Detection of an Ionized Oxygen Emission Line from a High Redshift Galaxy in the Reionization Era

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The Bing Bang radiation confirmed by cosmic microwave background (CMB) is originated from thermal emission of ionized gas. The ionized gas is then neutralized by atoms/electrons recombination, and our universe became transparent. However, it is known that our intergalactic space, at redshift less than 6, is filled with low density ionized gas again. Detailed observations of CMB suggest that our universe was reionized at redshift around 10. Our observation of an ionized oxygen [OIII]88 μm line has identified a candidate of such galaxies in the early universe [1], as shown in figures 1 and 2.

First stars in our universe are thought to be massive and short lived, which distributed heavy elements into interstellar space by supernovae. A cluster of such massive stars could be a strong source of UV radiation and ionized emission from the heavy elements. Our ALMA observation of a high redshift galaxy (SXDF-NB1006-2, z = 7.2) is one of such galaxies discovered by Subaru telescope having strong Lyα emission in the middle of reionization era.

Preceding to our ALMA observation, we estimated the emission strengths of far-infrared atomic fine structure lines from high redshift galaxies [2]. As a result, the ionized oxygen [OIII]88 μm line could be the brightest emission line under strong UV radiation and low metallicity conditions. This is also consistent with [OIII]88 μm observations by AKARI infrared satellite towards the Tarantula Nebula in the Large Magellanic Cloud.

The most interesting discovery from the ALMA observation of SXDF-NB1006-2 is that ionized carbon [CII]158 μm and dust emissions were not detected [1]. This indicates that the galaxy is deficient of neutral gas but dominated by ionized gas. Then UV radiation from massive stars are not absorbed by the interstellar medium and penetrate into intergalactic space, and we estimated that the UV radiation from the galaxy could contribute to the cosmic reionization. Our observation not only discovered the most distant oxygen, but also proposed a new tool to study the early history of our universe. With coming ALMA observations, we will be observing more on far-infrared atomic fine structure lines from the most distant objects to identify the cosmic reionization and structure formation in the early universe.

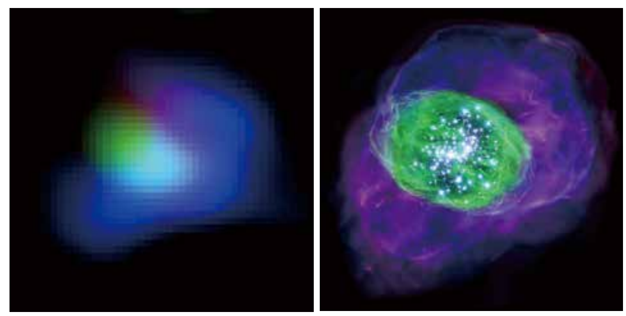

Figure 1: (left) 3-color image from observations: green for ALMA [OIII]88 μm, purple for Subaru Lyα and red for UKIRT UV radiation. (right) artist's illustration of SXDF-NB1006-2 showing that the UV emission from a massive star cluster is penetrating into intergalactic space and ionizing the neutral gas around.

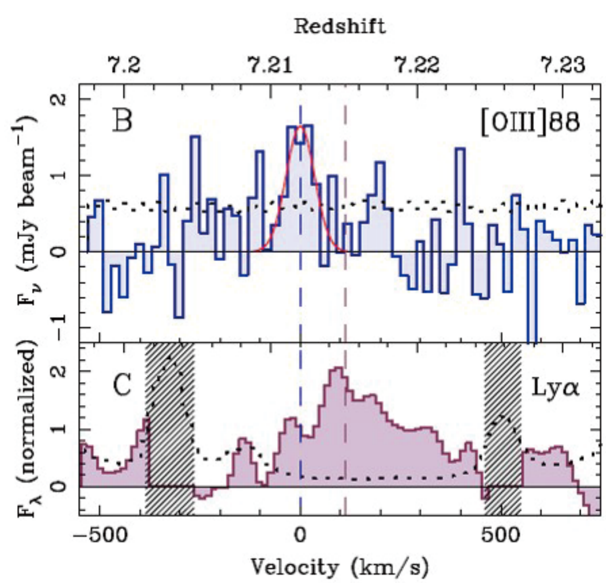

Figure 2: (upper) [OIII]88 μm emission spectrum observed by ALMA. (lower) Lyα emission by Subaru telescope. Peak is shifted due to absorption by neutral gas.

References

[1] Inoue, A. K., et al.: 2016, *Science*, **352**, 1559.
[2] Inoue, A. K., et al.: 2014, *ApJL*, **780**, L18.