Witnessing the emergence of reionization bubbles around large scale structures at z~8

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Subaru Instrument: ULTIMATE-WFI

Number of nights (hours): 20 nights

Condition of nights (moon phase, airmass, seeing): Bright/grey, airmass<2, seeing<0.4”

Time critical (year, season, date, time): N/A

Relevant CCS/other Roman program: High Latitude Wide Area Survey, High Latitude Time domain (SNe)

Category(exoplanet, galaxies, large scale structure, solar system, stellar physics, stellar population/ISM, super massive blackhole/AGN, IGM/CGM): large scale structure

Key words: reionization, Lyα emitters, narrow-band imaging, wide-field

The expansion of the Universe after the big-bang cools the Universe down to ~3,000K by z=1100 when protons and electrons are combined and become neutral hydrogen (HI). The hydrogen atoms are cooled further down and become molecular hydrogen and eventually form the first generation of stars which start illuminating the surrounding Universe – the “cosmic dawn” or the end of the “dark age” of the Universe. The strong UV radiation from those 1st generation of stars formed within the large-scale structures then progressively ionize the surrounding neutral hydrogen again (Fig. 1). Eventually, the entire inter-galactic space is re-ionized by the increased UV radiation from newly formed stars (and/or other sources, including blackhole-accretion disks). This dramatic event is called “reionization of the Universe”. It is extremely important to understand this process as it has changed the physical state of the whole Universe, which must have had strong impacts on successive galaxy formation and evolution in the early Universe.

In this proposal, we aim to witness the propagation of this reionization process as the expansion of ionization bubbles developed around proto-clusters in the large-scale structures where lots of stars are efficiently formed and illuminate the surrounding media (Fig. 1). For this purpose, we will conduct a wide-field (4 deg^2) narrow-band imaging survey with NB1063 filter to be installed on ULTIMATE-WFI which can capture Lyα emitters at z=7.7 (Fig. 2). If there remains neutral hydrogen around the newly formed galaxies, the Lyα photons emitted from star forming regions can be resonant scattered by the HI gas and attenuated, while if the inter galactic space is fully ionized, Lyα photons can penetrate through the ionized gas and reach us. Therefore, Lyα emitters are expected to be seen only through the ionized bubbles. If we compare the spatial distribution of Lyα emitters (LAEs) to be traced by ULTIMATE-WFI with that of normal star forming galaxies (LBGs: Lyman break galaxies) at the same redshift to be traced by Roman Space Telescope (which are unaffected by the presence of HI), we can thus map the neutral gas distribution hence the percolation process of the reionization (Fig. 1).

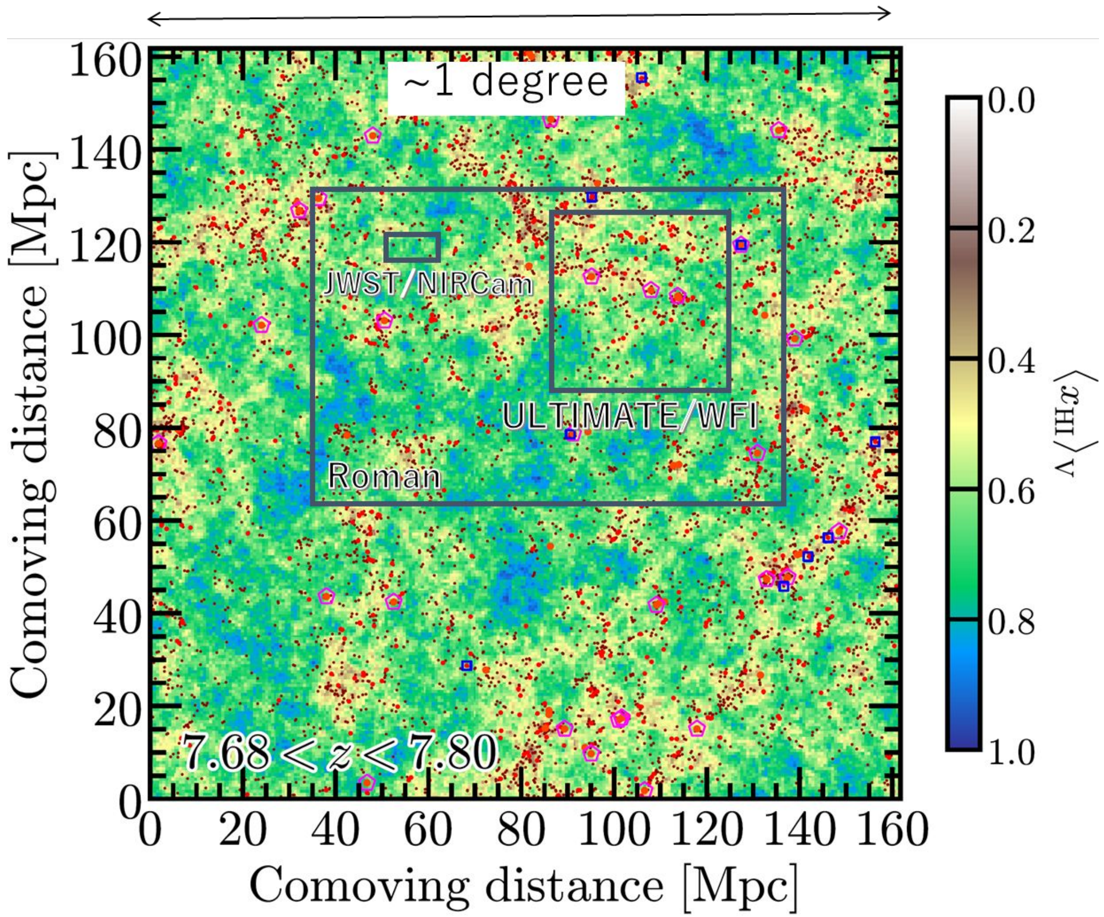

Figure 1: The distribution of neutral hydrogen and galaxies based on a simulation (Inoue+18). Average neutral fraction is $\langle x\_\mathrm{HI} \rangle$=0.64. Black, red, & orange dots are log($M_{halo}/M_{\odot}$) > 10.0, 10.5, & 11.0, respectively. Blue squares are LAEs detectable with ULTIMATE. Magenta pentagons are LBGs detectable with Roman.
Spatial distribution of Lyα emitters with respect to LBGs can trace the re-ionization bubbles because Lyα photons can escape and reach us only through the bubbles.

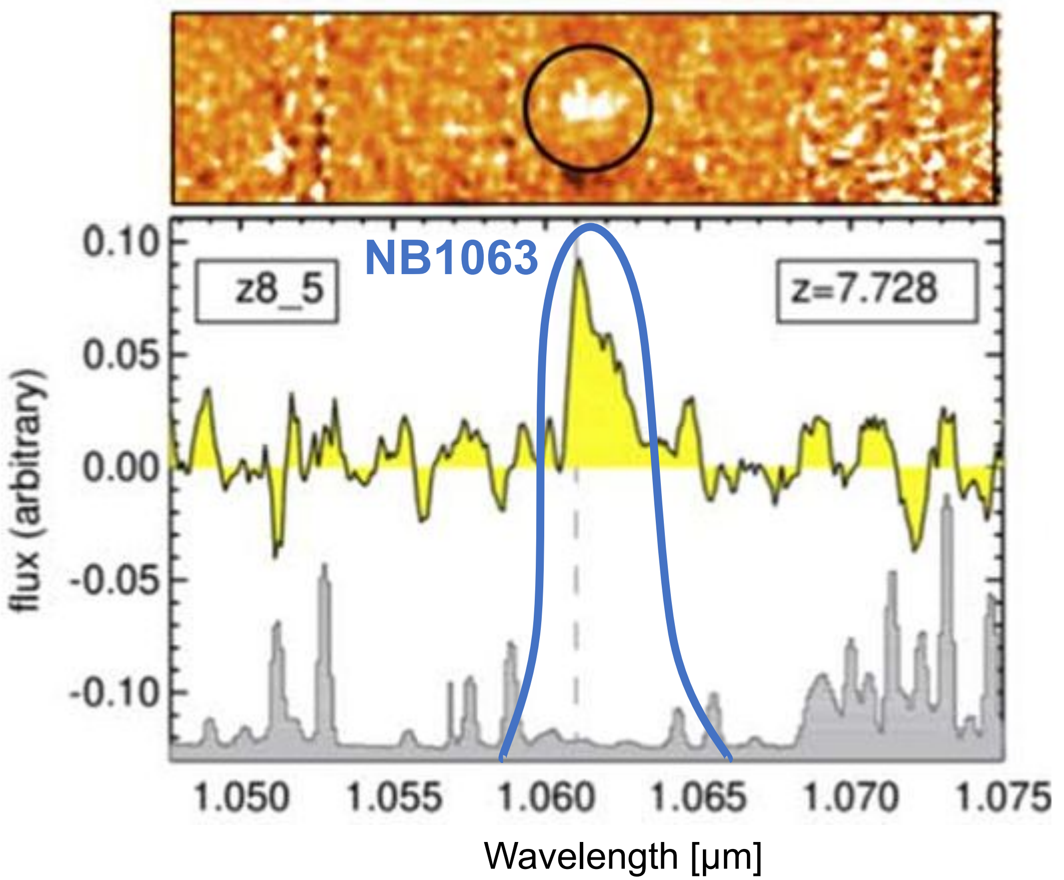

Figure 2: An example Lyα spectrum taken from (Tilvi+20). ULTIMATE-WFI's narrow-band filter NB1063 can capture redshifted Lyα emission lines at z=7.7.

In order to find >100 LAEs at z=7.7, we need to search for 4 deg^2 corresponding to 320 cMpc on a side, and reach down to 25.5 AB at 5σ. This requires 50 nights of ULTIMATE-WFI observations.
The 60% of this program (~30 nights) will be conducted as a part of the ULTIMATE-SSP, together with the higher redshift (z=8.8) search of LAEs with NB1185. Therefore, we request 20 nights of ULTIMATE time as a Subaru-Roman synergy program.

The proposed, unprecedentedly wide narrow-band imaging survey of LAEs at z~8 in the heart of the reionization epoch can sketch the ionization bubbles developing along the large scale structures (~300 cMpc) for the first time.

Summary

Significance of Synergy: This program will use 20 bright/grey nights out of the 100 Subaru synergy program with ULTIMATE-WFI. We will compare Lyα emitters traced by ULTIMATE-WFI narrow-band imaging and LBGs traced by Roman broad-band imaging, and therefore this is an ideal synergy program which requires coordinated data of both Subaru and Roman at the same area of the sky and at the same redshift.