An Early Phase of Environmental Effects on Galaxy Properties Unveiled by Near-Infrared Spectroscopy of Protocluster Galaxies at $z>2$

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Metals in the Universe are produced in the interiors of stars as they evolve and then released into surrounding gas through supernova explosions or stellar winds known as 'chemical evolution'. This means that the metallicity of the gases provides us with crucial insights on formation mechanisms of the galaxies. This work tries to diagnose the presence of environmental dependence of galaxy formation by investigating the gaseous metallicity of the protocluster galaxies at the redshift around two.

The metallicity of the gases in the protocluster galaxies can be derived from line ratios of multiple spectral lines emitted from them. Based on the line spectra taken by MOIRCS on the Subaru telescope, we estimated their gaseous metallicities [1] and compared them with those in the general field [3]. As a result, we find the excess of their gaseous metallicities in the protocluster regions by 0.10–0.15 dex relative to those of galaxies in the general fields (Figure 1). The metallicity excess in the protoclusters suggests biased star-formation histories in the dense regions. This may be caused by several effects as below,

- Recycling chemically enriched gas
- Stripping metal poor HI gas in outer region
- Advanced stage of downsizing galaxy evolution
- Top-heavy initial mass function
- Sampling bias

Among these possibilities, we suggest that the above two scenario may be the most effective factors that cause different gaseous metallicities of the protocluster galaxies, because gas inflow/outflow processes strongly control the chemical enrichment along with the stellar nucleosynthesis. If so, we can also explain the larger offset of the gaseous metallicities of the protoclusters from those in the fields at higher redshifts (Figure 1) since the redshift around two is considered to be the peak epoch of inflow and outflow activities. The result suggests that galaxy formation has already been influenced by environmental conditions in the era that star-formation activities are the most active across the universe. This would be an early phase of strong environmental effects seen in the present galaxy clusters.

However, we cannot fully rule out the other possibilities so far, and therefore we need to continue exploring the detailed physical properties of individual forming galaxies in the protoclusters to find clear evidence that proves such a hypothesis.

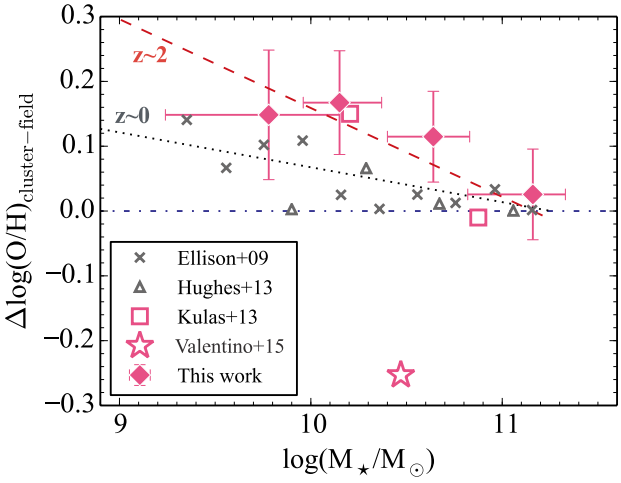

Figure 1: The offset of the averaged gaseous metallicities 12+log(O/H) of protocluster at $z\sim2$ (red; [1,4,7]) & cluster at $z\sim0$ (black; [5,6]) galaxies from those in general fields in the literature plotted against stellar mass.

References

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