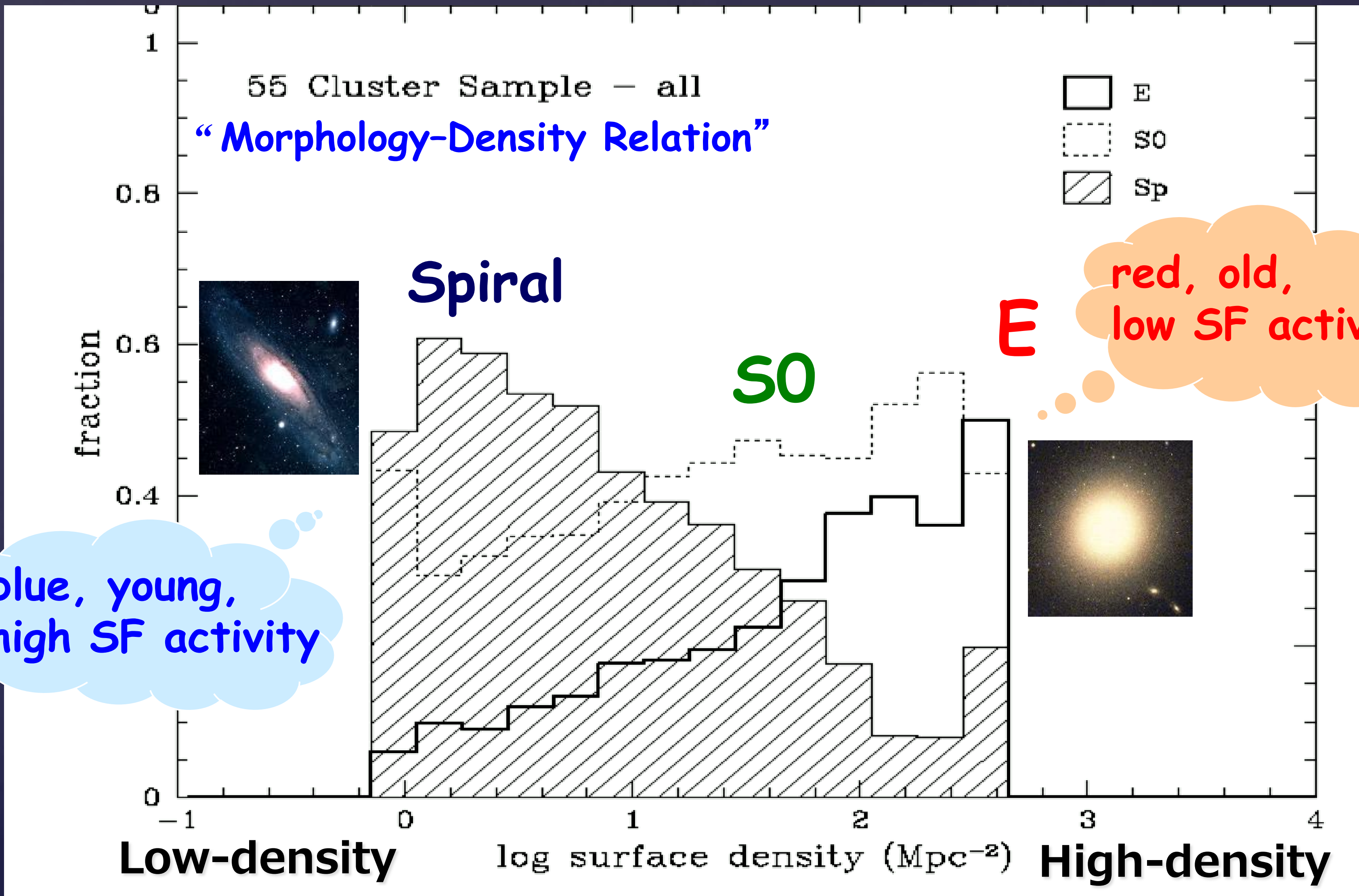
Subaru GLAO-WS (2014/7/29, Mitaka)

Microscopic views of galaxy formation and environmental effects with ULTIMATE-Subaru

Yusei Koyama (ISAS/JAXA)

MAHALO-Subaru collaboration

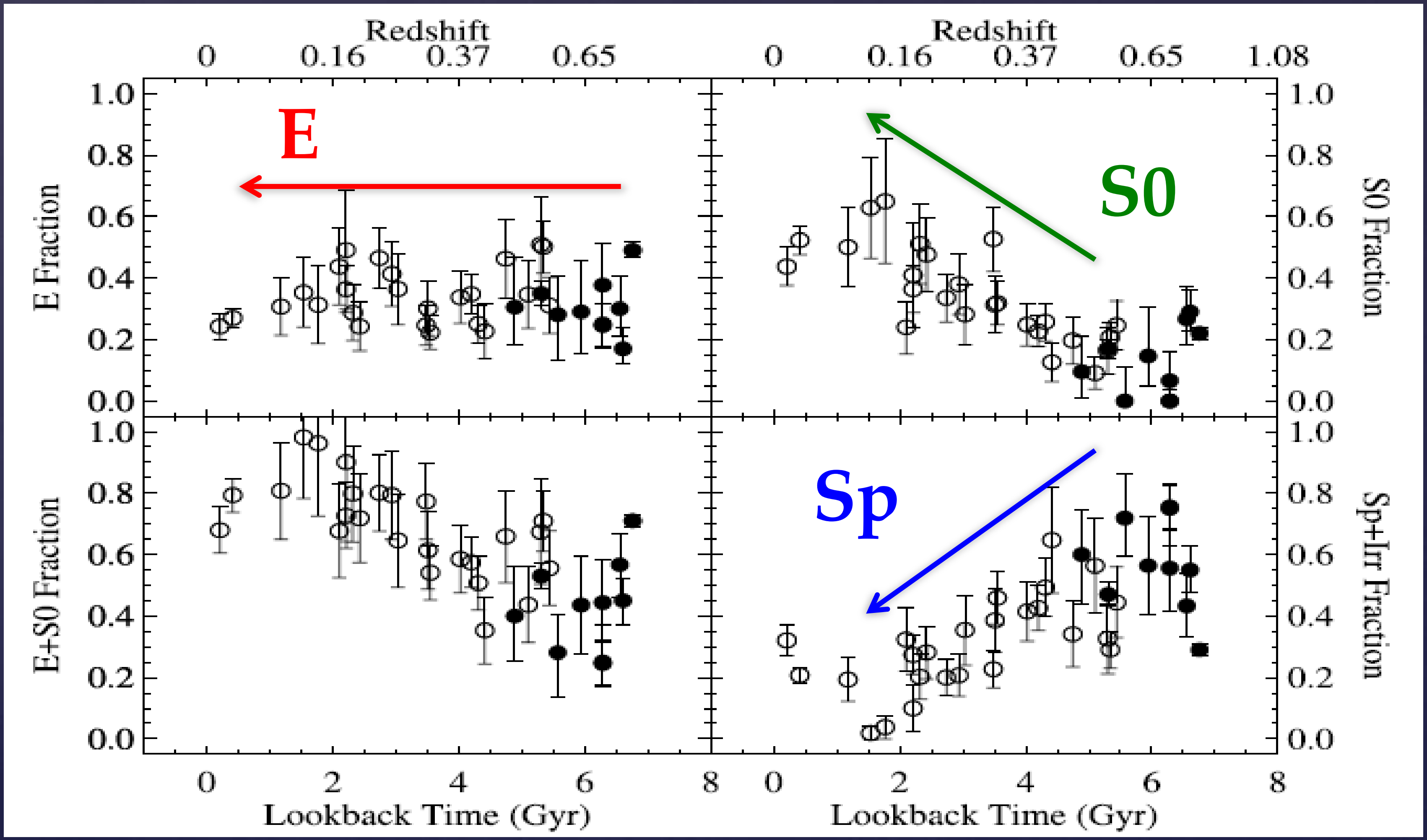
Galaxy evolution & environment



(Dressler 1980)

Morphological evolution in clusters

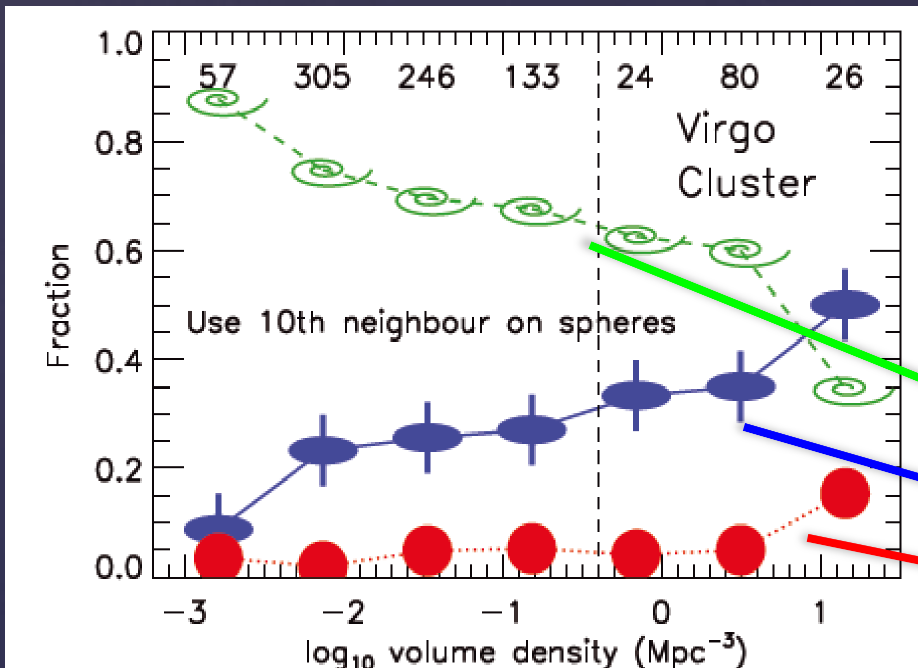
Rapid increase of S0s since z~1 coupled with decrease of spirals.



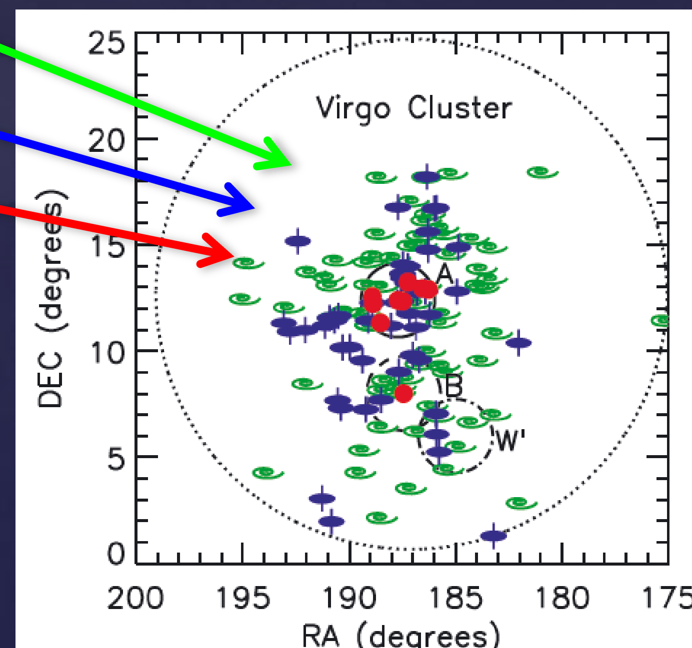
(Desai et al. 2007)

"Kinematical" M-D relation

A new look of the morphology-density relation from ATLAS-3D.



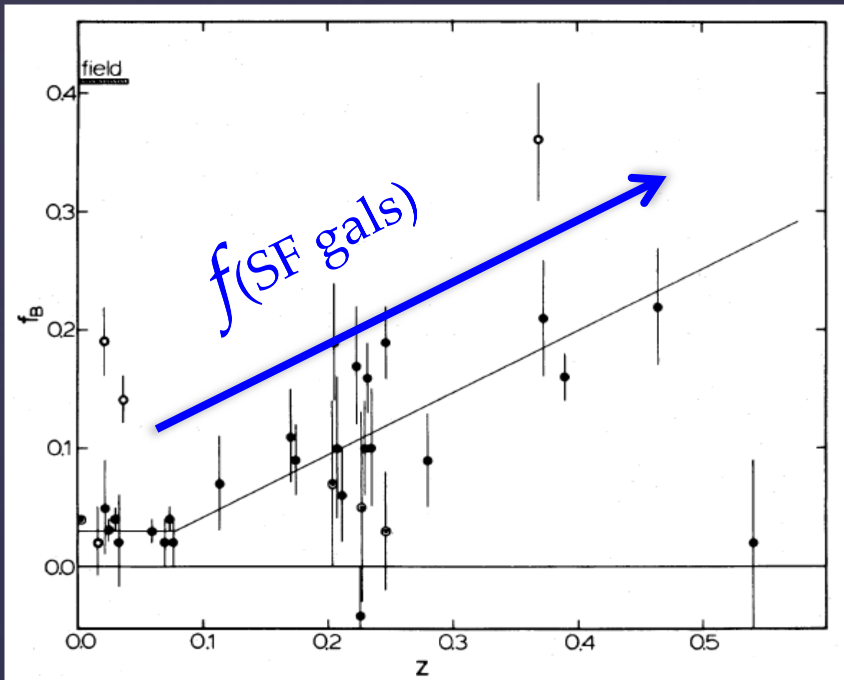
- Slow rotators:
  - Little/no rotation, misalignment between photometric and kinemetric axes.
- Fast rotators:
  - Regular disk-rotating early-types.



Understanding the kinematical evolution of galaxies and the role of environment is becoming increasingly important.

(Cappellari et al. 2011)

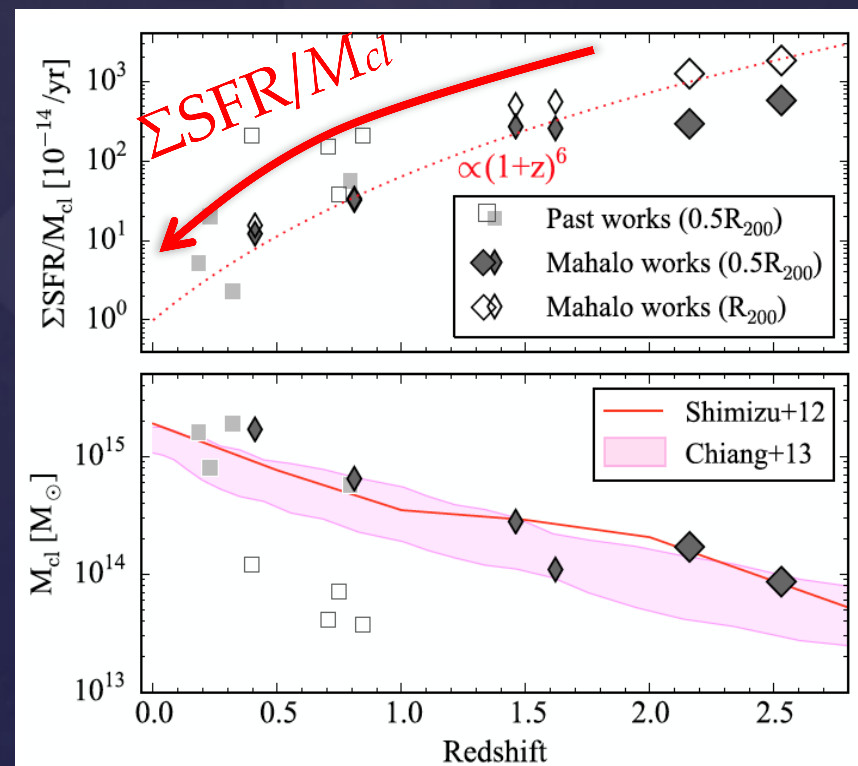
Star formation in clusters



- Butcher-Oemler effect :

  - SF (blue) galaxy fraction is higher in higher-redshift clusters.

  (Butcher & Oemler 1984)



- Cluster specific-SFR :

  - Cluster-mass-normalised SFR shows rapid decline since z~2. Accelerated SF quenching in cluster environments?

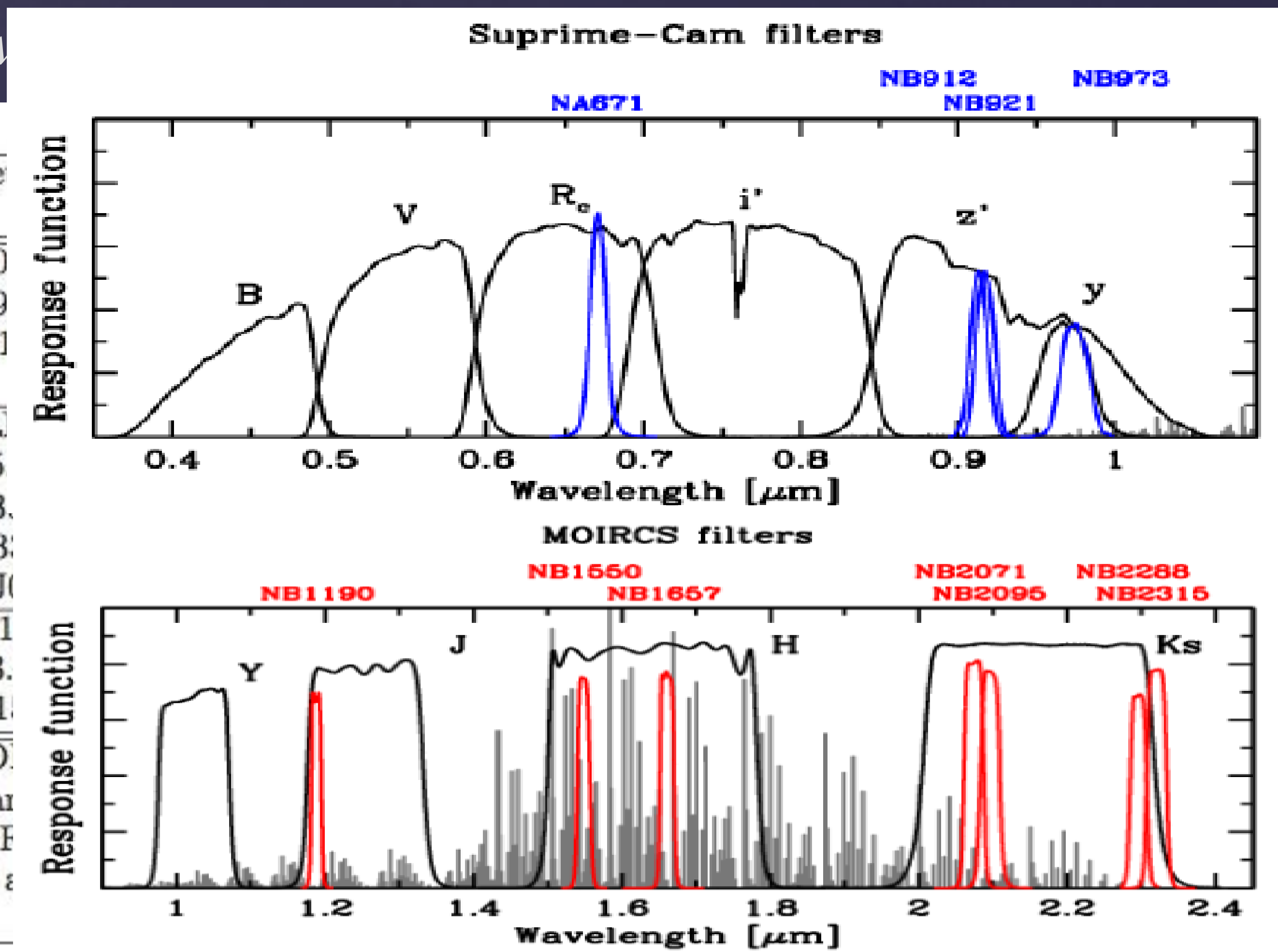
(Shimakawa et al. 2014)

MAHALO-Subaru project

Collaborator: T. Kodama (PI), M. Hayashi, K. Tadaki, I. Tanaka, R. Shimakawa, T. Suzuki, M. Yamamoto

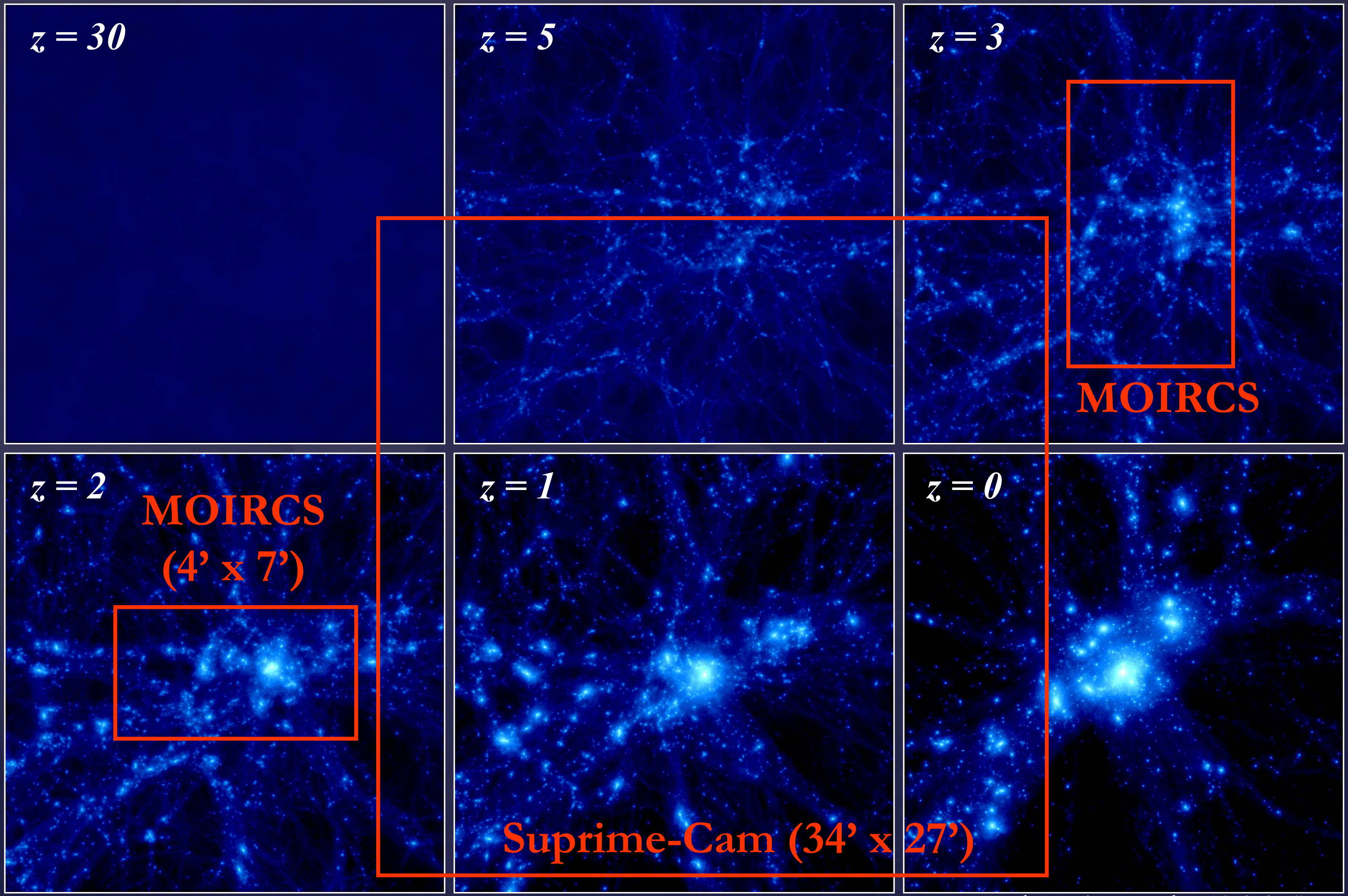
MApping H-Alpha and Lines of Oxygen with Subaru

Narrow



environ-ment	targe	atus (s of Jul. 2014)
Low-z cluster	CL00 CL09 RXJ1	odama+'04 oyama+'11 oyama+'10 served
High-z cluster	XCSJ 4C65 Q083 CL03 ClGJ	yashi+'10,11,14 yama+ '14 served served aki+'12
Proto-cluster	PKS1 4C23. USS1	yama+'13a naka+'11 yashi+'12
General field	GOO (62 ar SXDF (110 a	daki+'11a served aki+'13,14 yet yet

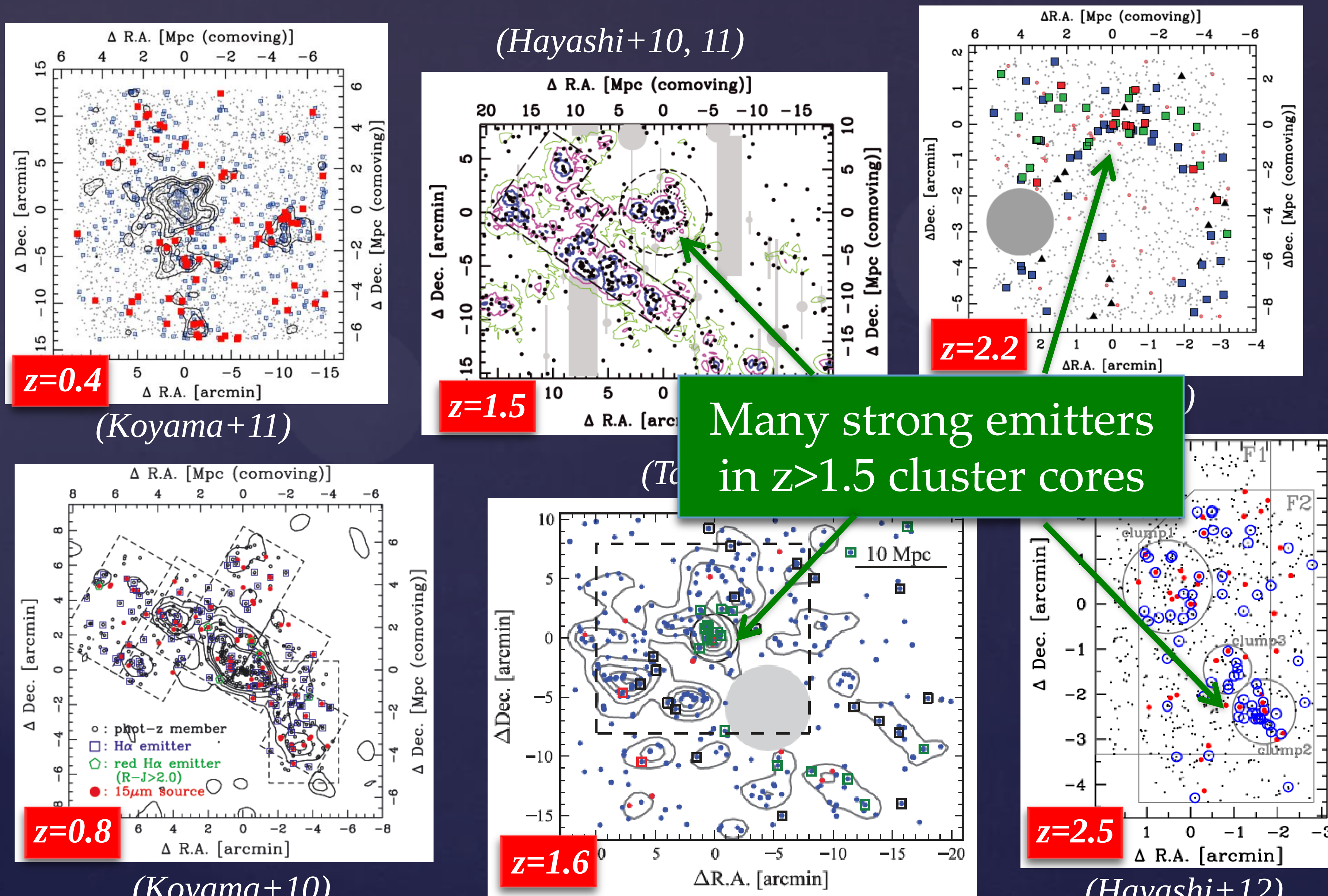
Big advantage of Subaru



M=6×10^14 Msun, 20Mpc×20Mpc (co-moving)

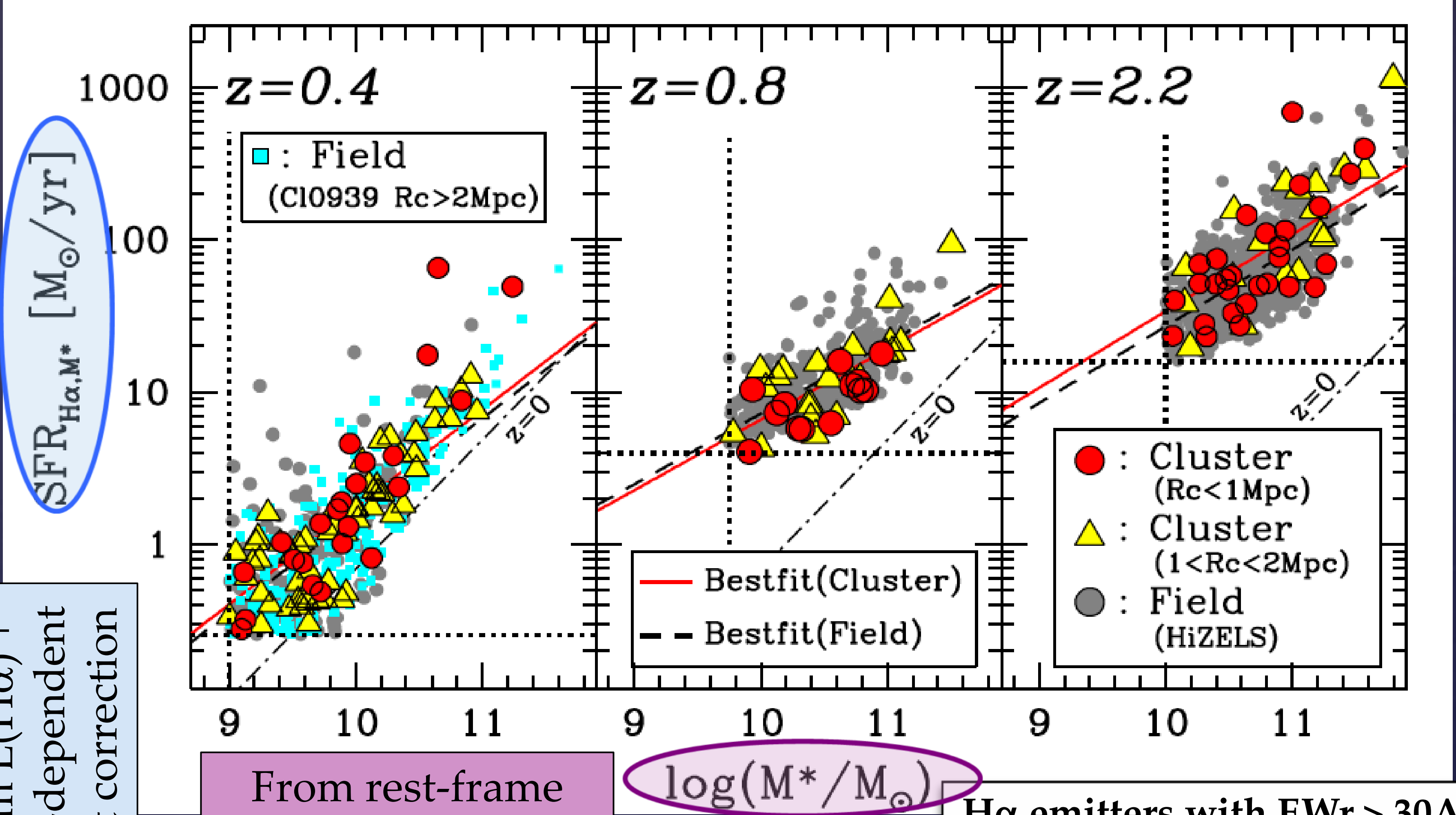
Yahagi et al. (2005)

High-z structures revealed by MAHALO



Cluster vs. Field comparison out to z~2

The MS location is always independent of environment since z~2 !



From L(Hα) + M★-dependent dust correction

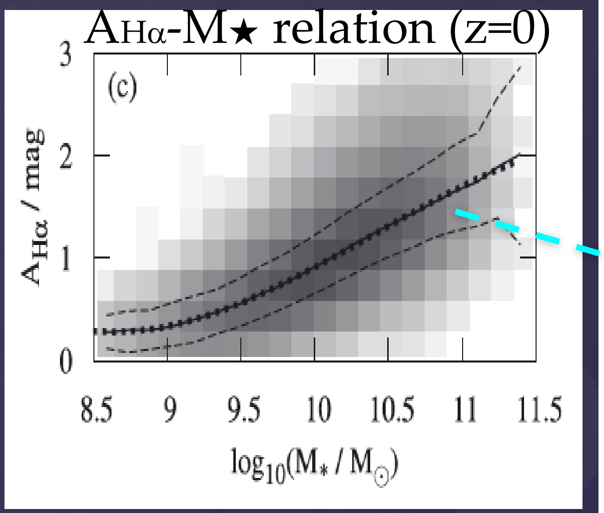
From rest-frame R-band photometry + M/L correction

Hα emitters with EWr > 30A

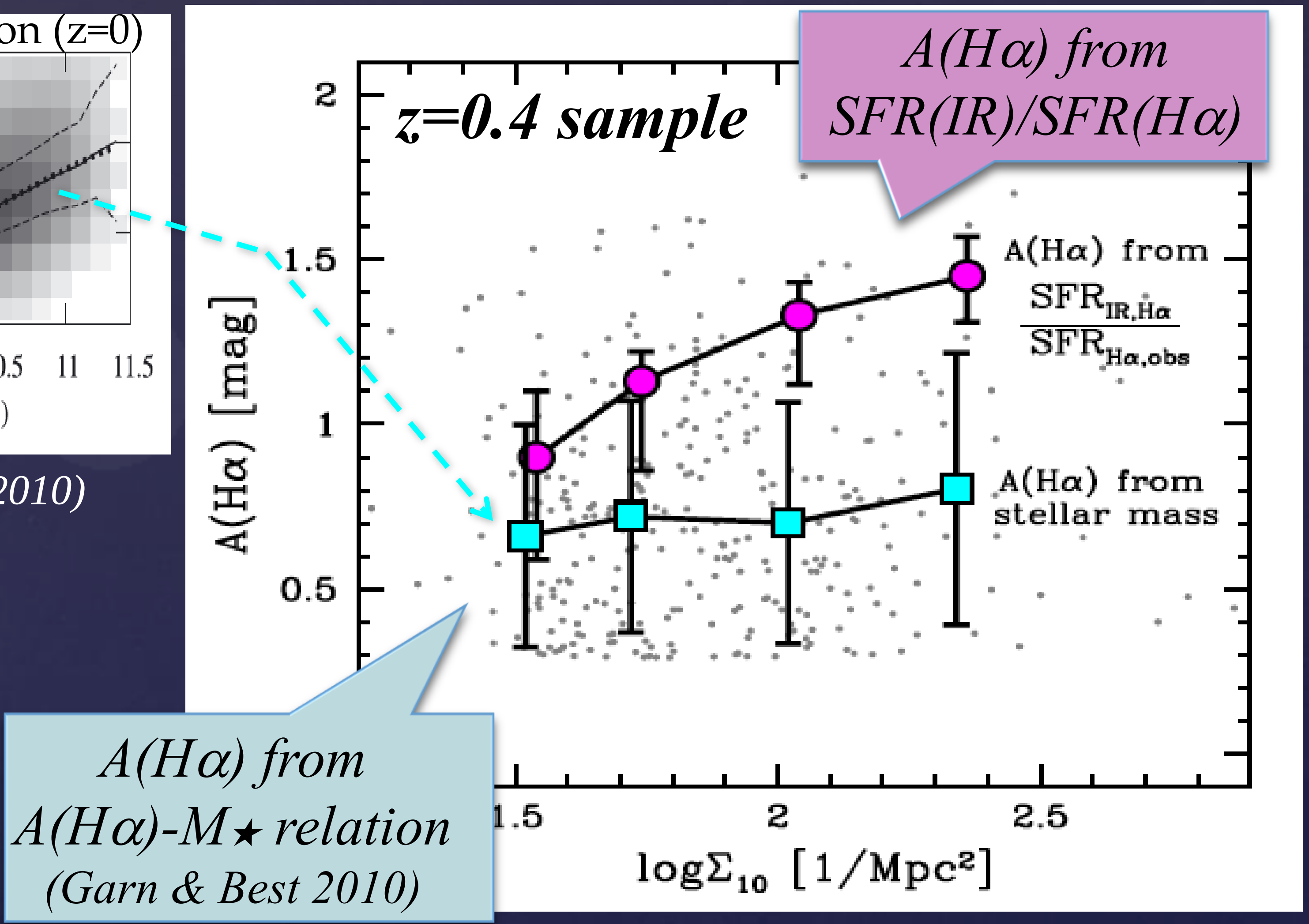
(Koyama et al. 2013b, MNRAS, 434, 423)

Dust extinction vs. environment (*z=0.4*)

Higher dust extinction (different SF mode) in high-density env?



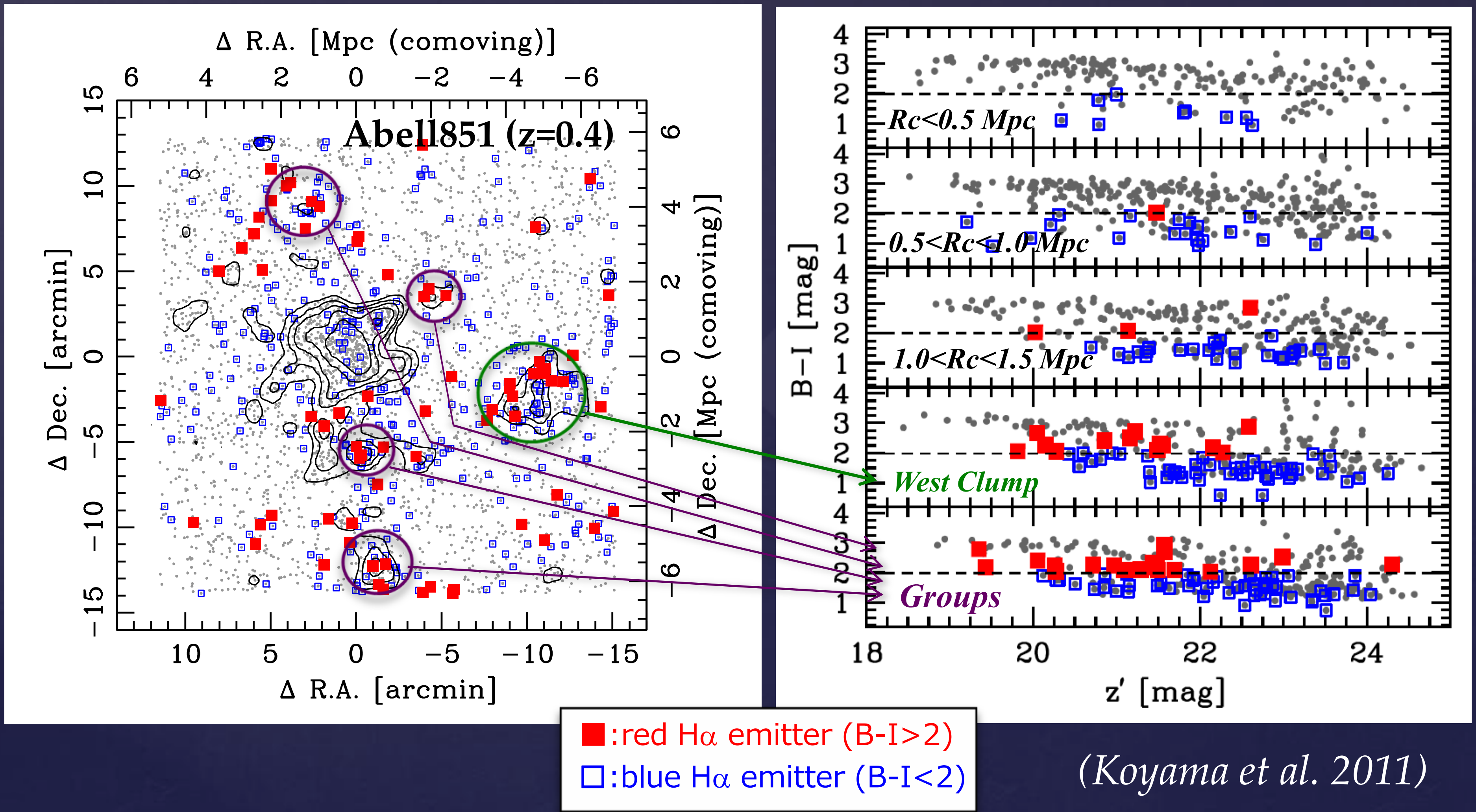
(Garn & Best 2010)



(Koyama et al. 2013b)

Red star-forming galaxies

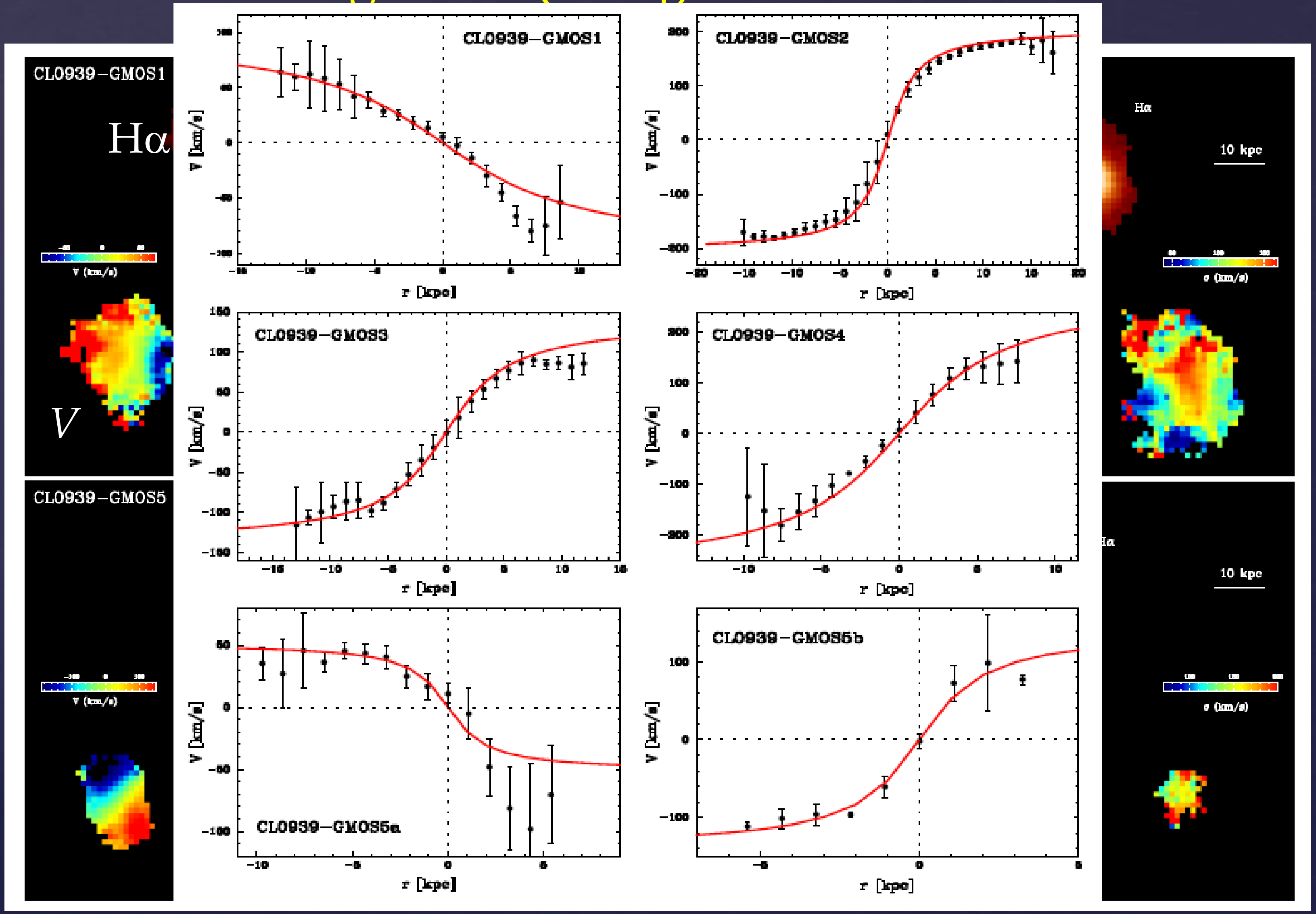
A key population most frequently seen in group-scale environments



(Koyama et al. 2011)

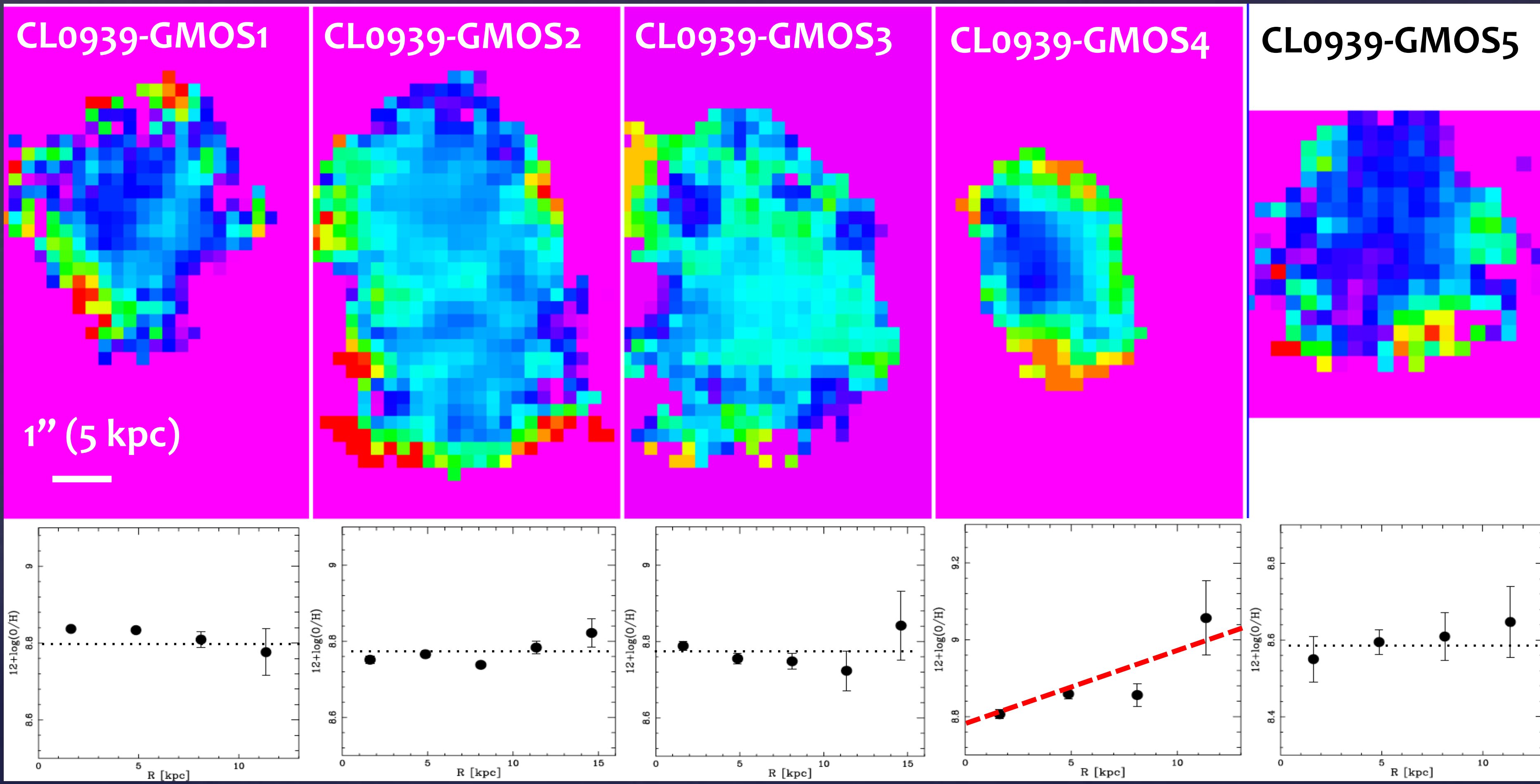
Red SF galaxies: progenitors of local S0s?

3-D views of red SF galaxies (z=0.4) with GMOS+IFU observation.



Metallicity gradient of red SF galaxies

Constant [NII]/Hα over the galaxies, but some hints of positive gradient?



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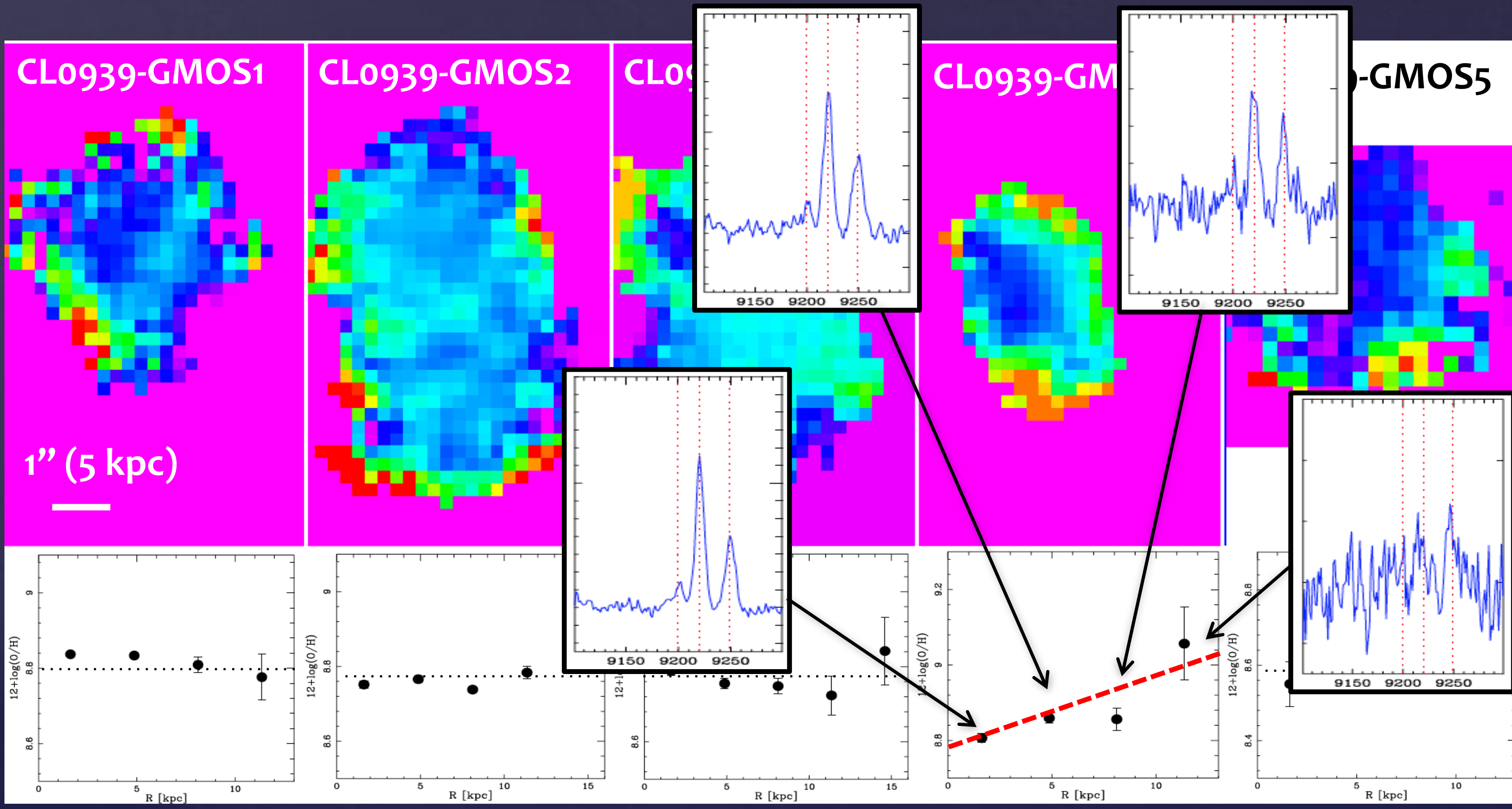
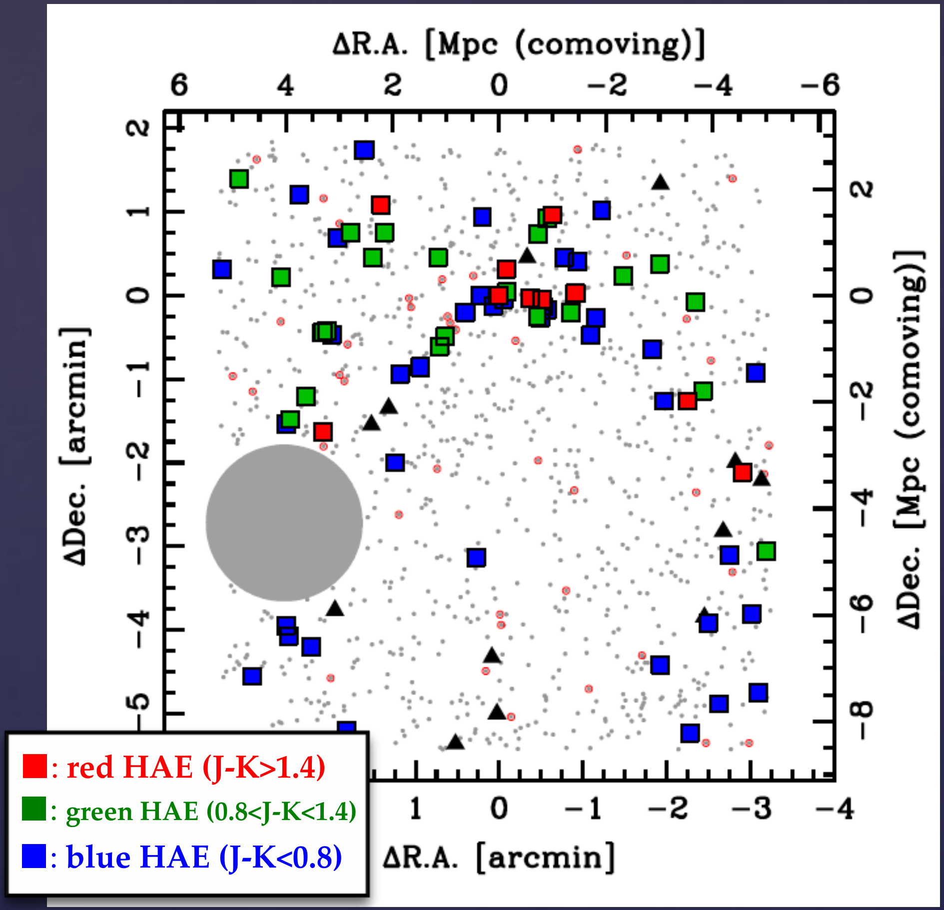
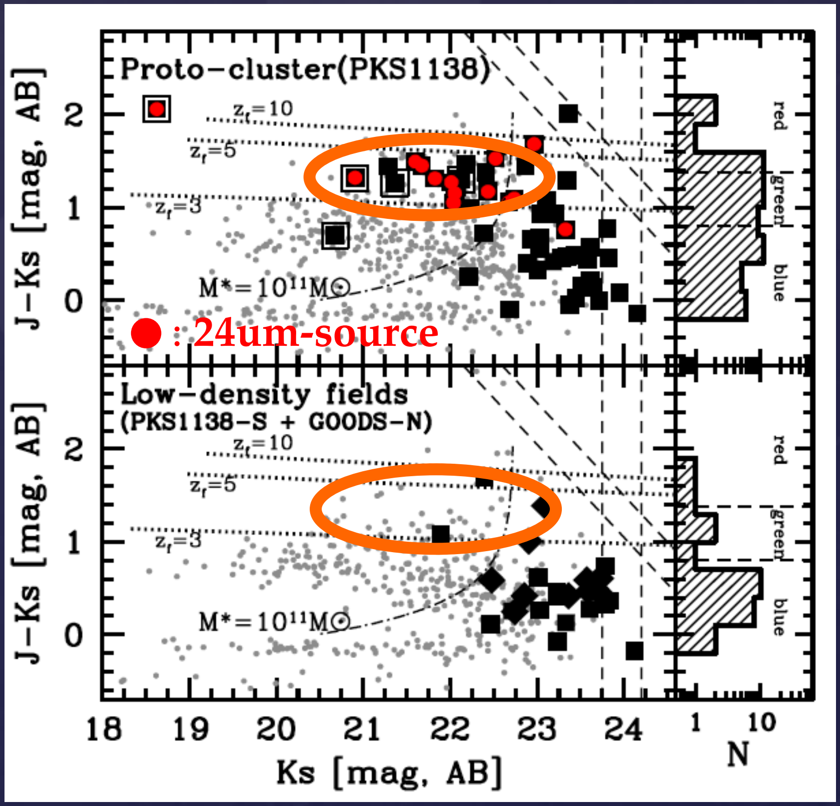


Massive SF galaxies in z>2 proto-cluster



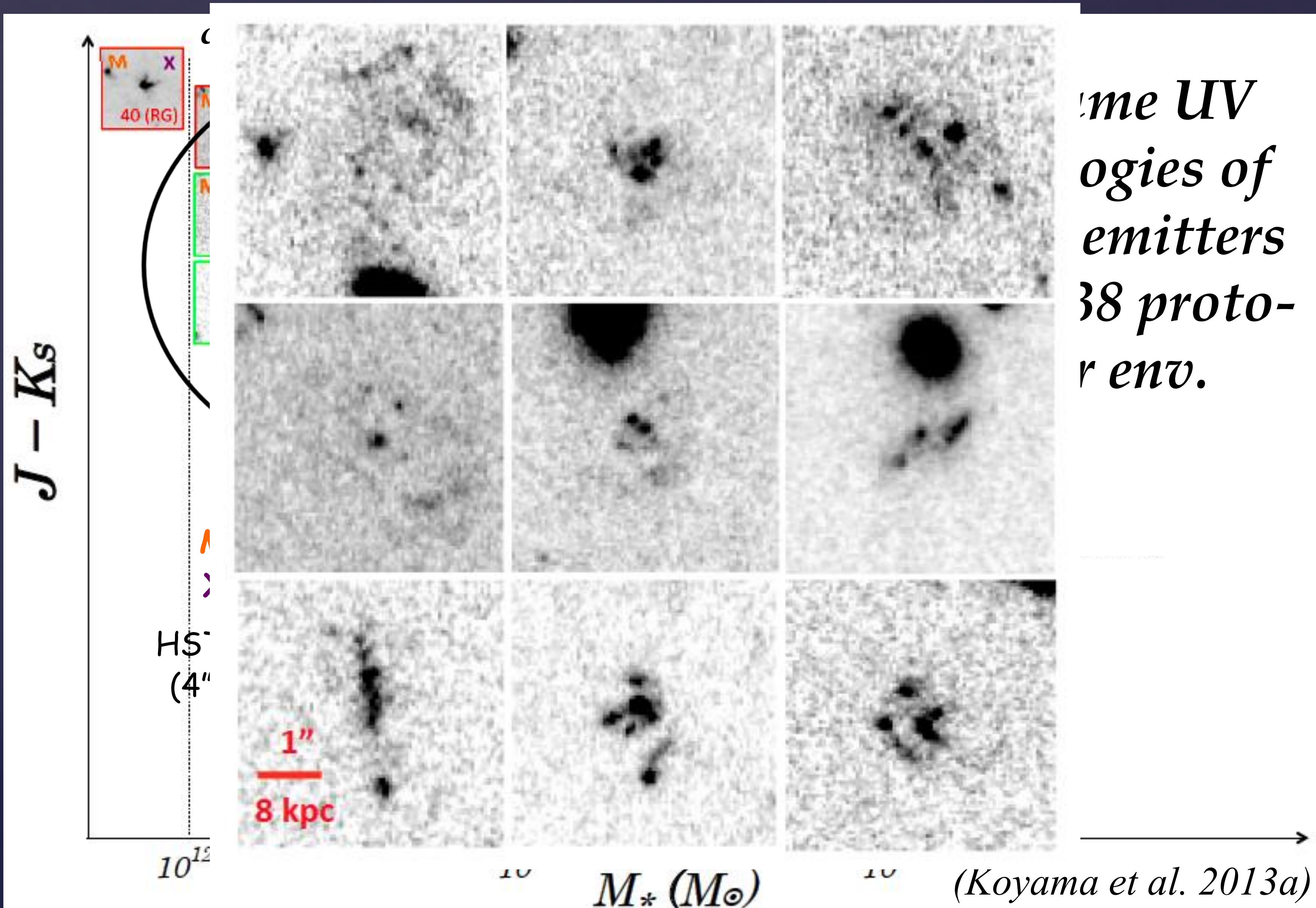
Our MOIRCS+NB(Hα) survey revealed red Hα emitters dominate the core of z=2.16 proto-cluster (PKS1138-262).



Red emitters are massive (M★ >10^{11}M⊙), and clearly dominate dense environment at z~2.

(Koyama et al. 2013a)

Big clumpy galaxies in proto-cluster env.



(Koyama et al. 2013a)

GANBA-Subaru

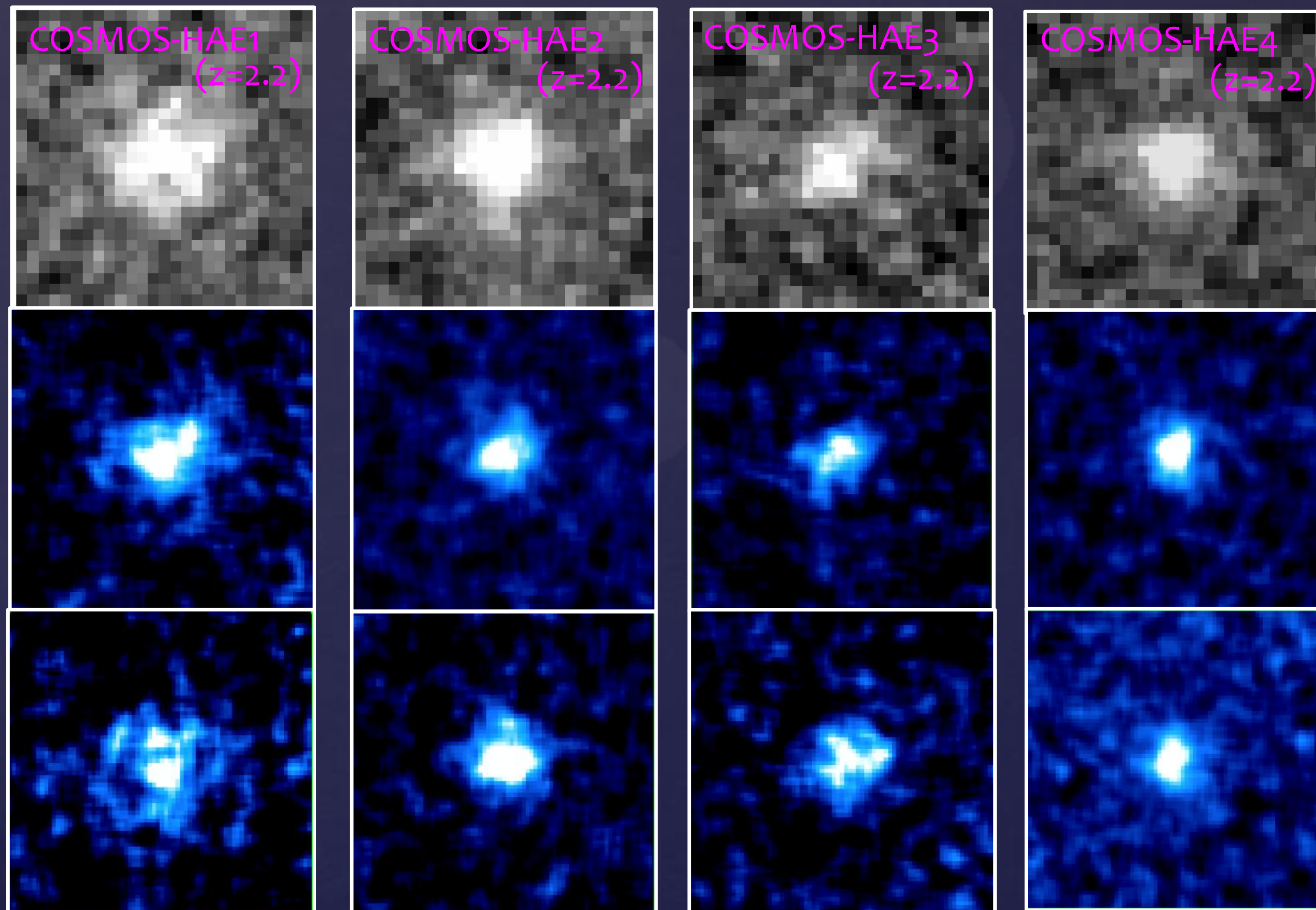
Collaborator: Y. Minowa, MAHALO-Subaru team, HiZELS team

Galaxy Anatomy with Narrow-Band AO imaging with Subaru

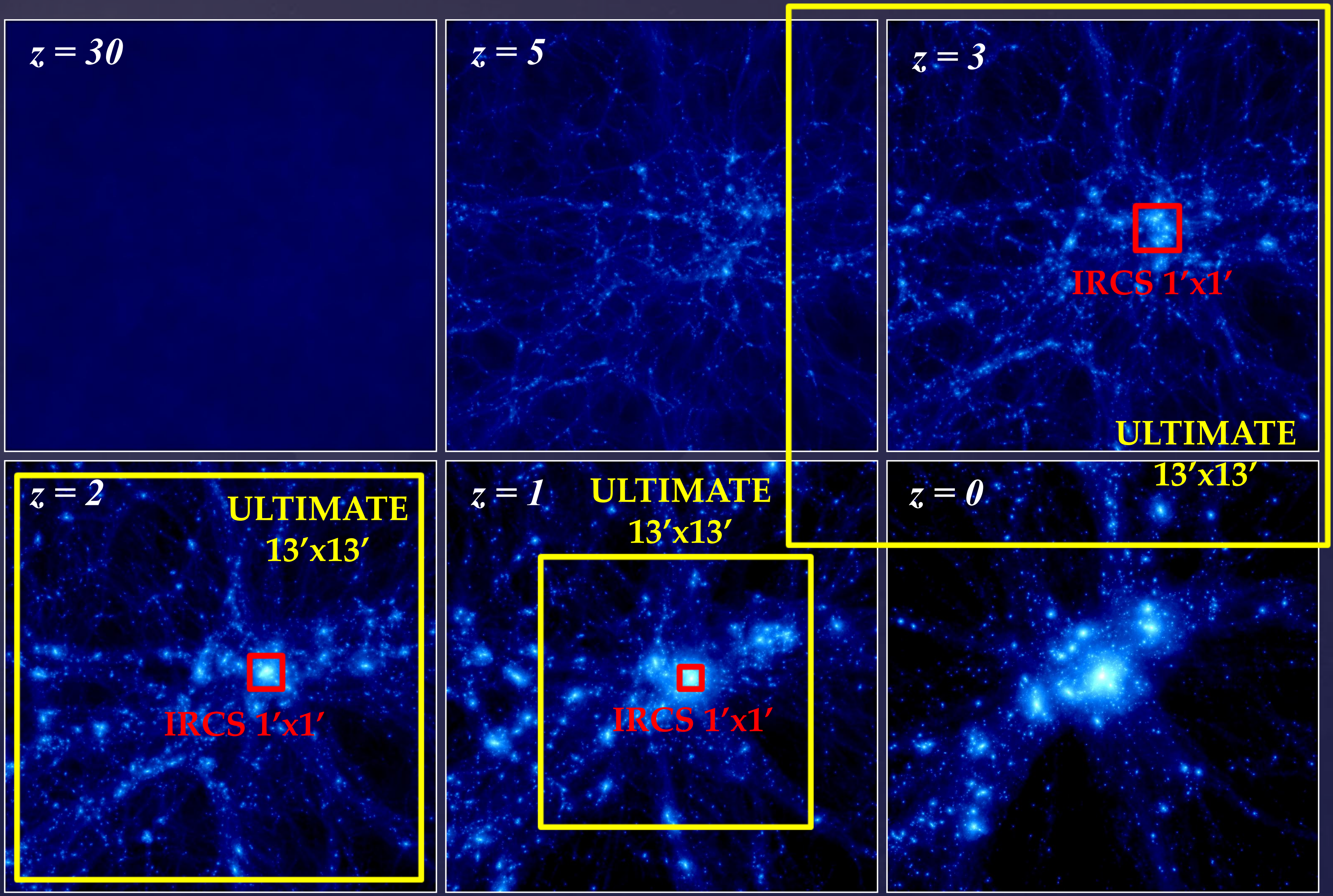
CFHT K-band
(seeing ~0.7”)
4”x 4”

IRCS K’-band
(AO ~0.2”)
4”x 4”

IRCS NB(H2)
(AO ~0.2”)
4”x 4”

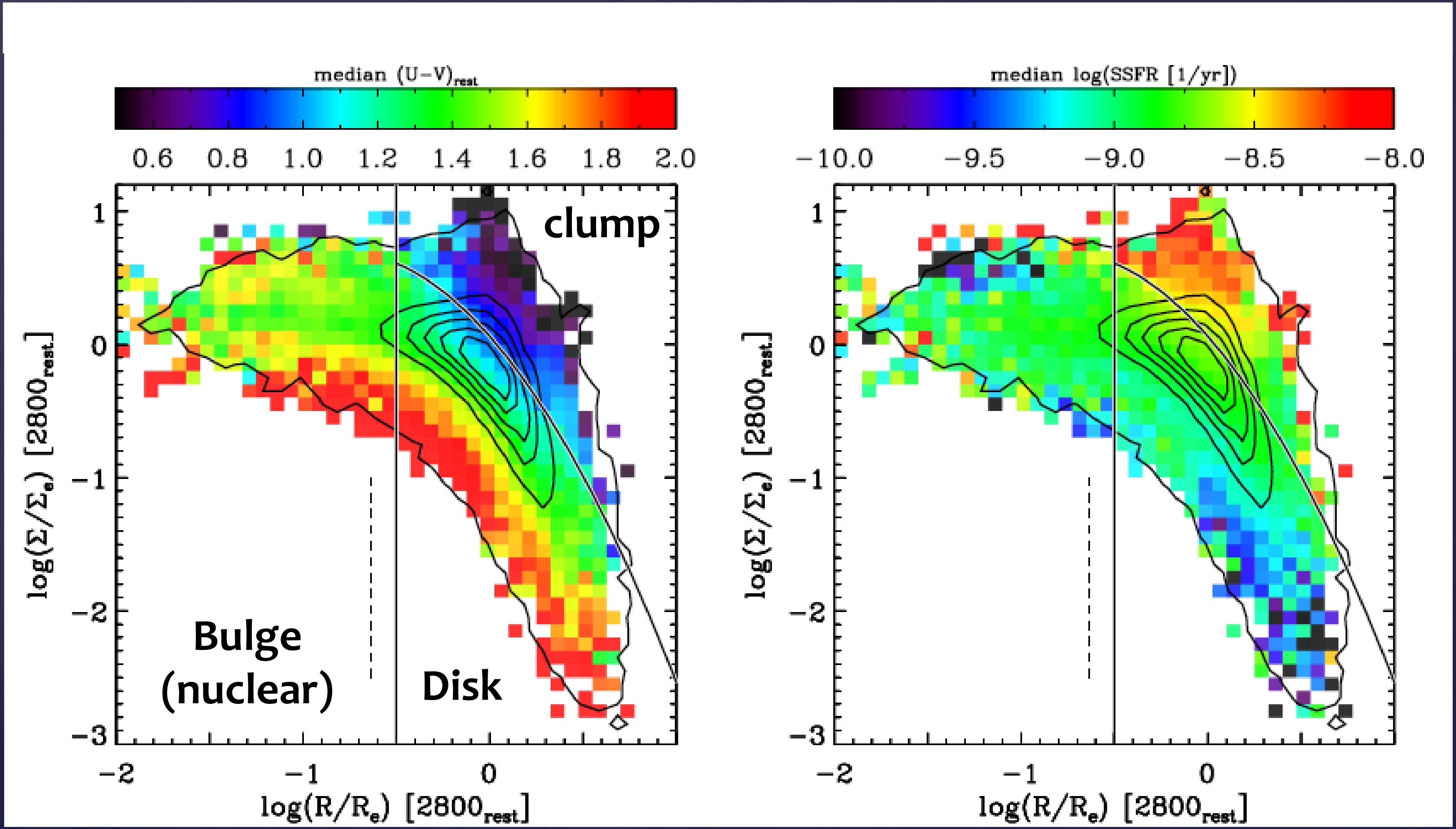


From "GANBA" to "ULTIMATE"



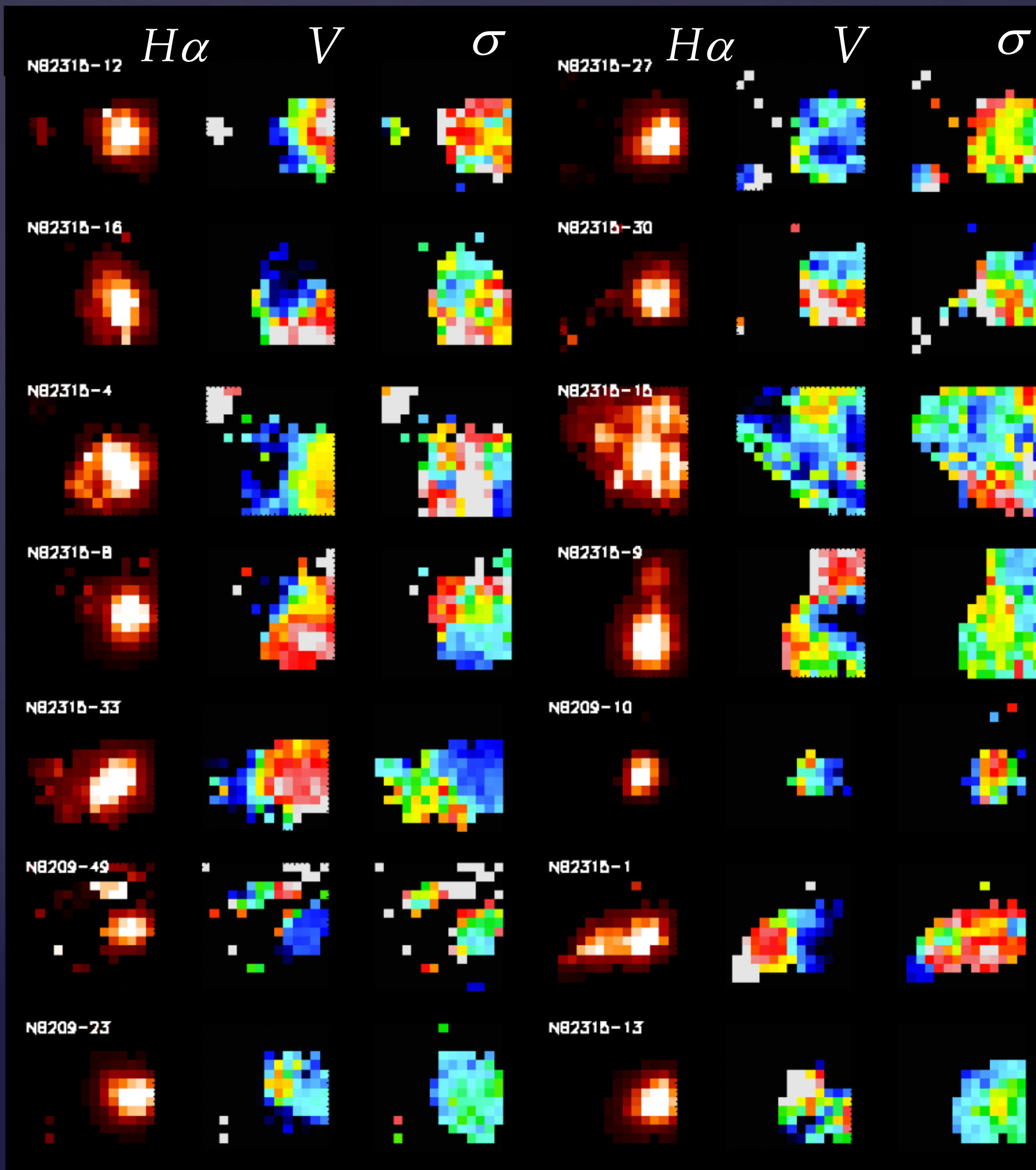
Pinpointing the site of stellar build-up

Galactic centre? On disk? In clumps? Any environmental dependence?



From CANDELS 3D-HST by Wuyts et al. (2013)

Follow-up with multi-IFU



KMOS: 24 IFUs over 7' FoV. Each IFU has 2.8"x2.8" with 0.2" sampling (i.e. 14x14 elements per IFU)

KMOS 3-D spectroscopy of ~20 Hα emitters at z=2.2/2.5 selected by our MAHALO project.

An extremely high success rate (~90%!) of our KMOS observation demonstrates that NB- based sample selection can provide excellent IFU targets.

Answers to the questions

(Q1) What is the optimum spatial sampling (or diameter in arcsec of each fiber in the bundle) and FoV of the bundle?

(A1) 0.2″ per fibre is fine. In terms of sample selection for TMT, it is probably most important to have highest multiplicity. However, with only 1″ FoV, we may miss a large fraction of signals from outskirts of galaxies. I therefore prefer config.1.

(Q2) What is the optimum and minimum number of the fiber bundles (or multiplicity) in the 13'.6 diameter FoV?

(A2) I think we don't need to have too many bundles – we can observe as many targets as we want by spending several fibre configurations. The FoV of each bundle (i.e. the point of Q1) must be a more important issue.

(Q3) What is the critical wavelength range in near-infrared covered by the Starbug system (0.9-2.0micron)?

(A3) I strongly recommend to have wavelength coverage at λ>2.0um (to observe Hα at z>2). If it is unrealistic, let's start from 0.9-2.0um in phase-1, and extend its wavelength coverage in phase-2?

(Q4) What is the optimum spectral resolution?

(A4) I think R~4000-5000 (following e.g. KMOS) will be a reasonable choice, with which we can resolve velocity structure within galaxies down to < 50 km/s.

(Q5) What is the sensitivity requirement for the phase-I instrument?

(A5) The expected sensitivity for phase-1 (~50% of MOSFIRE) is acceptable. Higher sensitivity is of course better, but I think earlier start of operation is more important – e.g. getting KMOS/VLT time is currently VERY hard (>10x oversubscribed), demonstrating that multi-IFU instruments can attract a great deal of attention from all over the world !

(Q6) Please describe a brief observation plan for your science case with the fiber bundle multi-object IFU.

(A6)

Phase 1: [1] we will do NB Hα imaging of MAHALO clusters (~10 clusters at 0.4<z<2.5) to get Hα size for complete sample of galaxies in cluster environments across cosmic time. [2] We will follow them up by using multi-IFU modes (~20 galaxies per cluster) to get their kinematics and metal gradient. For each cluster, we typically need ~4-5 hours to complete NB+BB imaging and ~6 hours to complete IFU obs, yielding ~100 hours (12 nights) to complete this survey.

Phase 2: A more complete 3D mapping of blank fields (e.g. full CANDELS fields) by using upgraded multi-IFU Starbugs by exploiting "mosaic" mode ?

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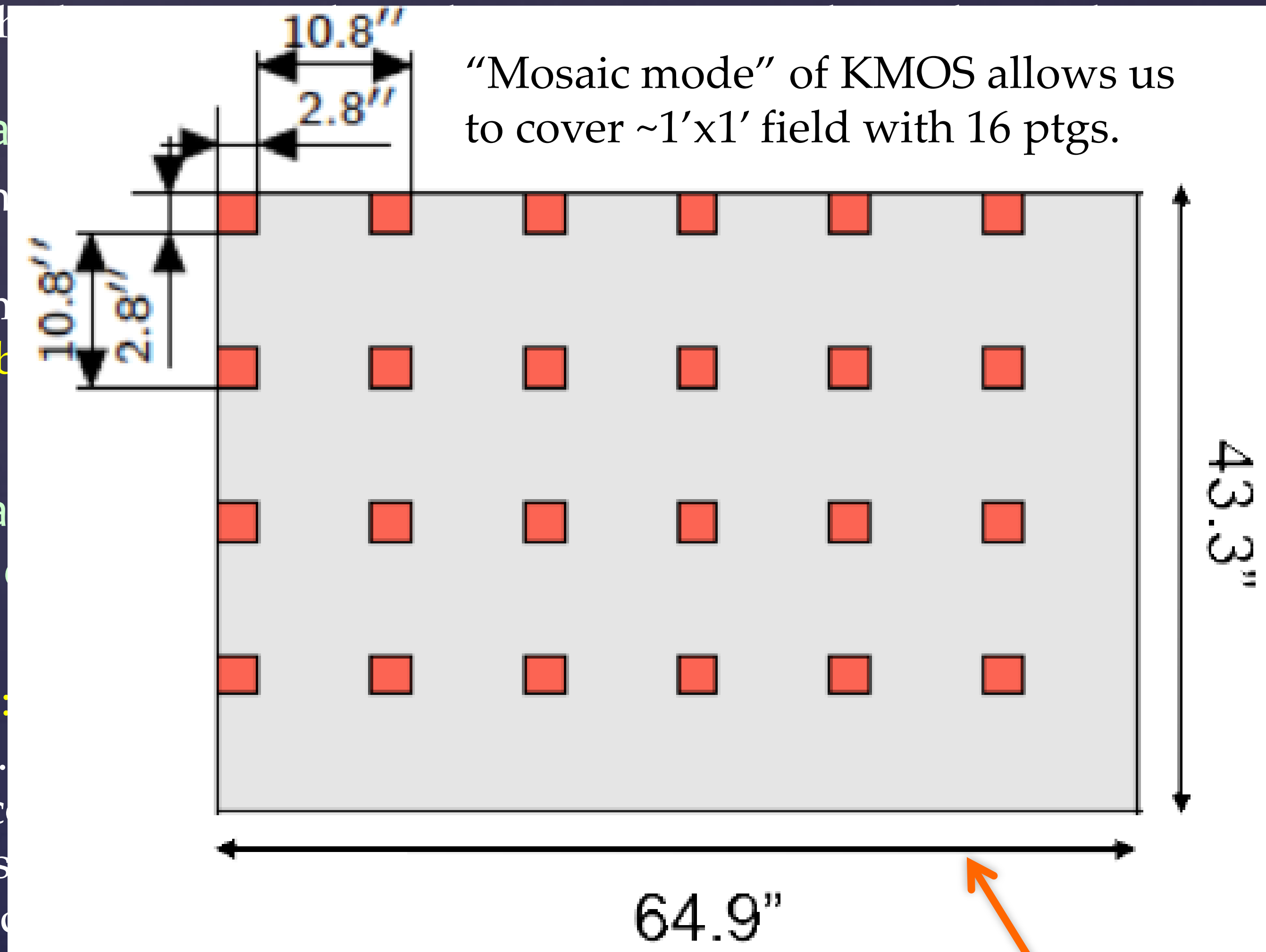

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(Q7) How could the proposed science cases be competitive or complementary to the science with 30m class telescopes (e.g. TMT) or space telescopes (e.g. JWST) in 2020s?

(A7) The proposed observations will provide an excellent sample to TMT/ALMA/SPICA. In this sense, I hope it to be complementary rather than completely competing with them. Wide-field NB survey + IFU follow-up will be a key strategy for Subaru GLAO to survive.

(Q8) Please describe the requirements for Phase-II instrument (Starbugs + dedicated spectrograph) to develop your science case.

(A8) I request to extend the wavelength coverage towards λ>2um (in case we can have a coverage of only λ<2um in phase-1). Also let's discuss the possibility of having more survey-like observation with "mosaic" mode.

(Q9) What is the unique point of the fiber bundle multi-object IFU with Starbugs compared to the imager or multi-object slit spectrograph?

(A9) The IFU observation will allow us to study kinematics and spatially resolved line ratios of high-z galaxies, which is not available with multi-slit spectroscopy.

Summary

(1) I agree that the multi-IFU + GLAO is a great combination for studying galaxy evolution and environmental effects out to z>2.

(2) The key strategy is wide-field NB imaging + multi-IFU follow-up, with which we can study the history of stellar build-up across cosmic time and environments.

(3) "MAHALO-Subaru" can provide an excellent sample of distant SF galaxies, and our on-going "GANBA-Subaru" project will provide an important test on what we can do with "ULTIMATE-Subaru".

(4) I strongly recommend to have sensitivity at λ>2um (which is essential to study dynamical properties of z>2 galaxies with Hα).

(5) Earlier start of operation is most important. Notice that KMOS/VLT is highly over-subscribed, meaning that everyone has a strong interest in using multi-IFU facilities.