Accelerated Evolution of the Lyα Luminosity Function at $z \gtrsim 7$ Revealed by the Subaru Ultra-Deep Survey

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Cosmic reionization is an event where protons and electrons being combined at $z \sim 1100$ were reionized. Lyα photons emitted from Lyα emitters (LAEs) at the epoch of reionization ($z \gtrsim 6$) would be attenuated by the neutral hydrogen (HI) in the intergalactic medium (IGM) around the LAEs. Therefore, evolution of the Lyα luminosity function (LF) is used as a probe of cosmic reionization. In previous studies, whether or not the Lyα LF evolves from $z = 6.6$ is debated [1,2]. Observations for $z \sim 7.3$ LAEs with Subaru telescope have also been conducted [3]. However, they cannot clearly conclude whether the Lyα LF evolves from $z = 6.6$ to ~ 7.3 due to the relatively shallow imaging that just reaches the bright Lyα luminosity limit of $L(\mathrm{Ly}\alpha) \sim 1.0 \times 10^{43}$ erg s^{-1}.

To solve the debate, one needs to detect a number of $z = 7.3$ LAEs down to the Lyα luminosity limit comparable to those of $z = 6.6$ LAE samples, and to derive the Lyα LF at $z = 7.3$ with a good accuracy. We have developed a new custom narrowband filter, *NB101*, to detect faint LAEs at $z = 7.3$. Since our *NB101* has a significantly narrower/sharper FWHM than filters used in the previous Subaru $z \sim 7.3$ surveys, *NB101* is more sensitive to an emission line than these filters. Using Subaru/Suprime-Cam with our *NB101*, we have observed SXDS and COSMOS fields (~ 0.5 deg^2) with a total integration time of 106 hr, which is one of the longest ever performed at Subaru telescope. We have reached a limiting luminosity of $L(\mathrm{Ly}\alpha) = 2.4 \times 10^{42}$ erg s^{-1}, which is about four times deeper than those achieved by the previous Subaru studies for $z \sim 7.3$ LAEs and comparable to the luminosity limits of previous Subaru $z = 3 - 6$ LAE surveys. Our observations allow us to derive the Lyα LF at $z = 7.3$ with an unprecedented accuracy.

We identify in total of seven LAEs at $z = 7.3$ (Fig. 1) and conclude that the Lyα LF decreases from $z = 6.6$ to 7.3 at the >90 % confidence level [4]. Moreover, by calculating the Lyα luminosity densities, we find a rapid decrease of the Lyα LF at $z \sim 7$ for the first time (Fig. 2). Because no such accelerated evolution of the ultraviolet (UV) LF or the cosmic star formation rate (SFR) is found at $z \sim 7$, this accelerated Lyα LF evolution is explained by physical mechanisms different from a pure SFR decrease [4]. By the comparison of simple theoretical models, we estimate the HI fraction, x_{HI}, of IGM at $z = 7.3$. However, because there is a possible tension between our x_{HI} estimate and the measurements of Thomson scattering optical depth of cosmic microwave background, the accelerated Lyα LF evolution cannot be explained by a simple scenario of rapid increase of x_{HI} [4]. These results may support new physical pictures suggested by recent theoretical studies, such as the existence of HI clouds within cosmic ionized bubbles [5]. We refer the reader to our published paper [4] for more details.

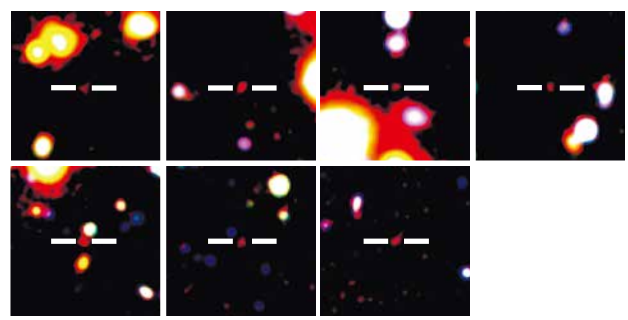

Figure 1: Color composite images of $z = 7.3$ LAEs found in the *NB101* ultra-deep imaging survey [6].

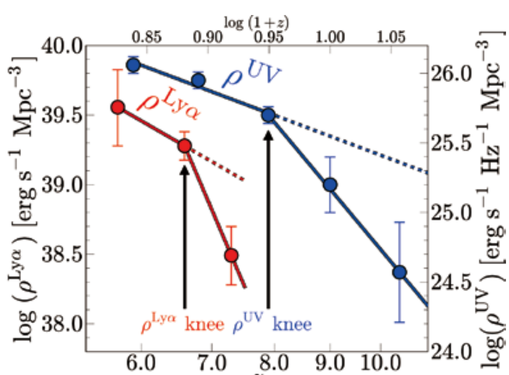

Figure 2: Evolution of Lyα (red) and UV (blue) luminosity densities [4]. The evolution of Lyα luminosity density is accelerated at $z \gtrsim 7$, while the UV luminosity density rapidly decreases at $z \gtrsim 8$.

References

[1] Hibon, P., et al.: 2010, *A&A*, **515**, A97.
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[4] Konno, A., et al.: 2014, *ApJ*, **797**, 16.
[5] Bolton, J. S., et al.: 2013, *MNRAS*, **429**, 1695.
[6] Subaru web release (2014/11/18).