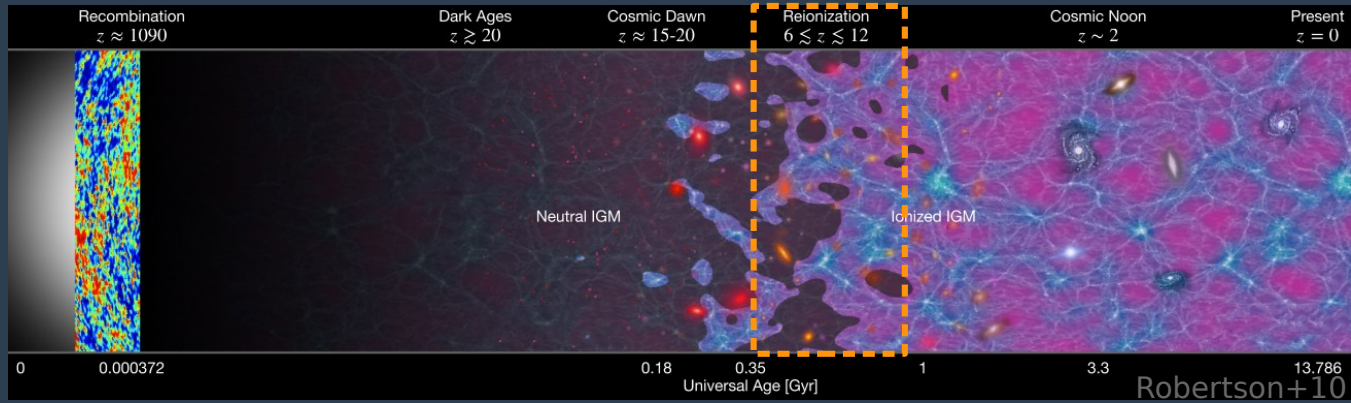
Science Cases for PFS-SSP survey: Probing the End of Reionization with High-z Lyα Emitters

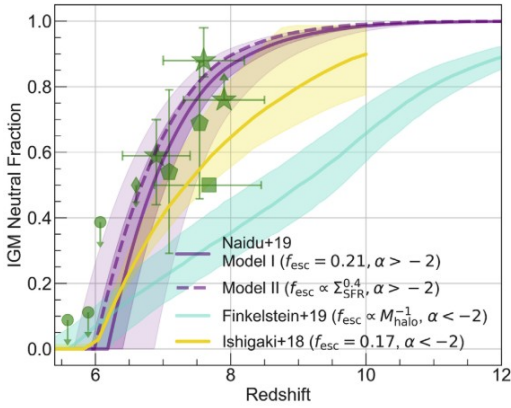
Satoshi Kikuta (NAOJ) et al.



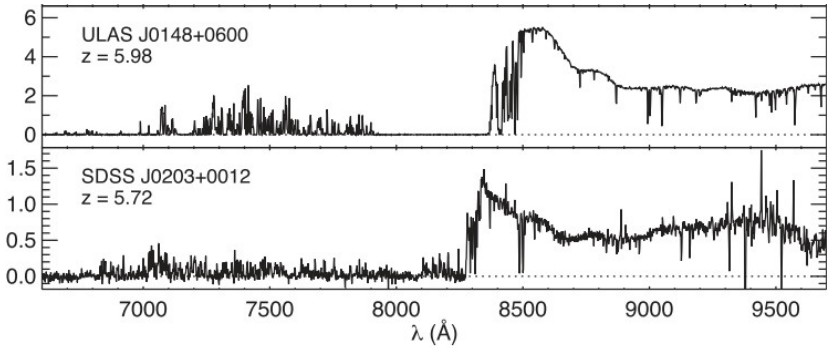
Galaxy-IGM workshop 2022 @ Kushiro

Missing Piece of the Reionization Puzzle: Source, History, and Topology

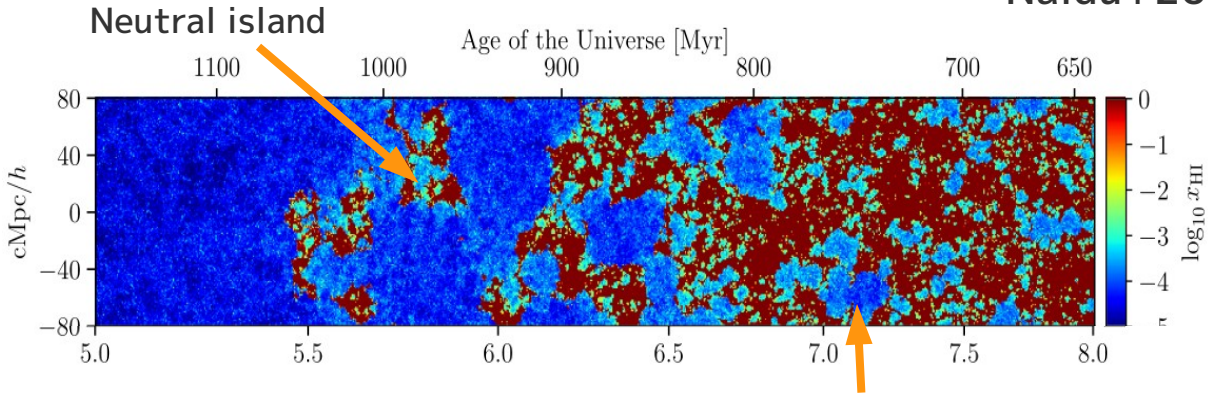
- **What** drives reionization?
  - Low-mass star forming galaxies? Faint AGNs? Or others?
- **When** and **how** it ended?
  - Starts early and prolonged? Late and abrupt?
  - Large neutral "islands" still exist at z~5.5 – "patchy" reionization?
- **LAEs at z=5-7 are still useful!**



Naidu+20

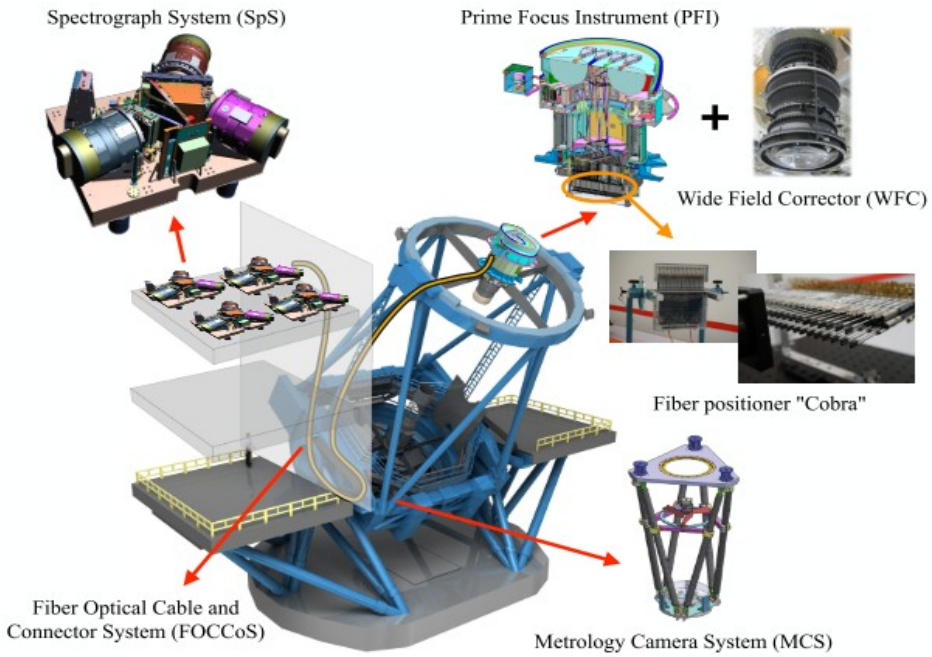


QSO GP trough observation: Becker+15



Theory: Kulkarni+19

PFS (Prime Focus Spectrograph) & PFS-SSP (Subaru Strategic Program) overview



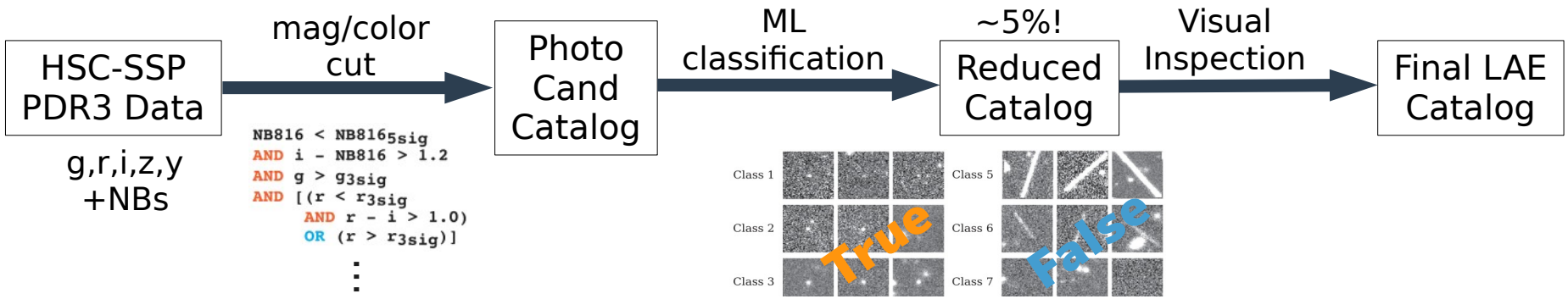
- A very wide-field fiber spectrograph (**380nm -1260 nm**, R=2300 - 4300)
- **~2400 reconfigurable fibers** in the **1.3 deg² FoV**
- **PFS-SSP**: **A 360 night survey** is planned
- Observations will start in **Feb 2024** (as of Mar 2022)
- LAEs are observed as part of the PFS Galaxy Evolution program

Planned galaxy sample and depth

Type	Redshift range	Selection	Exp. Time (hrs)	Expected # of spectra ($\times 10^3$)
Continuum	0.7 – 2	$y, J < 22.8$	2, 12	261,14
IGM	2.1 – 3.5	$y < 24.3, g < 24.7$	6, 12	30.3, 14
LBG	3.5 – 7	$y < 24.5$	6	22
LAE	2.2, 5,7, 6.6	$L_{Ly\alpha} > 3\times10^{42}$ erg s^{-1}	3, 6, 12	7.4, 4.5, 2.8
AGN	0.5 – 6.0	various (see text)	1 – 5	4.2

Detailed instrumental parameters available **here**: https://pfs.ipmu.jp/research/parameters.html

Data & LAE Selection Strategy (Update Version of Ono+21)



- LAEs are selected from **HSC-SSP PDR3** (Aihara+22)
  - Typical 5σ depth in UD: 26.3 (NB816), 26.2 (NB921)
  - NB selection (Shibuya+18) → Eliminate artifacts with **machine-learning** and human eyes (Ono+21, PDR2 / S18A)
- Using all available NB data (incl. CHORUS NBs), LAEs at z=2.2, 3.3, 4.9, **5.7**, **6.6**, 7.0, 7.3 can be obtained

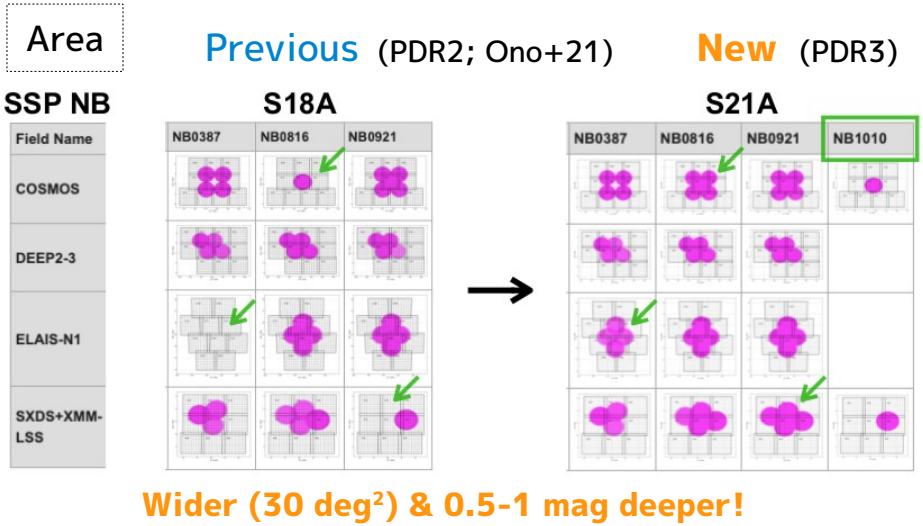
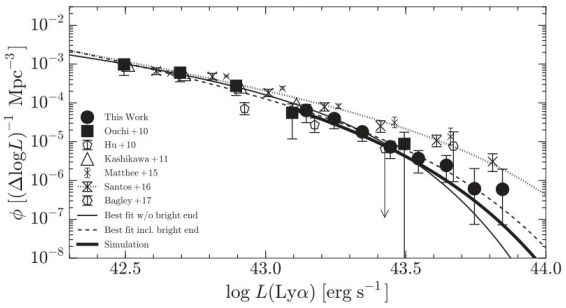


Figure courtesy of Shibuya-san

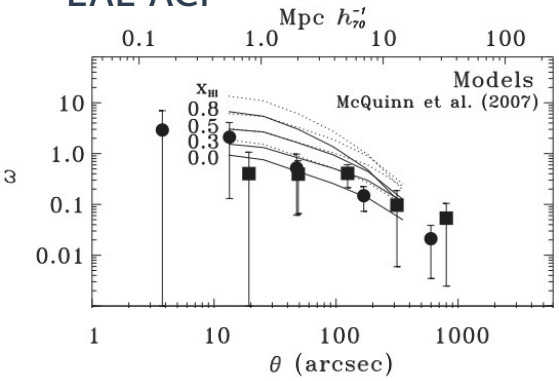
Science Cases for PFS-SSP: Statistics of z>6 LAEs with spec-z

- Largest spectroscopic sample at EoR will be obtained
  - Update **Lyα Luminosity Function, Auto Correlation Function, Lyα EW Distribution Function** of LAEs at z>5.7 **with spec-z** (led by Umeda-san)
  - Constrain $\mathbf{X_{HI}}$ with smaller uncertainty → **History**
- Synergy with 21cm emission observations with MWA, SKA (Kubota+18) ⋯ see session 6
  - Cross-correlation with 21cm line and LAEs → Detection of ionized bubble (**Topology**)

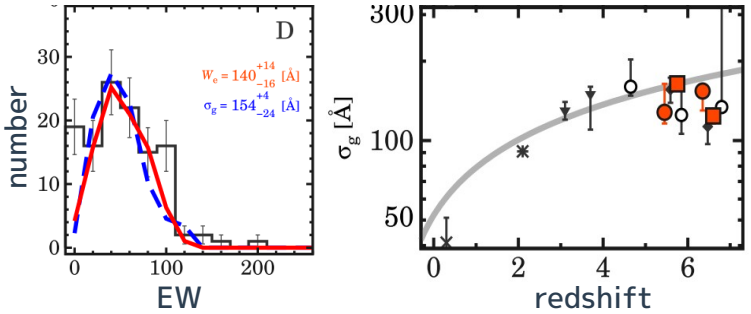
LAE LF



LAE ACF



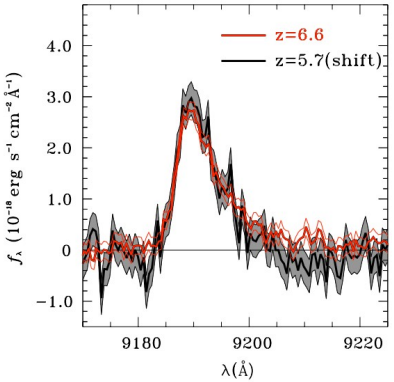
Lyα EW distribution



Ouchi+18, Konno+18, Shibuya+18 (Results from SILVERRUSH, based on HSC-SSP PDR1)

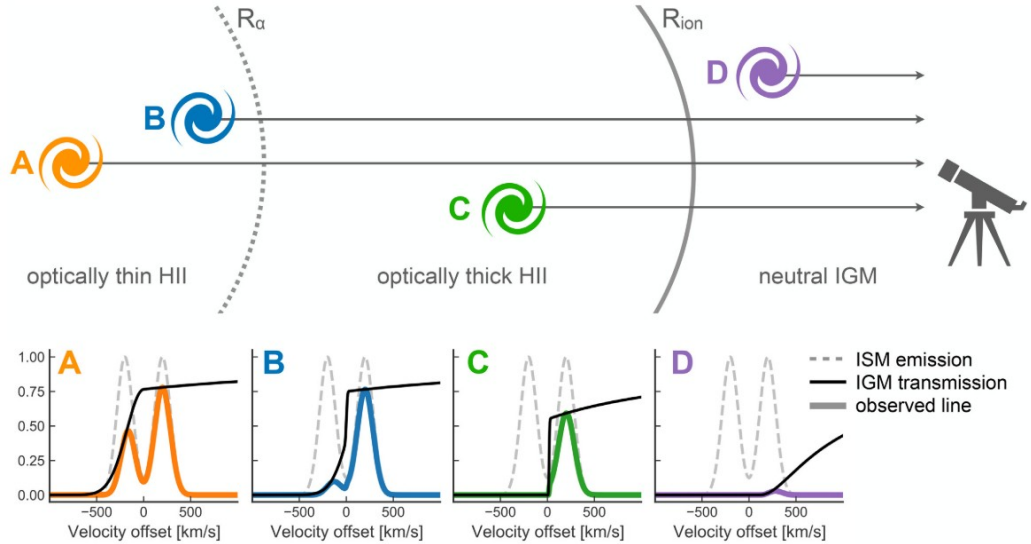
Variation of Lyα Line Profile: History and Topology

- IGM absorption affects typical Lyα line shapes **as a function of x_{HI}**
- Probe dependence on various properties
  - **Luminosity**: constraint on **Source** (and LAE's intrinsic property)
  - **Redshift**: **more direct** constraint on **History**
  - **Environment**: constraint on **Topology**
    - Bright neighbor / overdensity may assist Lyα to escape via ionized bubble

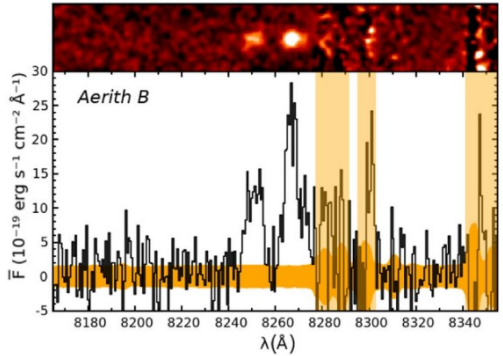


Ouchi+10

No evolution found



Mason+20

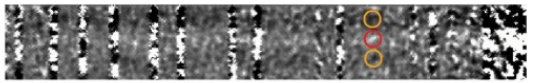


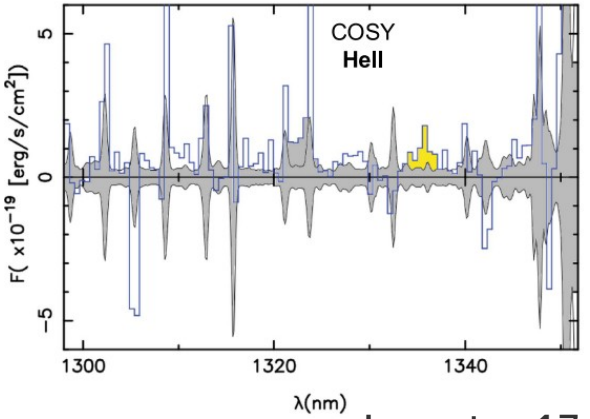
LAE at z=5.8 in a proximity of a QSO (Bosman+20)

Search for Non-Thermal Sources (Faint AGNs, etc.)

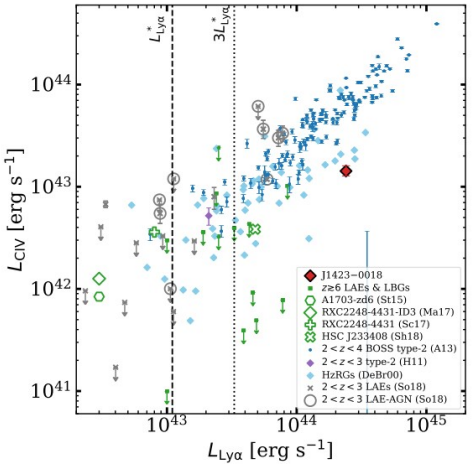
- PFS can also observe UV metal emission lines such as **NV, CIV, HeII** (and **CIII]** for z=5.7) – sign of AGNs
- AGN fraction in LAEs affects the **Source** and **Topology** (outside-in; Miralda-Escude+20)
  - ~300 LAE $L_{Lya} > 10^{43}$ erg/s at z=5.7, 6.6 will be observed
    - CIV is simultaneously detectable ($L_{CIV} > 10^{42}$ erg/s, if AGN)
  - Co-evolution history can be constrained from comparison with z=2-3

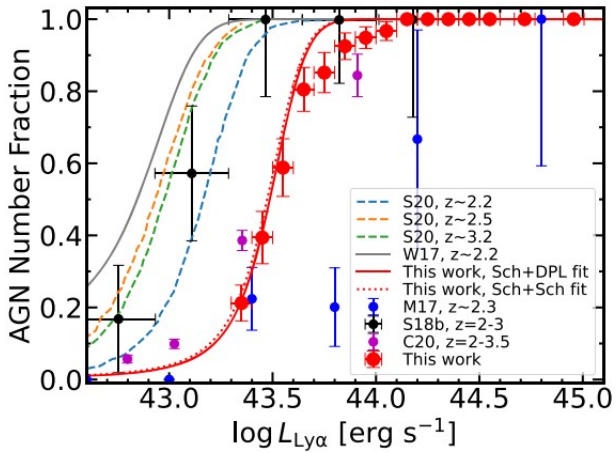
Detection of NV and HeII from z=7.15 LAE "COSY"





Laporte+17



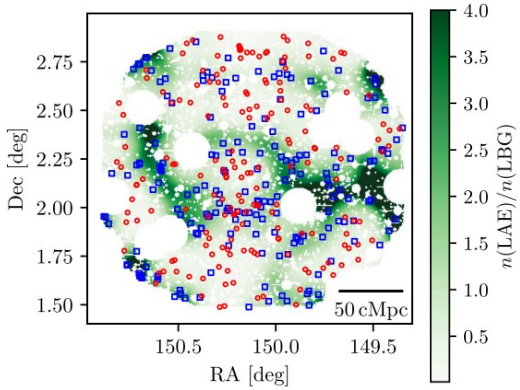


L_{CIV} VS L_{Lya} of AGNs; Onoue+21

f_{AGN} at z=2-3; Zhang+21

Summary + Appendix

- We are constructing ML-aided catalogs of LAEs at various redshift (z=2.2 – 7.3) based on the final HSC-SSP datasets
- Subset of LAEs will be observed in PFS-SSP;
  Using the high-z LAE sample, we probe the end of reionization
  - Its **Source** mainly from AGN fraction
  - Its **History** from Evolution of LF/ACF/EW distribution and Lyα line shape
  - Its **Topology** from the relation btw. Lyα line shape and environment, cross-correlation with 21cm emission, AGN fraction
- Bonus science in COSMOS:
  - morphology VS Lyα line shape with JWST image (COSMOS-Webb/PRIMER)
  - n(LAE)/n(LBG) (Yoshioka+22) VS Lyα line shape



Yoshioka+22