

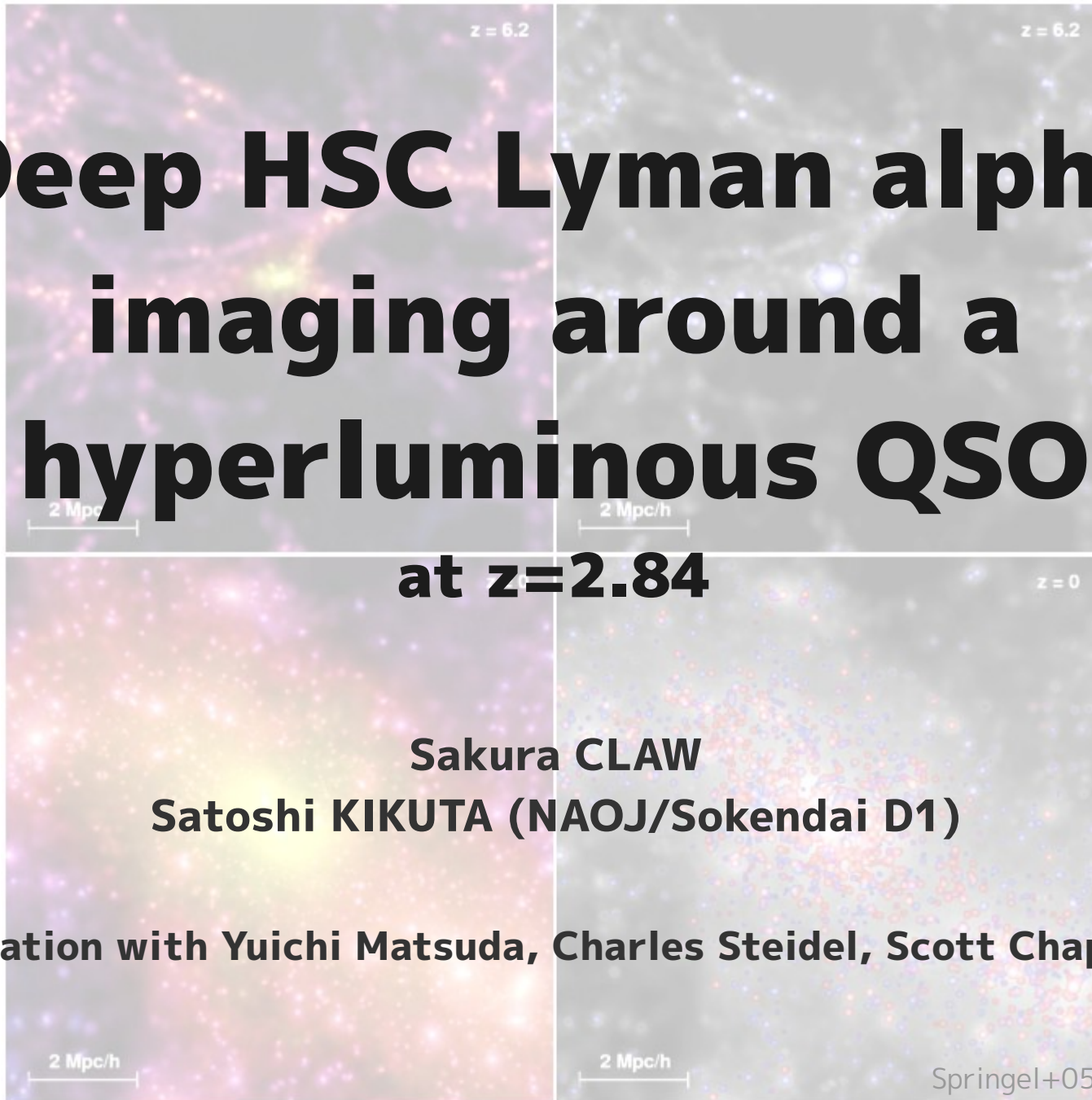
Deep HSC Lyman alpha imaging around a hyperluminous QSO

at $z=2.84$

Sakura CLAW

Satoshi KIKUTA (NAOJ/Sokendai D1)

in collaboration with Yuichi Matsuda, Charles Steidel, Scott Chapman, et al.

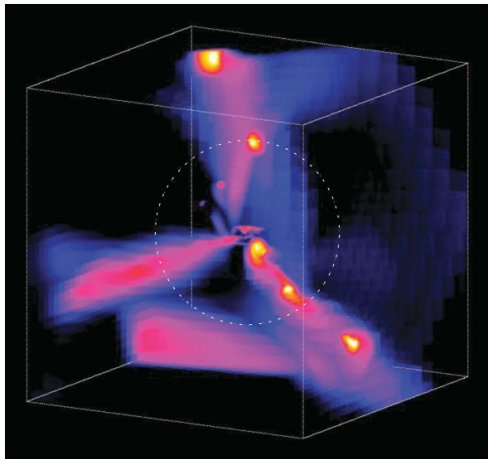


Hydrogen in the Universe

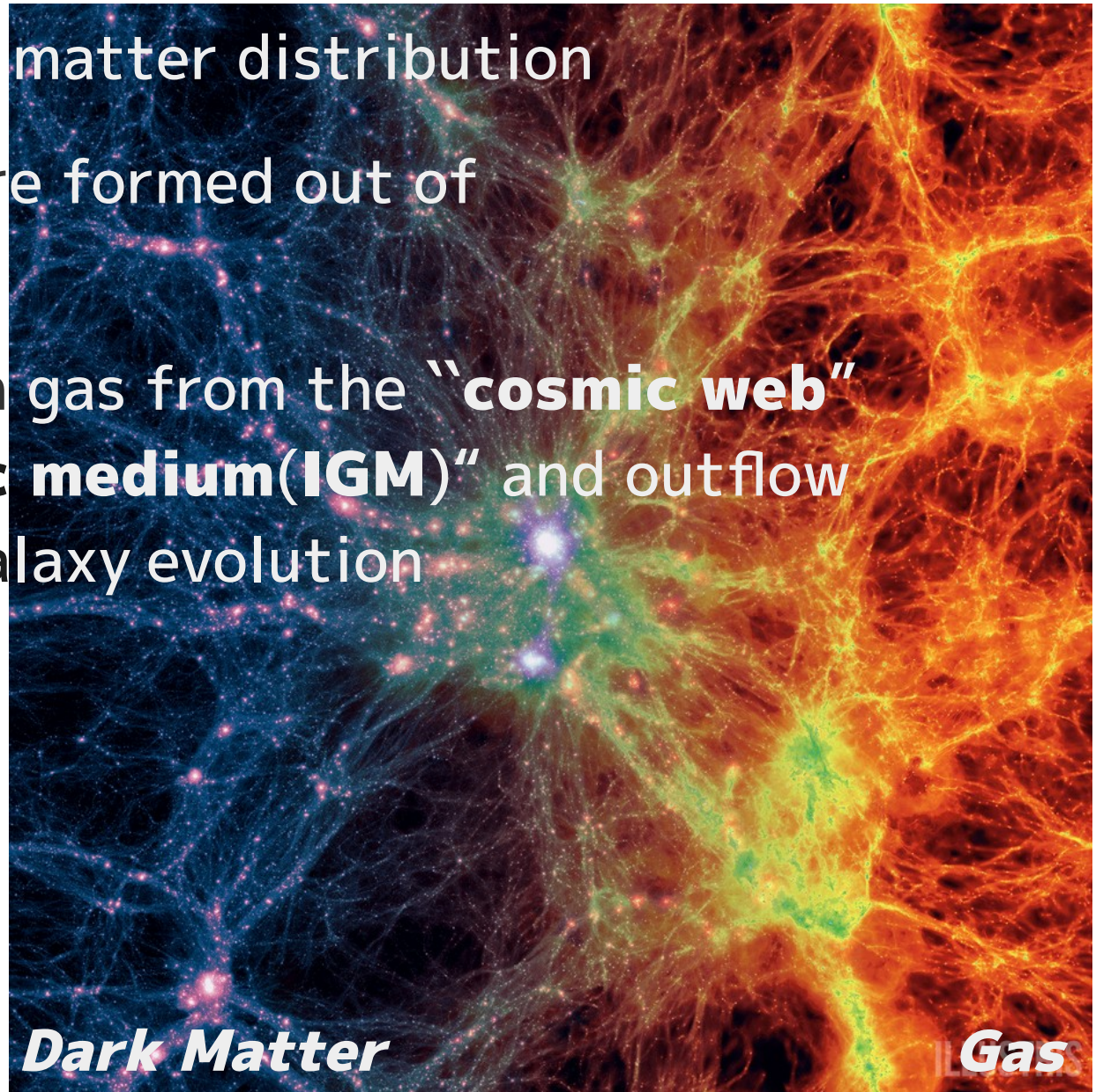
Hydrogen traces dark matter distribution

All galaxies & stars are formed out of hydrogen gas

Accretion of hydrogen gas from the “**cosmic web**” or the “**intergalactic medium (IGM)**” and outflow govern subsequent galaxy evolution



Dekel+09



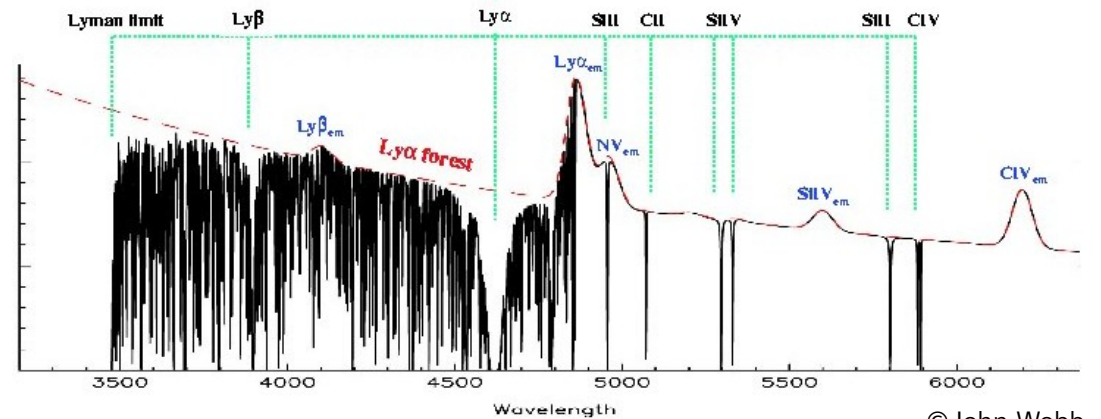
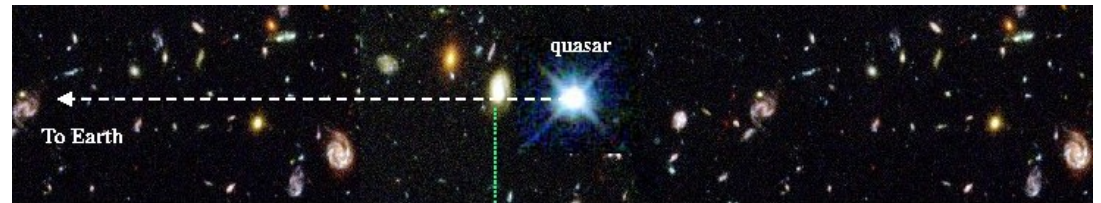
How can we know about the IGM?

Use background QSOs
=luminous AGNs

→ one-dimensional

small volume probed

sparsness of b.g. QSO

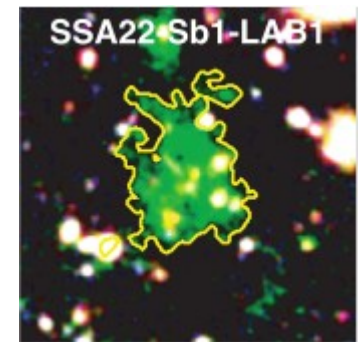


©John Webb

We want to see the cosmic web **DIRECTLY!**

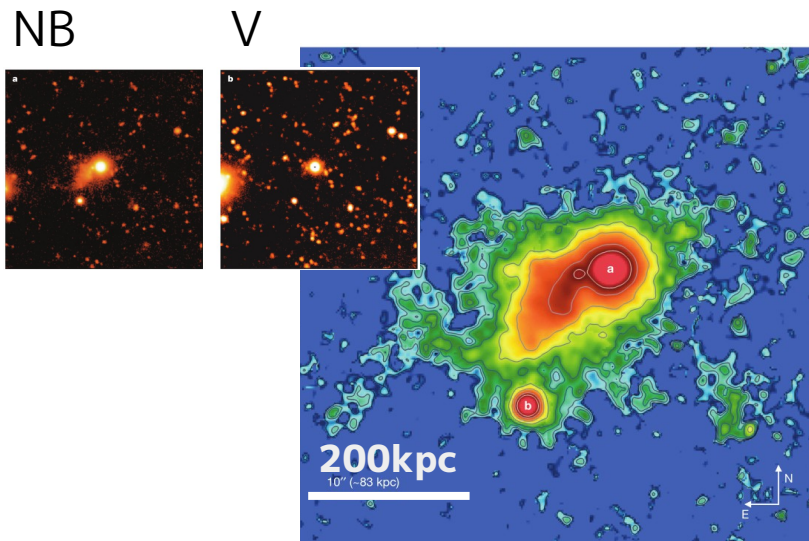
Alternative option:

Direct detection **in emission** via
Lyα imaging with narrow-band filters!

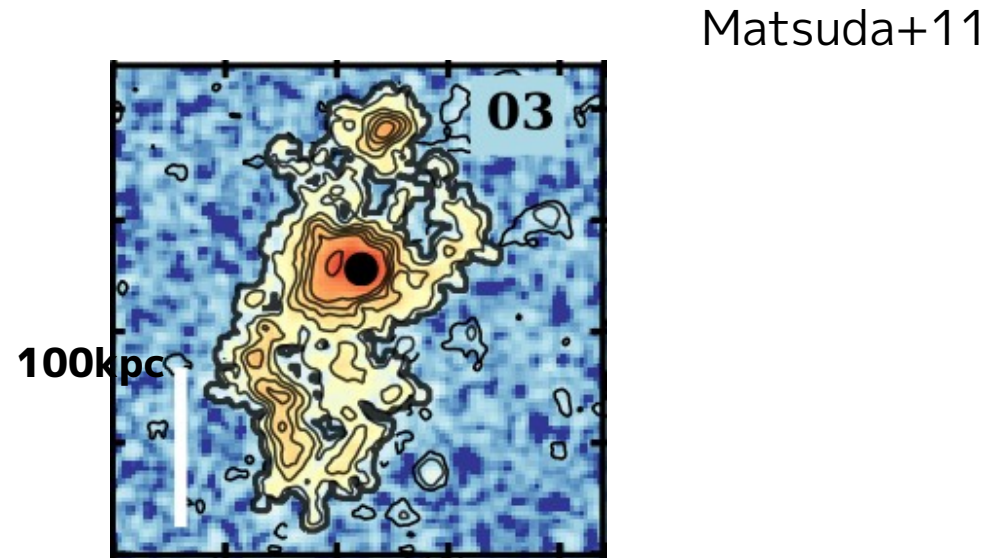


Matsuda+11

The Ly α nebulae



Cantalupo+14



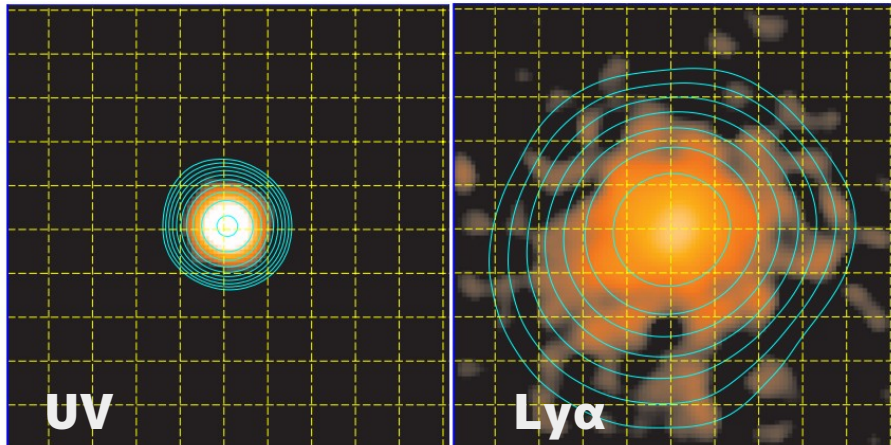
Borisova+16

>100kpc scale Ly α nebulae are found

Reaching for the IGM?

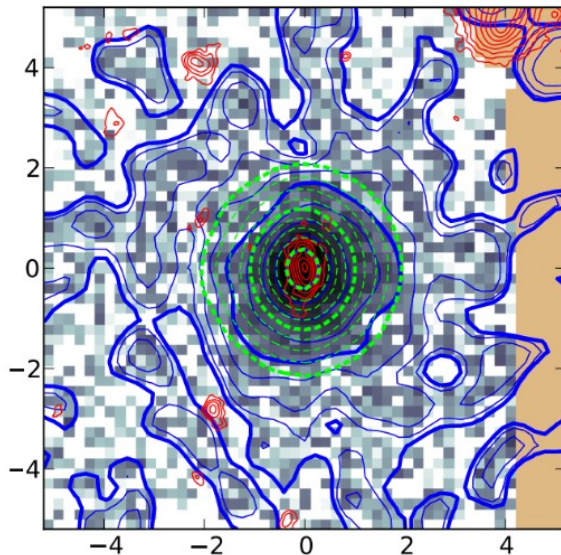
Ly α nebulae around normal galaxies

Diffuse Ly α nebula is ubiquitous!

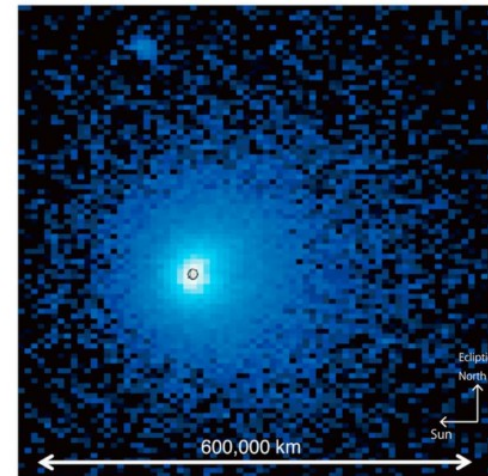


Stacked UV(left) and Ly α (right) image of LBG @ $z=2.65$ (Steidel+11)

Ly α nebulae are important to answer fundamental questions:
How do galaxies form?
How do galaxies get their gas?
How are they connected with the cosmic web (i.e., environment)?



LAE(Ly α emitter) observed with MUSE
gray scale & blue contour: Ly α
Green contour: UV
(Wisotzki+16)



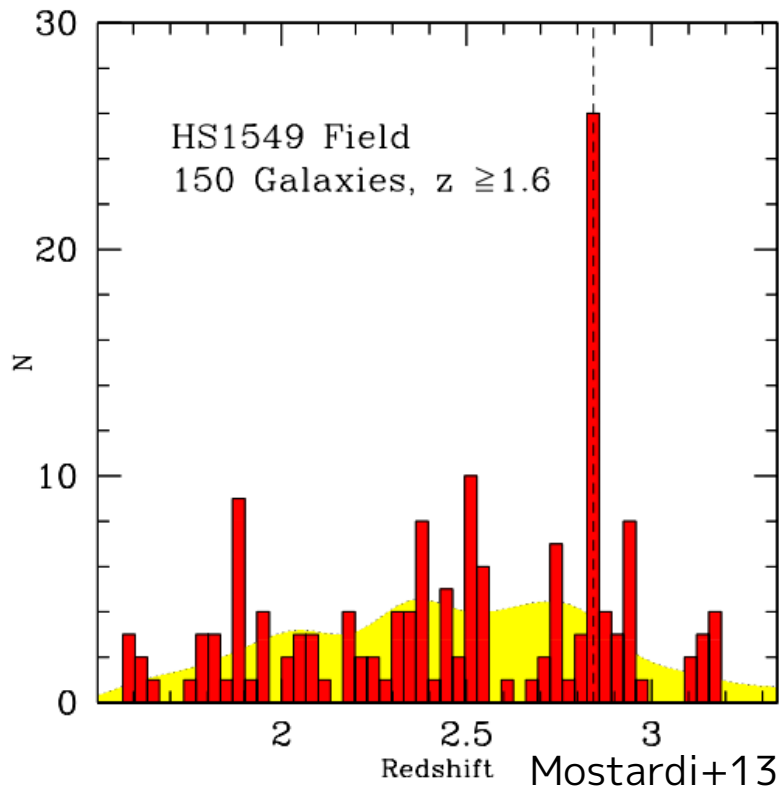
Even around the Earth!!
Kameda et al. 2017

Geophysical Research Letters

Observation: HS1549+1919

Hyperluminous QSO at $z=2.84$

- $L_{1450}(\nu L\nu @ \lambda=1450\text{\AA})=1.5\times 10^{14} L_{\odot}$, $M_{\text{BH}}=4.6\times 10^9 M_{\odot}$
 $\ast L_{\odot}=3.8\times 10^{33} \text{ erg/s}$ (Trainor & Steidel 2012)
- reside in massive overdensity (proto-cluster)
- Deep imaging & spectroscopic data available at the center



To [redacted]

Thank you for your encouragement and support;

I could not have done this without you. To
paraphrase the words of a friend of ours:

All the other girls here are stars,

You are [HS1549+1919]!

[...Quoted from Ph.D. thesis of [redacted].]

Observation: HS1549+1919

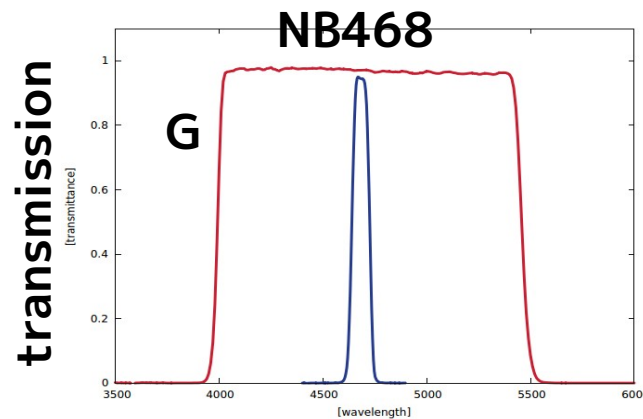
Hyper Suprime-Cam(**HSC**) Observation (S16A-110, PI: Yuichi Matsuda)

FoV= **1.5 deg diameter** = 42 pMpc/165 cMpc @ z=2.84

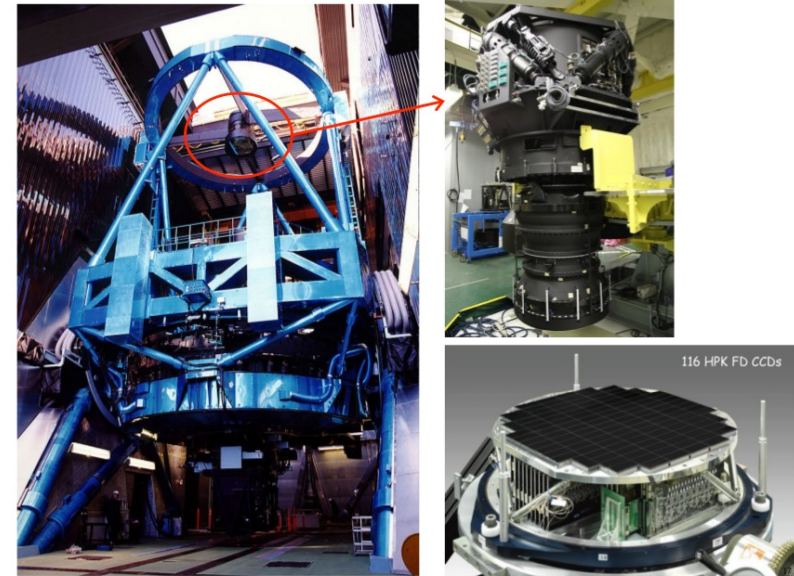
G 2.2 hr (389 shots) → 27.4 mag (5 σ , 1.5" aperture)

NB468 6.3 hr (113 shots) → 26.7 mag (5 σ , 1.5" aperture)

Data reduced using HSC pipeline



← stacked image



LAE detection

Source detection & photometry
with SExtractor (Bertin & Arnouts 96)

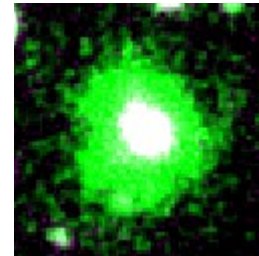
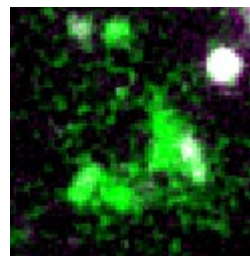
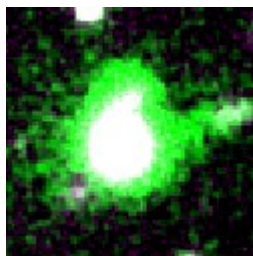
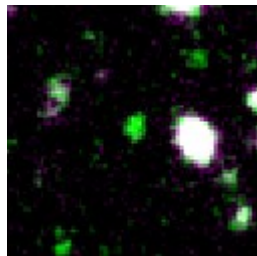
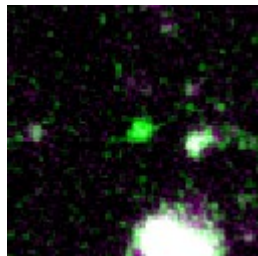
LAE Selection criteria:

$$NB < 26.57(5\sigma)$$

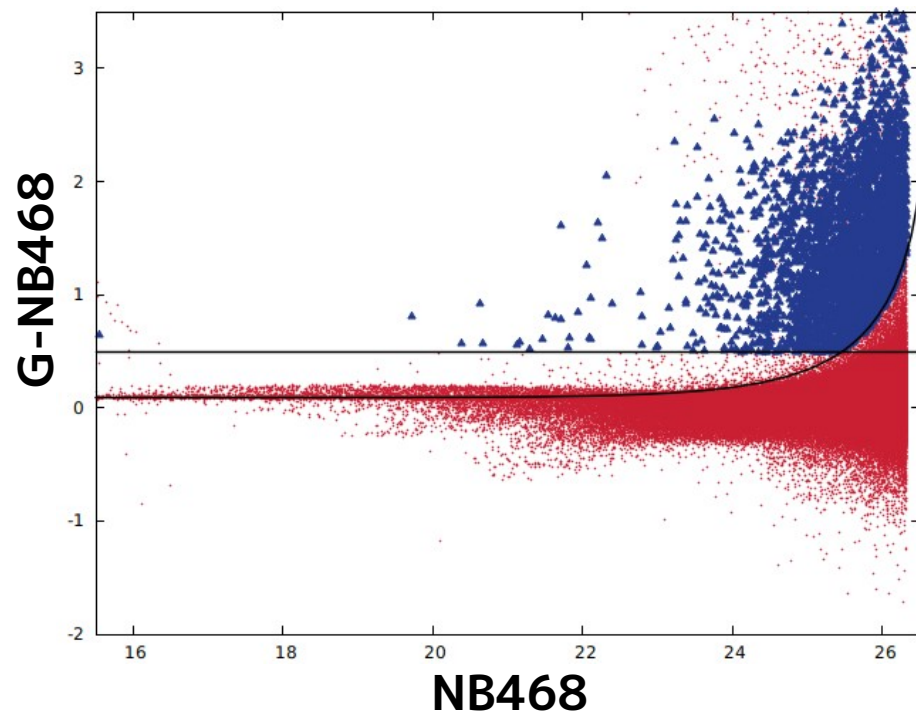
$$G - NB > \max\{0.5, 4\sigma(G-NB)\}$$

(rest EW > ~12Å)

→ **3490** LAEs found within **36 arcmin**
from HS1549 (1.2 deg diameter)



False-color
image
R: G
G: NB
B: G

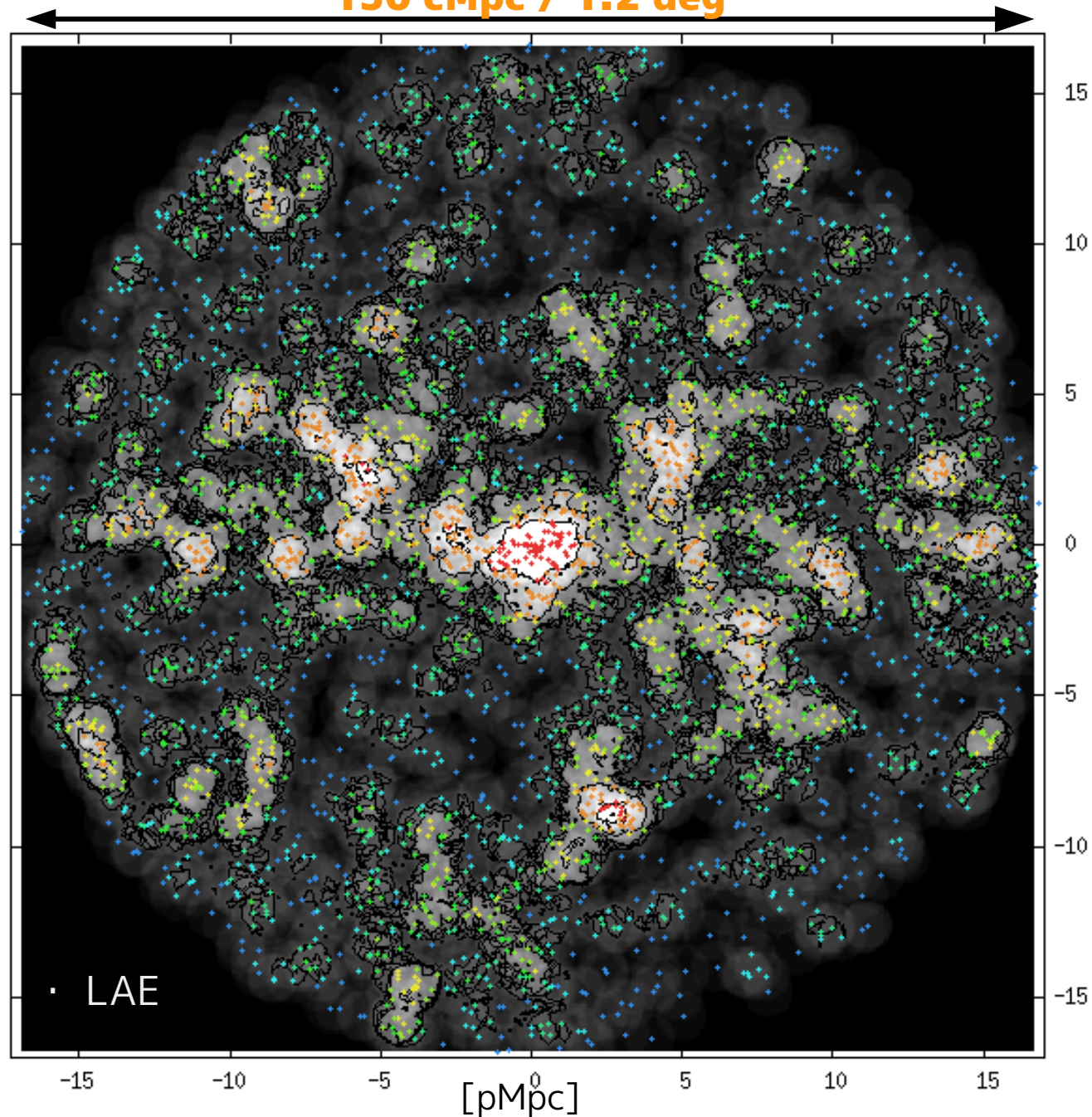
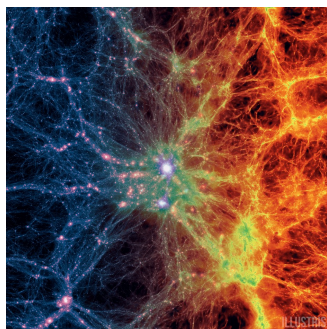


Very large LAEs found → try to systematically select them

Result: Large Scale Structure of LAEs

130 cMpc / 1.2 deg

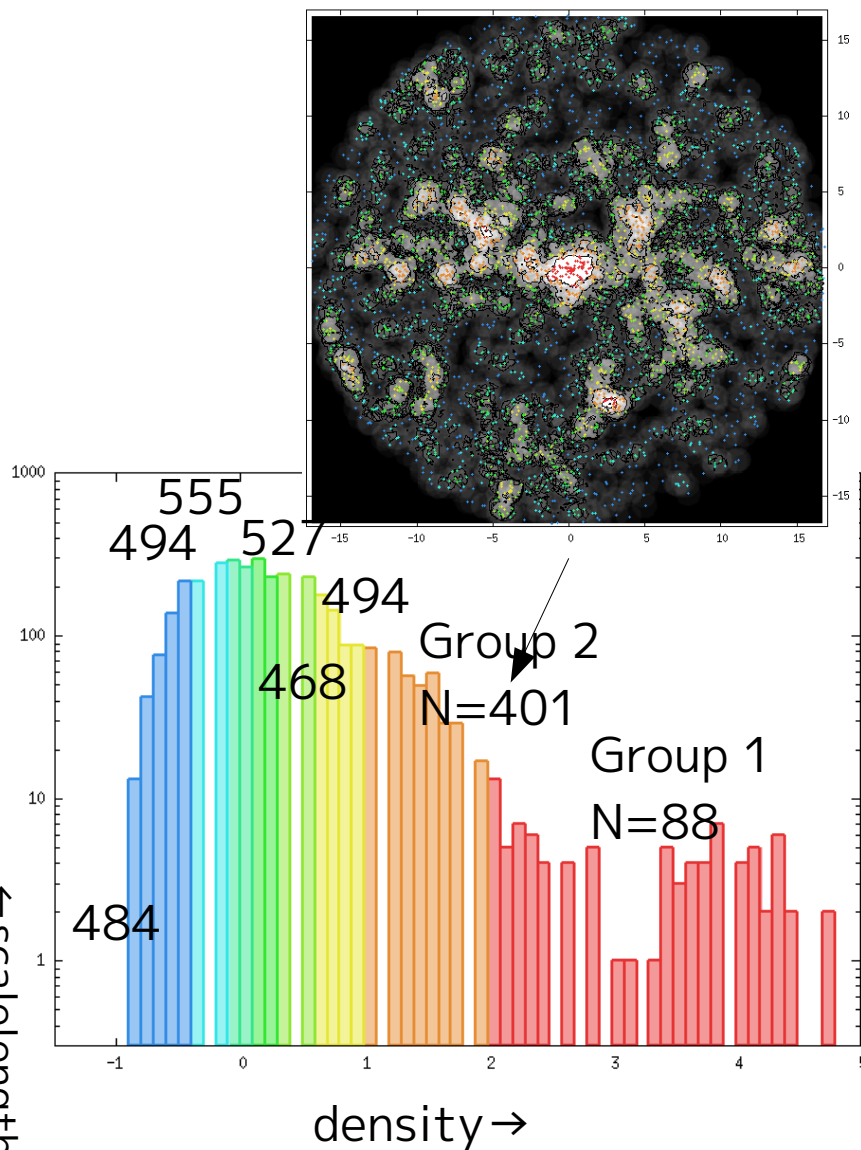
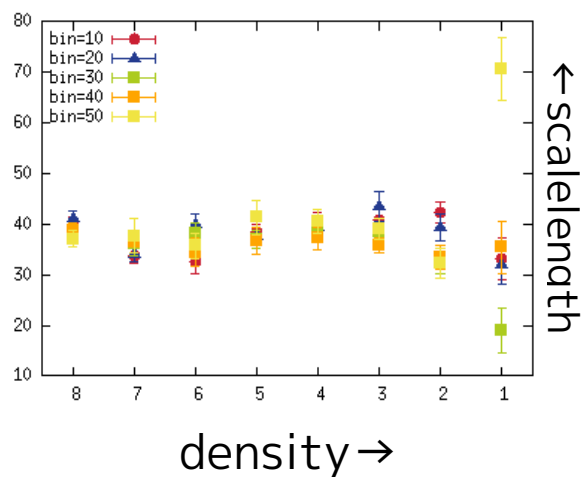
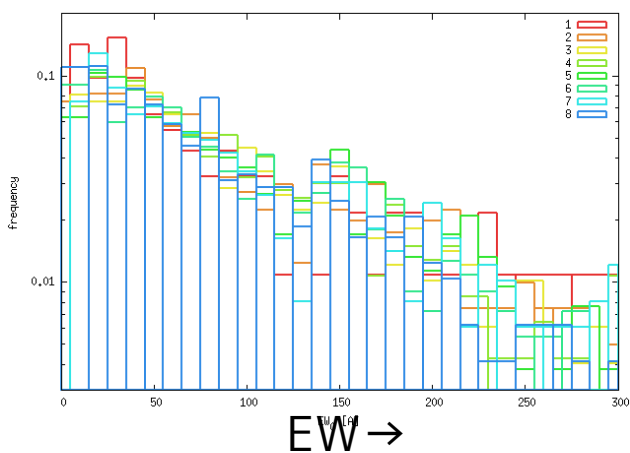
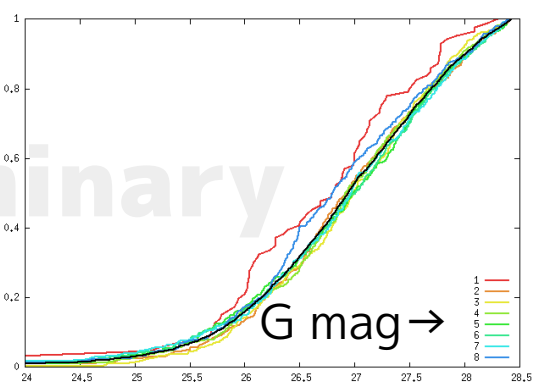
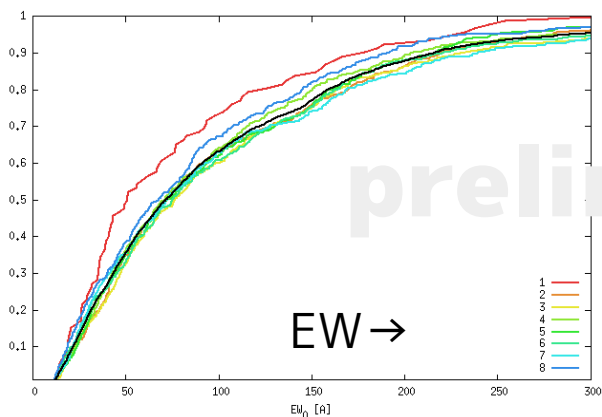
- Protocluster around HS1549 (at the very center) + lower peaks at north-east and west
- Voids at north and south of HS1549
- 1 pointing of HSC can probe **diverse environments!**



Power of HSC: dependence on environments

CAUTION: preliminary!

EW scale length VS δ_{gal}

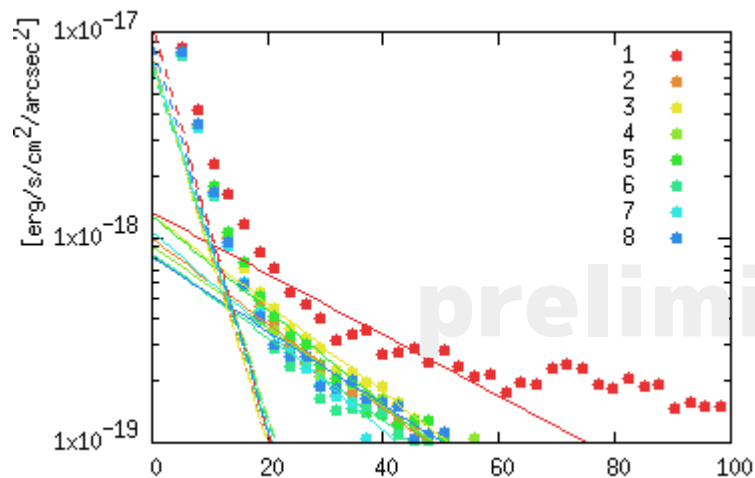


Power of HSC: dependence on environments

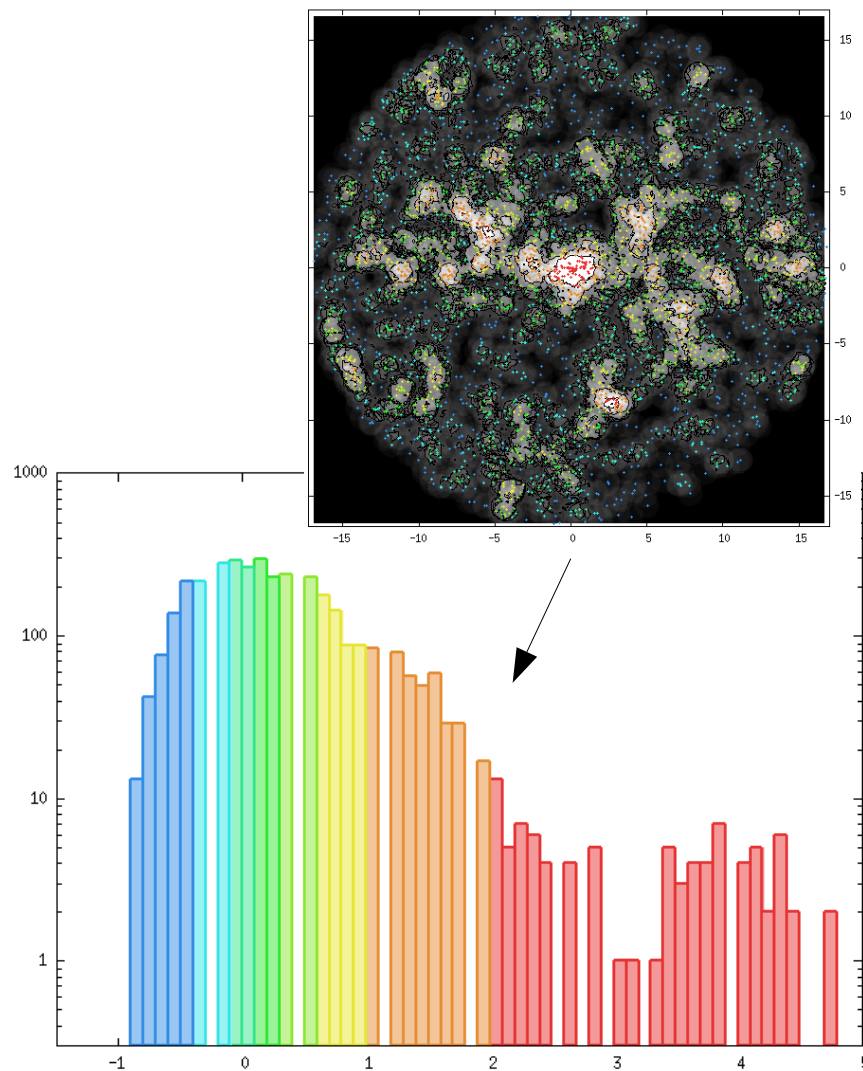
CAUTION: preliminary!

LAH scale length VS δ_{gal}

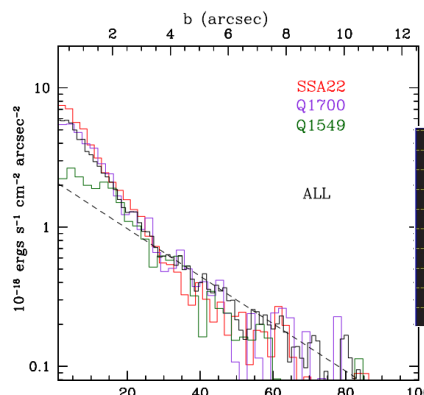
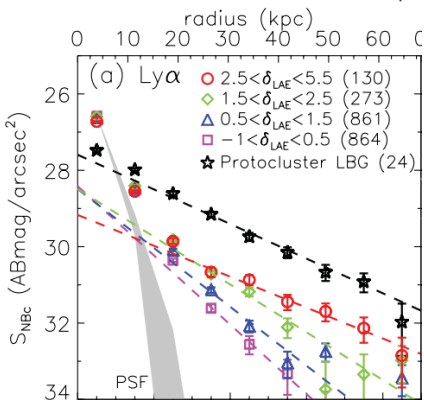
- Clear excess in overdensity as in SSA22 (Matsuda+12)



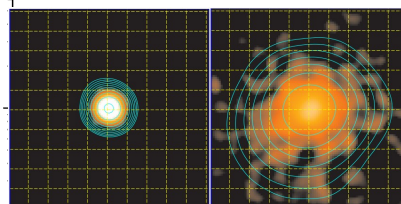
Matsuda+12 SSA22 [physical kpc]



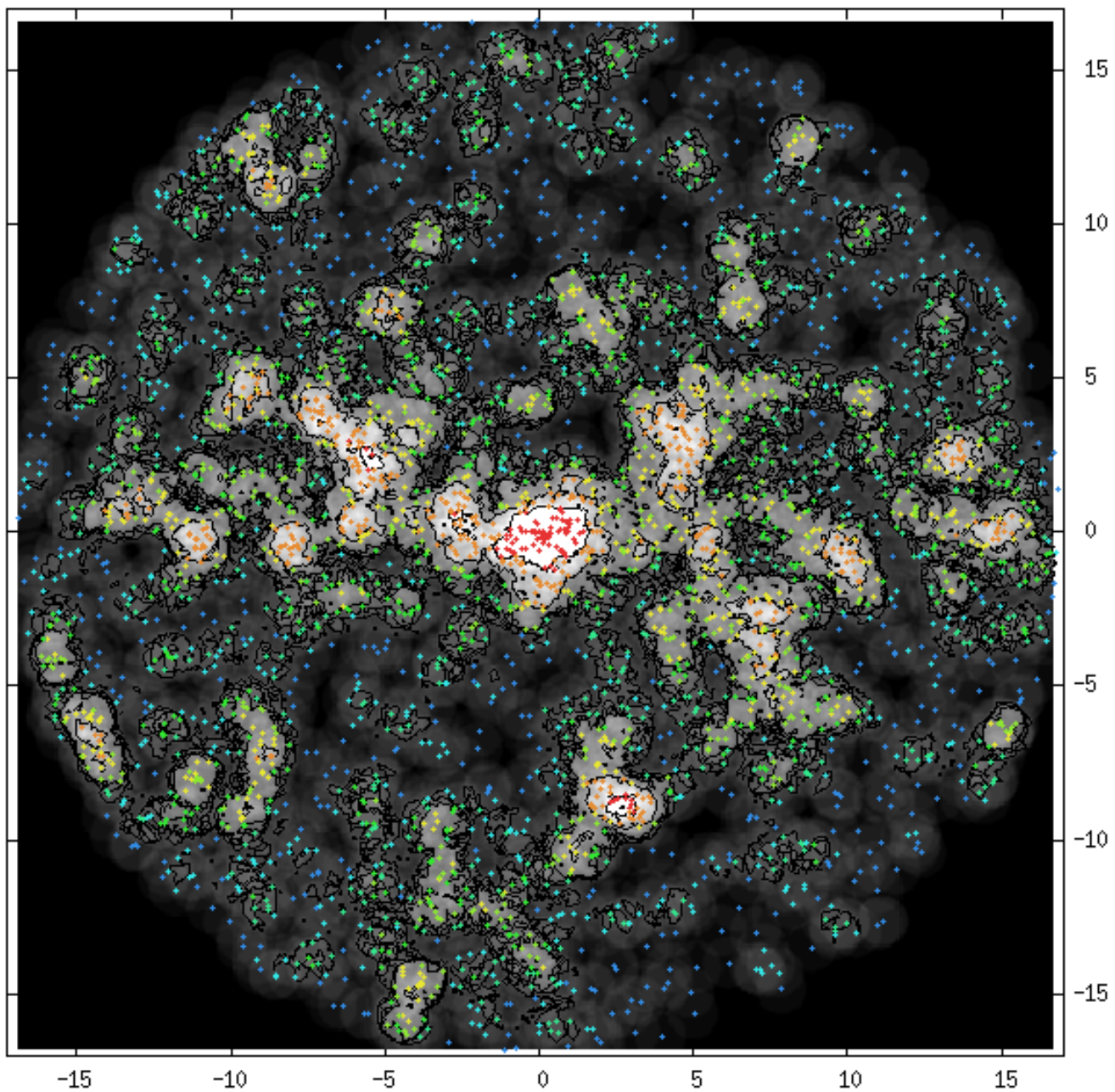
LAHs are ubiquitous, but their extent depend on environments

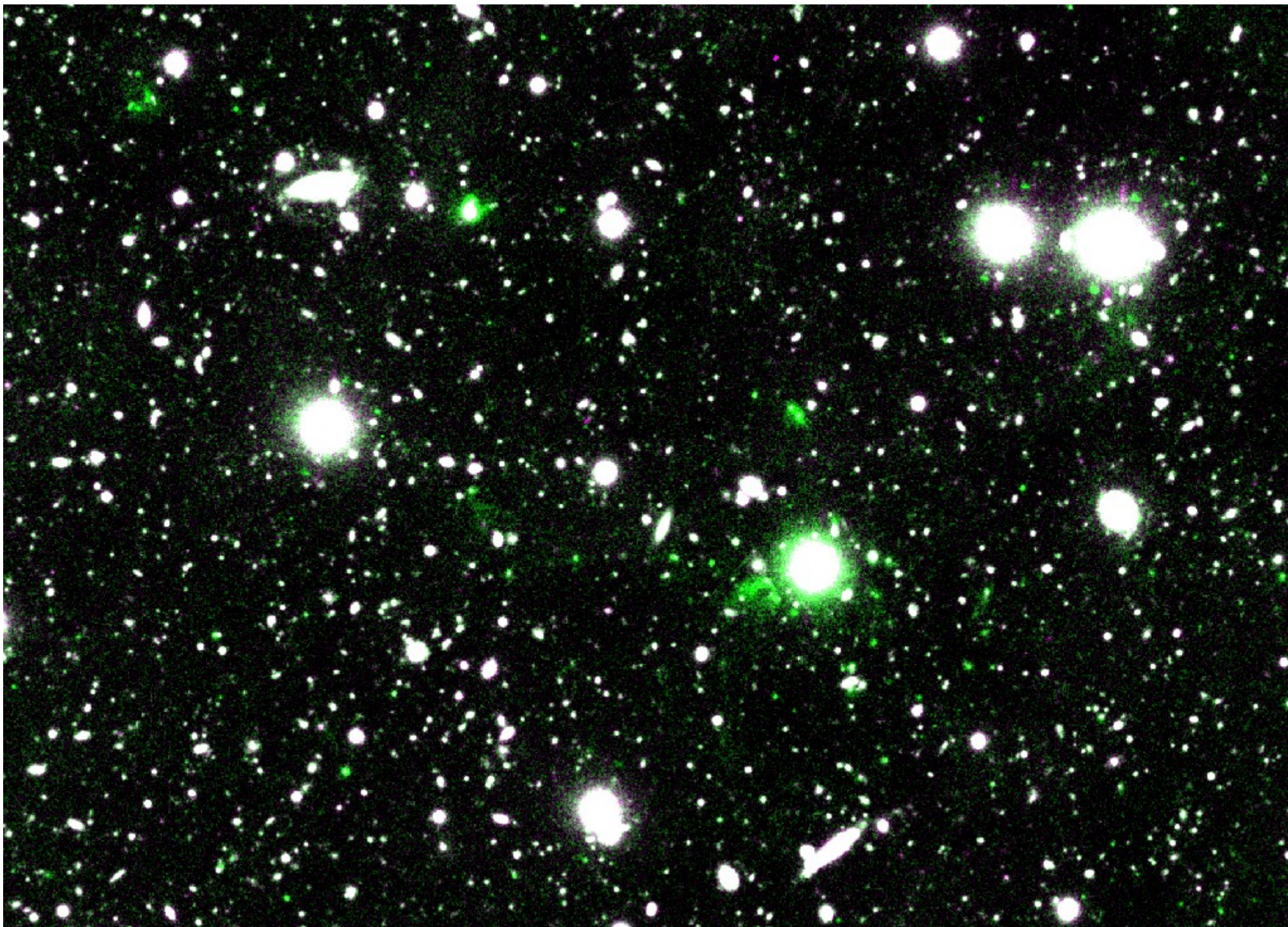


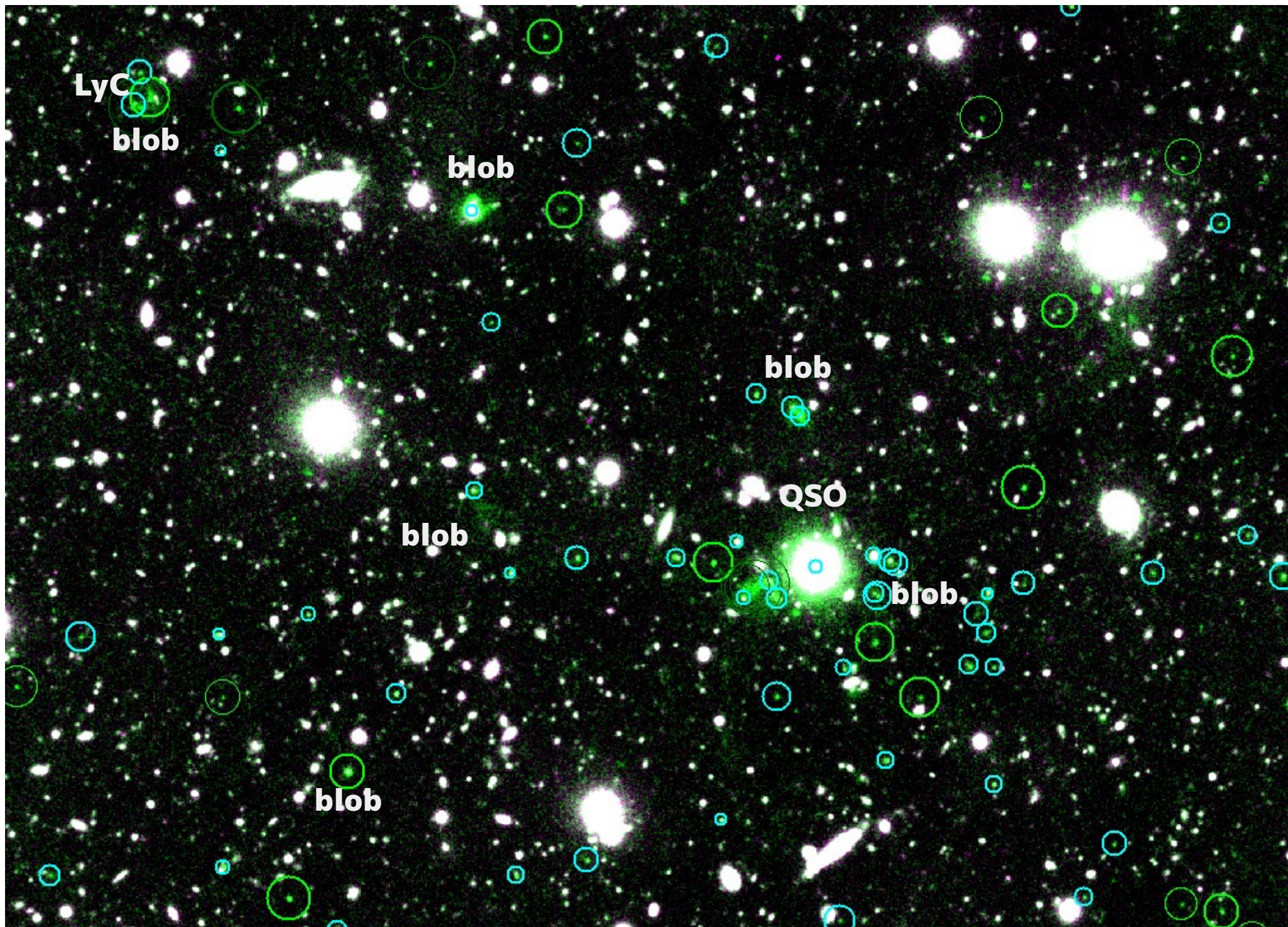
Steidel+11 SSA22, HS1549, HS1700



180328 Sakura CLAW







LyC

blob

blob

blob

QSO

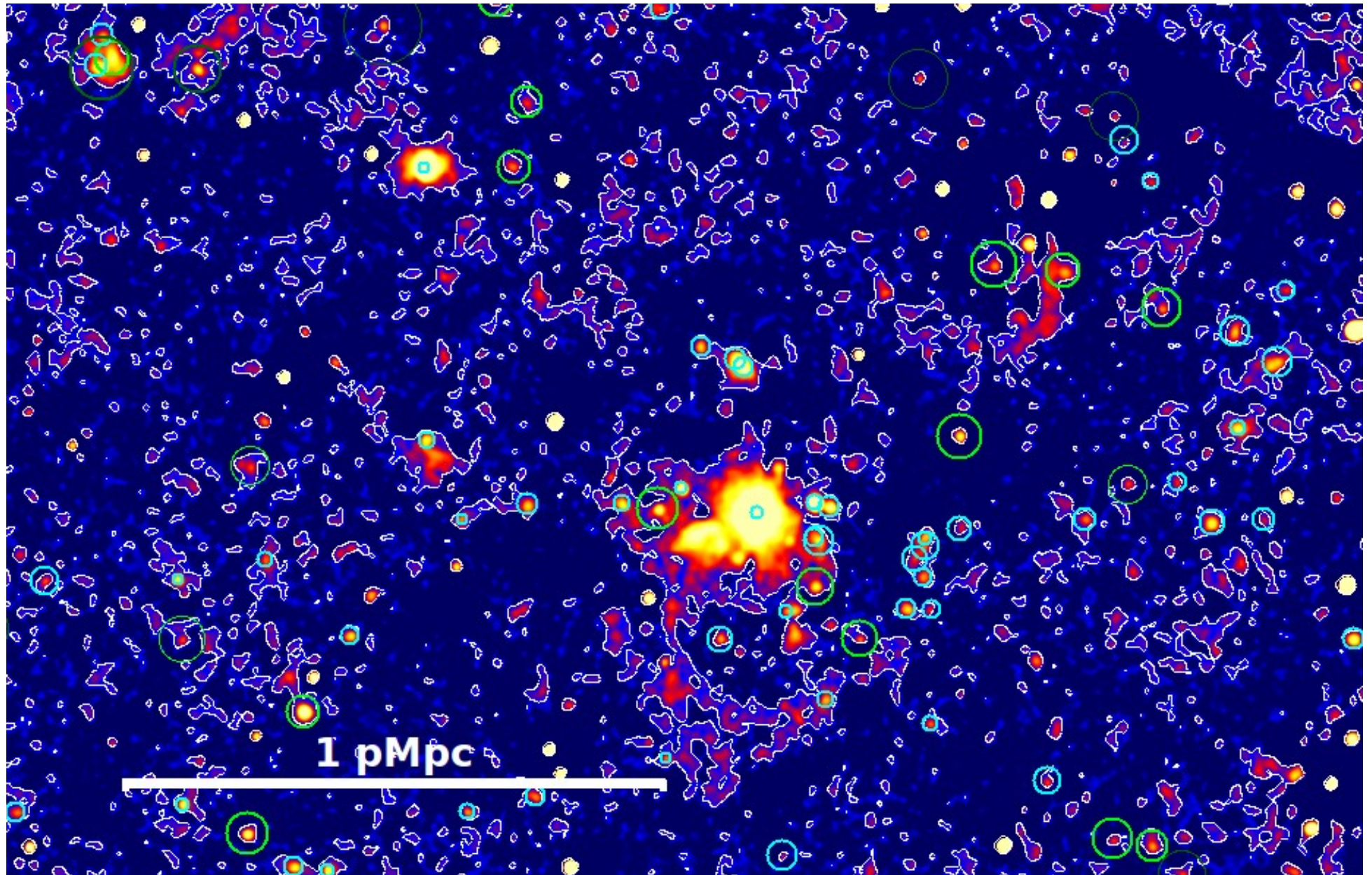
blob

blob

blob

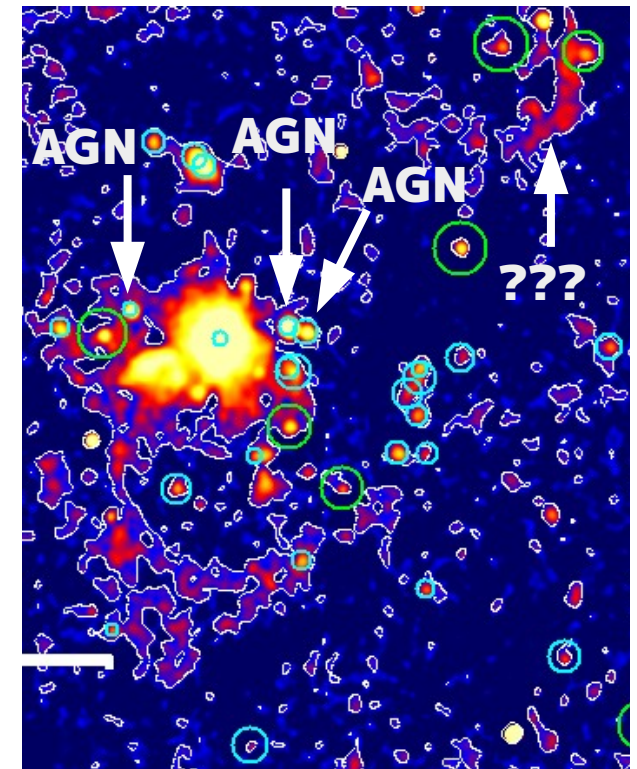
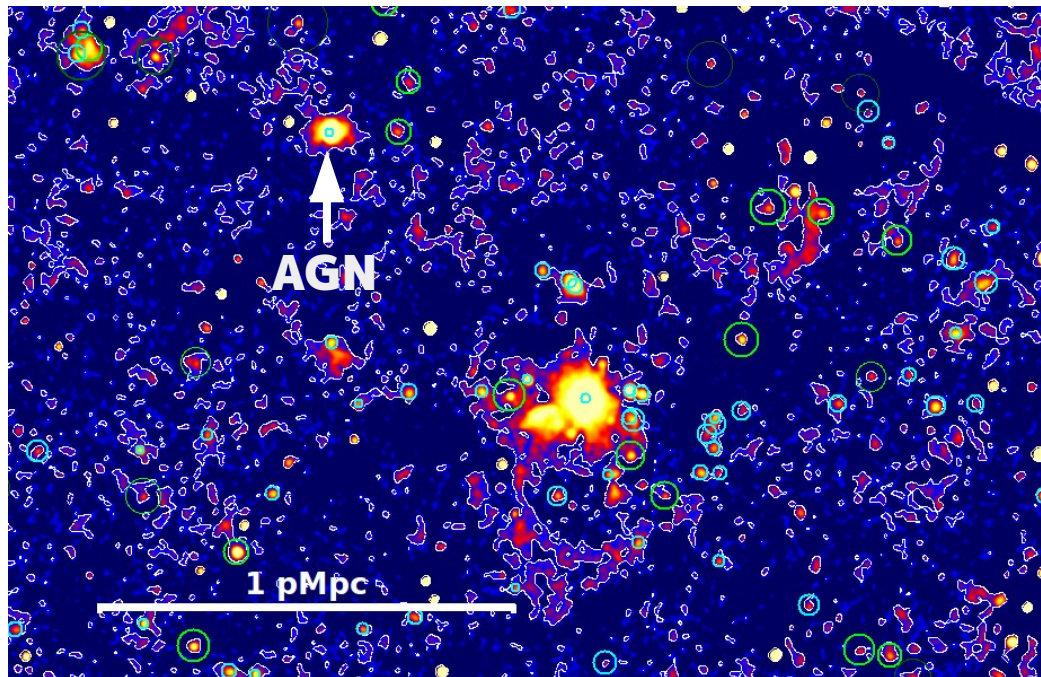
Smoothed Ly α Image

Contour level
 $5e-19$ erg/s/cm²/arcsec²



Gigantic Ly α nebula detected

- Mpc-scape association of Ly α
 - Multiple very bright LABs($\log L_{\text{Ly}\alpha} > 44$) & AGNs (Steidel+, in prep)
 - Tail-like structure toward south
 - Dark galaxy at the northwest of the QSO?
- Super-peculiar environment!



Future Plan

- Multiwavelength follow-up program
 - Keck/KCWI obs. to constrain kinematics of LAHs
 - JCMT/SCUBA2 obs. under way
 - Current data already revealed a cluster of bright SMGs
 - Planning ALMA follow-up to resolve SCUBA2 sources / blindly detect fainter dust obscured sources

Summary

- We have conducted deep NB imaging obs. of hyperluminous QSO HS1549+1919 at $z=2.84$ with Hyper Suprime-Cam(HSC).

- **Mapping out the Large Scale Structure**

We (will) study dependence of various physical properties on their environment

- EWs of LAEs around the QSO seem not to be boosted
- LAHs are clearly more extended in overdense regions

- **Lighting up the cosmic web**

We detect a hint of the cosmic web gas

- The best targets to investigate the “baryon cycle” within halo and galaxy with state-of-the-art IFSs, such as KCWI → accretion rate / outflow rate