Imaging of Diffuse H I Absorption Structure in the SSA22 Protocluster Region at $z = 3.1$

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When and how galaxies formed and evolved are big questions in the modern astronomy. It is generally considered that gas composed of hydrogen, helium, and so on fell into dark matter overdensity region, the gas was compressed to form stars, and stars were assembled to form galaxies. Unlike the dark matter and stellar component of galaxies whose behaviors are easily predicted theoretically or easily investigated observationally, behaviors of gaseous matter is still mysterious. Comparing spatial distribution of galaxies and gas is important, especially in distant porto-cluster region because galaxy formation at high-redshift is considered to preferentially occur in such a high density environment.

So far, gas in the distant Universe has been investigated through absorption lines (e.g., H I Lyα, Lyβ, C IV, O I) imprinted in the background QSO spectra. In this work, we used galaxies, not QSOs, as background light sources to map gas structure traced by the absorption systems with high spatial resolution. Furthermore, we developed a new scheme to characterize strength of H I Lyα absorption by the foreground gas using multi-band photometry including narrow-band data (we call ΔNB method) [1]. Continuum flux of background light-sources and absorption flux by the foreground H I gas, which are spectroscopically measured in other work [2], are estimated from the broad-band and narrow-band photometry, respectively (Figure 1). This ΔNB method enables us to investigate the absorption systems in wider area with shorter observing time than spectroscopy, while we can investigate only H I gas at a given redshift corresponding to a used narrow-band filter.

We applied the new scheme to imaging data of $z = 3.1$ SSA22 proto-supercluster region, which were taken with the Subaru/S-Cam. We obtained a very wide (~ 50 Mpc) map of H I gas structure with ~ 3 Mpc spatial resolution (Figure 1). The H I gas absorption is significantly strong over the entire SSA22 field, compared with those in the two control fields (SXDS and GOODS-N fields). On the other hand, it is also revealed that gas distribution in the proto-supercluster region does not align with the galaxies' distribution perfectly in relatively small scale (~ 3 Mpc). These suggest that the H I gas not only is associated with the individual galaxies but also spreads out diffusely across intergalactic space only within the proto-supercluster. Such a diffuse gas component may be an ancestor of Warm Hot Intracluster Medium (WHIM[3]) which is associated with nearby superclusters and occupies roughly half of baryons in the Universe.

We also investigated the H I absorption strength as a function of distance from the nearest $z = 3.1$ galaxy. We confirmed that the absorption becomes stronger at the distance less than 100 kpc, which may be due to the H I gas associated with the individual galaxies. Anti-Correlation between strengths of absorption by the circumgalactic H I gas and of Lyα emission from the galaxies themselves is also found, which suggests that observed properties of distant galaxies are affected by the circumgalactic gas distribution and neutrality.

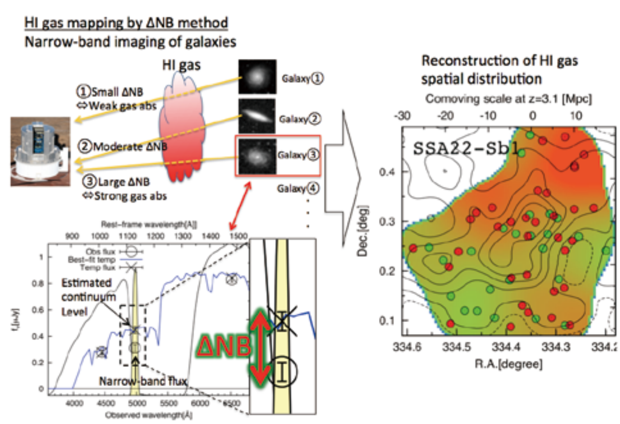

Figure 1: Schematic picture of H I gas mapping by our ΔNB method. We conduct imaging observations of galaxies with multiple filters. Absorption flux by $z = 3.1$ H I gas is evaluated from an offset between the observed narrow-band flux and continuum flux (ΔNB), where the latter is estimated from the broad-band fluxes. Right panel shows spatial distribution of ΔNB values estimated in the SSA22 porto-supercluster region. Redder color means stronger H I Lyα absorption. Contours shows number density of Lyα emitters.

References

[1] Mawatari, K., et al.: 2017, *MNRAS*, **467**, 3951.
[2] Lee, K.-G., et al.: 2014, *ApJ*, **795**, L12.
[3] Zappacosta, L., et al.: 2005, *MNRAS*, **357**, 929.