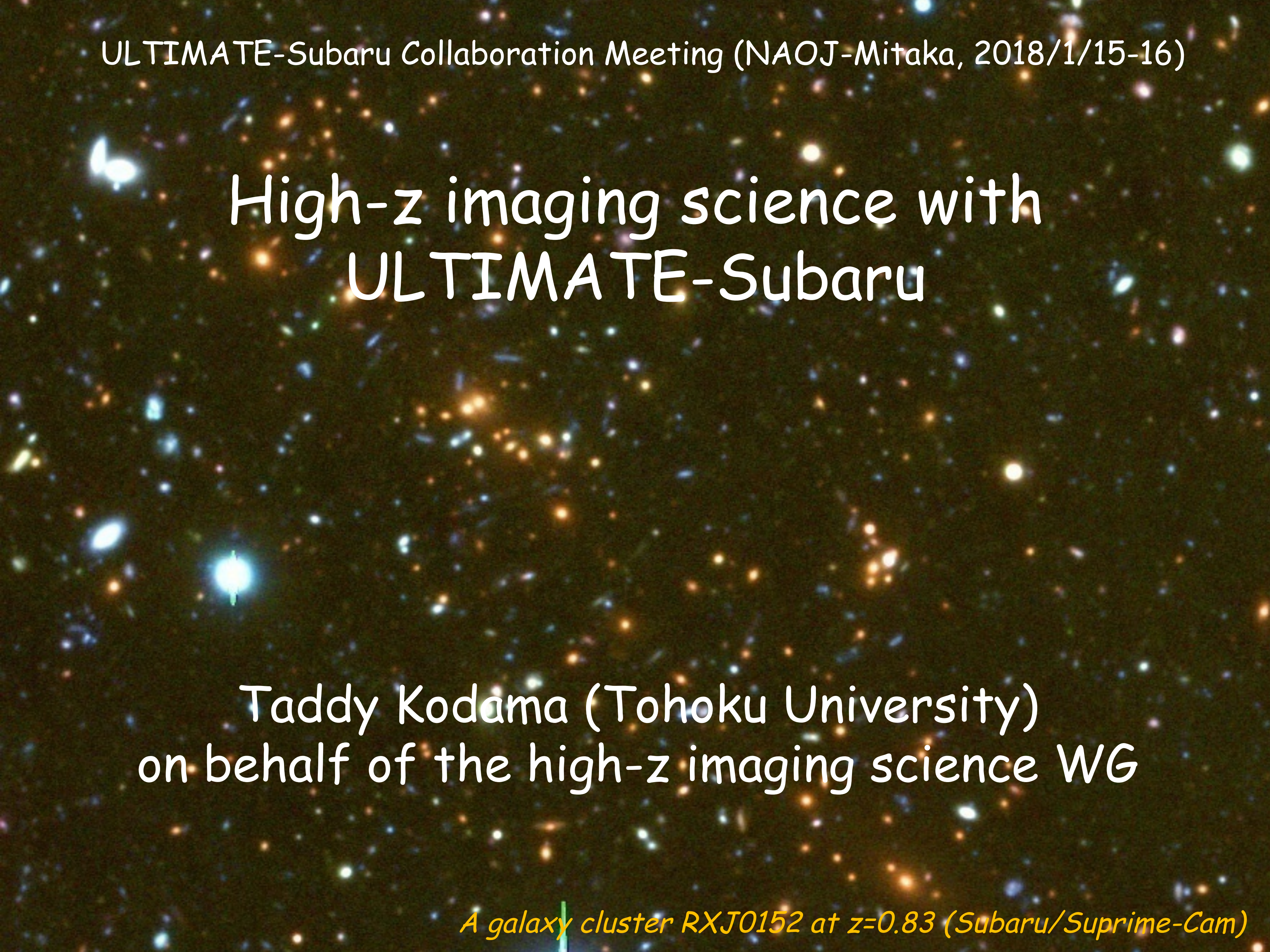
ULTIMATE-Subaru Collaboration Meeting (NAOJ-Mitaka, 2018/1/15-16)

High-z imaging science with ULTIMATE-Subaru

Taddy Kodama (Tohoku University)
on behalf of the high-z imaging science WG



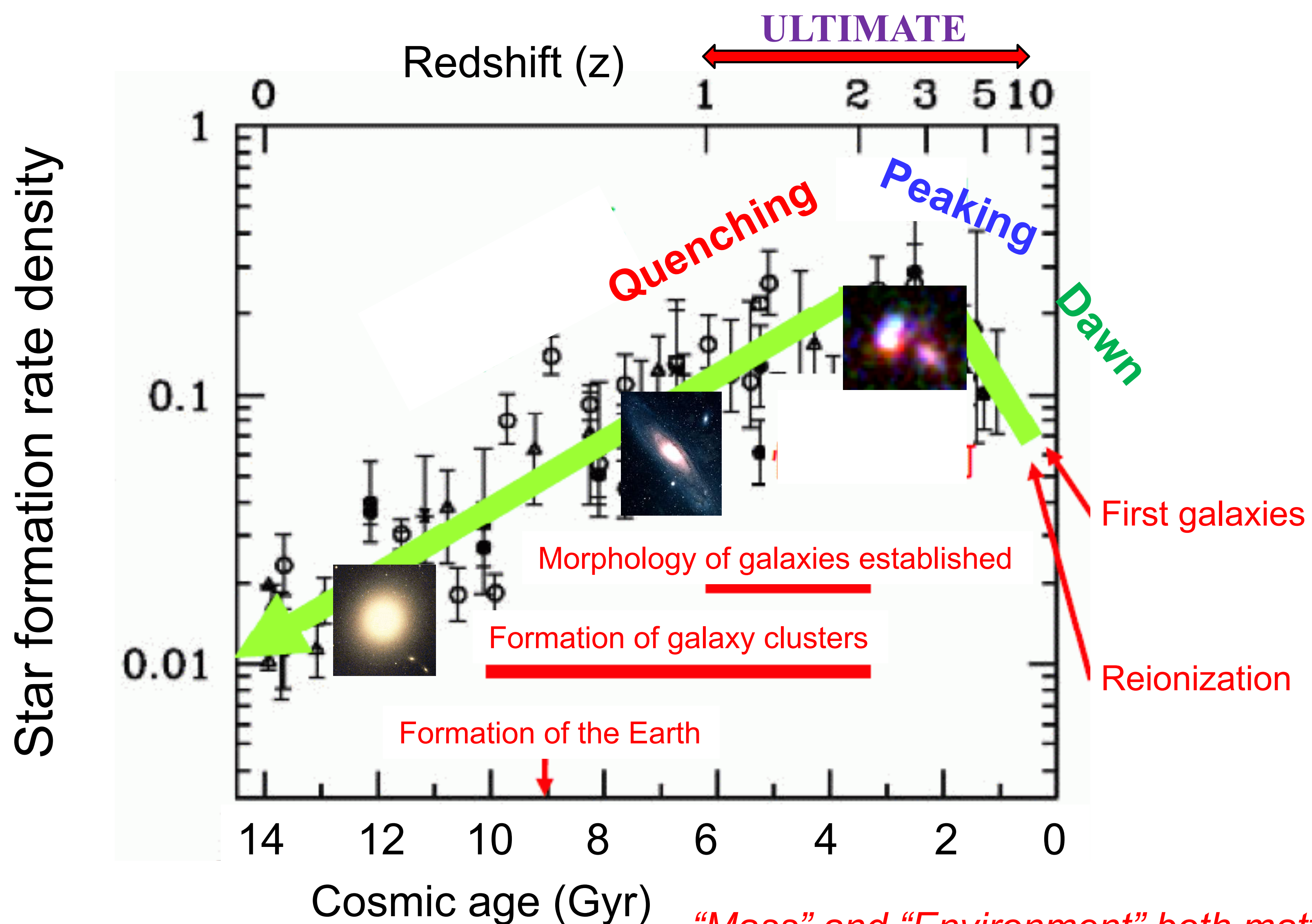
A galaxy cluster RXJ0152 at z=0.83 (Subaru/Suprime-Cam)

“Current” high-z imaging science WG

Masao Hayashi (NAOJ)
Ikuru Iwata (Subaru)
Satoshi Kikuta (Sokendai/NAOJ)
Tadayuki Kodama (Tohoku Univ.)
Kotaro Kohno (Univ. of Tokyo)
Yusei Koyama (Subaru)
Yen-Tin Lin (ASIAA)
Yuichi Matsuda (NAOJ)
Yosuke Minowa (Subaru)
Masato Onodera (Subaru)
Takatoshi Shibuya (Univ. of Tokyo)
Rhythm Shimakawa (UCSC)
Tomoko Suzuki (NAOJ)
Ichi Tanaka (Subaru)

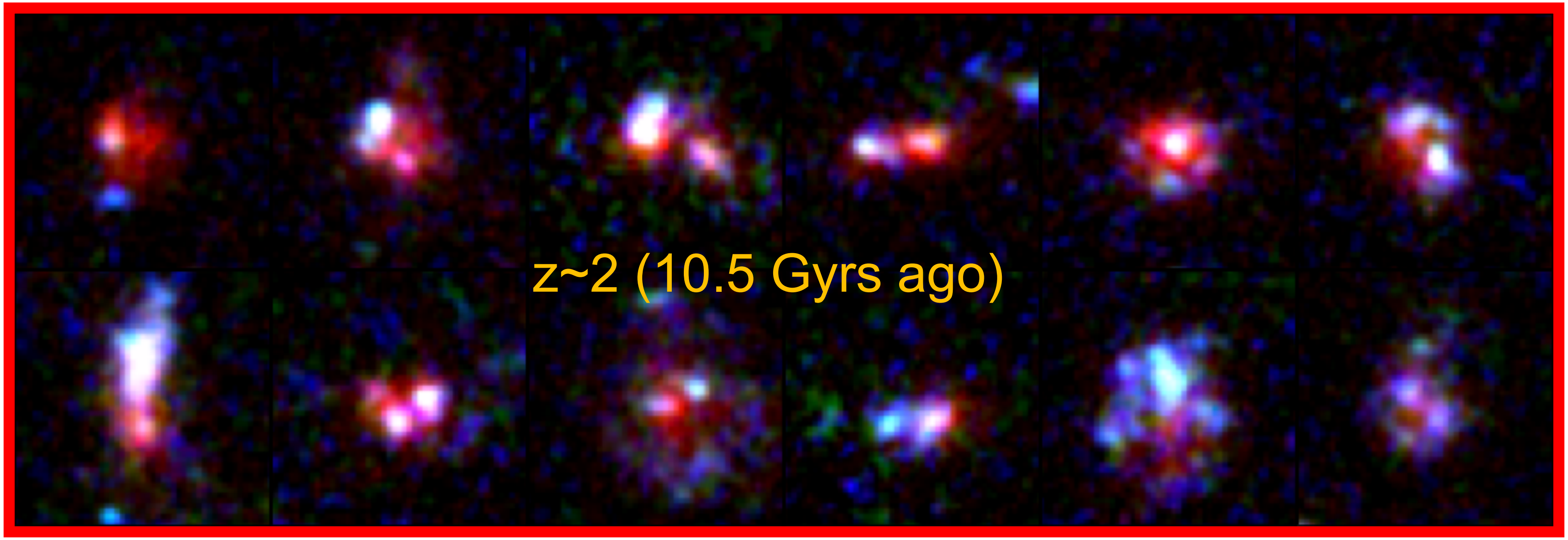
Any international/domestic colleagues are more than welcome to our WG !

What makes the acceleration of galaxy formation at z>2 and the subsequent quenching at z<2?



"Mass" and "Environment" both matter!

Many of galaxies are in vigorous formation phase at the cosmic noon



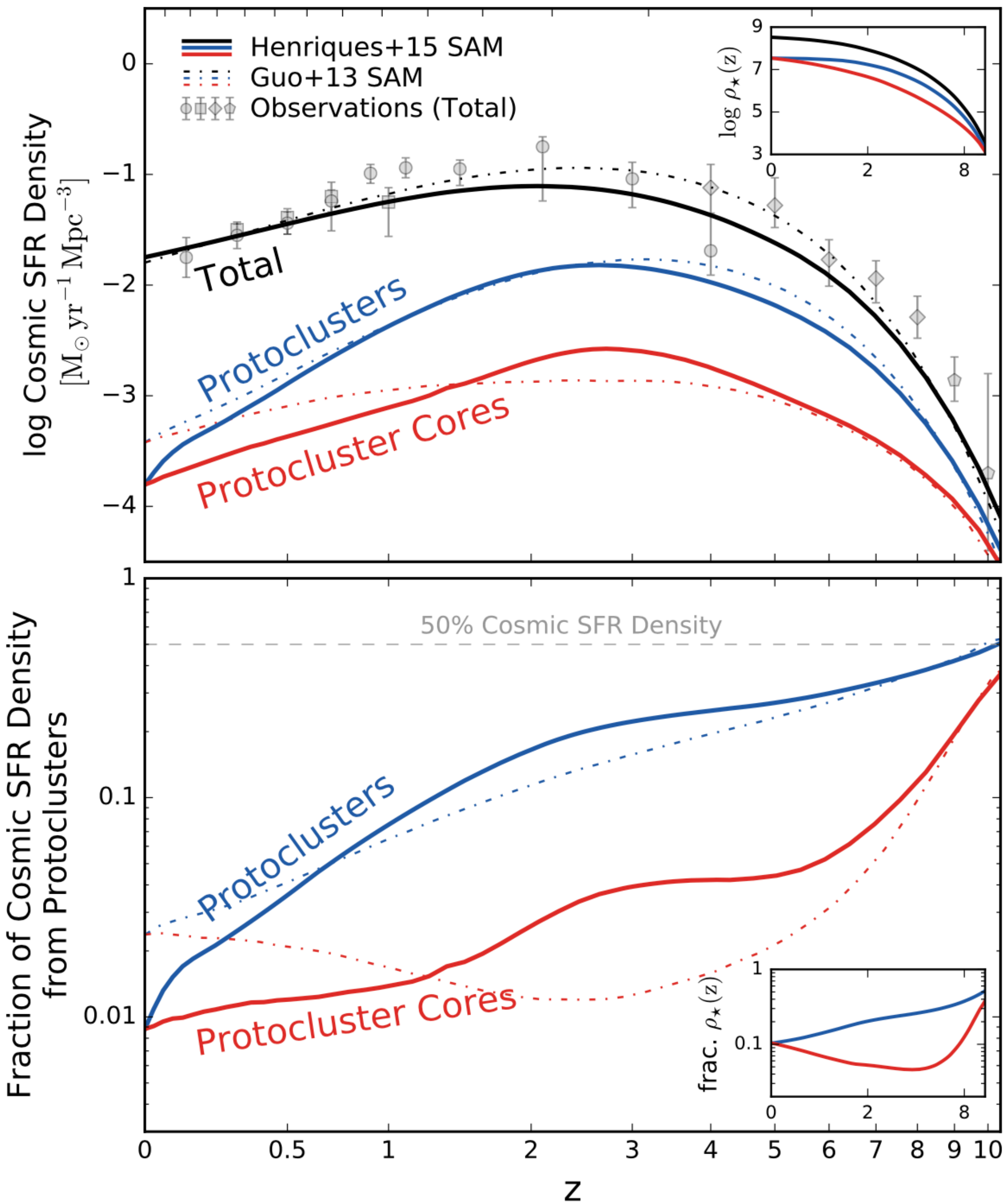
"Clumpy" SFGs are common at the cosmic noon (~40% of HAEs)

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

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

Tadaki, TK, et al. (2012)

Proto-clusters play major roles at the cosmic noon



In the cosmic noon (1<z<4; 4Gyr), Universe and clusters formed 50% and 75% of their total stellar mass.

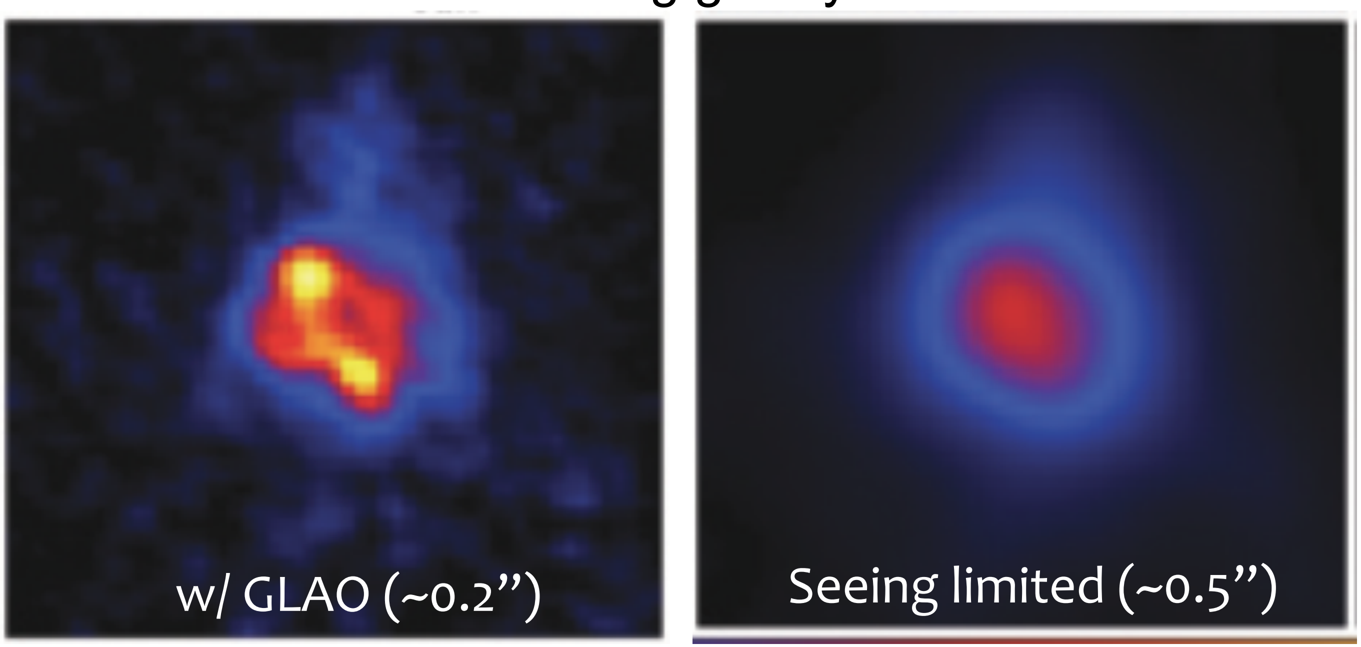
The fractional CSFRD in (proto-)clusters is only 1% at z=0, but increases to 20% at z=2 and 50% at z=10.

Why 0.2" ?

0.2" ⇔ 1.5kpc at $1<z<3$

- For compact QGs ⇒ Sensitivity gain (~2x)!
- For extended SFGs ⇒ Anatomy (bulge & clumps)!
- Comparable to HST resolution (WFC3, H-band)

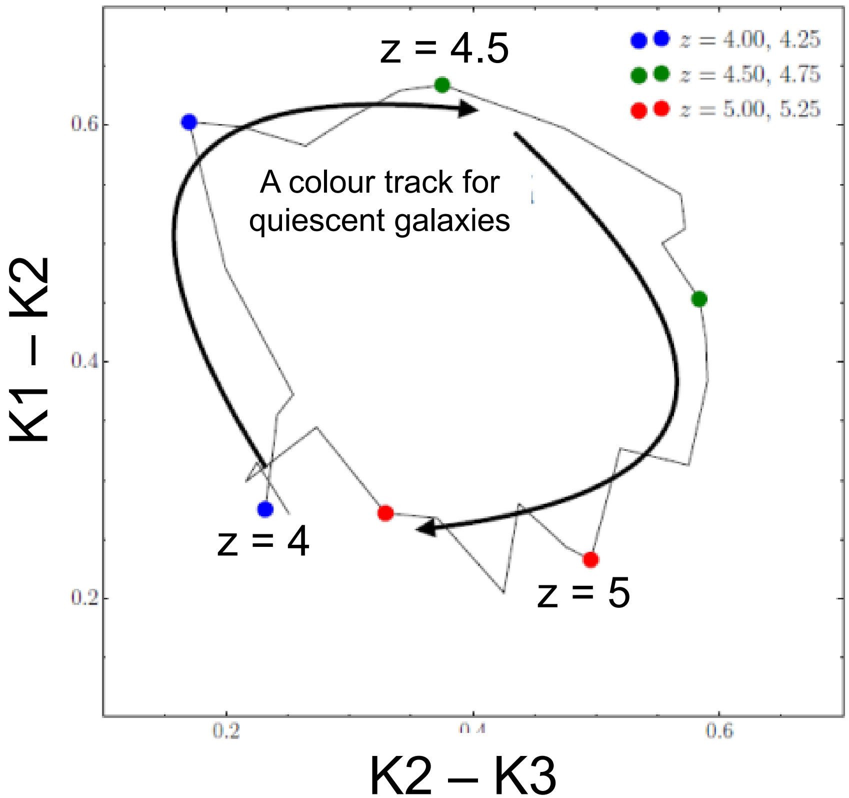
A star-forming galaxy at z~2



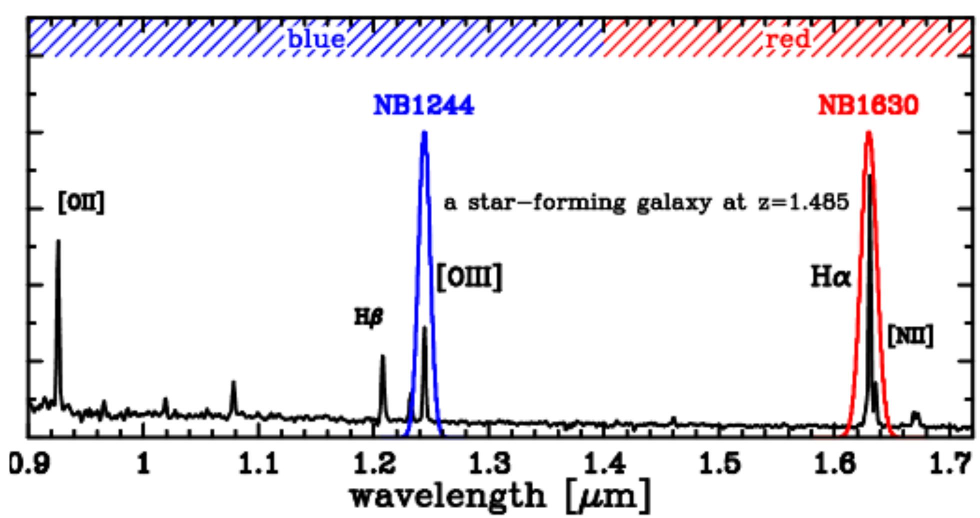
Why K-band?

- Balmer break to z<5 ⇒ Stellar mass!
- Hα to z=2.6, [OIII] to z=3.7 ⇒ SFR!
- Advantage over WFIRST (<2μm)

Medium-Band Filters



Pair Narrow-Band Filters

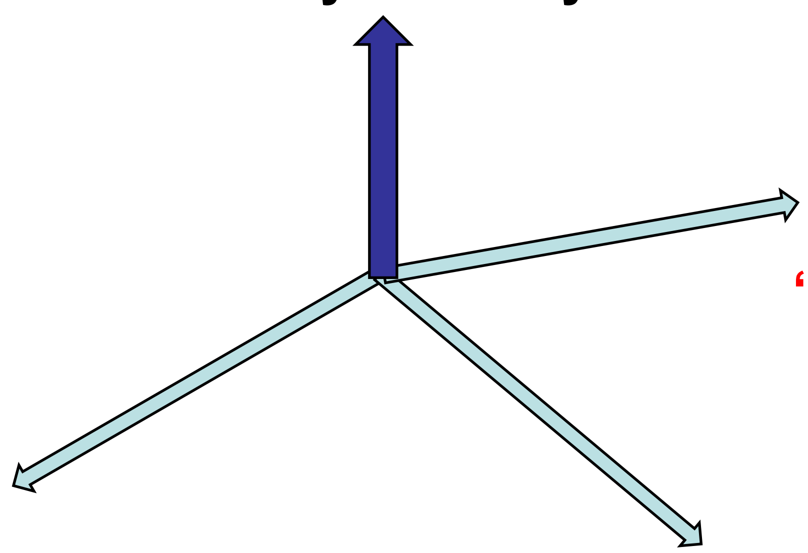


Why 14 arcmin?

- Statistical anatomy along three axes (z, env, mass)

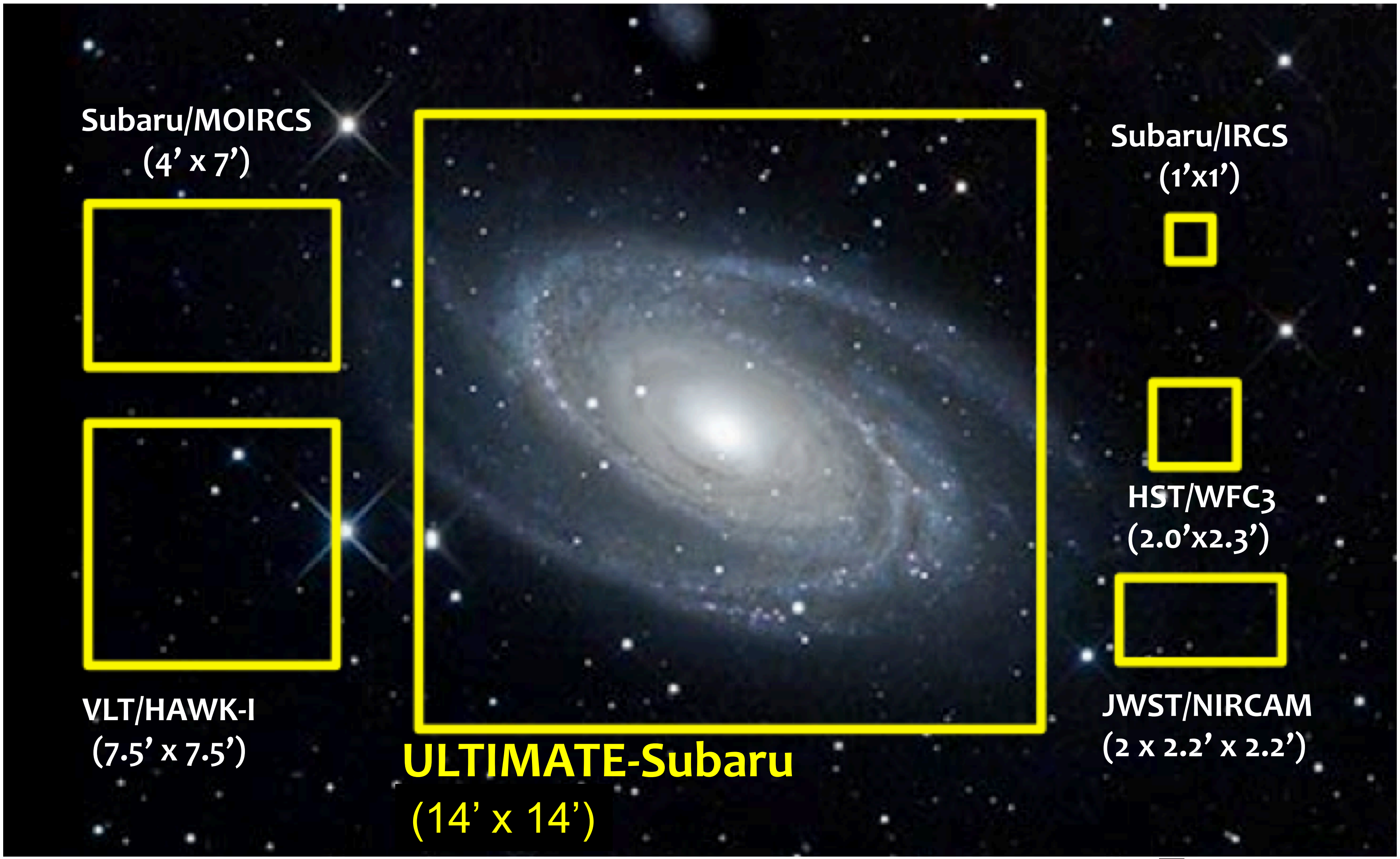
  >1,000 galaxies over 27(=3^3) cubes

- Advantage over JWST (2 arcmin)



FoV comparison of NIR instruments in 2020's at λ>2μm

※ Note that there is no wide-field space mission which can probe NIR at λ>2μm!



©☐ Y. Koyama

Key science (high-z imaging)

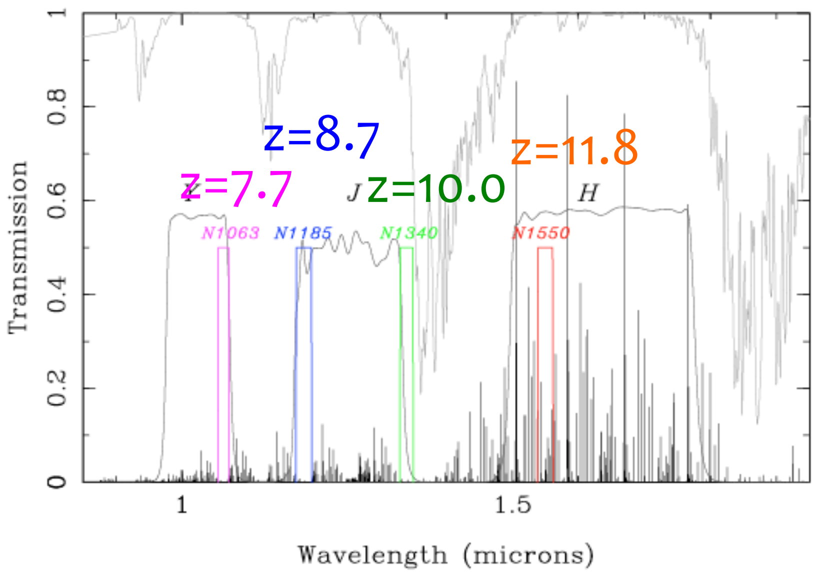
- Hunting z>7 LAEs and other UV lines at z>4 with NB
- Stellar mass assembly, LSS, size/morphology evolution, from a mass-selected sample since z~5 with MB
- High resolution mapping of stellar mass and SF activities to resolve internal physics of galaxy formation

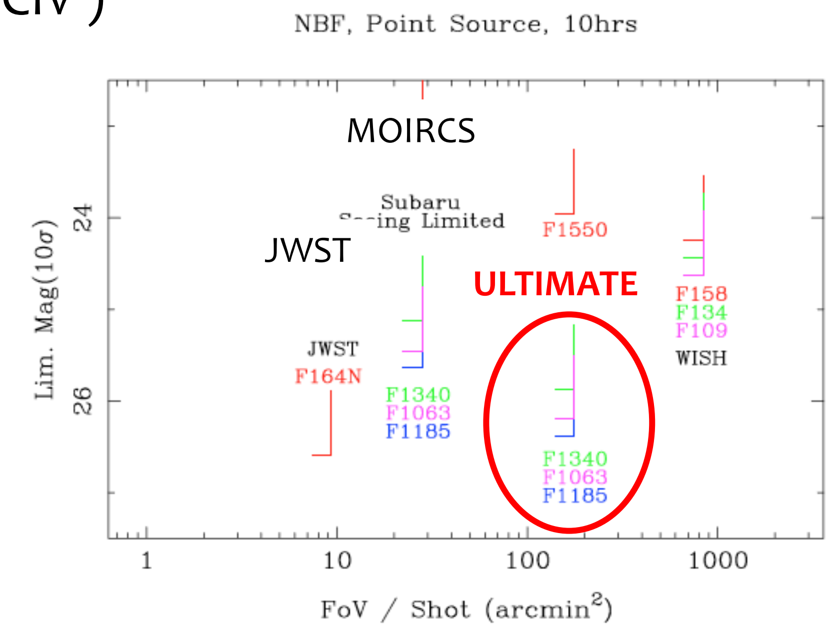
→ How are galaxies (bulge/disk) built-up with time? When and How are they quenched?

Searching for z>7 galaxies at the birth

Direct extension of LAE survey with S-Cam/HSC towards z>7

(+ other UV lines – e.g. CIII], OIII, HeII, CIV)



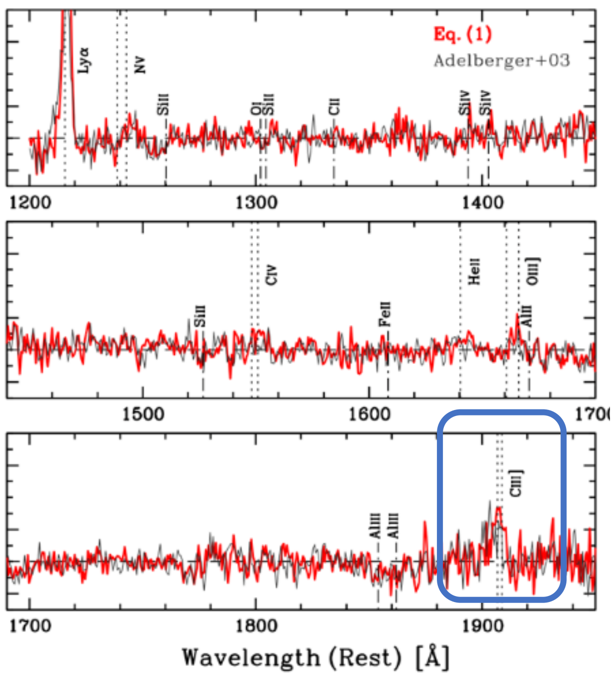


Filter	redshift	$L_{\rm lim}$	No ev.	Slow ev.	Rapid ev.
NB1063	7.7	1.62×10^{42}	36	17	1.8
NB1185	8.7	1.98×10^{42}	31	8.6	0.19
NB1340	10.0	2.91×10^{42}	9.7	1.5	5.3×10^{-3}

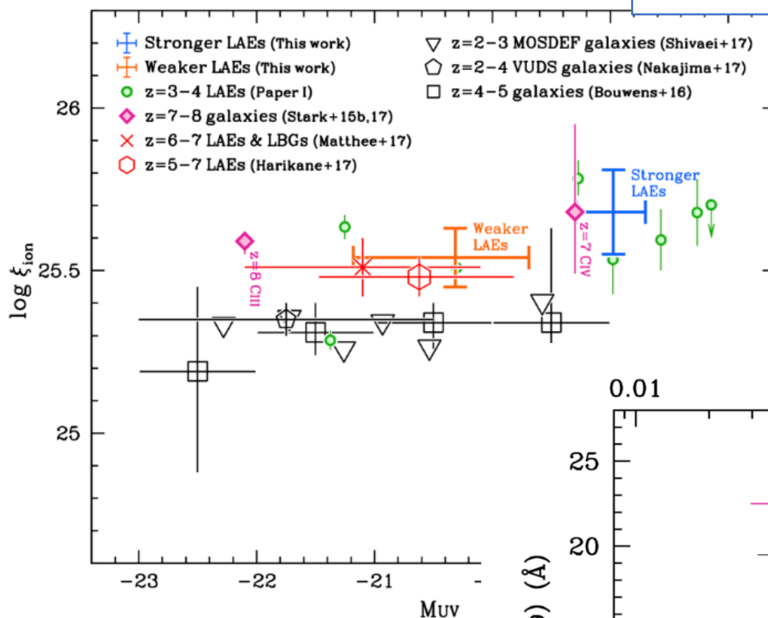
Expected Num. of LAEs per 15' FoV (10-h integration)

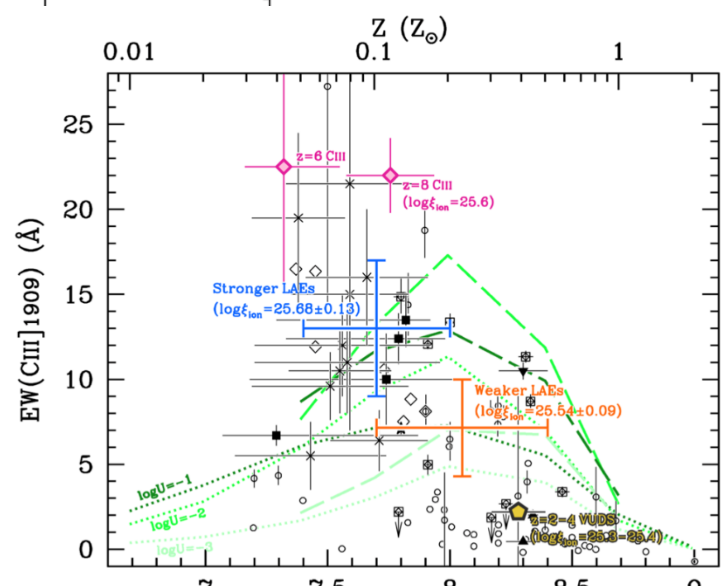
CIII]$_{\lambda\lambda1909}$ to diagnose ISM conditions, radiation nature of galaxies at z>4

Ionizing photon production



Composite spectrum of ~70 LAEs at z=3.1 (Nakajima+ 2018)





ISM metallicity

SWIMS-18 strategy for ULTIMATE

Super multi-λ (NIR) imaging survey of the Cosmic Noon over a 1-deg^2 unbiased field + some high density regions on Subaru (8.2m; 2018-2020) and TAO (6.5m; 2020-)

- 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)

SWIMS-18

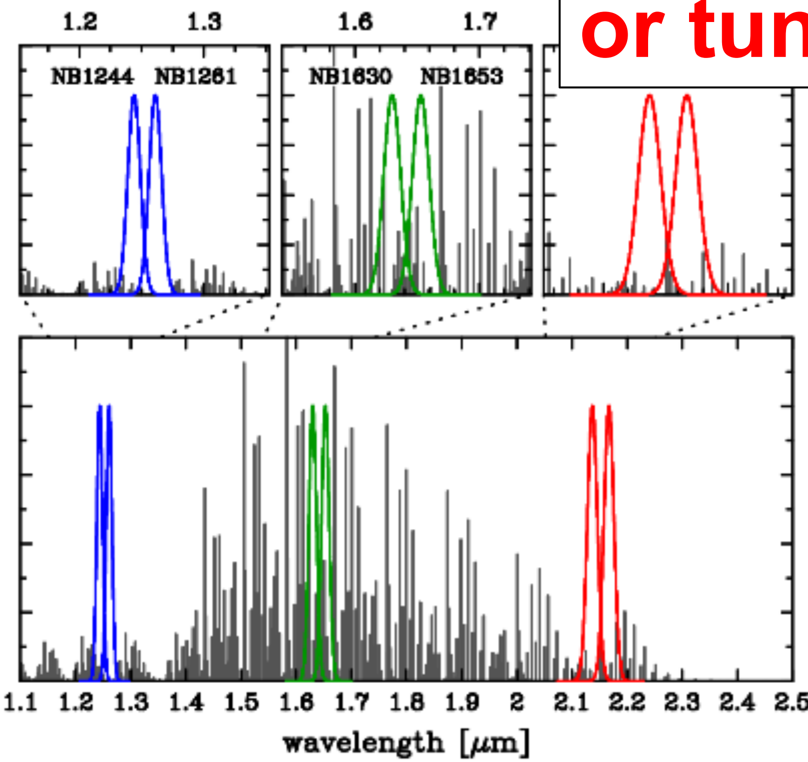
SFR-limited sample at z=0.9, 1.5, 2.3, and 3.3

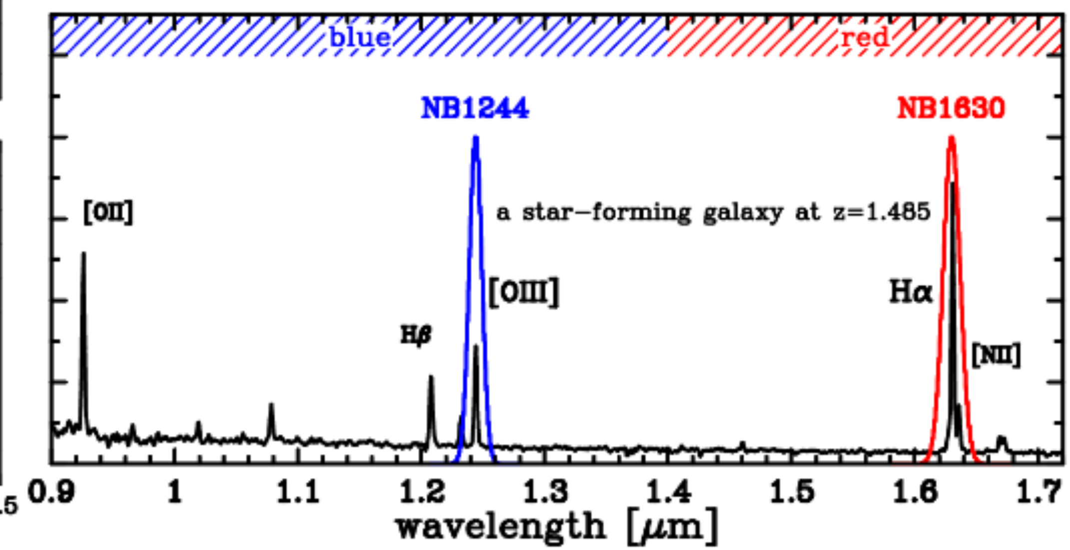
NB filters	λ_c (μm)	FWHM (μm)	z(Hα) 6563Å	z([OIII]) 5007Å	z(Hβ) 4861Å	z([OII]) 3727Å	HSC filter pairs NB921 (Hβ@z=0.895)	Cluster targets
NB1244	1.244	0.012	0.895	*1.484*	1.559	2.337	NB926 ([OII]@z=1.485)	CL1604+4304(z=0.895)
NB1261	1.261	0.012	0.922	*1.519*	1.595	2.384	NB718 ([OII]@z=0.926)	CL1604+4321(z=0.920)
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	NB395 (Lyα@z=2.25) NB515 (Lyα@z=3.23)	J0932+0925 (z=2.25)
NB2167	2.167	0.021	*2.302*	3.328	3.458	4.814	NB527 (Lyα@z=3.32)	HS1700+64 (z=2.30)
								J1541+2702 (z=3.33)

or tunable filters?

& Hα) with 4 pair NBFs

→ Redshift identification & Ionization states (ratio)





Nine Medium-band filters (MBF) SWIMS-18

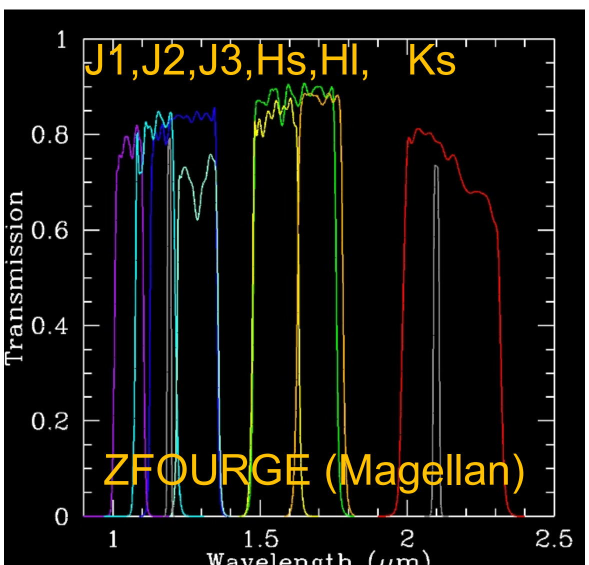
M*-limited sample of galaxies up to z~5

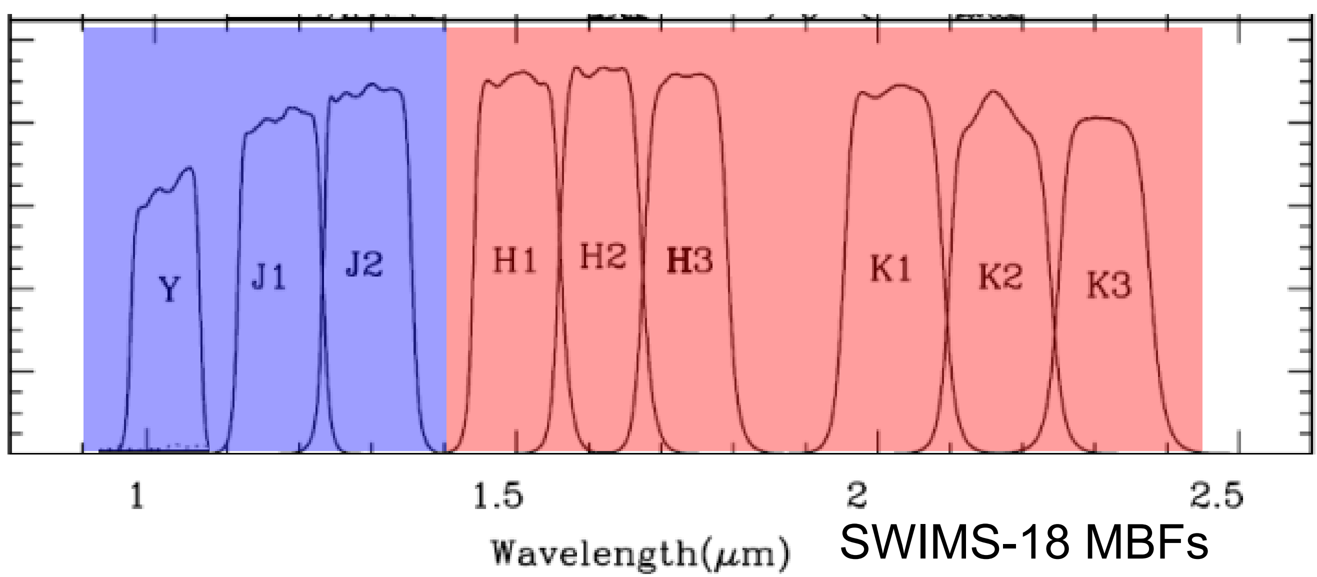
MB filters	λ_c (μm)	FWHM (μm)	z_s(Bal.Lim.) 3645Å	z_s(D4000) 4000Å
Y	1.05	0.10	1.74	1.50
J1	1.17	0.12	2.05	1.78
J2	1.29	0.12	2.37	2.08
H1	1.50	0.12	2.95	2.60
H2	1.62	0.12	3.28	2.90
H3	1.74	0.12	3.61	3.20
K1	2.03	0.14	4.38	3.90
K2	2.17	0.14	4.76	4.25
K3	2.31	0.14	5.14	4.60

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

Improved measurements of phot-z and SED-based Av.

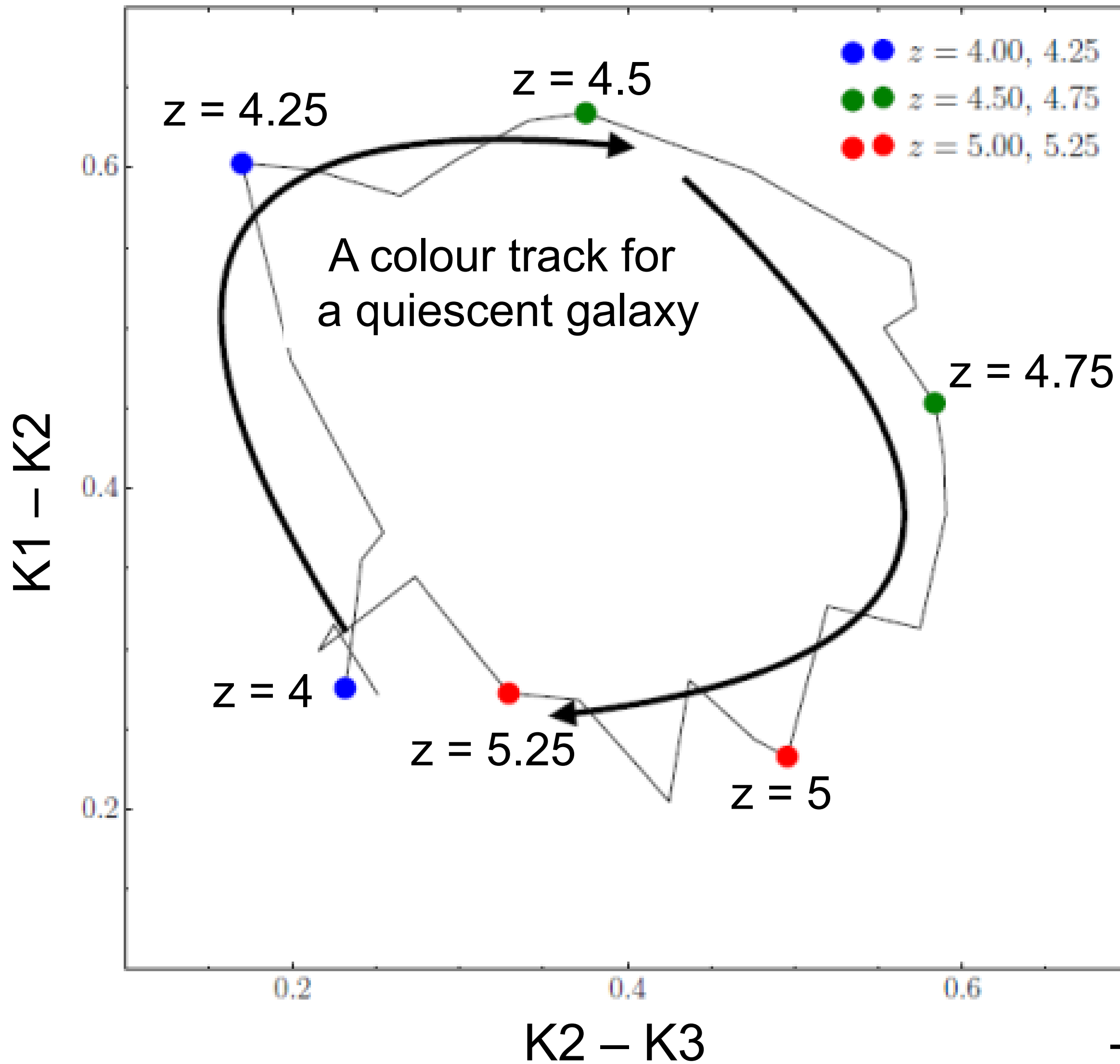
Will open a new window to 4<z<5 with K1,K2,K3 !





SWIMS-18 MBFs

K1, K2, and K3 capture the Balmer break feature at 4 < z < 5

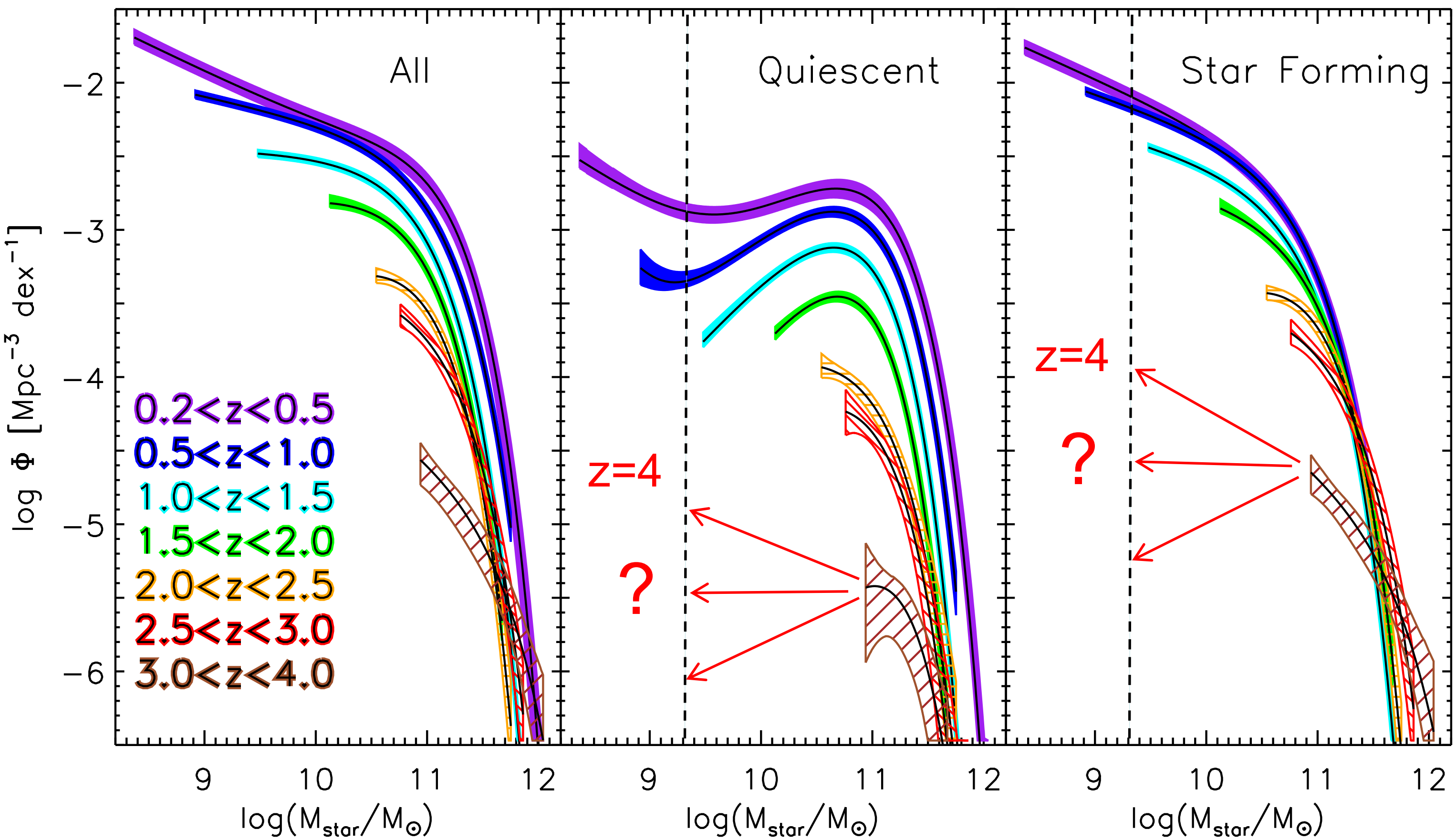


Toshikawa et al.

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

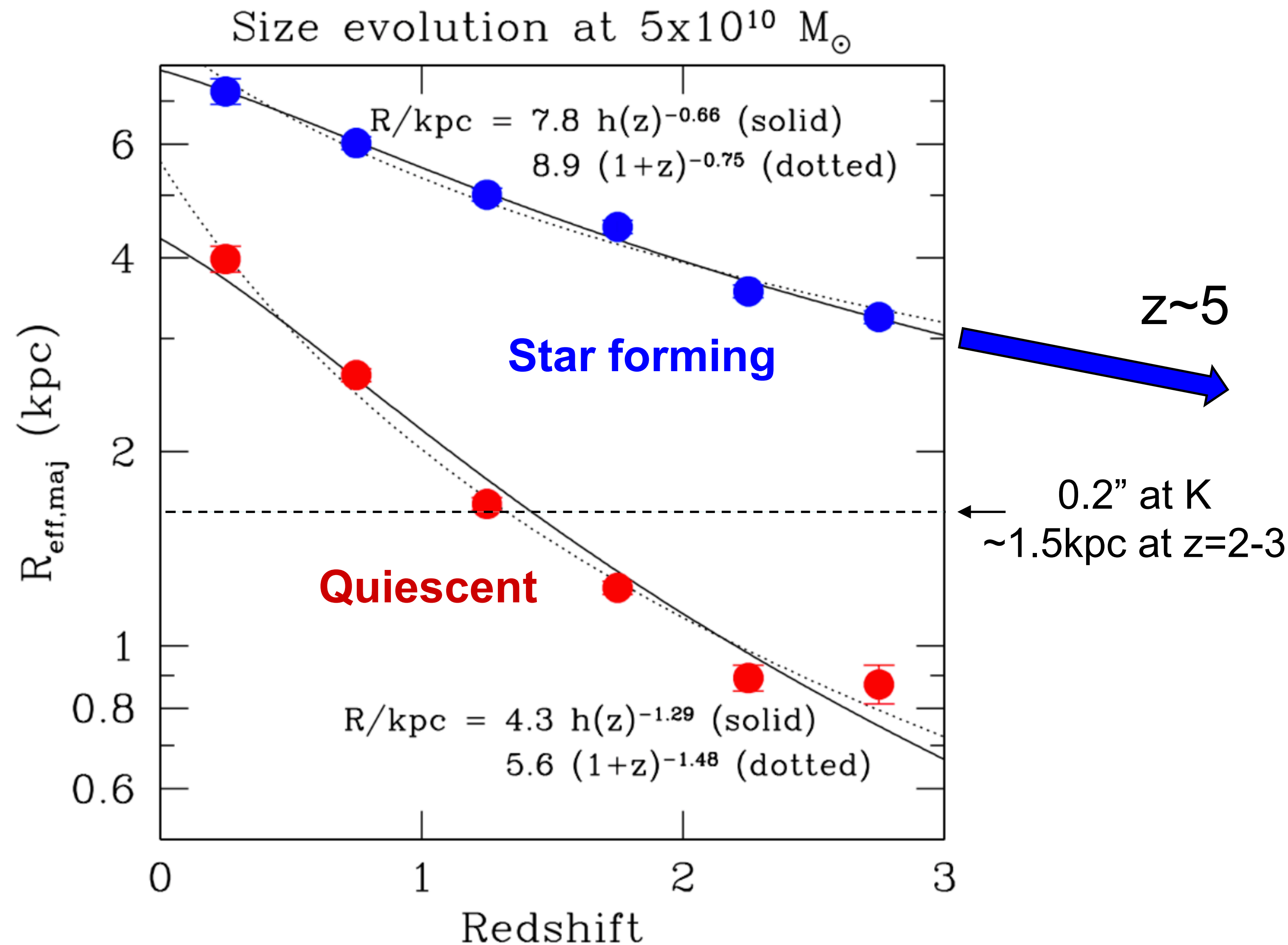
ULTRA-VISTA (COSMOS) Muzzin et al. (2013)

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



Down to 2 (5) x 10^9 $M_\odot$ back to z~4 (5) with ULTIMATE MB imaging (10hr/band)

Size Evolution of Star-Forming Galaxies back to z~5



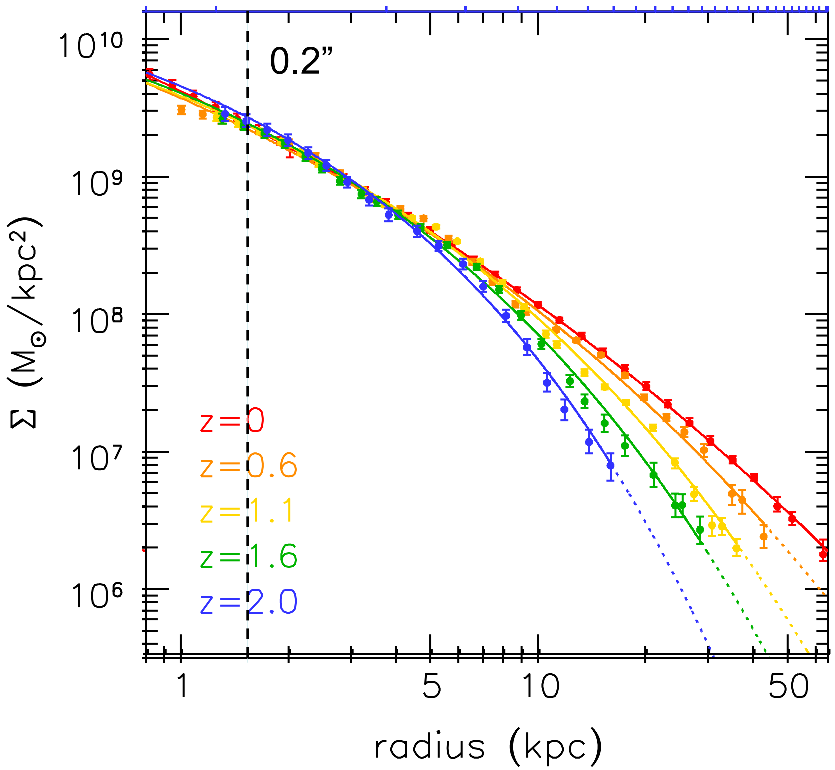
van der Wel et al. (2014)

Mass profile evolution within galaxies back to z~5

Stellar mass radial profiles

Giant galaxies (e.g. elliptical galaxies)

M_{stars}= 3 × 10^{11} $M_{\odot}$ (z=0)
$N_{comoving}$(>M)= 2 × 10^{-4} Mpc^{-3}

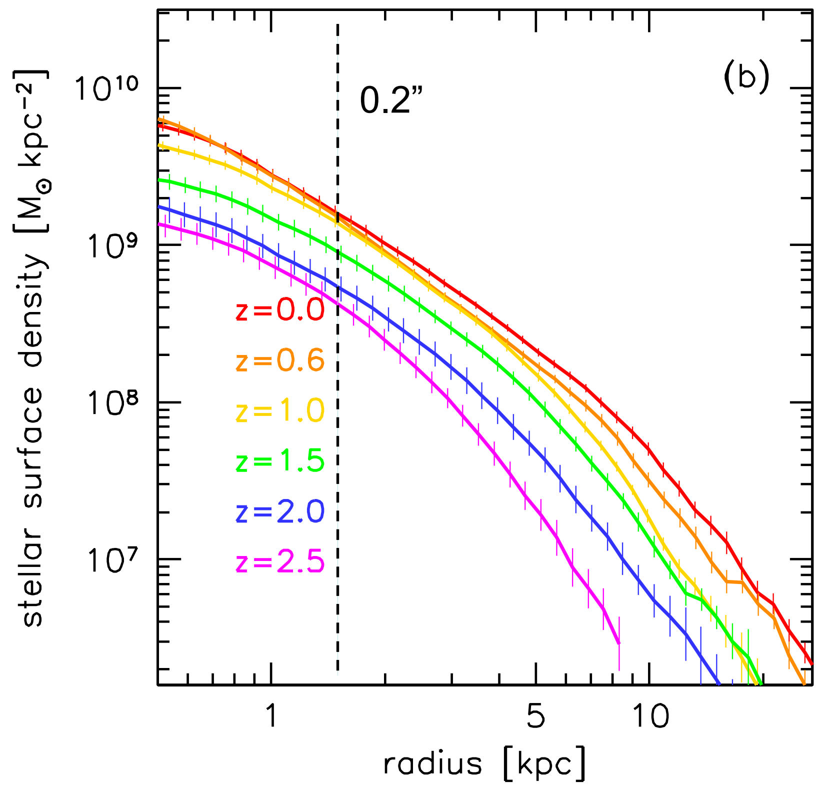


van Dokkum et al. (2010)

inside-out growth!

Milky-way class galaxies

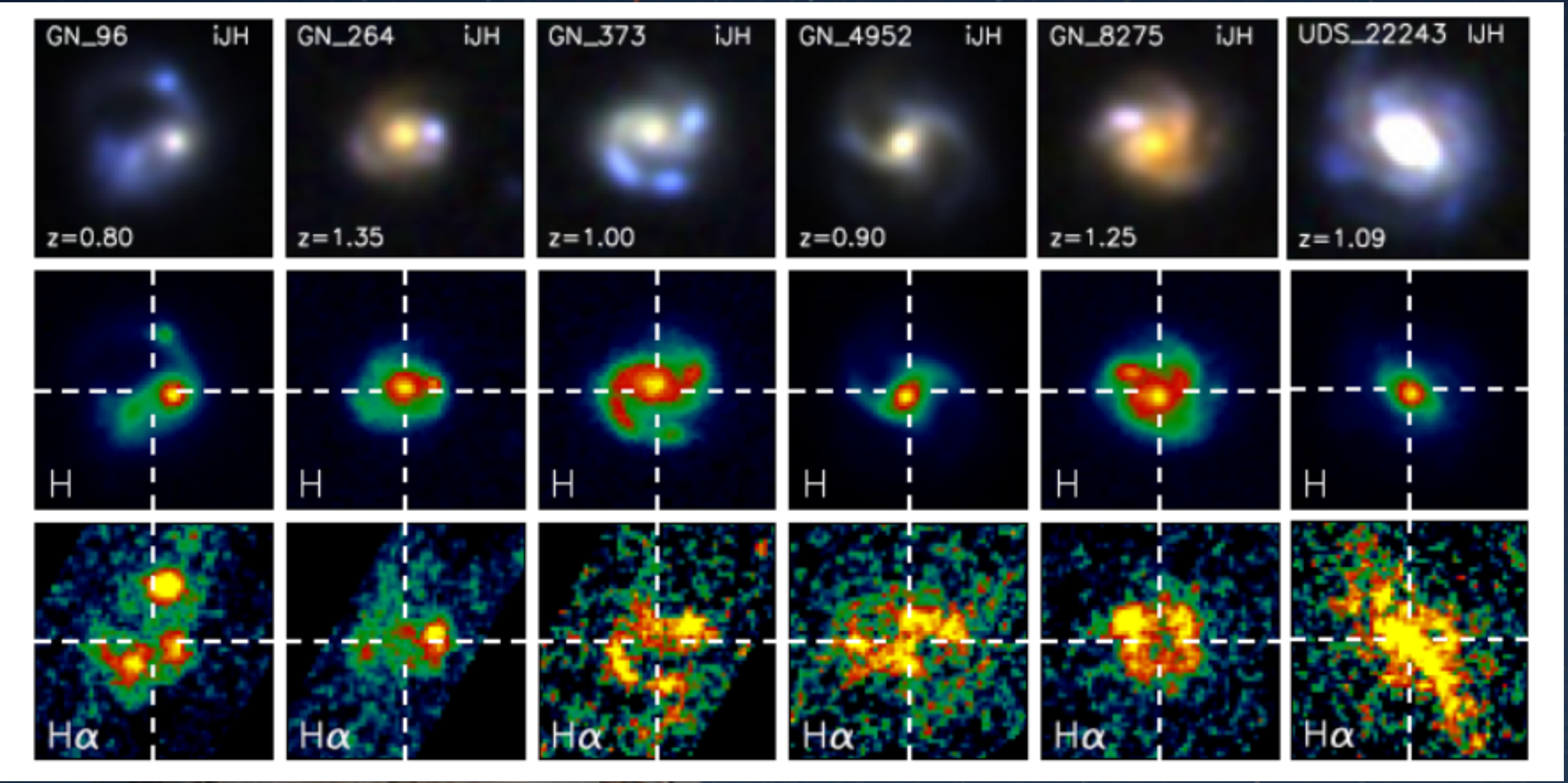
M_{stars}= 5 × 10^{10} $M_{\odot}$ (z=0)
$N_{comoving}$(>M)=1.1 × 10^{-3} Mpc^{-3}



van Dokkum et al. (2013)

Bulges and Disks grow together at z>1.

Mapping/Resolving SF activities and stellar mass distributions within galaxies in making



Hα map of z~1 galaxies from 3D-HST (Wuyts et al. 2013)

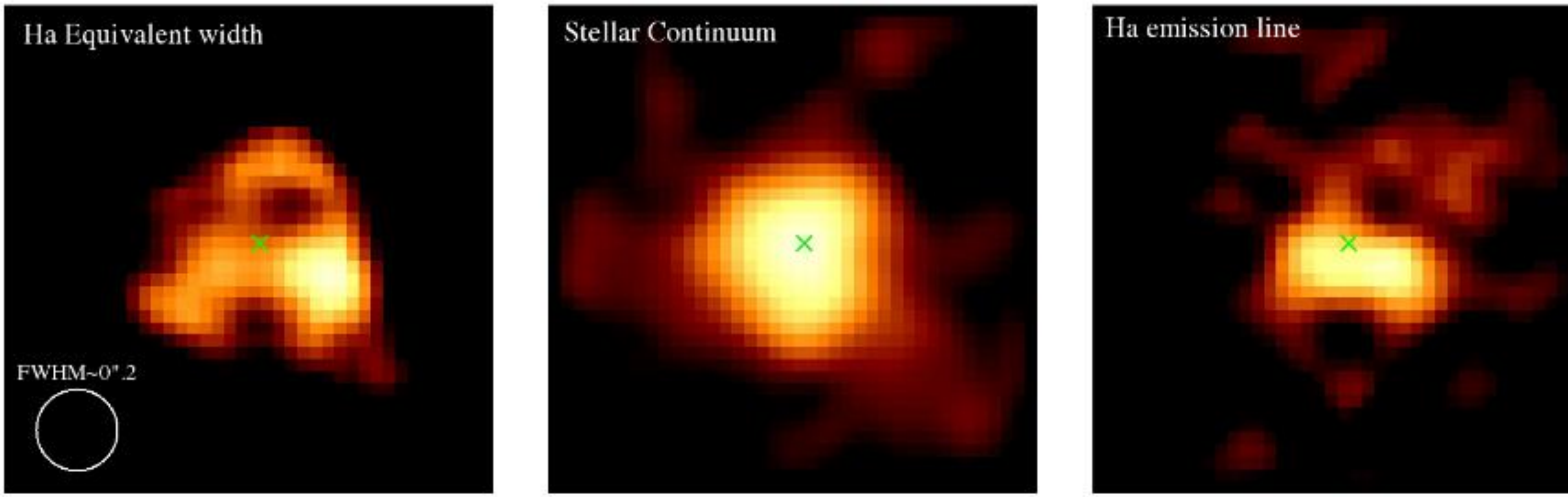
GANBA–Subaru at 2<z<3.7 at the K-band

Galaxy Anatomy with Narrow-Band AO imaging with Subaru

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

(0.2" ~ 1.6 kpc)

EW(Hα) ~ sSFR | Continuum ~ M_{stars} | L(Hα) ~ SFR



A Hα emitter at z~2.19 (NB2095 + AO188) in SXDF-CANDELS

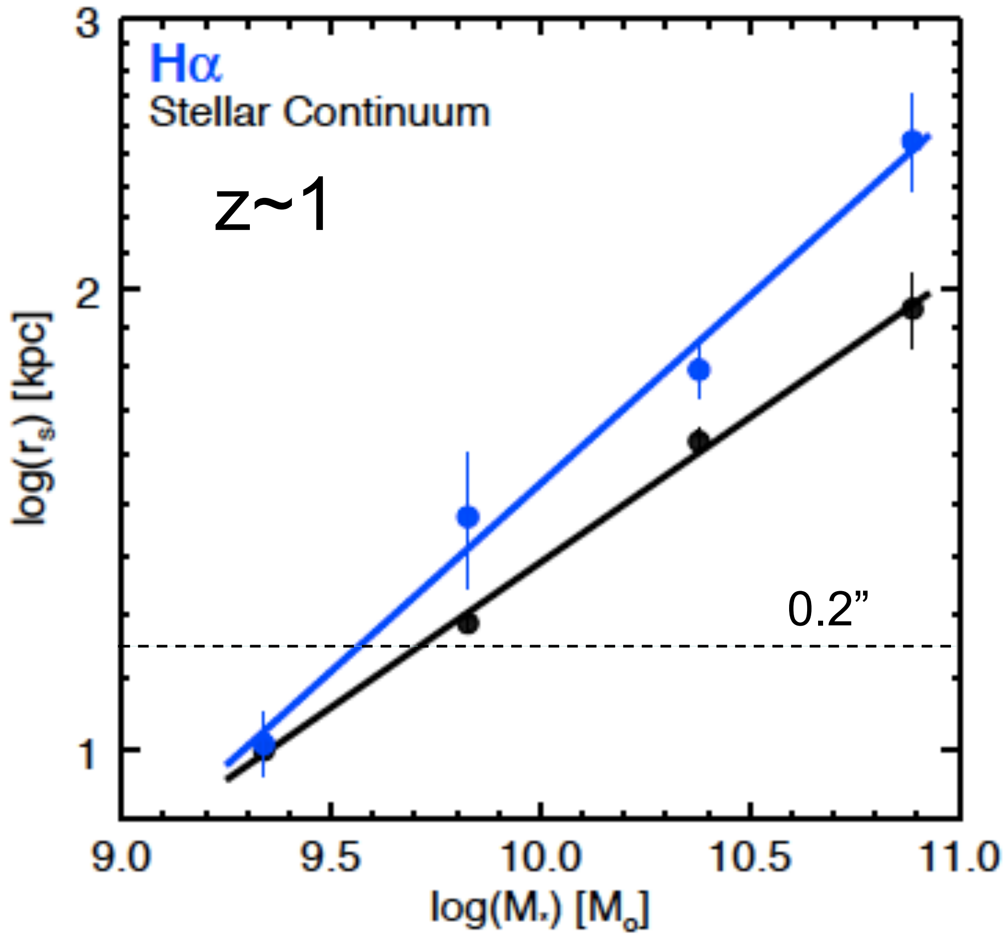
Being-truncated bulge + Off-center star-forming clump ?

Minowa et al. (2018; submitted)

ULTIMATE-Subaru will provide truly statistical data of this kind !

Propagation of star formation/quenching within galaxies

Hα / [OIII] compactness back to z~2.5 / 3.7



3D-HST
(grims spec.)

Nelson et al. (2015)

Inside-out quenching (versus compaction)?

Distant clusters (z<1.5) discovered by HSC[2]

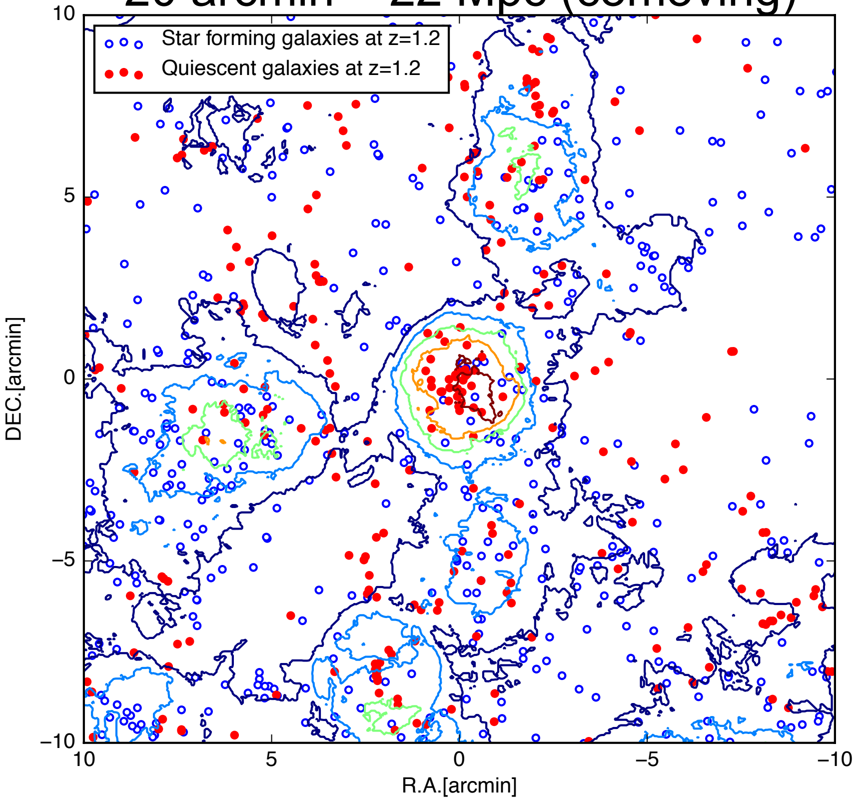
"Normal" cluster at z=1.2 showing excesses in both QGs and SFGs

"Blue dominated" cluster at z=0.8 with a lack of overdensity in QGs

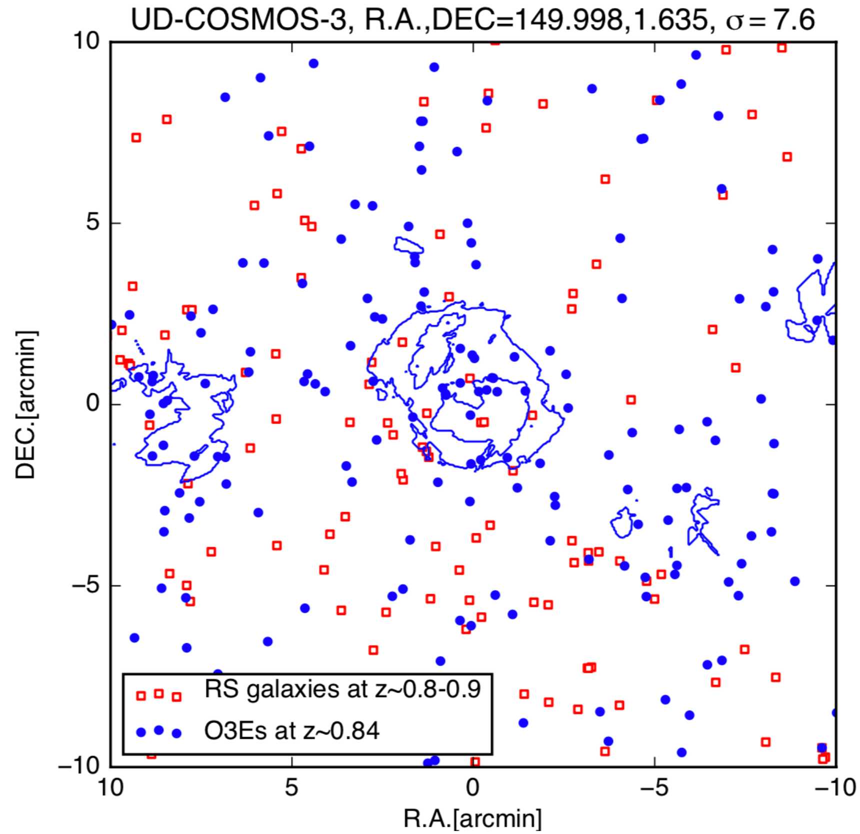
Blue Cloud ([OII], [OIII] emitters)

Red Sequence (r'i'z'-selected)

20 arcmin = 22 Mpc (comoving)



DEEP2-3

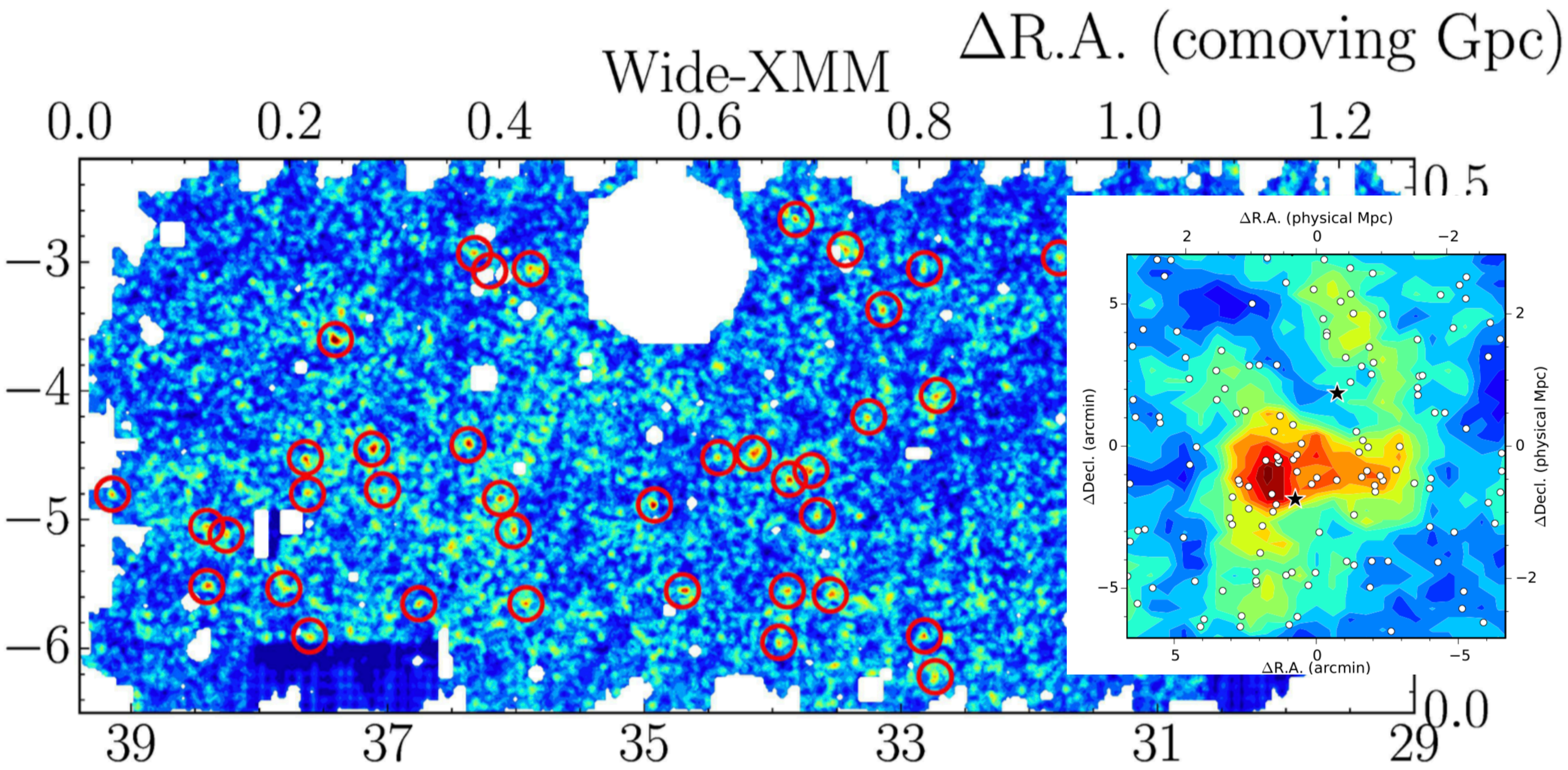


COSMOS

Yamamoto et al., in prep.

GOLDRUSH

Proto-clusters at 2<z<6 with LBGs over 1,400 deg^2 (HSC-SSP-W)



179 proto-clusters at z~3.8 over 121 deg^2 using HSC-SSP-Wide (*g*-dropouts)

Toshikawa et al. (2017), Onoue et al. (2017)

ULTIMATE will provide rest-frame optical view of proto-clusters (e.g. M*, SFR)

ULTIMATE-K survey

Narrow/Medium/Ks band imaging with GLAO+WFI (15′)

- 0.75 mag deeper (point-source), 8 / 250 times wider FoV than MOIRCS / IRCS, and 0.2″ spatial resolution.
- NB survey with 0.2″ seeing (Extension of MAHALO/GANBA)
  Propagation/quenching of SF in galaxies with Ha,[OIII] map for 1,000s of SFGs at 2<z<3.7 with a 1.6kpc resolution.
- MB survey (K1, K2, K3 (+Ks)) (Extension of SWIMS-18)
  10 hrs exp. (26mag; 5σ)/FoV/band = 640hrs/deg^2 for 4 filters
  Mass assembly history back to z~5 with Balmer break galaxies at 4<z<5 of ~4,000 / deg^2 (?)
- WFIRST/EUCLID only to <2μm. JWST has a tiny FoV (2.2′^2 x 2)

Summary

- ULTIMATE will be an excellent tracer of stellar mass out to z~5 at rest-frame optical.
- Stellar mass assembly history all the way from $5 \times 10^9\ M_\odot$ at z~5 to the present-day.
- Size/profile evolution from z~5.
- Super-cluster (LSS) scale assembly history from z~5 together with HSC+PFS.
- Hunting z>7 Lya emitters at the bright-end.