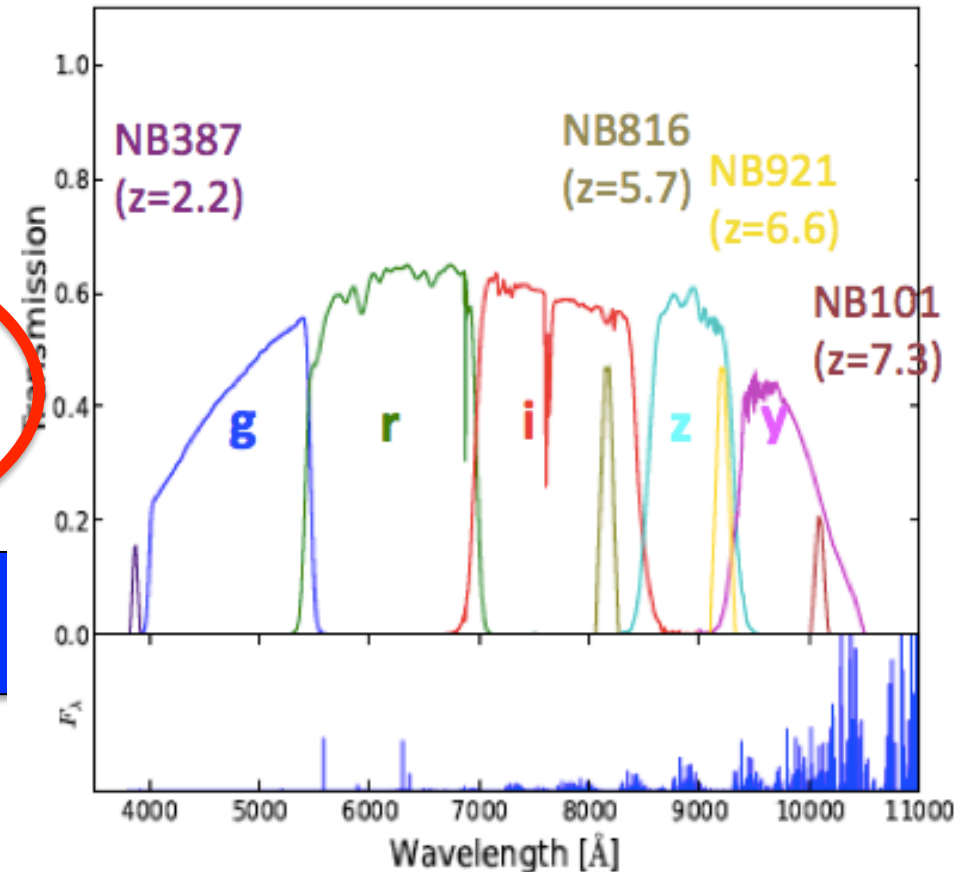
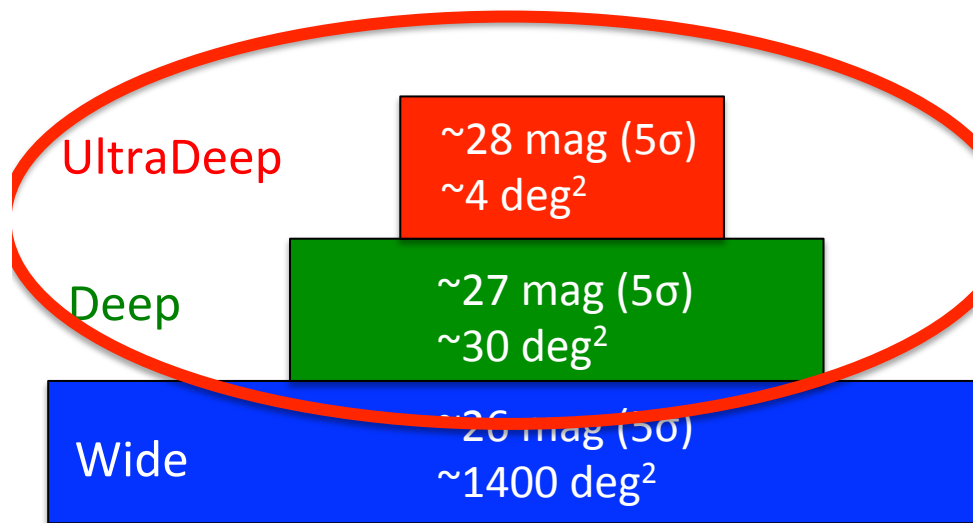


Early Results of the Subaru HSC Survey for Ly α Emitters

Masami Ouchi
(U. Tokyo, ICRR)

c) HSC Builder's blog

Subaru HSC Survey



- 300 night observations starting in 2014
 - 5 BBs and 4 NBs (LAEs at $z=2.2-7.3$)
 - 3 layers. Narrowband data for LAEs in UltraDeep and Deep layers
 - ~1/3 data are analyzed ($\geq 1/2$ are obtained). Completing in 2019.

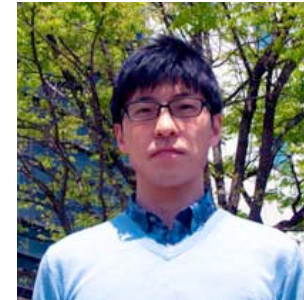
HSC High-z Galaxy Team



Yoshiaki Ono



Takatoshi Shibuya



Jun Toshikawa



Akira Konno



Yuichi Harikane



Haibin Zhang



Ryo Higuchi



Ryohei Itoh

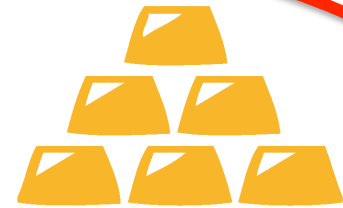
- HSC imaging: **Kazuhiro Shimasaku**, **Haruka Kusakabe**, Yoshiaki Taniguchi, Masakazu Kobayashi, Masaru Kjisawa, Tohru Nagao, Satoshi Kawanomoto, Akio Inoue, **Masayuki Umemura**, **Masao Mori**, **Kenji Hasegawa**, **Yuichi Matsuda**, **Shiro Mukae**, **Kimihiko Nakajima**, Shiang-Yu and many others
- Follow-up Spectroscopy: **Michael Rauch** (**Magellan**), Richard Ellis (**VLT**), Peter Capak, Andreas Faisst, Crystal Martin (**Keck**), Marcin Sawicki, Chris Willot (**Gemini**), and many

Twin High-z Galaxy Projects

1) Dropouts



GOLDRUSH

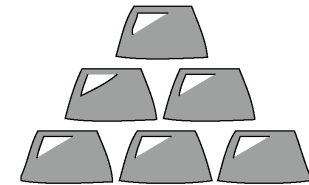


Great Optically Luminous Dropout Research Using Subaru HSC

2) LAEs



SILVERRUSH



Systematic Identification of LAEs for Visible Exploration and Reionization Research
Using Subaru HSC

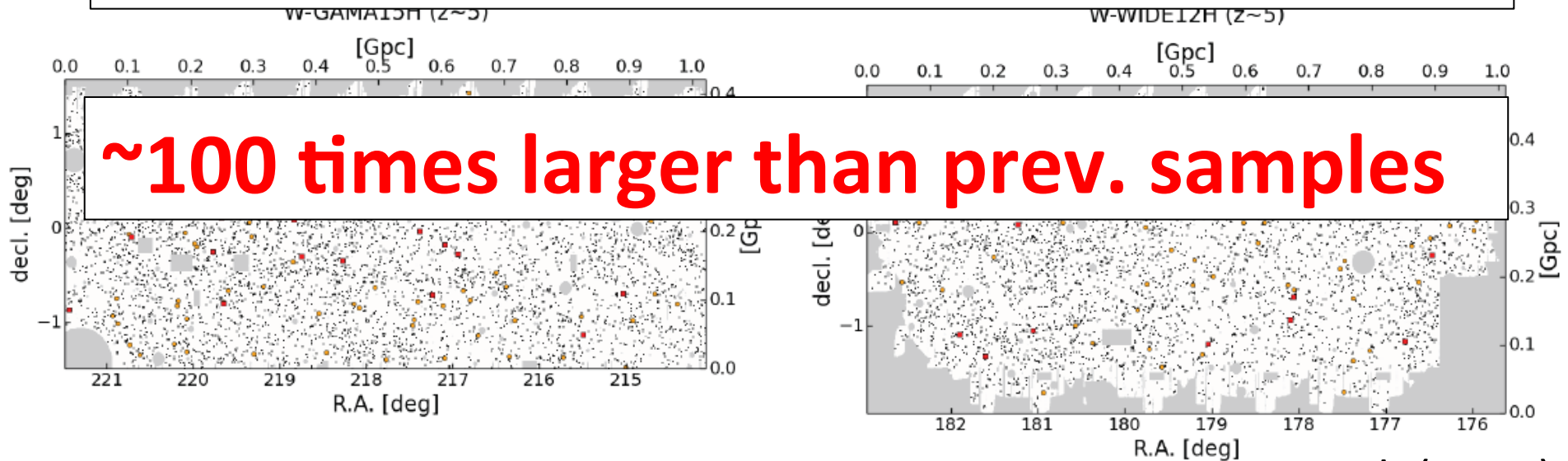
1) Dropouts



Examples



**579,555 galaxies at $z=4-7$ in 100 deg^2
 1.4 Gpc^3 (cosmology scale)**



Ono et al. (2017)

- See Ono/Harikane's talk

Twin High-z Galaxy Projects

1) Dropouts



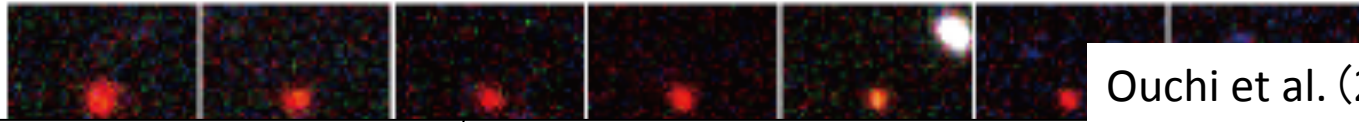
Great Optically Luminous Dropout Research Using Subaru HSC

2) LAEs

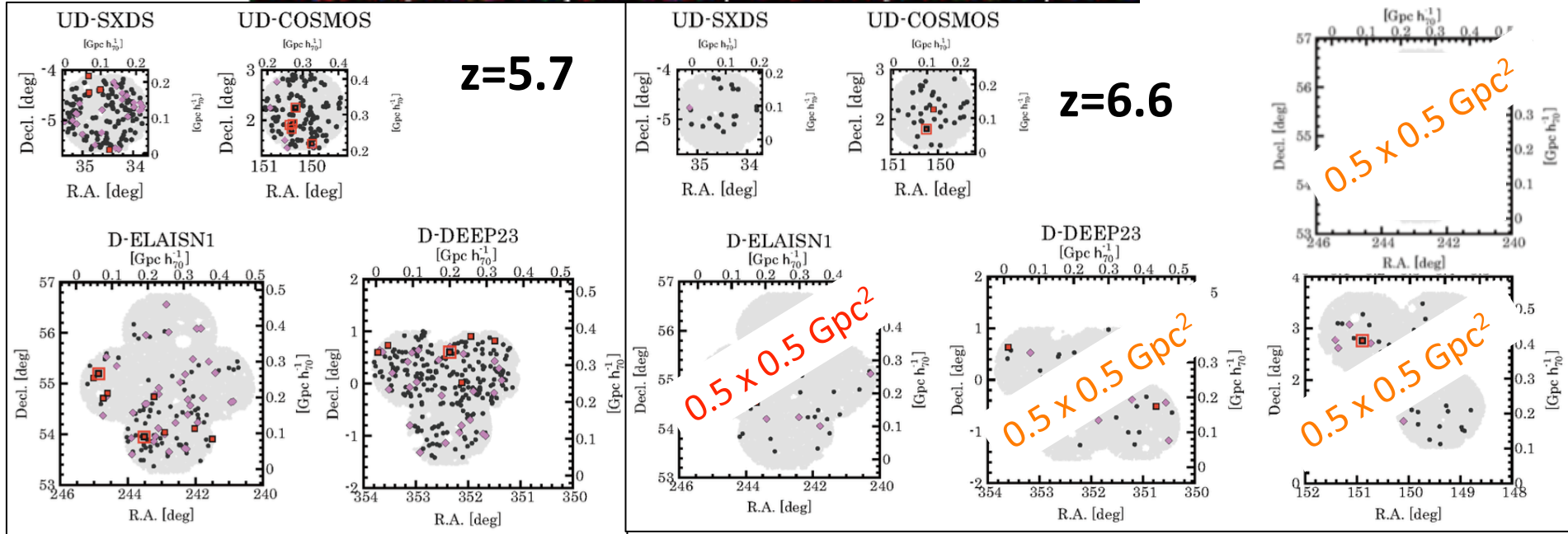


Systematic Identification of LAEs for Visible Exploration and Reionization Research
Using Subaru HSC

2) LAEs



Ouchi et al. (2017)



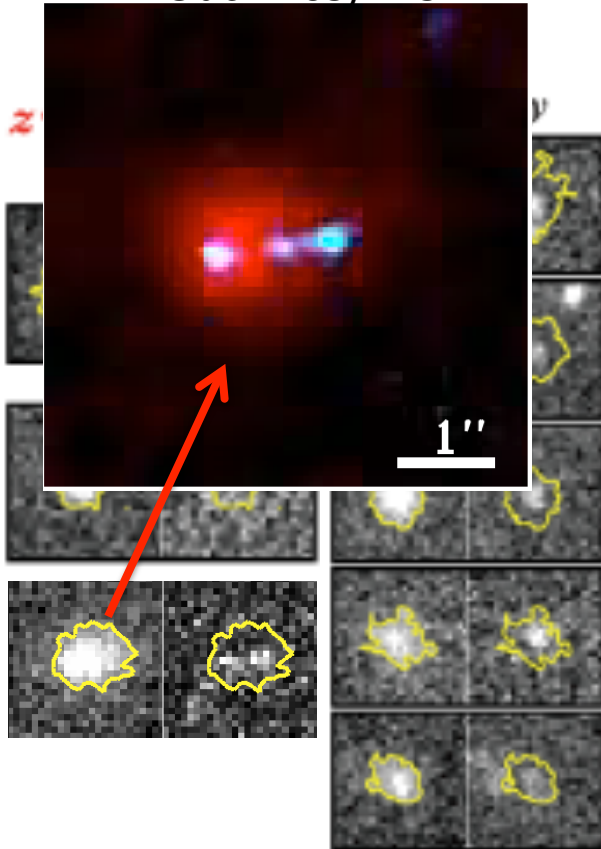
UD-SXDS	02:18:00	-05:00:00	6941	225	25.7	0.5	224
D-DEEP23	23:30:22	-00:44:38	15737	60	25.2	0.5	423
D-ELAISN1	16:10:00	+54:17:51	19998	60	25.3	0.5	232
Total	—	—	49763	—	—	—	1081

- 2,354 Ly α Emitters (LAEs) at $z \sim 6-7$ (i.e. EoR) over $\sim 20 \text{ deg}^2$
First cosmological-scale (1 Gpc^2) Ly α probe at the EoR !!

Shibuya et al. (2017a)

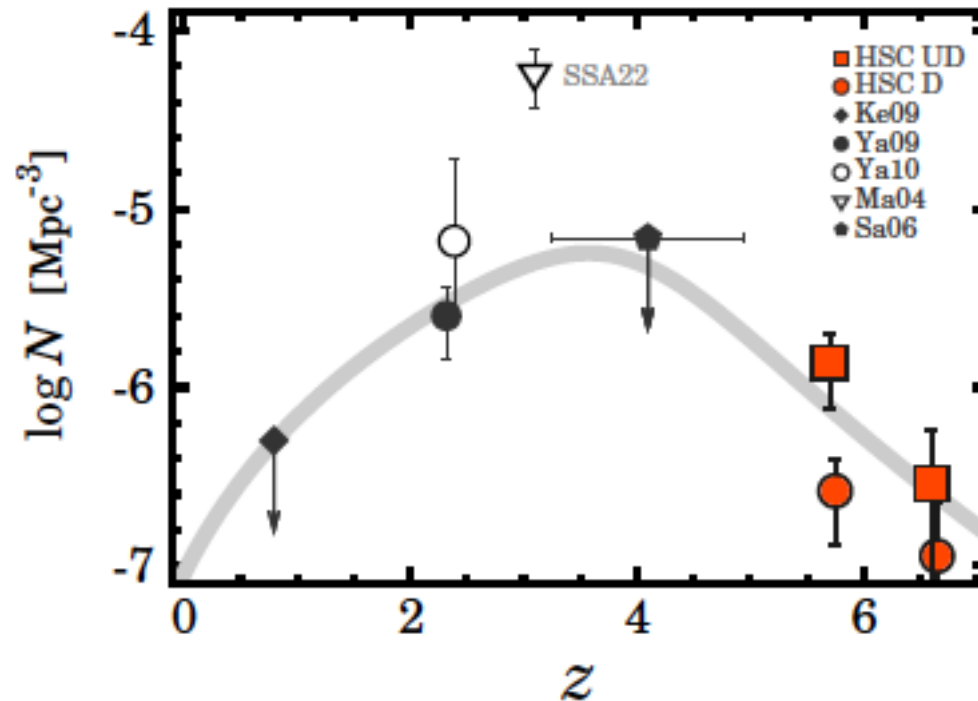
Extended Ly α Sources at z=6-7

Ouchi+09/+13



Spatially extended Ly α sources

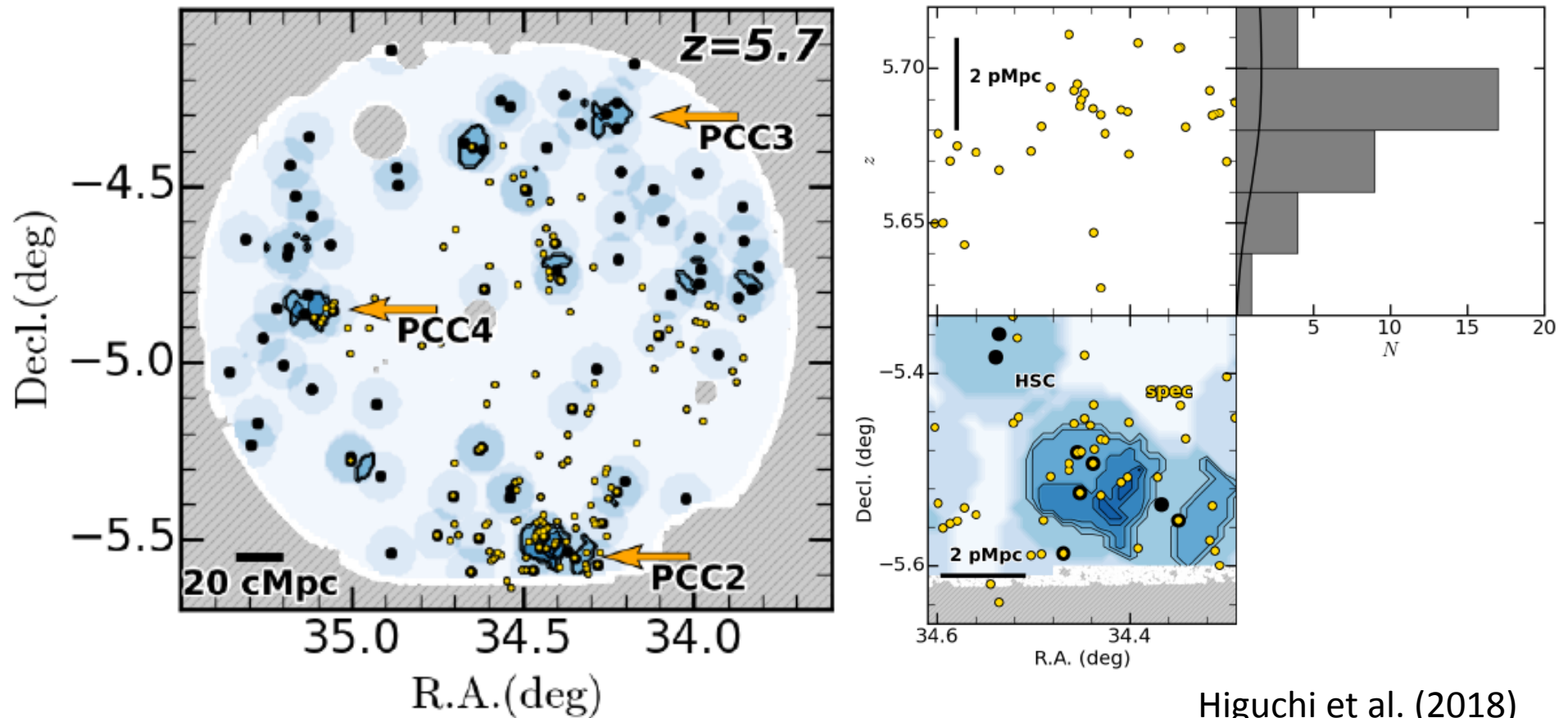
Extended Ly α



Shibuya et al. (2017a)

- Identifying **11** spatially extended Ly α sources (**6 spec. confirmed**).
- Number density of extended Ly α sources increases at $z \sim 0-2$, peaks at $z \sim 2-4$, and decreases at $z \sim 4-6$, similar to Madau-Lilly plot?, although the selection (SB and size) is not homogeneous.
- Very rare sources (0.5/deg²). JWST spec. targets.

Proto-Cluster Candidates at $z \sim 6-7$



Higuchi et al. (2018)

- Identifying 14 and 28 overdensities ($\geq 5\sigma$) at $z=5.7$ and 6.6
 - Example: Overdensity: $\delta=13.3$ (7.2σ)
- Numerical simulation of LAE model: 50-60% of these overdensities will evolve into galaxy clusters w a total mass of 10^{14} Mo today (Higuchi et al. 2018)

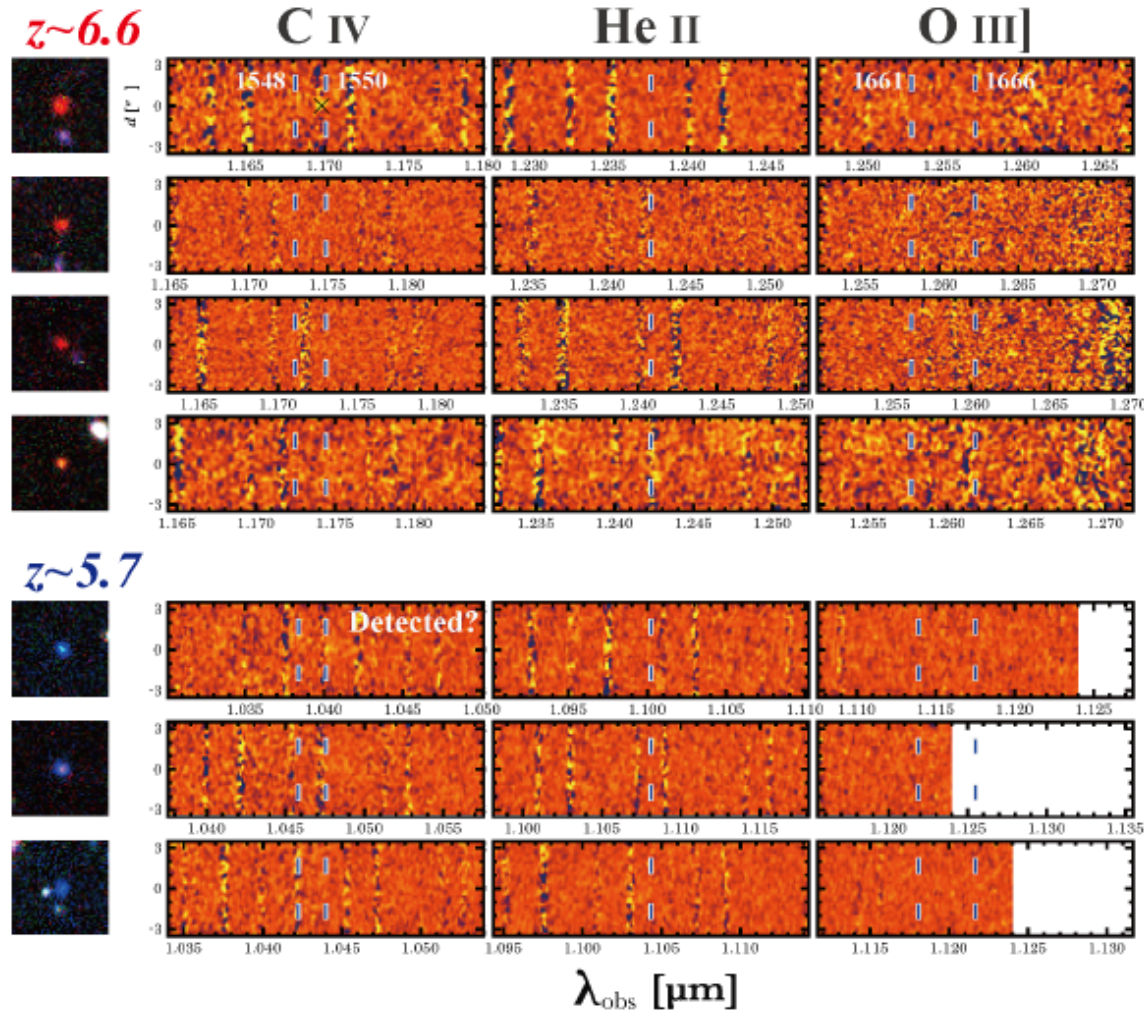
Confirmed Proto-Cluster at $z=6.57$

This plot is not open for public. Sorry.

- HSC-z7PCC9 made of ≥ 9 LAEs at $z=6.57$
 - $\delta=7$ (5σ)
 - Himiko is included, but located near the edge.
 - Merging proto-clusters?

Ono et al. in prep.

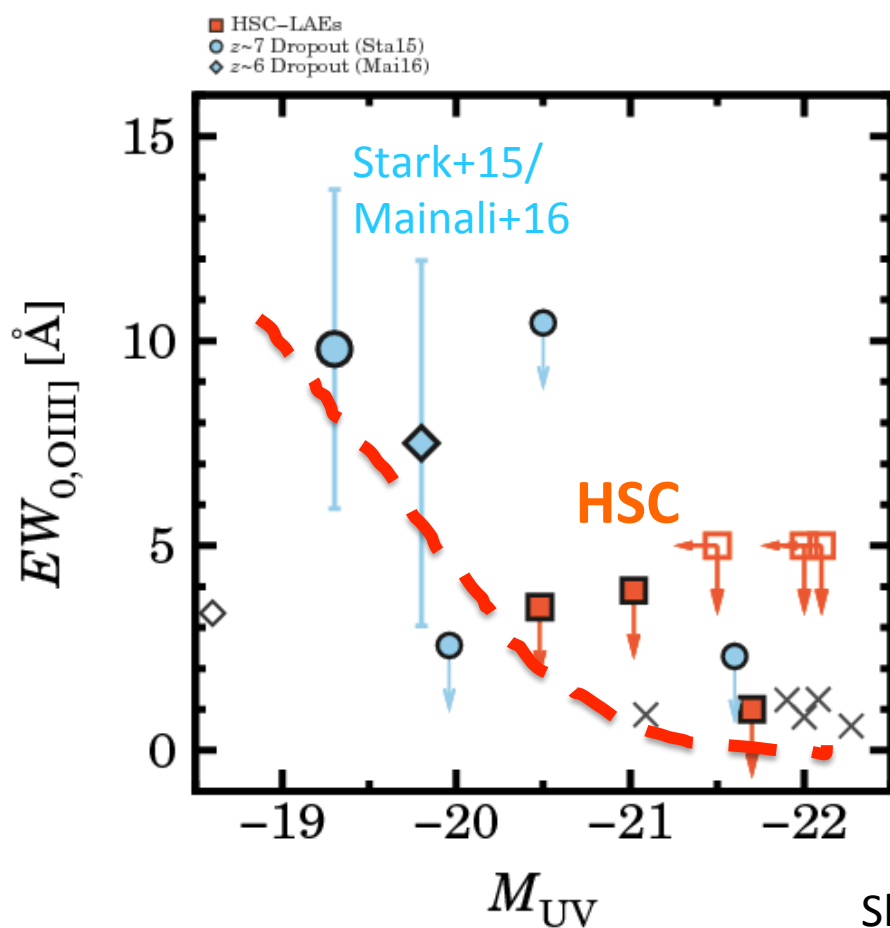
MOSFIRE and MOIRECS Spectroscopy



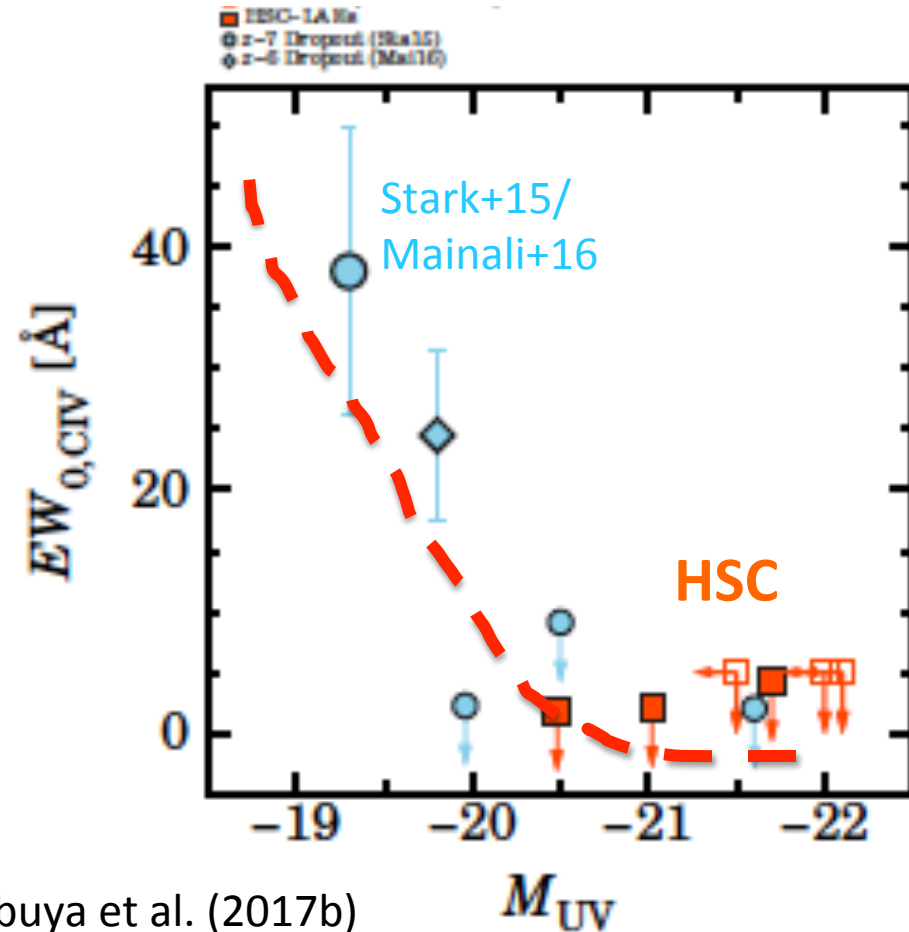
Shibuya et al. (2017b)

- NIR spectroscopy: Data **depth comparable with those of Stark et al. 2015/17**
 → No signature of strong nebular lines...
- Many nebular line detections of Stark et al.'s galaxies at $z \sim 6-7$. Puzzling??

EW(neb) depending on M_{UV}

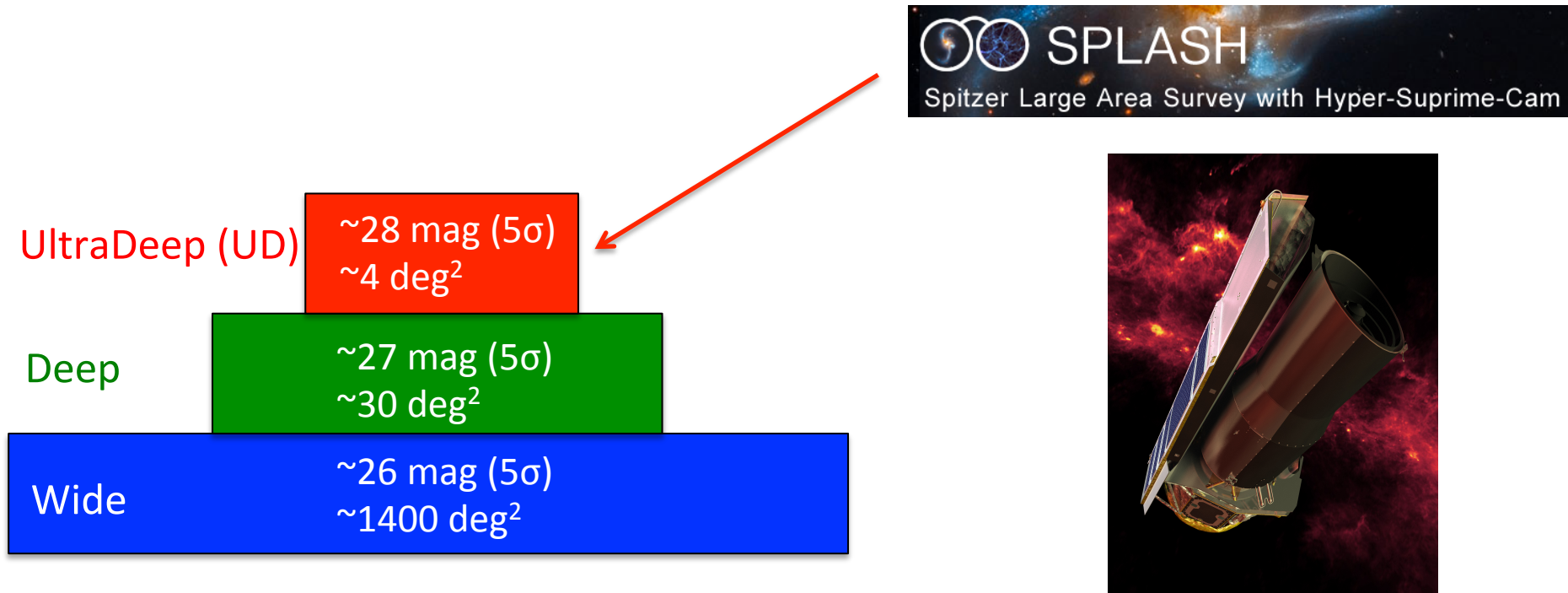


Shibuya et al. (2017b)



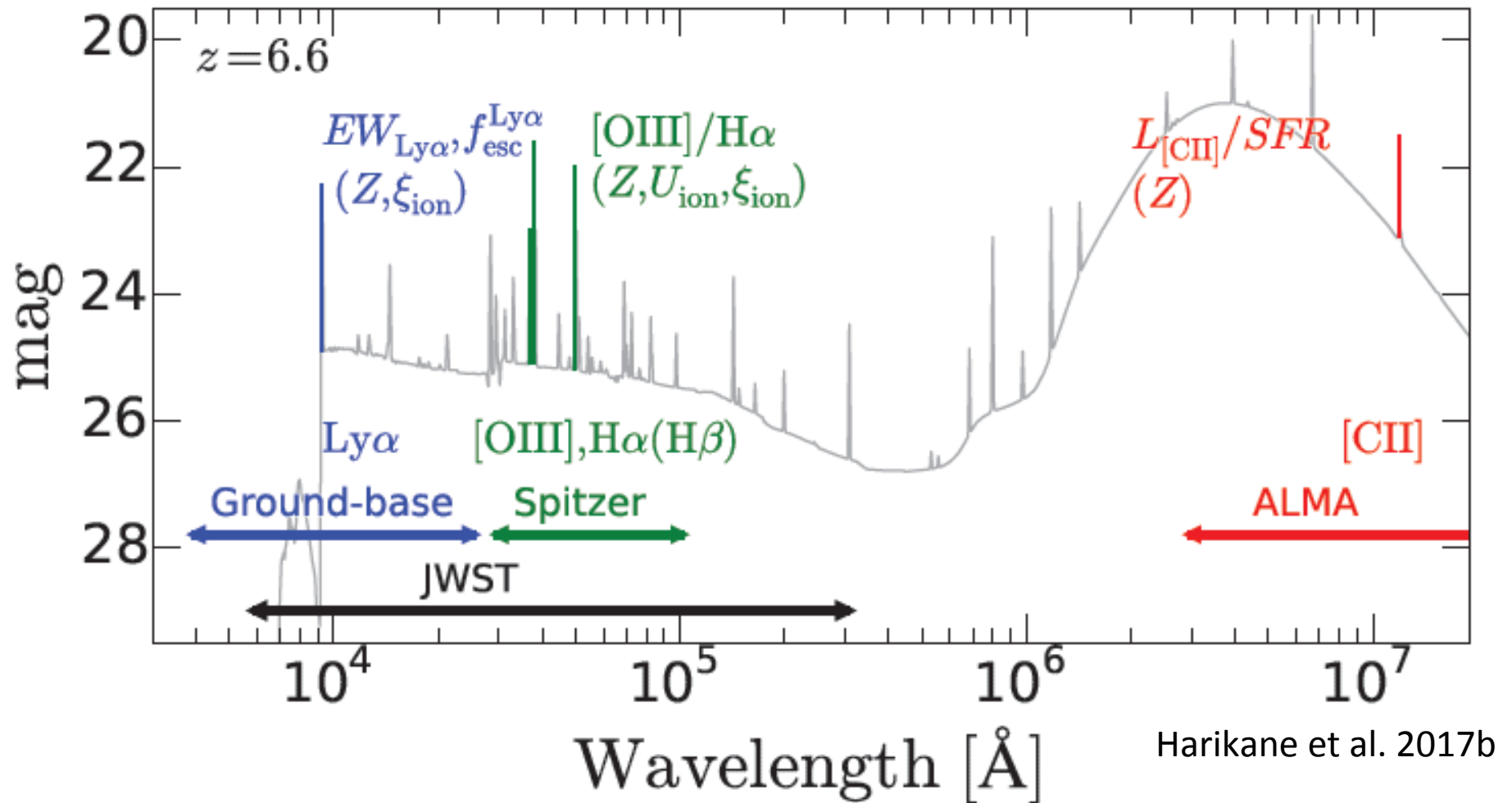
- HSC LAEs have M_{UV} **brighter** than Stark's galaxies.
- EW(neb) vs. M_{UV} → Possible trend: Bright M_{UV} galaxies have a weak nebular emission. Similar to those of $z \sim 2$.
- Maybe the dependence of metallicity? (via mass-metallicity relation)

Deep Spitzer/IRAC Imaging in UD



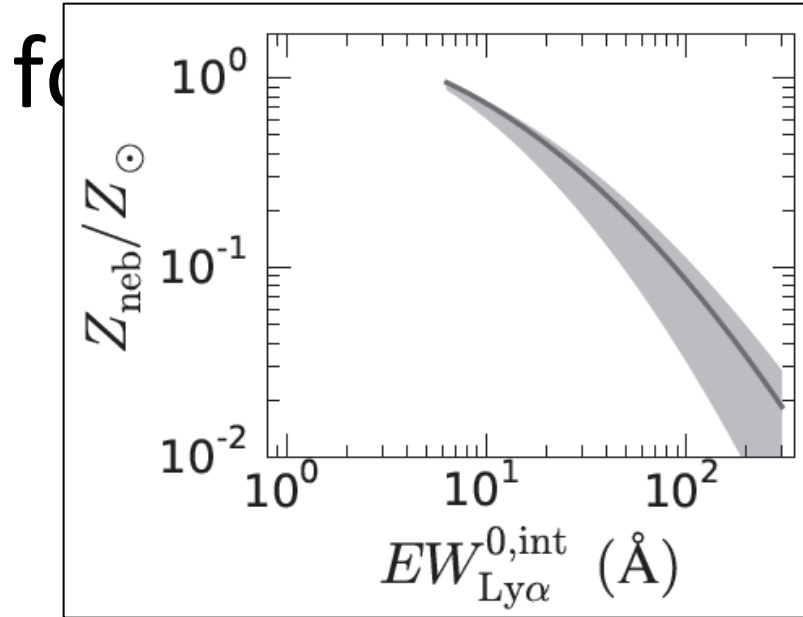
- Spitzer Large Area Survey with Hyper-Suprime-Cam (SPLASH; PI: P. Capak)
- Covering UD areas of HSC survey.

Studying Galaxies w Major Emission Lines

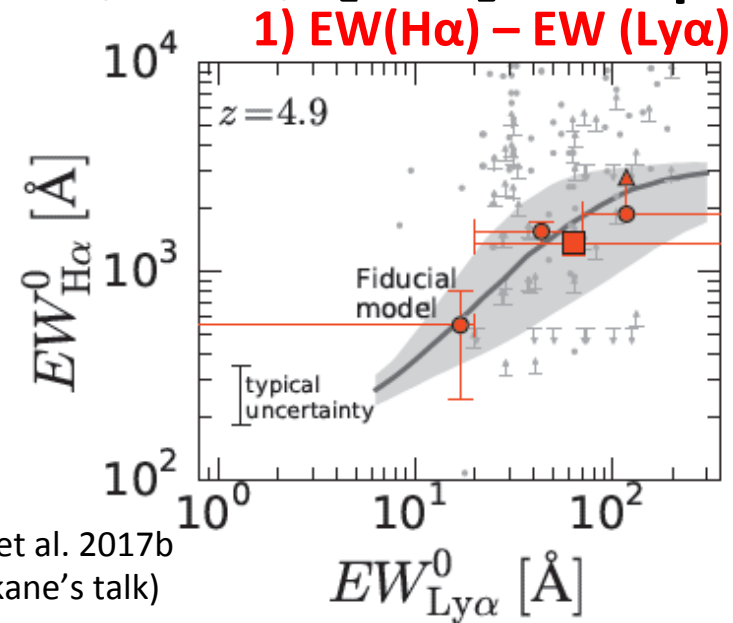


- HSC survey + Spitzer SPLASH + ALMA obs
- Major emission lines → **states of inter-stellar medium** (metal, ion. param etc)

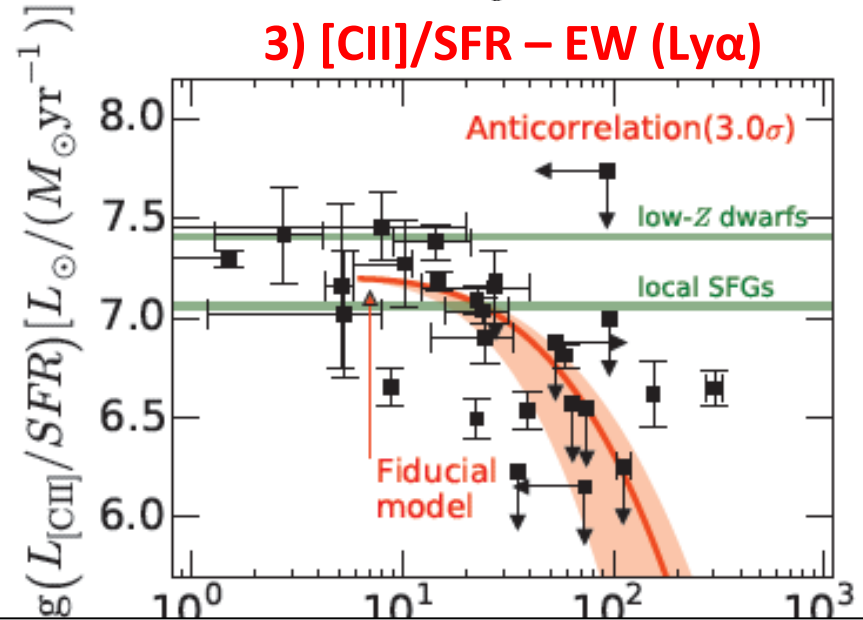
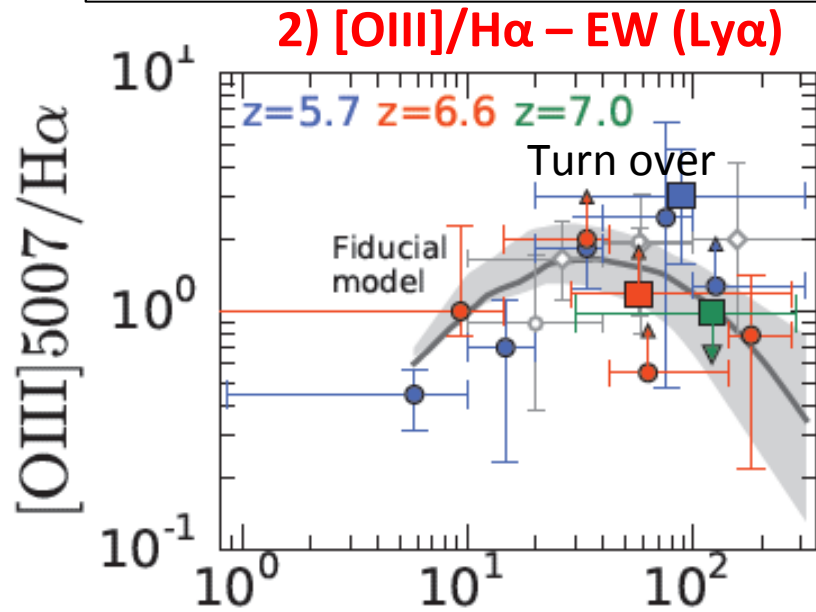
Census of Ly α , [OIII]5007, H α , [CII]158 μ m



.0

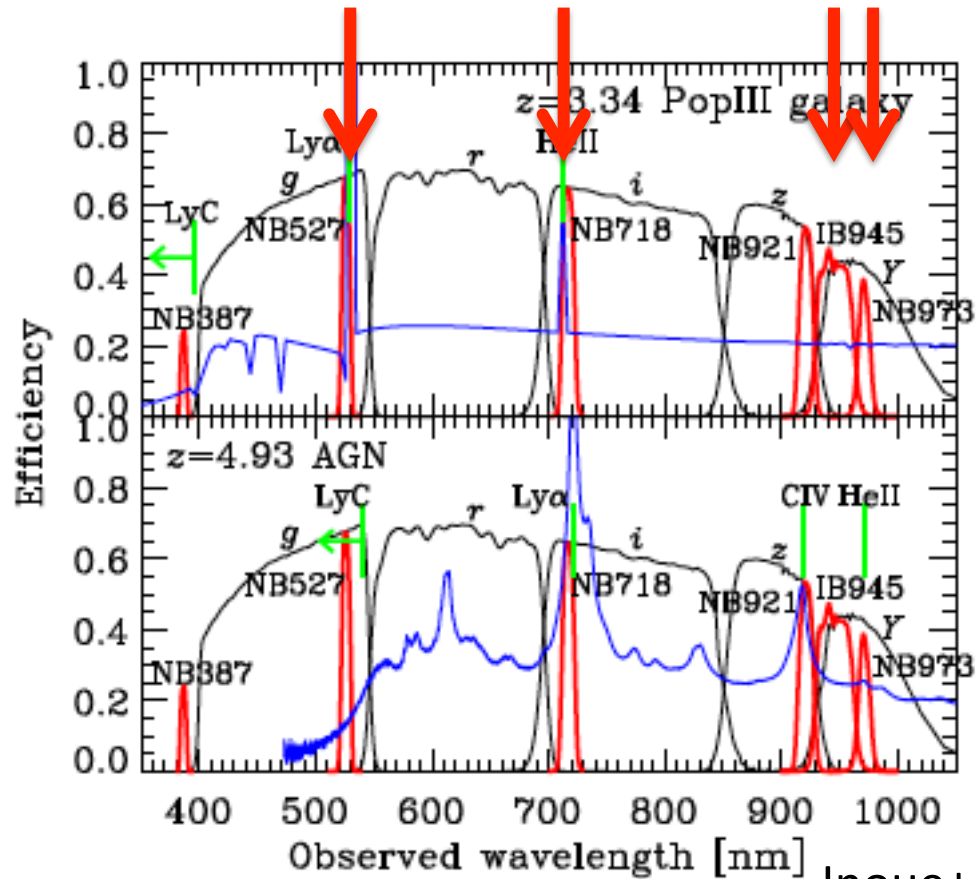


Harikane et al. 2017b
(see Harikane's talk)



- Covering the vast parameter space of $\log U_{\text{ion}} = -3$ to -1 , stellar age 10^6 – 10^9 yr (Beagle model)
- $EW(\text{Ly}\alpha) - Z$ anti-correlation \rightarrow Explaining all of the Ly α , [OIII], H α , [CII] correlations

Further HSC NB Survey (CHORUS)



Inoue+

Itoh+18

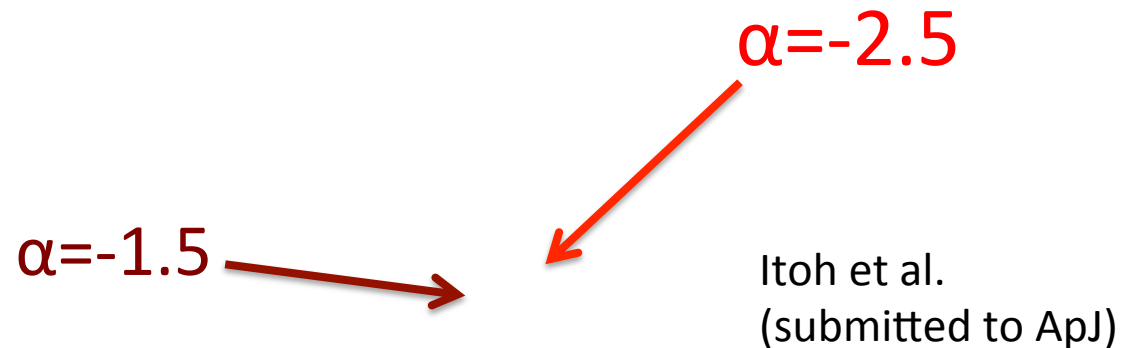
COSMOS 1.6deg²

SXDS/UDS 1.5deg²

- Cosmic HydrOgen Reionization Unveiled with Subaru (CHORUS) Survey (PI. Inoue)
- 4 NB (NB527, NB718, IB945, and NB973) imaging missing in the HSC survey
- Ultra deep imaging (~10-20 hour exp.) → NB973 data results

$z=7.0$ Ly α Emitters & Luminosity Function

This plots are not open for public. Sorry.



- 32 candidates of LAEs at $z=7.0$
- Consistent with LFs of
DECAM (Zhenya+17) at the bright-end and Suprime-Cam (Ota+17) at the faint-end
- Smooth luminosity function. Steep slope of $\alpha=-2.5$. (See Itoh's talk)

Summary

- Early HSC survey results
 - GOLDRUSH: Dropouts (579,555 dropouts at $z=4-7$ in 100 deg^2)
 - See Ono/Harikane's talk
 - SILVERRUSH: (2,354 LAEs at $z=6-7$ in $\sim 20 \text{ deg}^2$)
 - 11 spatially extended Ly α sources. Madau-Lilly-plot like evolution??
 - 42 **proto-cluster candidates at $z\sim 6-7$** , one at $z=6.57$
 - Weak nebular lines in bright LAEs → **Muv-EW(neb) relation**
 - **Major emission lines (HSC/Spitzer data+ALMA data)** → **Turn-over** of [OIII]/Ha as a function of EW(Ly α). Sequence controlled by metal?
 - New CHORUS LAEs at $z=7.0$ in 3 deg^2
 - **Smooth** luminosity function. **Steep slope of $\alpha=-2.5$.**

See Ono, Harikane, Zhang, Higuchi, and Itoh's talks/posters.