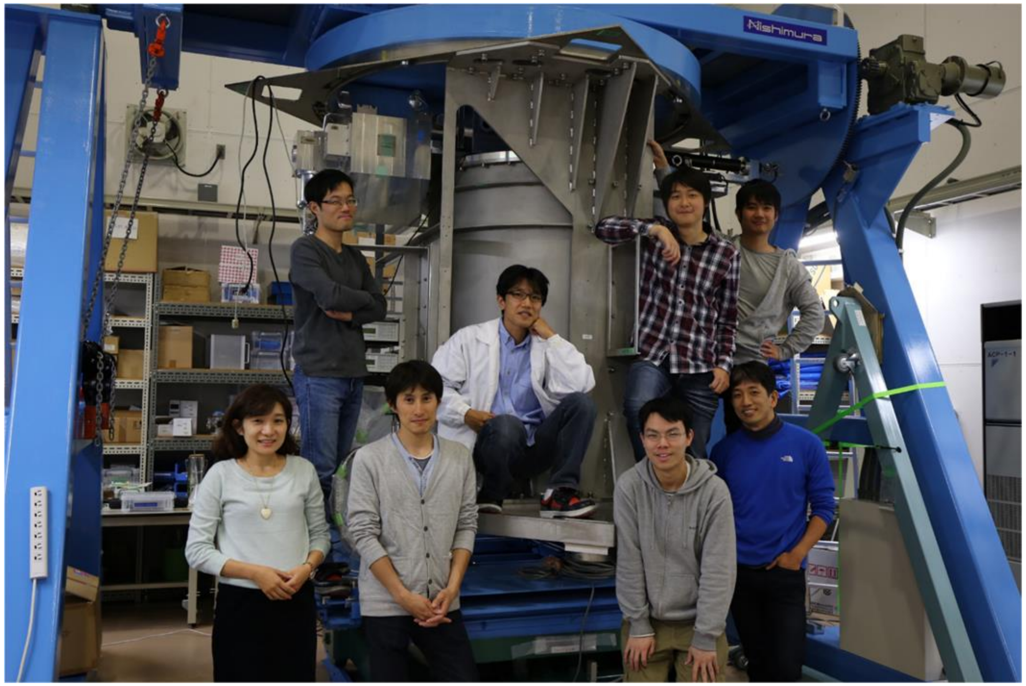
Suzuki et al., in prep.

SWIMS (TAO)

PI: Motohara, K. (IoA, U. Tokyo)

- Wide Field Imager and Multi-Object Spectrograph for TAO 6.5m telescope (IoA, U. Tokyo)
- 2-color (0.9-1.4/1.4-2.4um) simultaneous imaging/spectroscopy
- Initially operated at Subaru (2016~2018?)





SWIMS-18 Survey

Super multi-λ (NIR) imaging survey of the "Cosmic High Noon"

SWIMS is the new wide-field NIR camera and spectrograph to be installed on TAO 6.5m telescope in Chile, and will be mounted on Subaru for 2016-2018.

18 filters (6 NBs, 9 MBs, and 3 BBs) will be available !

Narrow-Band			Medium-Band				Broad-Band			
Band	λ_0 (μm)	FWHM (μm)	Band	λ (μm)	λ_0 (μm)	FWHM (μm)	Band	λ (μm)	λ_0 (μm)	FWHM (μm)
NB1244	1.244	0.012	Y	1.00-1.10	1.05	0.10	J	1.17-1.33	1.25	0.16
NB1261	1.261	0.012	J1	1.11-1.23	1.17	0.12	H	1.48-1.78	1.63	0.30
NB1630	1.630	0.016	J2	1.23-1.35	1.29	0.12	Ks	1.99-2.30	2.15	0.30
NB1653	1.653	0.016	H1	1.44-1.56	1.50	0.12				
NB2137	2.137	0.021	H2	1.56-1.68	1.62	0.12				
NB2167	2.167	0.021	H3	1.68-1.80	1.74	0.12				
			K1	1.96-2.10	2.03	0.14				
			K2	2.10-2.24	2.17	0.14				
			K3	2.24-2.38	2.31	0.14				

Simultaneous observations of blue (<1.4μm) and red (>1.4μm) channels !

Blue	Red	
NB1244 (6h)	NB1630 (3h)	NB2137 (3h)
NB1261 (6h)	NB1653 (3h)	NB2167 (3h)
Y (3h)	H1 (2h)	K1 (1h)
J1 (3h)	H2 (2h)	K2 (1h)
J2 (3h)	H3 (2h)	K3 (1h)
J (1.5h)	H (1h)	K_s (0.5h)

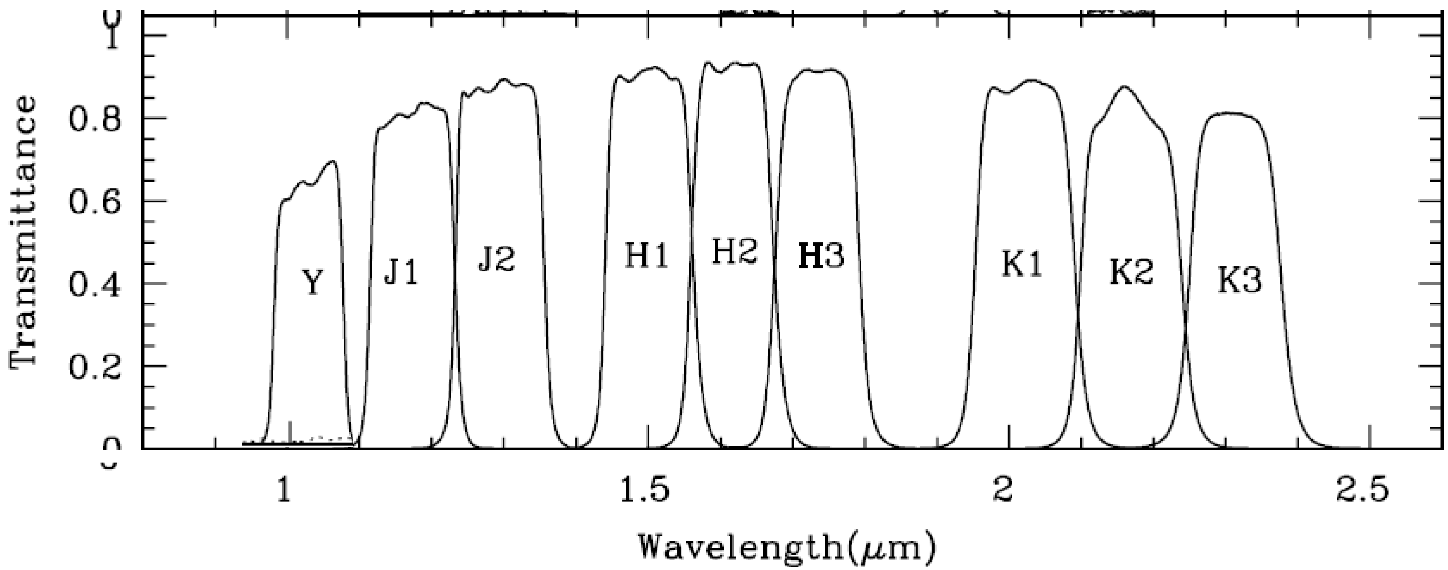
SWIMS-18 Medium-Band Filters (9)

M*-limited sample of galaxies up to z~4—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	5.60

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

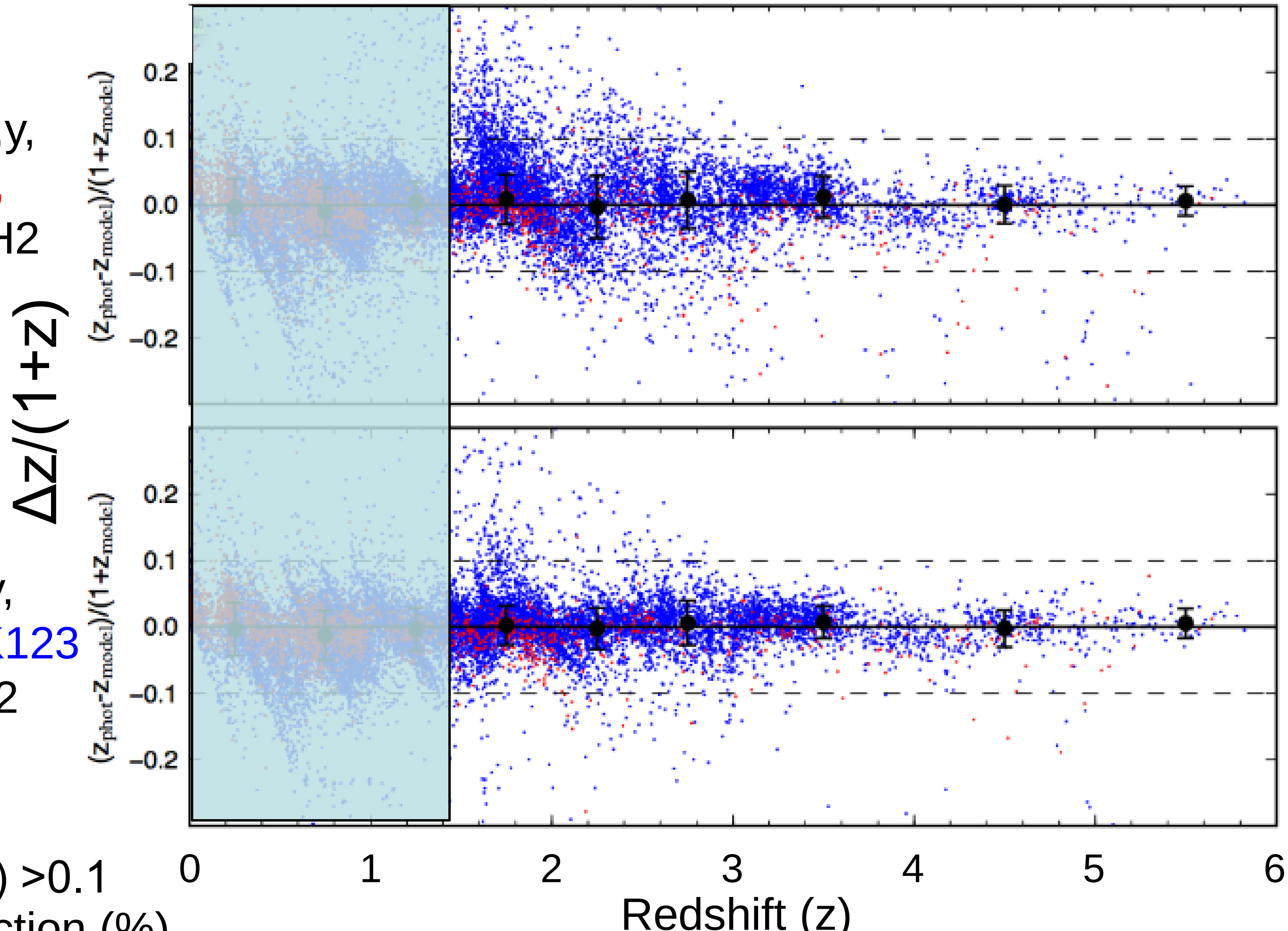
Will open a new window to
3.5<z<5 with K1,K2,K3 !



Improvement of Photometric Redshifts at 1.5<z<5.5

U,g,r,i,z,y,
J,H,K,
CH1,CH2

WITHOUT
SWIMS-18
MB filters



U,g,r,i,z,y,
YJ12H123K123
CH1,CH2

WITH
SWIMS-18
MB filters

Tadaki,
et al.

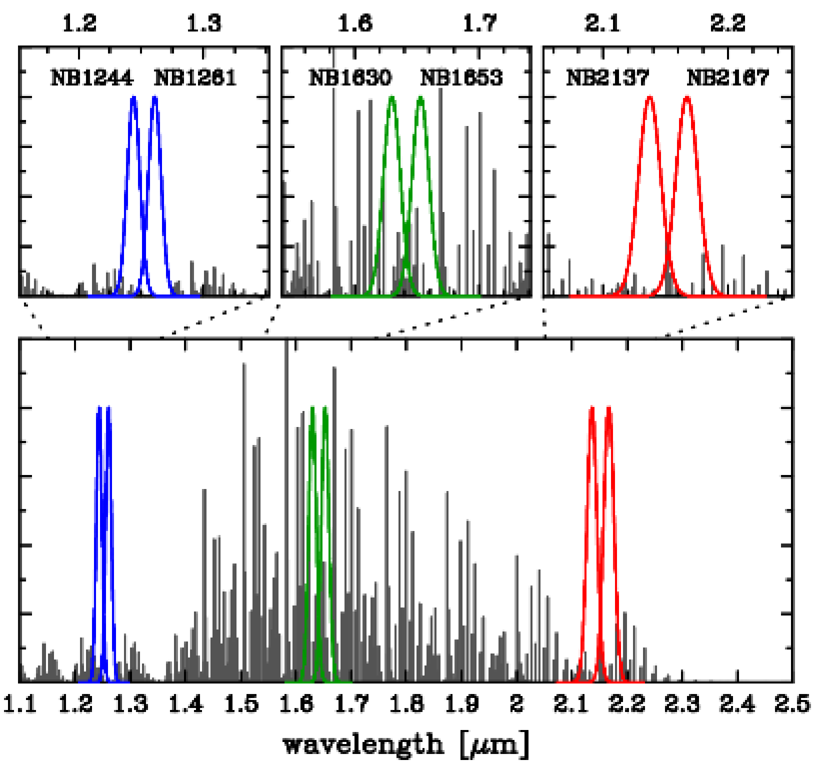
Δz/(1+z) >0.1
Outlier fraction (%)

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

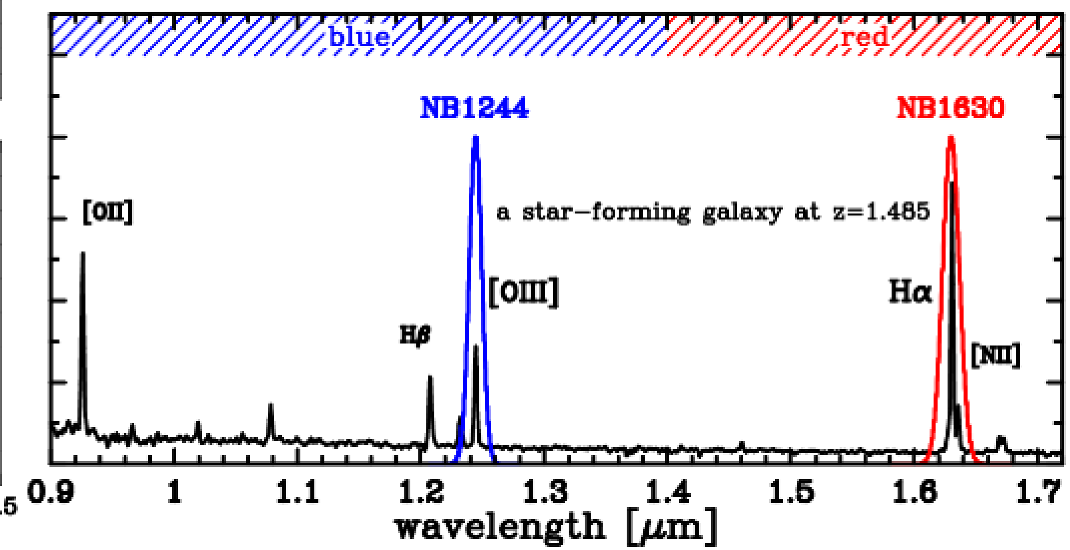
SWIMS-18 Narrow-Band Filters (6)

SFR-limited sample of star forming galaxies at 0.9<z<3.3

NB filters	λ_c (μm)	FWHM (μm)	z(Hα) 6563Å	z([OIII]) 5007Å	z(Hβ) 4861Å	z([OII]) 3727Å	z(Paα) 1.875μm	note
NB1244	1.244	0.012	0.895	*1.484*	1.559	2.337	–	CL1604+4304(z=0.895)
NB1261	1.261	0.012	0.922	*1.519*	1.595	2.384	–	CL1604+4321(z=0.920)
NB1630	1.630	0.016	*1.484*	*2.256*	2.354	3.374	–	※ HST F126N 1.259 0.015
NB1653	1.653	0.016	*1.519*	*2.302*	2.401	3.436	–	
NB2137	2.137	0.021	*2.256*	3.268	3.396	4.734	0.140	
NB2167	2.167	0.021	*2.302*	3.328	3.458	4.814	0.156	

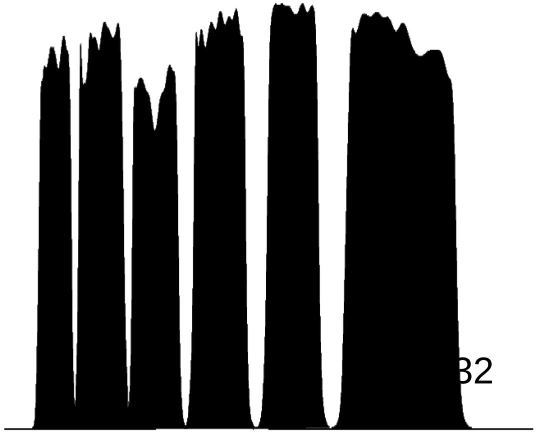


Dual Emitters ([OIII] and Hα) Survey
with Pair NB filters (4 pairs)



Z-FOURGE @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 > Z-FOURGE ?

(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
  λ<1.4μm (blue channel) and λ>1.4μm (red channel) with a dichroic mirror
  → Survey efficiency is doubled
- Large amount of time allocation to some dedicated programs
  → 0.7-1.5 yrs of observing time for 1 sq. deg. (×10 Z-FOURGE),
  optimal for environmental studies with clusters of $>10^{14}M_{\odot}$

Survey Design for SWIMS-18 (imaging)

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

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 0.7-1.5 yrs of observing time at TAO

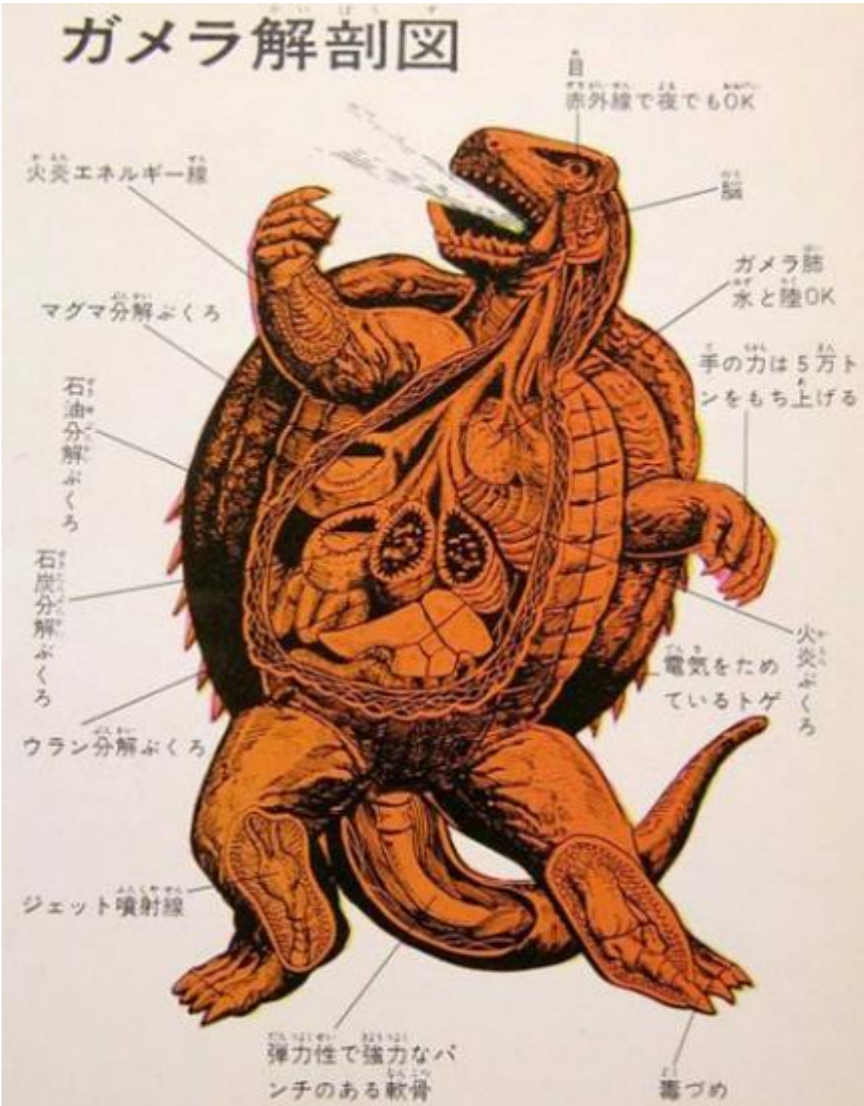
1/10-1/30 of the survey will be done with Subaru as a pilot study when SWIMS is mounted on Subaru for 3 yrs (2016-2018)

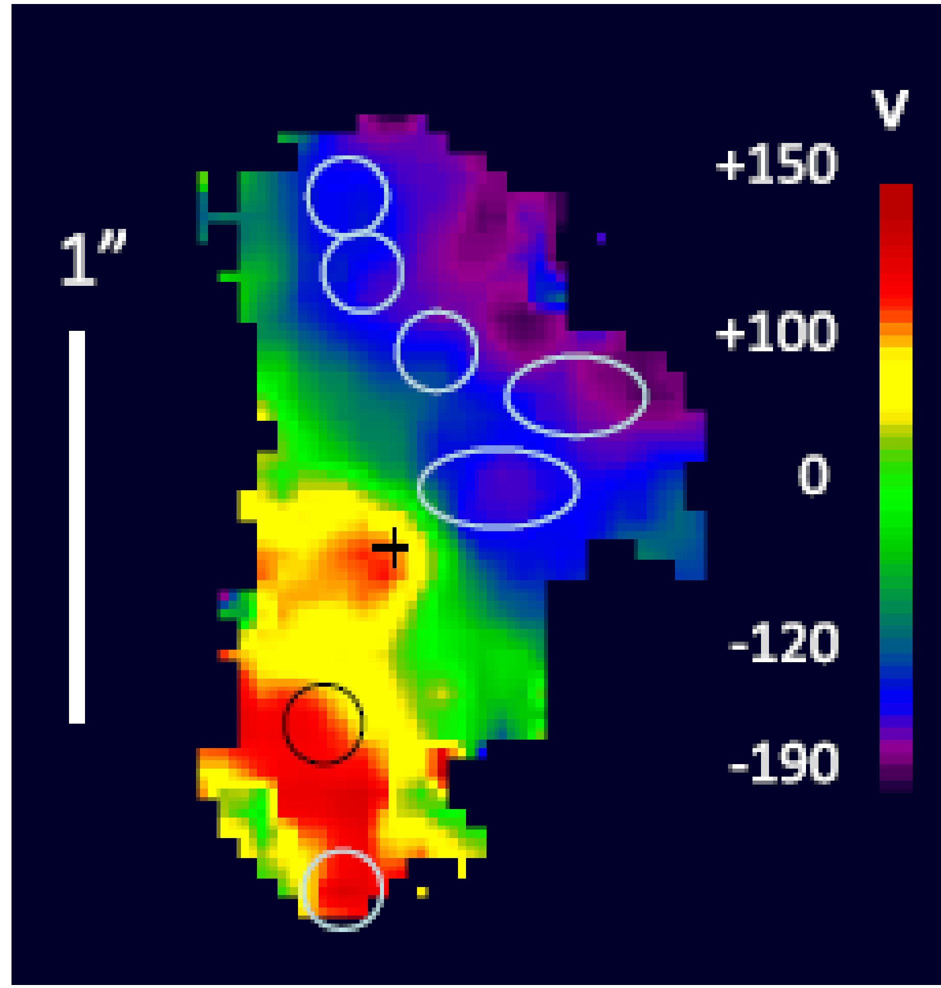
Thirty Meter Telescope (TMT; optical-NIR) (Mauna-Kea, Hawaii; 4200m)

A large international collaborations among USA, Japan, Canada, India, and China

High-z Galaxy Anatomy is *"Ohako"* for TMT

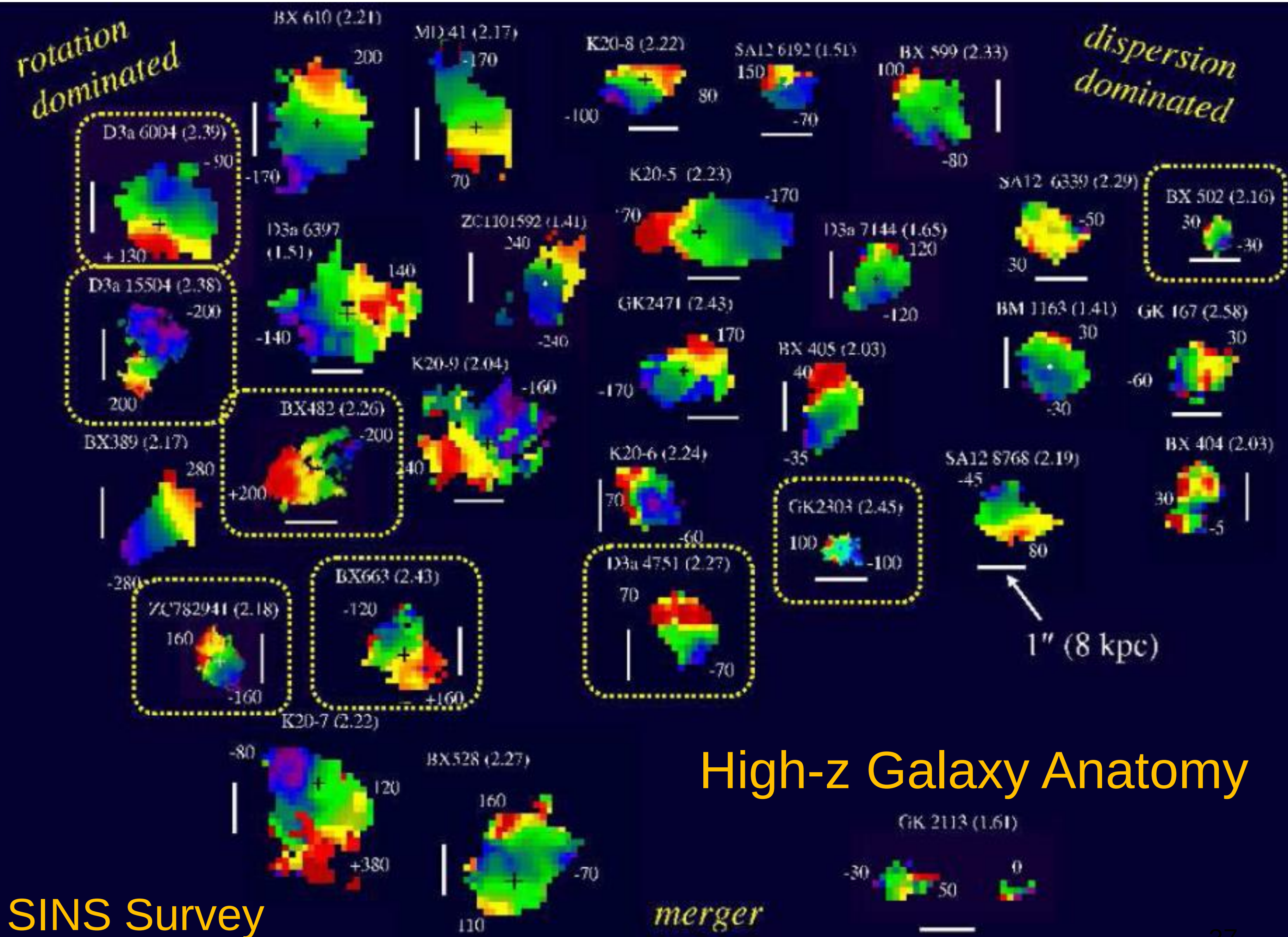
IFU (3D spectroscopy) w/AO





Rotation of gas-rich clumpy disk of a SFG at z=2.4 resolved with IFU (SINFONI) on VLT

Genzel et al. (2011)



High-z Galaxy Anatomy

SINS Survey

z~2 UV selected galaxies; VLT/SINFONI w/o AO; Vc/σ~2-4

Foerster-Schreiber et al. (2009)

ALOHA TMT
THIRTY METER TELESCOPE

"ALOHA-TMT"

Anatomy with Lines of Oxygen and Hydrogen with AO on TMT

Resolving internal structures/kinematics within galaxies under construction

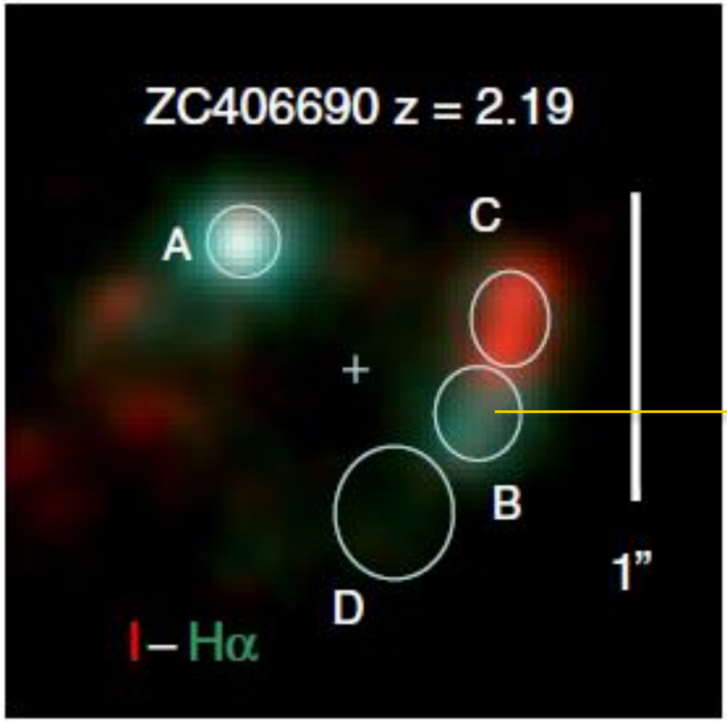
Huge light collecting power (13 × Subaru), and
High spatial resolution (0.015"@2μm with AO)

~3 mag deeper for point sources and
~1.5 mag deeper for extended sources
compared to Subaru (8.2m diameter)

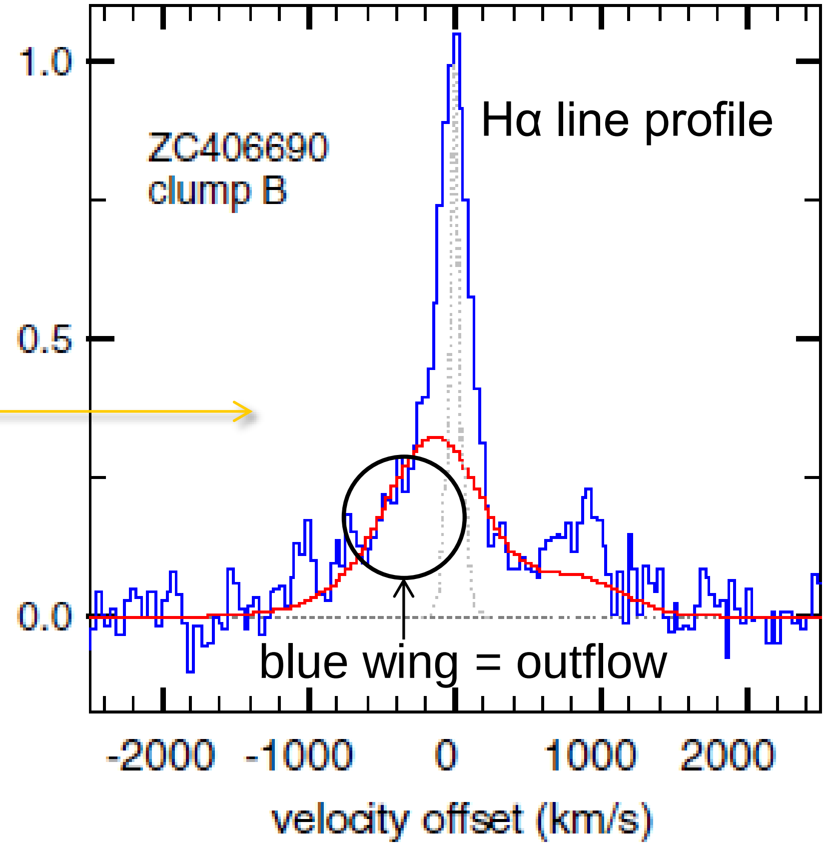
0.015"@2μm ⇔ ~0.1kpc @z>1

TMT can resolve stars and ionized gas in distant galaxies
with high resolution, comparable to ALMA (molecular gas and dust)!

Gas outflows from clumpy galaxies (feedback in action)



Genzel et al. (2011)

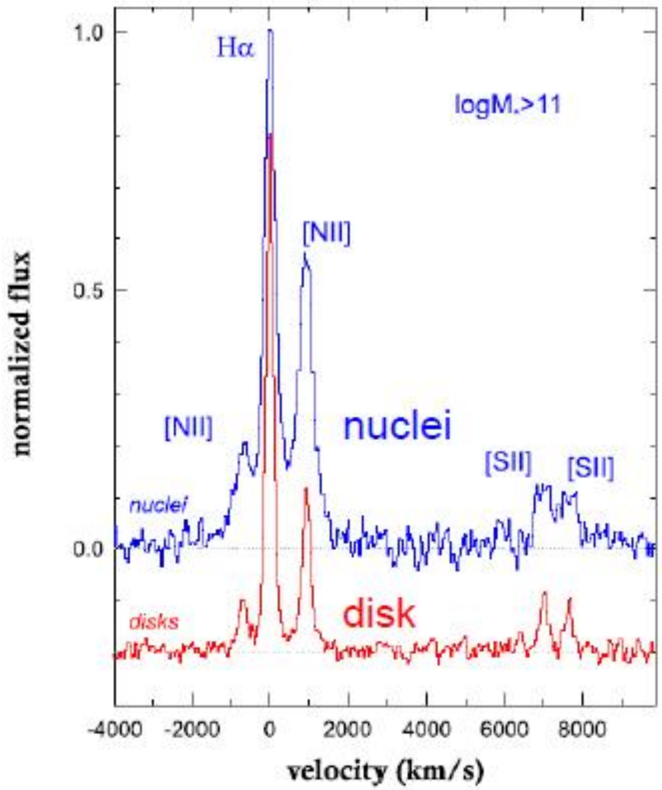


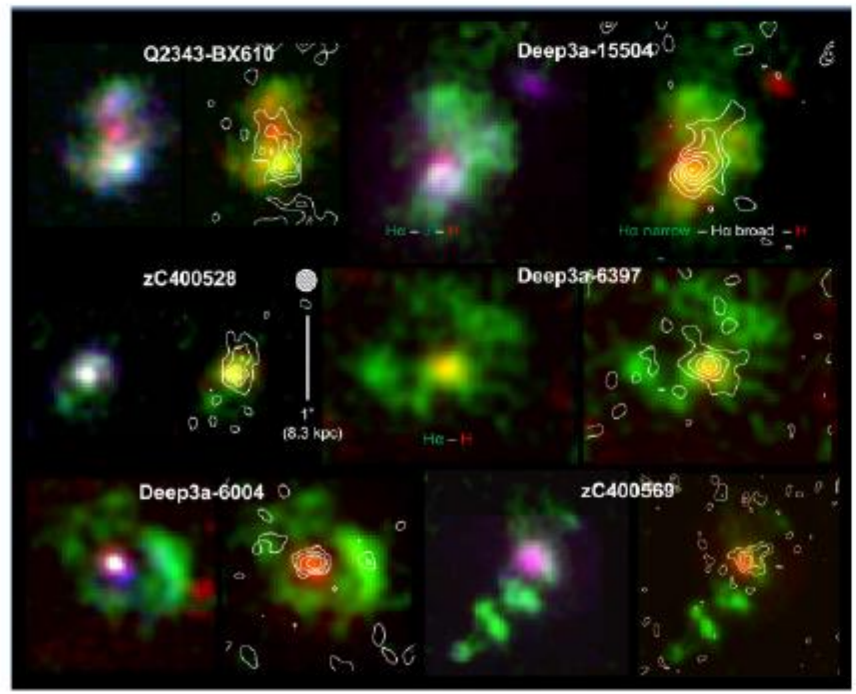
Gas outflow from the star-bursting clump-B (~500km/s)

F_{broad}/F_{narrow} (outflow strength) scales with SFR, suggesting "stellar" feedback.

Stacked Hα spectrum of massive SFGs at z=1-3

8 galaxies with log M*>11



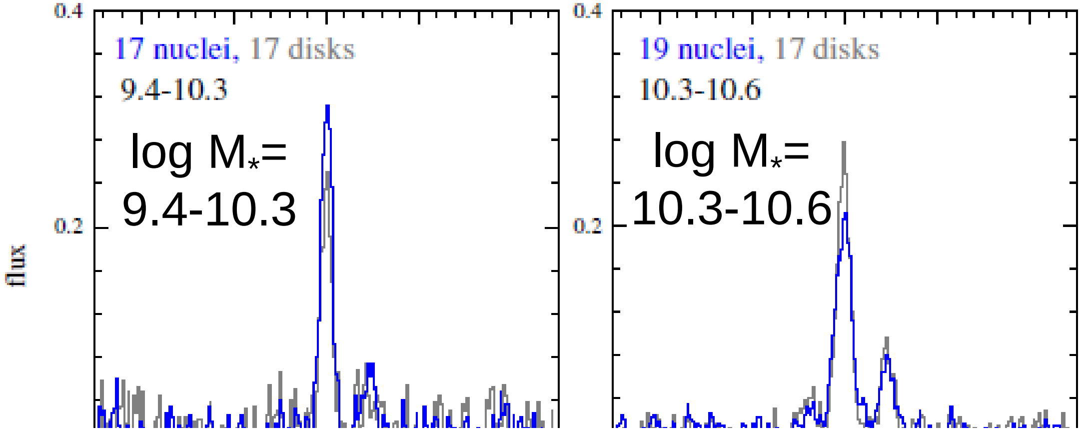


the spectra in the central region show a broad component

which is a signature of gaseous outflows.

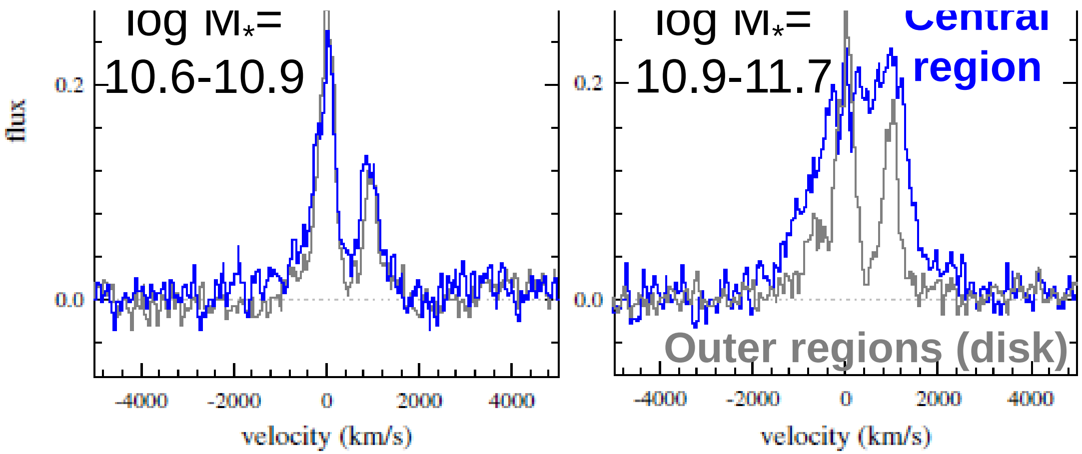
Genzel et al. (2014)

Outflows by Star Formation and AGN (feedback)



Low mass (log M*<10.9)
SF driven outflow
(Δv_{broad}~300km/s)

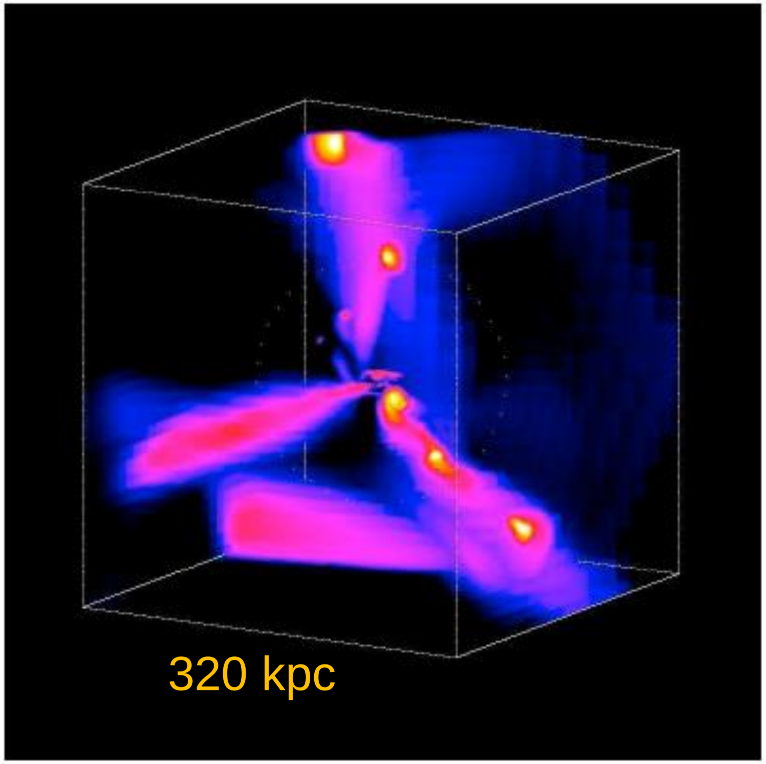
Based on stacking analysis now, and with 1kpc resolution at best. With TMT, we can resolve individual galaxies in space (0.1kpc), velocity, and line ratios, which tells us internal physics of galaxy formation such as star formation, inflows, and outflows.



High mass (log M*>10.9)
AGN driven outflow

Genzel et al. (2014)

Detection of cold streams (gas feeding)

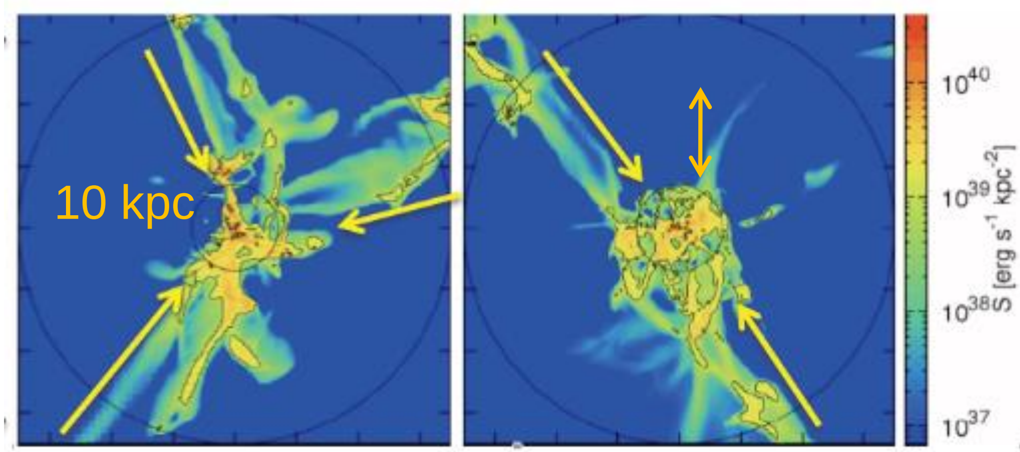


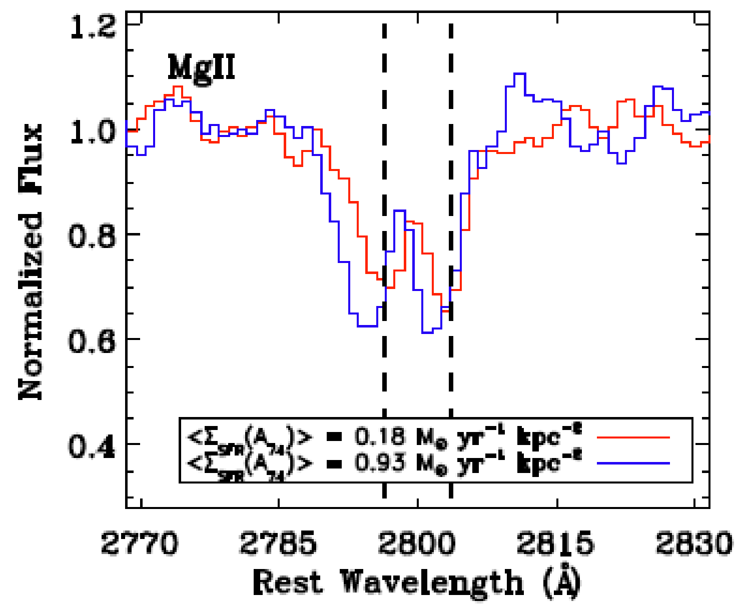
Dekel et al. (2009, Nature)

A major channel of gas accretion at high-z?
Responsible for high SFR and clumpy structures?

However, no convincing evidence discovered yet!

Goerdt et al. (2010)

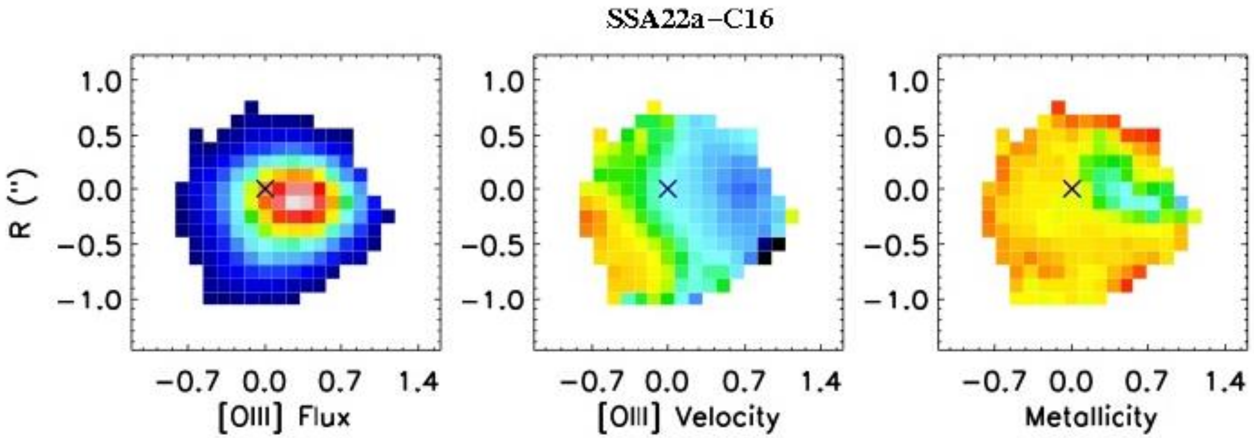




Relative velocity of absorbing gas in the front.
Blueshift → outflow (figure above)
Redshift → inflow (new!)

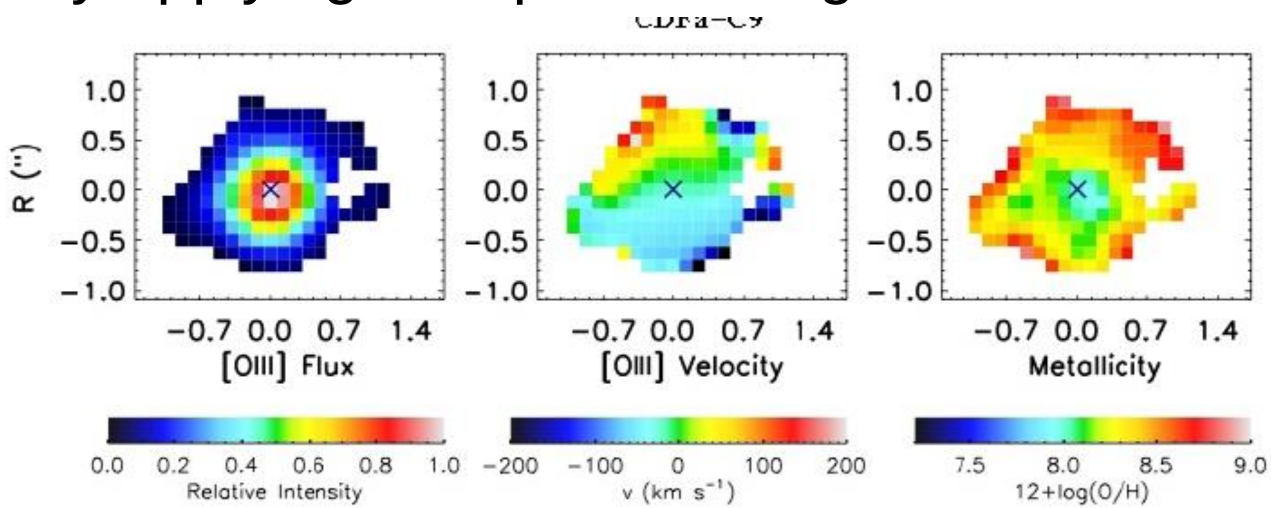
Spatially resolved chemical evolution within galaxies

→ Propagation of SF and gas in/outflows



2D map of line ratios (metallicity indicators) such as [OIII]/Hβ and [NII]/Hα

TMT will disentangle between metallicities and ionizing states by applying multiple line diagnostics for individual galaxies!



VLT/SINFONI

Cresci et al. (2010)

Low metallicity in the central region → Dilution of metals by gas accretion?

Summary

- Mahalo-Subaru has been mapping out star formation activities across cosmic times (0.4<z<3.6) and environments, covering the peak epoch of galaxy formation.
- SWIMS-18 will be sensitive up to z~5 (Balmer break) and to z~3.3 (Hα, OIII emitters), with unique sets of medium-band/narrow-band filters.
- Aloha-TMT will spatially and kinematically resolve galaxies at high-z and tell us internal physics of galaxy formation such as localized SF, feeding, and feedback.


HAWAIIAN ISLAND
MAHALO
ALOHA STATE


Aloha