Properties of Star-Forming Galaxies in a Cluster and Its Surrounding Structure at $z = 1.46$

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Galaxies in the local Universe have properties dependent on environments as galaxy clusters tend to be dominated by massive, passively evolving galaxies with an elliptical morphology [1]. Galaxy clusters at high redshift (z) provide important clues to understanding galaxy formation and evolution, since going back to as high redshift as possible enables us to approach the epoch when galaxy clusters were formed. Indeed, recent surveys suggest that there are a lot of active, star-forming galaxies even in clusters or proto-clusters at $z \gtrsim 1.5$ and the prominent sequence of red galaxies in color–magnitude diagram, which is peculiar to galaxy clusters at $z \lesssim 1$, seems to be formed during $z \sim 1$–3 [2].

XMMXCS J2215.9-1738 cluster at $z = 1.46$ is one of the most massive galaxy clusters at $z > 1$ [3]. We conducted a wide-field [OII] emission line survey in and around this high-z cluster with Suprime-Cam on the Subaru Telescope, and selected 380 [OII] emitting galaxies in the region of 32×23 arcmin^2. Among them, 16 [OII] emitters in the central region of the cluster were confirmed by near-infrared spectroscopy with MOIRCS on the Subaru Telescope. Thanks to the wide-field coverage, we found that [OII] emitters are distributed along filamentary large-scale structures around the cluster for the first time (Figure 1), which are among the largest structures of star-forming galaxies ever identified at $1.3 \lesssim z \lesssim 3.0$. We defined several environments such as cluster core, outskirts, filament, and field as shown in Figure 1, and investigated the environmental dependence of properties of star-forming galaxies at $z = 1.46$.

The colour–magnitude diagram of $z' - K$ vs. K for the [OII] emitting galaxies shows that a significantly higher fraction of [OII] emitters with red $z' - K$ colours is seen in the cluster core than in other environments. It seems that the environment which hosts such red star-forming galaxies shifts from the core region at $z = 1.46$ to the outskirts of clusters at lower redshifts. The multi-colour analysis of the red emitters indicates that these galaxies are more like nearly passively evolving galaxies which host [OII] emitting AGNs, rather than dust-reddened star-forming [OII] emitters. We also find that the cluster has experienced high star formation activities at rates comparable to that in the field at $z = 1.46$ in contrast to lower redshift clusters, and that star formation activity in galaxy clusters on average increases with redshift up to $z = 1.46$. In addition, line ratios of [NII]/Hα and [OIII]/Hβ indicate that a mass–metallicity relation exists in the cluster at $z = 1.46$, which is similar to that of star-forming galaxies in the field at $z \sim 2$.

In summary, we have found that star formation activity of galaxies at $z = 1.46$ is not yet strongly dependent on environments, and that even the cluster core is experiencing high star forming activity comparable to those in other lower-density regions [4].

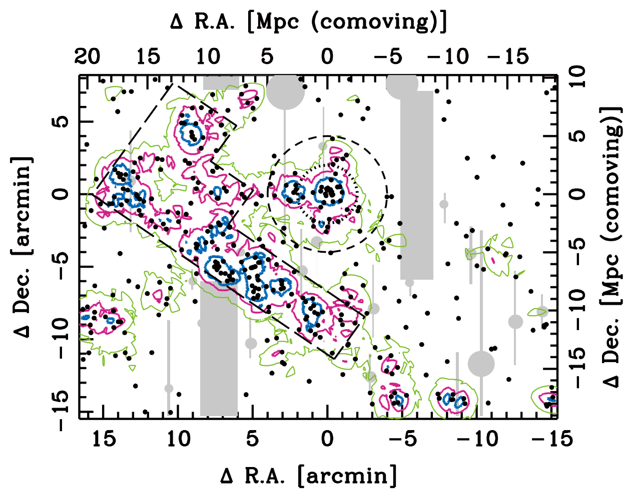

Figure 1: Distribution of 380 [OII] emitters at $z = 1.46$ in and around the cluster. North is up, and east is to the left. The axes show relative coordinates from the cluster centre. Black dots show the [OII] emitters. Cluster core, outskirts, and filament regions are defined by a dotted-line circle, broken-line circle, and long-dashed lines, respectively. The rest of the area is defined as the field. Blue, magenta and green contours show the local density of [OII] emitters.

References

[1] Dressler, A., et al.: 1997, *ApJ*, **490**, 577.
[2] Kodama, T., et al.: 2007, *MNRAS*, **377**, 1717.
[3] Stanford, S. A., et al.: 2006, *ApJ*, **646**, L13.
[4] Hayashi, M., et al.: 2011, *MNRAS*, **415**, 2670.