

WFIRSTとすばるで迫る 銀河と銀河間物質の共進化

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Proposal and Members

WFIRST-Subaru Studies for the Galaxy and IGM Co-Evolution

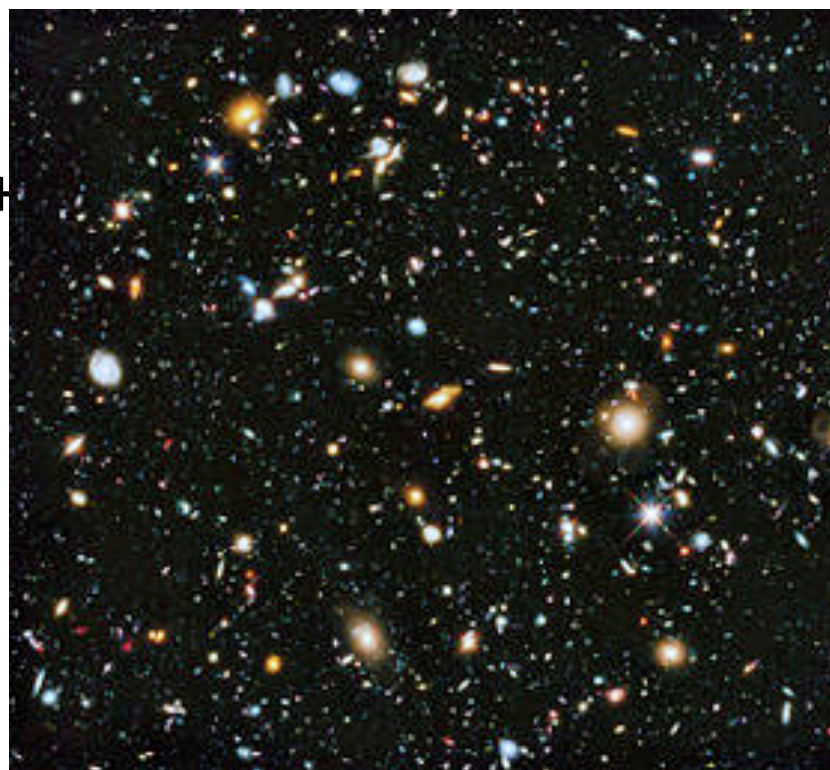
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- After the proposal submission,
 - SKA-Japan EoR: Hasegawa, Ichiki (Nagoya), Takahashi (Kumamoto), Takeuchi, Tashiro (Nagoya), Yajima (Tohoku)
- 30 members from 11 institutions, so far.
- Your participation/contribution is very welcome!

---Our Discussion---

WFIRST: Powerful for Galaxy Form. Studies

- WFIRST is a super HST.
 - Large area **NIR imaging** (x200+
 - Very deep (wide mass range)
 - High spatial res. (morphology)
 - Slitless **NIR spec.** w mid res.
 - Rest-opt neb lines: flux limited
- New window for GF studies



HST 4 arcmin² image (Harrington+14)

- No similar data are taken with any other new facilities incl. Subaru/HSC+PFS, VLT/MOONS, JWST..

---Our Discussion---

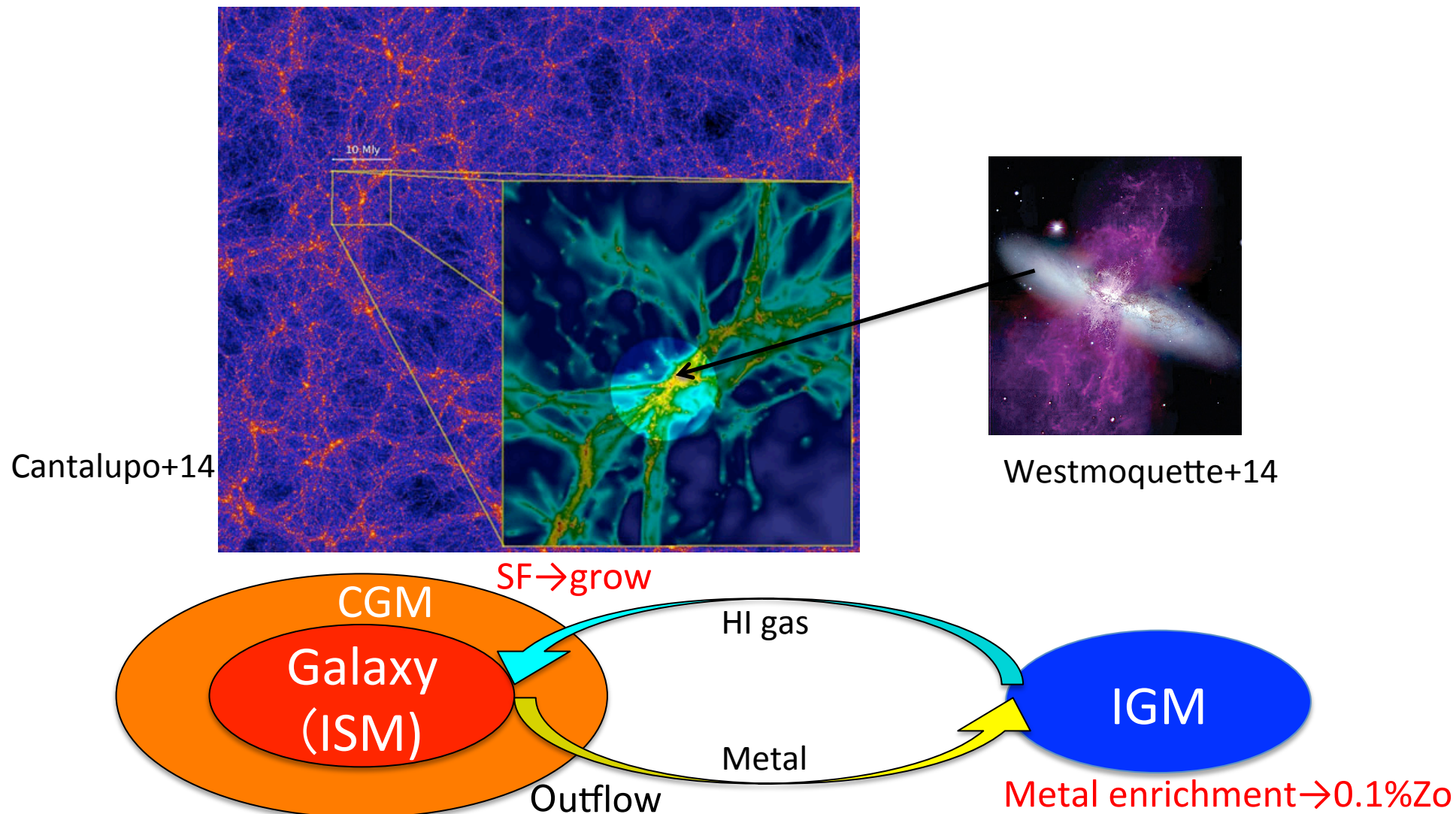
Important Data Missing in WFIRST/HLS

- Data **missing in WFIRST/HLS**
 - (1) Deep optical broadband images (-> LSST etc.)
 - (2) Deep optical narrowband (NB) images
 - (3) Deep optical spectra

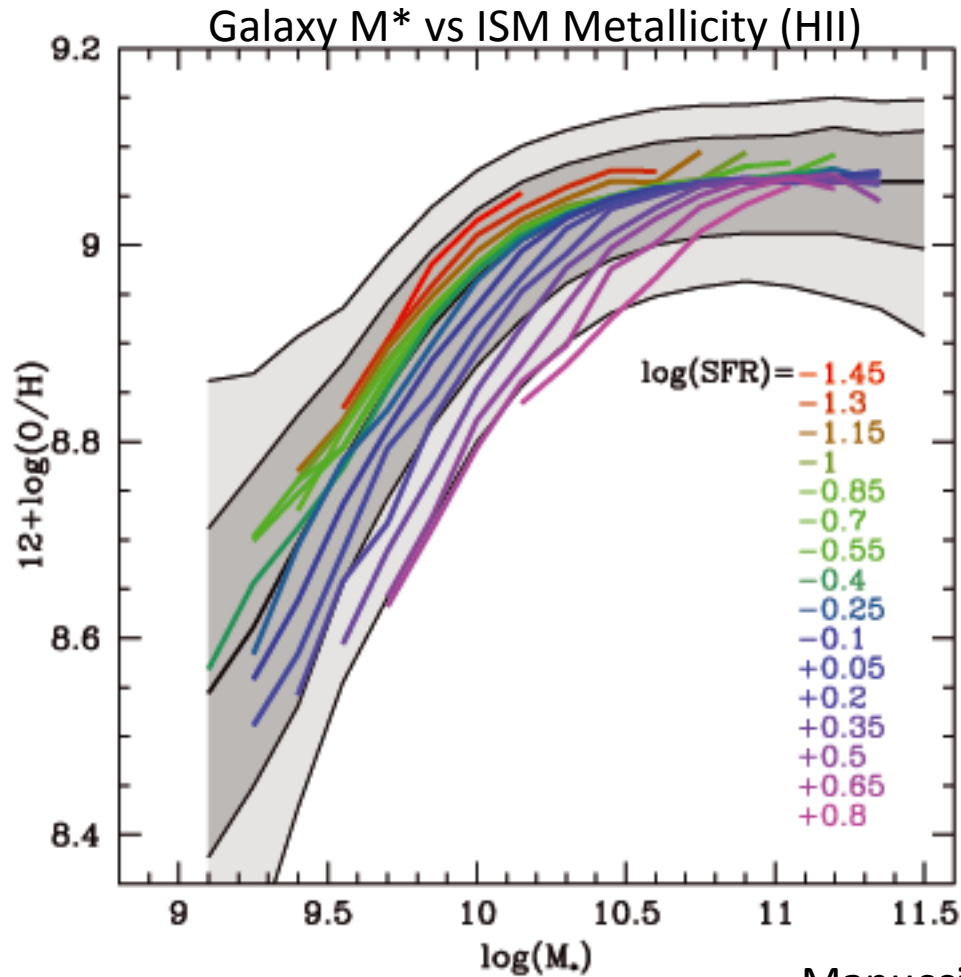
---Our Discussion---

Important Science Missing in WFIRST/HLS

A) Galaxy-IGM Co-evolution at $z < 6$



SFR M_* -Z Relation



Manucci+10

SFR

$$\frac{dM_*}{dt} \equiv \psi = \epsilon_* M_g \quad (1)$$

Inflow Outflow

$$\frac{dM_g}{dt} = -(1-R)\psi + (a-w)\psi \quad (2)$$

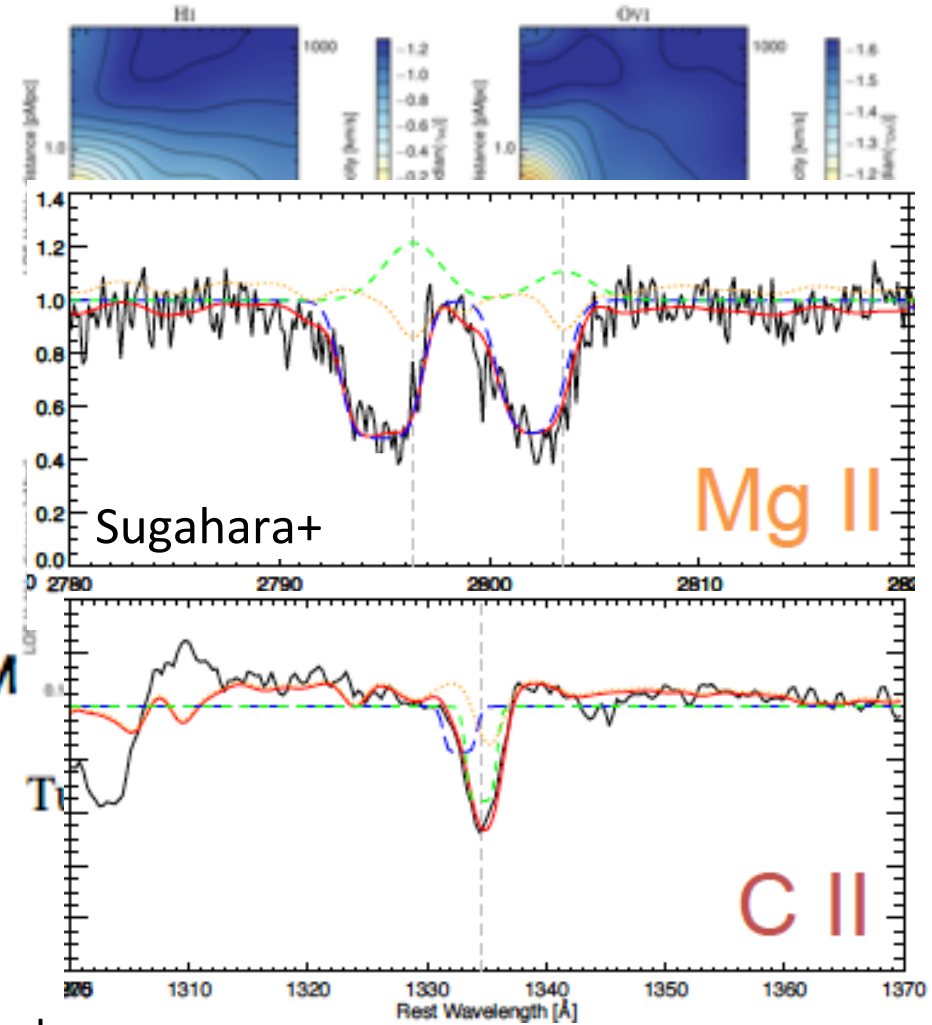
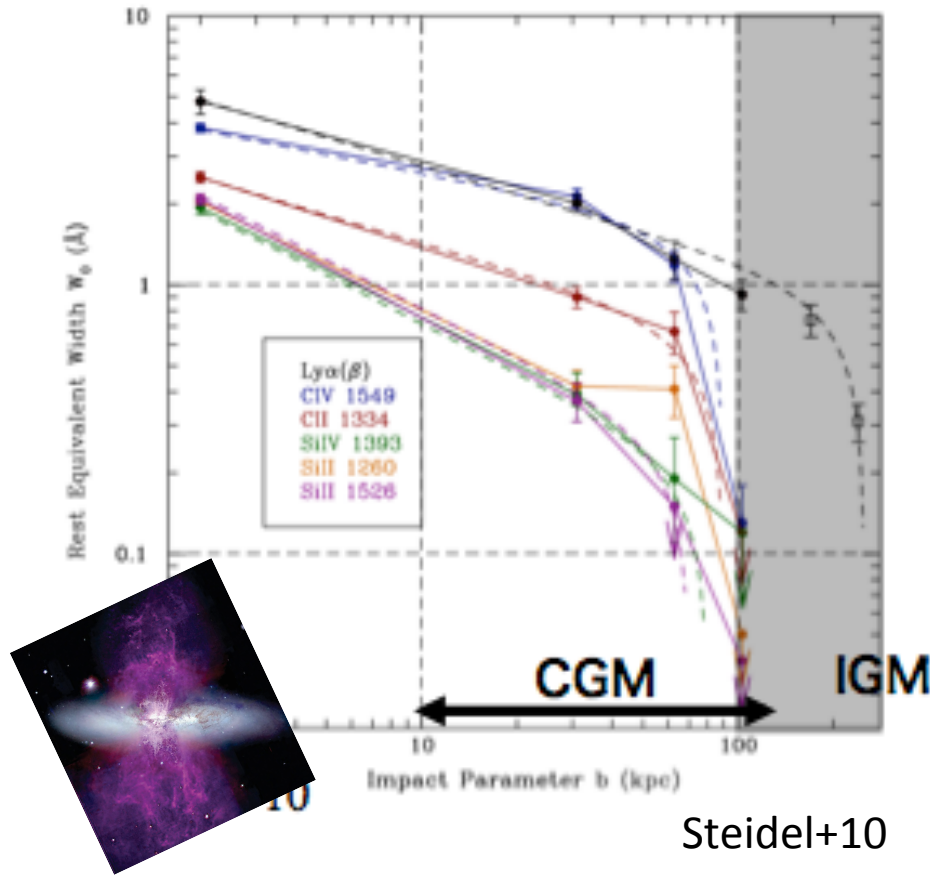
Metal (O/H)

$$M_g \frac{dX}{dt} = y(1-R)\psi - aX\psi, \quad (3)$$

Dayal+13

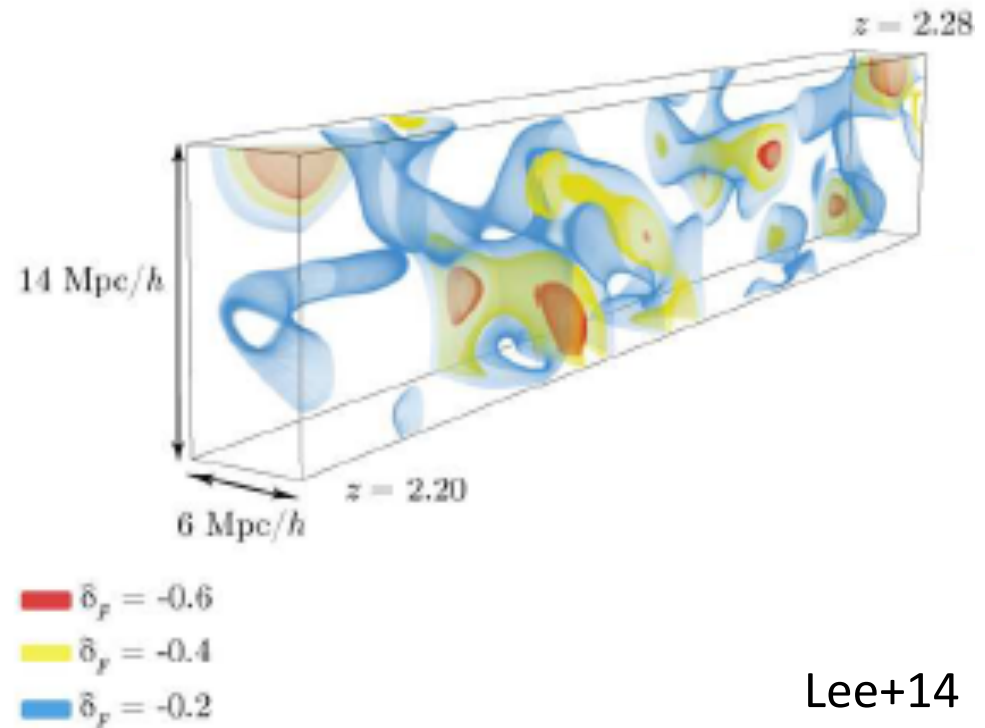
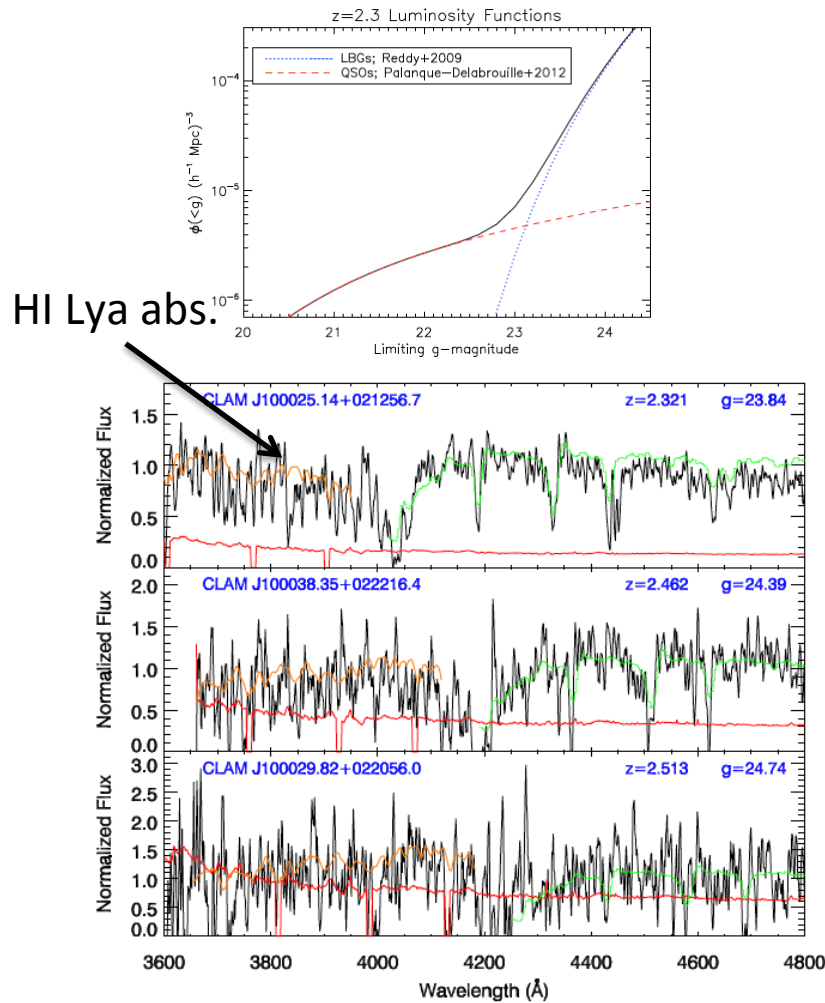
- Inflow and outflow balance makes the relation (e.g. Dayal et al. 2013)

Galaxy-IGM Relation Studies



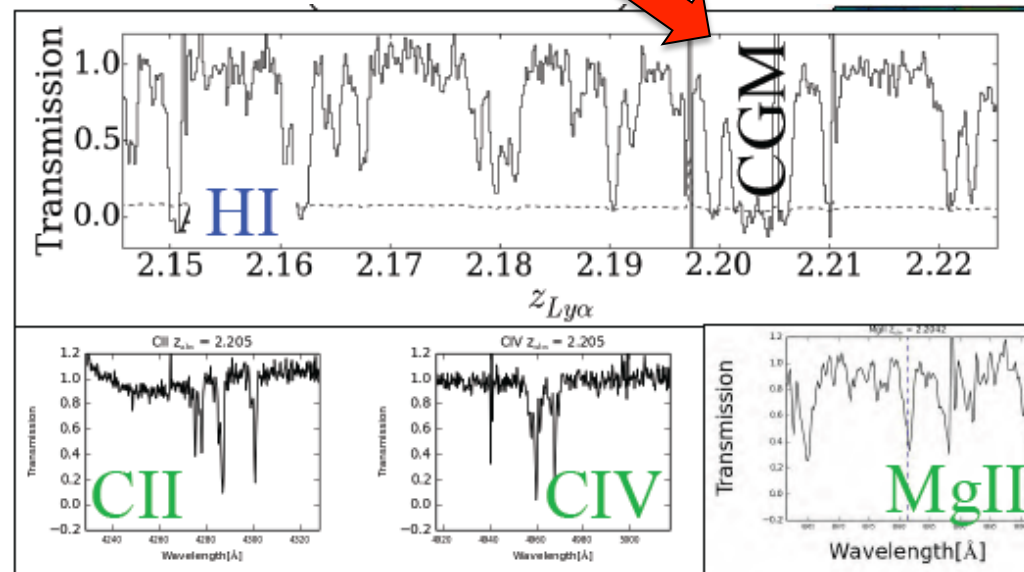
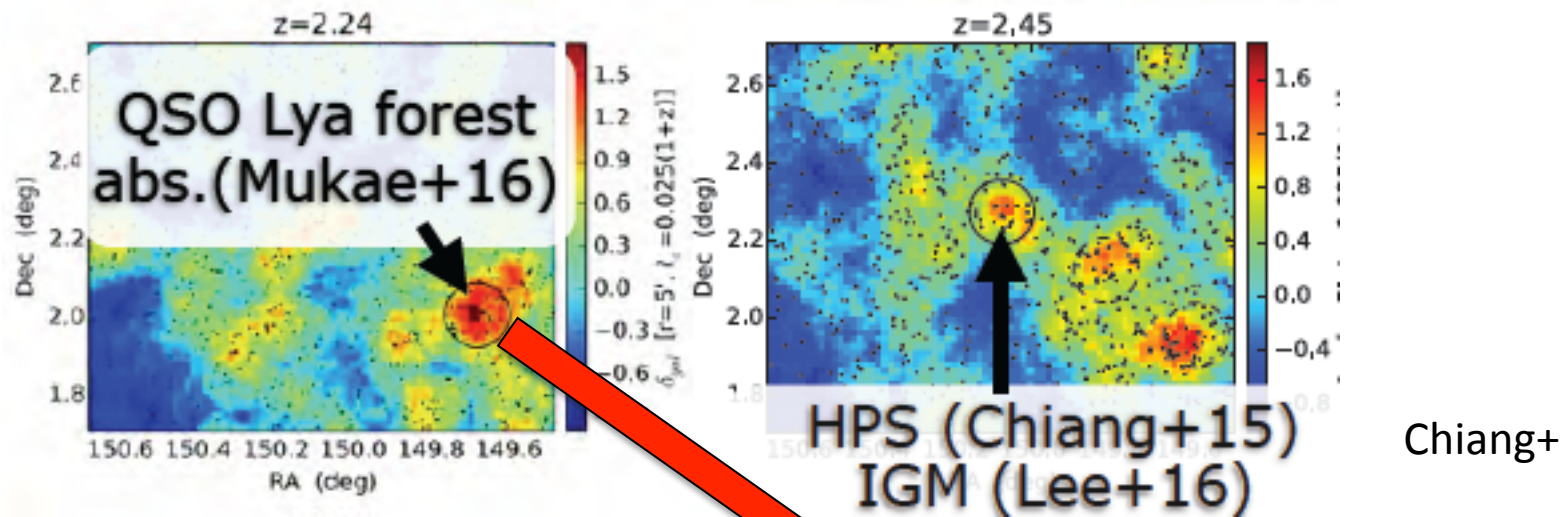
- Only up to CGM (10-100kpc) scale.
- Not reaching IGM due to the small survey volumes.
- **Inflow/outflow**: Missing ISM absorption lines (η w morphology for moment/energy driven)
 → Subaru (rest UV spectra → IGM) + WFIRST (morphology, rest opt spectra → Galaxy)

Galaxy-IGM Relation Studies



- HI Tomographic reconstruction technique (Lee et al. 2014)
- 3-4 Mpc spatial resolution
- Mapping out LA galaxy (WFIRST)-HI IGM (Subaru) relation

Galaxy-IGM Relation Studies



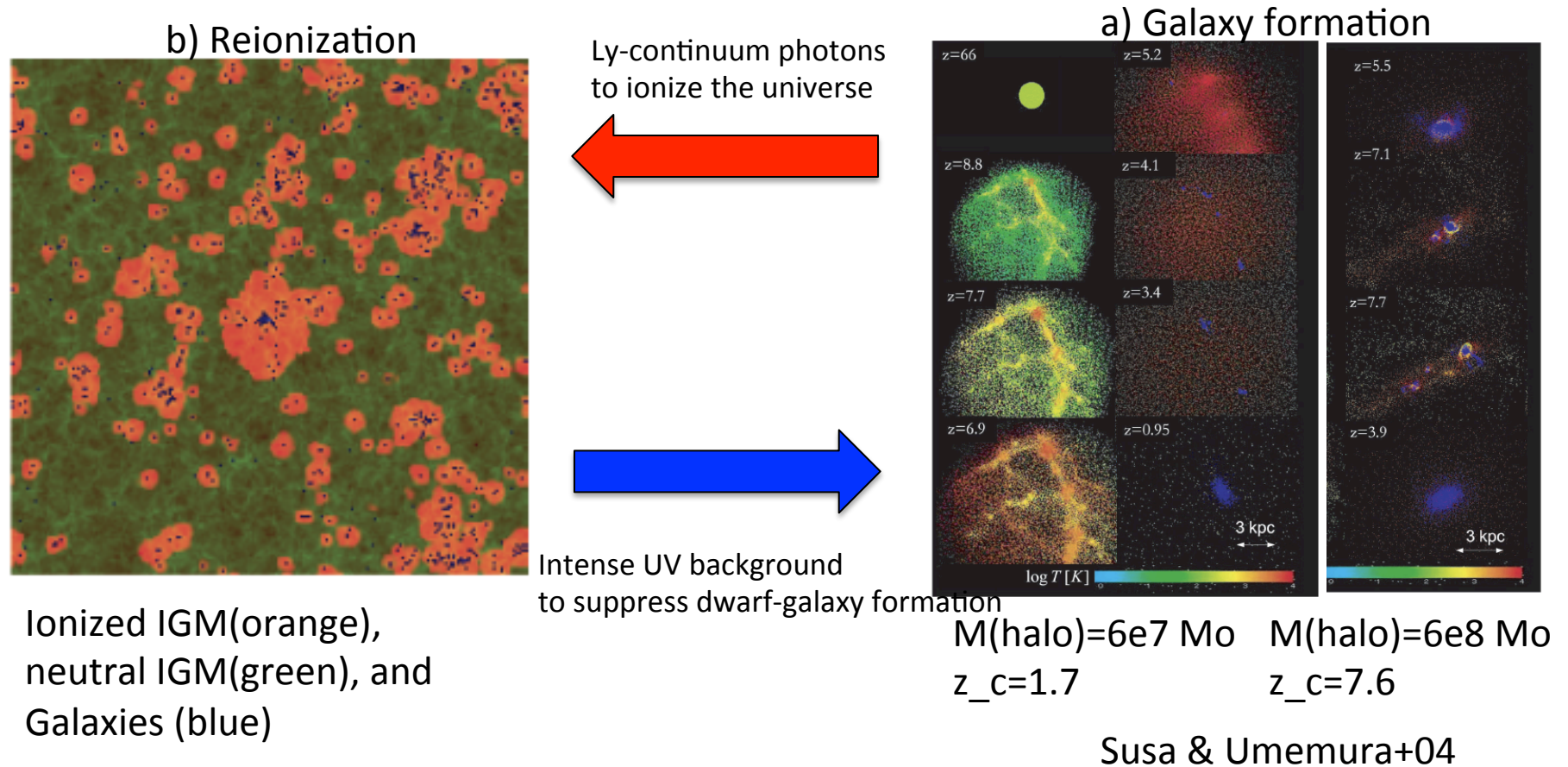
- Metal gas in galaxy spec stacks and QSO (see+ Steidel+10)

Why are WFIRST+Subaru Data Needed?

- Subaru data
 - PFS spec -> HI tomography (5 Mpc res) & metal lines in IGM
 - HSC NB -> Complementary HI Ly α em. distribution in CGM
- WFIRST
 - Deep NIR images -> Galaxy M* & morphology down to dwarfs
 - Deep NIR spec -> Diagnostic lines for galaxy ISM (Z, q, n_e & R)
- Other projects? -> No.
 - Subaru/HSC+PFS SSP -> No M* and morphology
 - WFIRST only -> No HI tomography and metal lines.

Important Science Missing in WFIRST/HLS

B) Galaxy-IGM coevolution at $z > 6$ (Reionization)



- a) and b) are tightly related.
 - Ionizing photons to ionize the universe
 - UV BG radiation in IGM to suppress galaxy formation via heating

Three Major Questions of Reionization

1. What reionized the Universe?

Is the standard scenario (galaxy) correct?

2. What is the start/end of reionization (x_{HII} vs z)?

Early/late (Sharp/extended) reionization?

→ HSC SSP down to $\Delta Q_{\text{HII}} \sim 10\%$ up to $z \sim 7$

3. How did the reionization proceed?

Inside-out? Outside-in or filament last?

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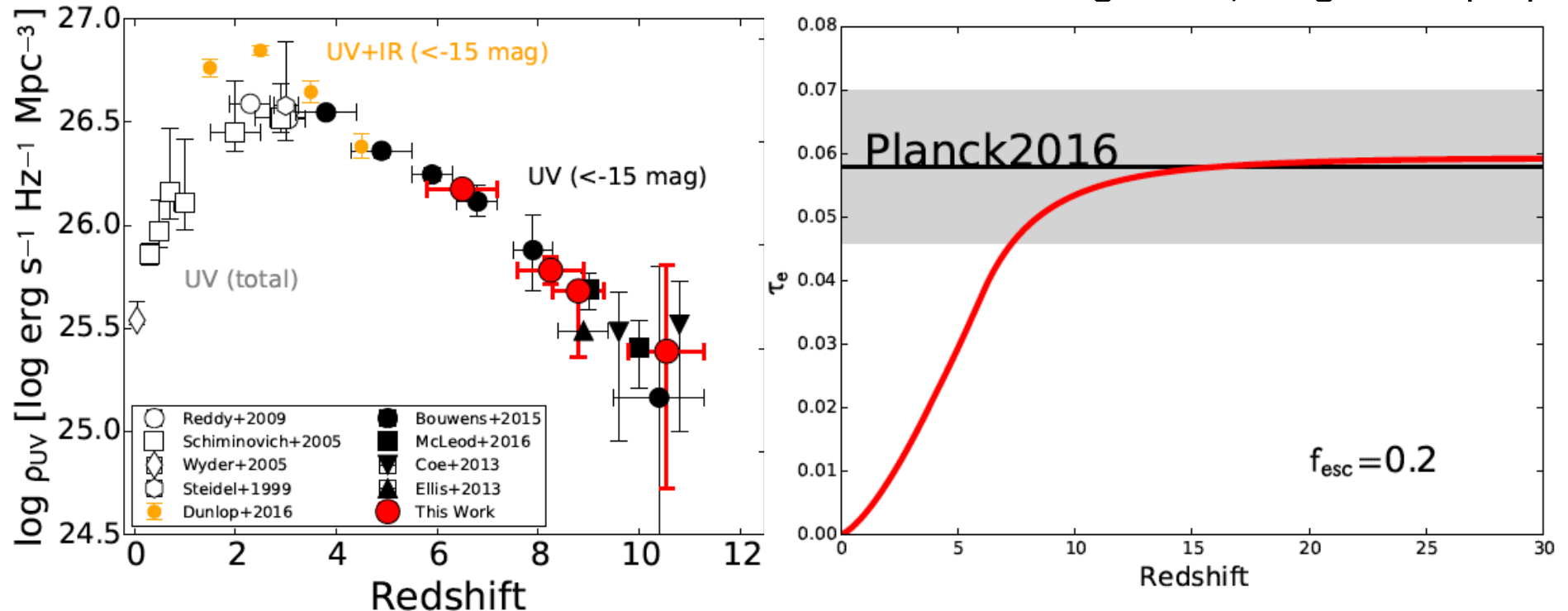
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What Reionized the Universe?

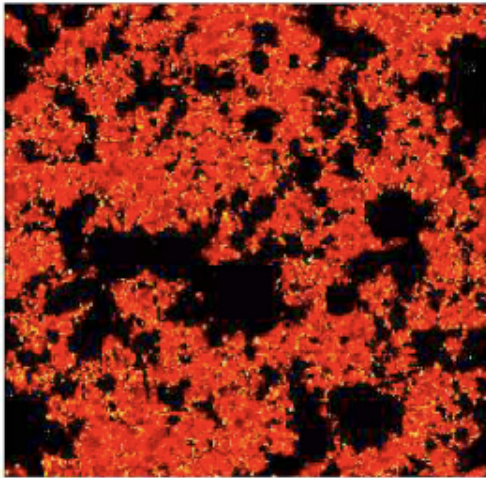
Ishigaki+15, Ishigaki+ in prep.



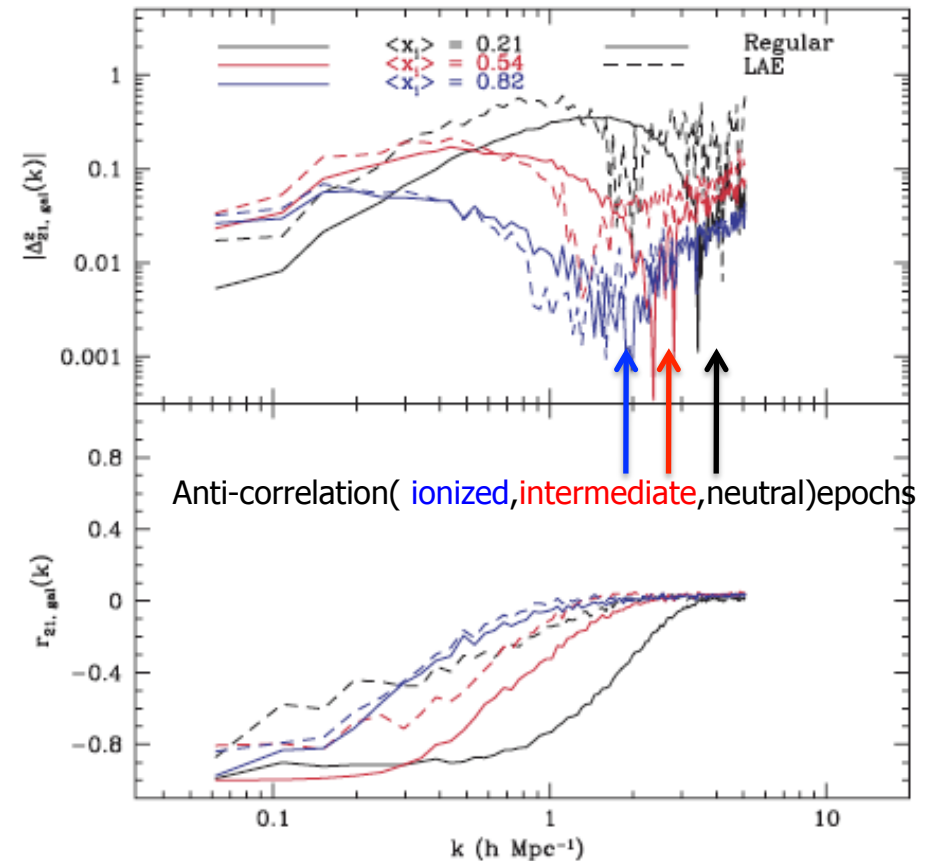
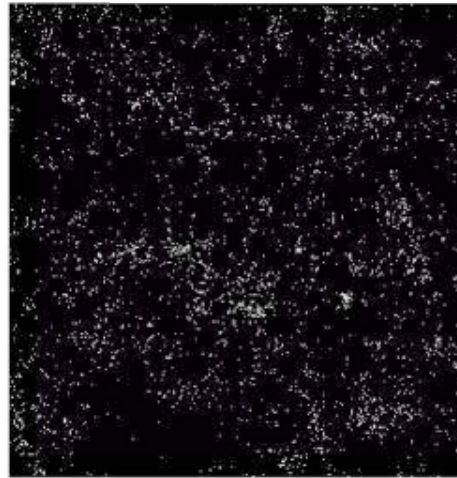
- SF galaxies could explain reionization, but unknown f_{esc}
- Moreover, AGN contribution is unknown (Matsuoka-san's talk)

Reionization Process?

21cm



Galaxies



Lidz et al. (2009)

- HSC SSP+LOFAR: 21cm-galaxy cross-power spectrum at ~ 3 sigma det (Lidz+09).
- No constraints beyond the “detection”

Addressing the Reionization Problems

- Subaru data
 - Optical NB images + spectra -> **LAEs** at $z=6-7$, f_{esc} ($z < \sim 5$)
- WFIRST
 - Deep NIR data -> **LBGs** and **AGNs** at $z=6-13$



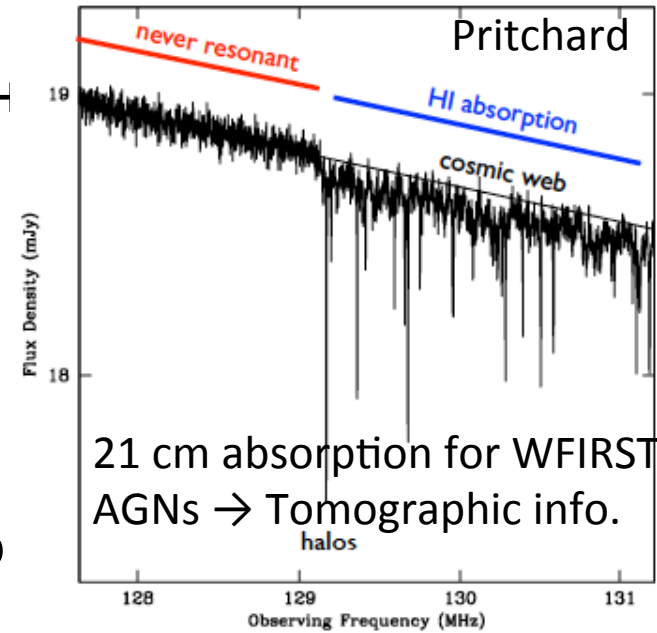
- SKA-Low Deep ($\sim 10-100 \text{ deg}^2$)
 - HI 21 cm distribution
 - Combination of HI 21 cm and (**LBGs** + **LAEs** + **AGN**) dist.

(Subaru+WFIRST) + SKA

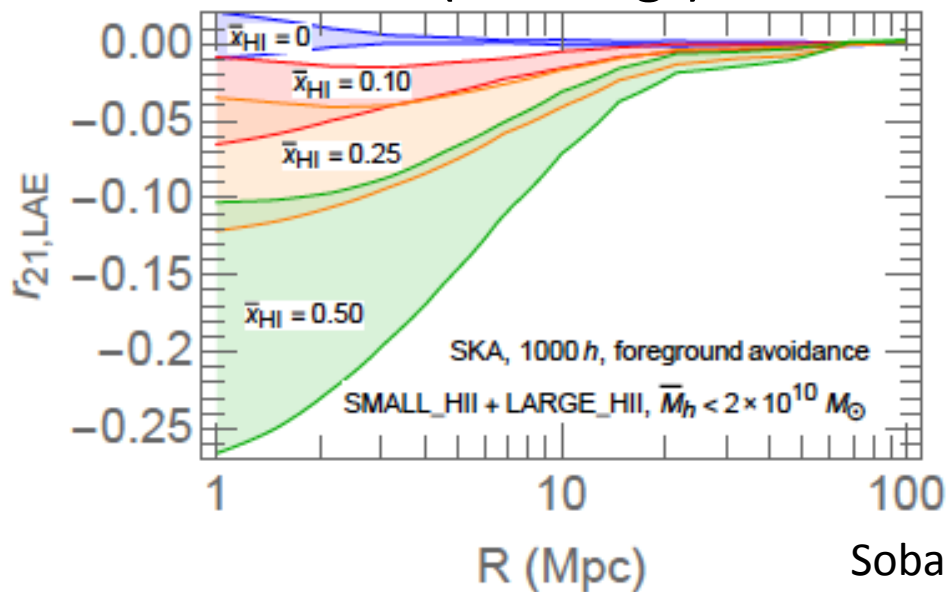
- SKA EoR survey (SKA prev. plan; Hasegawa+)
 - Shallow 10,000 deg² (10hr/pt)
 - Medium 1,000 deg² (100hr/pt)
 - **Deep 100 deg² (1000hr/pt)**

Arrange (Subaru+WFIRST) + SKA survey (TBD)
 (Iwata, Ouchi, Hasegawa, Takahashi+)
 → Cross-correlation btw. HI 21, LAEs, and dro

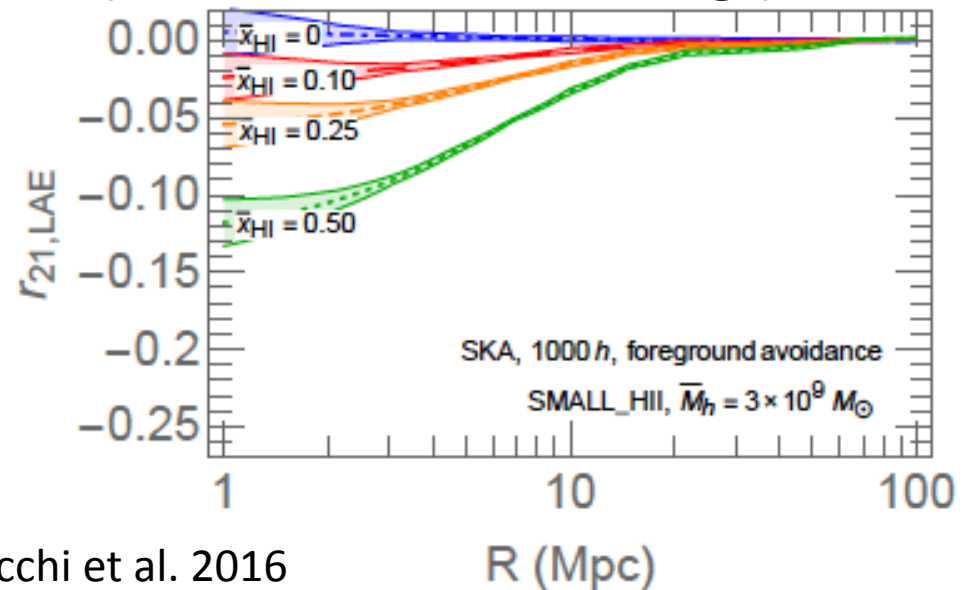
z=7 QSO Mortlock+2011



HSC SSP (UD4deg²) + SKA1



~ (Subaru+WFIRST 100deg²) + SKA



Required Data

- **Subaru**

- HSC imaging (65 nights -> ~40 nights): griz, NB527, NB921
 - 60,000 LAEs at $z=3.3$ and 6.6 (2000 LABs+Lya filaments)
 - 1 Million LBGs at z up to 6
- PFS spec. [0.38-1.26 μm] (65 nights):
 - $z\sim 1-4$ 100,000 galaxies incl. line em. and bright passive gals.
 - 300 gals/deg² for tomographic reconst. -> 5 h⁻¹ Mpc HI map resolution
 - LyC measurements up to $z\sim 5$
 - Outflow indicator abs lines

- **WFIRST/HLS**

- Imaging: Y,J,H,F184
 - All galaxies above for morphology (+M*)
 - 30,000 LBGs at $z\sim 6-13$ (incl. AGNs)
- Spec [1.3-1.8 μm]: [OII],Hb,[OIII] line (+G4300,Hd for passive)

+Arrangement with **SKA Low Frequency EoR Survey**

Summary

- Galaxy-IGM coevolution over $z=2-7$ (13) w Subaru/HSC,PFS + WFIRST (+SKA arrange. for $z>6$)

- Galaxy-IGM(HI,metal) connection over LSSs at $z<6$

- HI Tomography and metal dist. (Subaru)
- Morphology and stellar mass down to high- z dwarfs (WFIRST)

- Cosmic reionization at $z=6-7$ (up to 13)

- LAEs (Subaru)
- LBGs and AGN (WFIRST)
- HI 21cm (SKA)

Cross-corr. of the 3 samples to distinguish major reionization scenarios (+21cm absorption system w the AGNs for coarse tomographic info.)