HIGH REDSHIFT GALAXY CLUSTERS IN ELIAS-N1/N2 FIELDS WITH A NEW COLOR SELECTION TECHNIQUE

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ABSTRACT

Galaxy clusters, the largest gravitationally bound systems, are an important subject of study to place constraints on cosmological models. Moreover, they are excellent places to test galaxy evolution models in connection to their environments. To date, massive clusters have been found unexpectedly (Kang & Im 2009; Gonzales et al. 2012) and the evolution of galaxies in clusters is still controversial (Elbaz et al. 2007; Falloon et al. 2013). Finding galaxy cluster candidates at $z > 1$ in a wide, deep imaging survey data will enable us to solve such issues of modern extragalactic astronomy. We report new candidate galaxy clusters in one of the wide and deep survey fields, the European Large Area ISO Survey North1 (ELAIS-N1) and North2 (ELAIS-N2) fields, covering a sky area of 8.75 deg$^2$ and 4.85 deg$^2$ each. We also suggest a new useful color selection technique to separate $z > 1$ galaxies from low-$z$ galaxies by combining multi-wavelength data.

Key words: galaxies: clusters: general – galaxies: distances and redshifts – cosmology: large-scale structure of universe

1. INTRODUCTION

Galaxy clusters, an extremely dense environment in the universe, are one of the important objects for studying how the evolution of galaxies can be affected by their environment (Muzzin et al. 2013). Moreover, we can put constraints on cosmological models from their mass function, space density and clustering information (Gladders et al. 2007; Mortonson et al. 2011). For all those reasons, interest in galaxy clusters has been increased steadily in recent years.

In particular, it is important to study galaxy clusters at $z > 1$, as galaxy evolution at $z \sim 1$ is still not understood (Elbaz et al. 2007; Falloon et al. 2013) and some studies show that the mass of galaxy clusters at $z > 1$ seems to be higher than expected values from models (Kang & Im 2009; Gonzales et al. 2012). Nevertheless, there is a limitation on studying galaxy clusters at $z > 1$ due to the shortage of deep and wide near-infrared data.

We merged wide and deep optical - NIR datasets from the European Large Area ISO Survey North1 (ELAIS-N1), one of the fields of the UKIRT Infrared Deep Sky Survey Deep Extragalactic Survey (UKIDSS DXS; Lawrence et al. 2007) fields and the survey was originally designed for detecting high-$z$ galaxy clusters at $z \sim 1$ over 35 deg$^2$ with J and K band imaging ($J_{AB} = 23.2$ and $K_{AB} = 22.7$, 5$\sigma$ mag). ELAIS-N1 and N2 cover 8.75 deg$^2$ and 4.85 deg$^2$ of the northern hemisphere sky each, so they offer wide areas to uncover large structures such as galaxy clusters.

The multi-wavelength data of the fields is also deep enough to detect faint galaxies at $z > 1$ when we include Canada France Hawaii Telescope (CFHT; Gwyn et al. 2008) data having a depth of $z_{AB} \sim 25.54$ (5 $\sigma$ mag) and the Spitzer Wide-area InfraRed Extragalactic survey (SWIRE; Lonsdale et al. 2003) whose 5$\sigma$ depth is 21.43 AB mag. ELAIS-N1 and N2 cover 8.75 deg$^2$ and 4.85 deg$^2$ of the northern hemisphere sky each, so they offer wide areas to uncover large structures such as galaxy clusters.

The multi-wavelength data of the fields is also deep enough to detect faint galaxies at $z > 1$ when we include Canada France Hawaii Telescope (CFHT; Gwyn et al. 2008) data having a depth of $z_{AB} \sim 25.54$ (5 $\sigma$ mag) and the Spitzer Wide-area InfraRed Extragalactic survey (SWIRE; Lonsdale et al. 2003) whose 5 $\sigma$ depth is 21.43 AB mag. ELAIS-N1 and N2 are also one of the wide Infrared Medium deep Survey (IMS; Im et al. in prep) fields where we have been performing a wide-field imaging survey in Y and J band using UKIRT WFCAM, with a depth of 23 AB mag.

3. NEW COLOR SELECTION METHOD

The Stellar Bump Sequence technique is popularly used to detect cluster galaxies and was originally designed for selecting passive red galaxies (PGs) from their red sequence. Therefore, we can miss many blue star-forming...
galaxies (SFGs) at high-z with the SBS technique. Nevertheless, we need high-z SFGs samples to study galaxy evolution. We suggest a new color selection technique using two colors, $J - 3.6\mu m$ and $3.6\mu m - 4.5\mu m$. This technique is more effective for selecting $z > 1$ galaxies, even SFGs, as the two colors are sensitive to not only the stellar bump but the 4000 $\AA$ break of galaxies.

We applied our new technique to UKIDSS Ultra Deep Survey (UKIDSS UDS; Lawrence et al. 2007) data and compare it to the results from Muzzin et al. (2013). Figure 1 shows that the new color selection technique is more efficient in detecting galaxies at $z > 1$ with low-z galaxy contamination.

4. GALAXY CLUSTER CANDIDATES AT $z > 1$

We divided selected galaxies into four redshift bins using the color-color diagram, which is composed of three colors, $z - J$, $J - 3.6\mu m$ and $3.6\mu m - 4.5\mu m$ (Figure 2). The histogram of Figure 2 shows the redshift distribution of galaxies in the four color bins.

We investigated the number density of galaxies within 1Mpc radius for all the galaxies in four redshift bins and selected overdensities at $> 3\sigma$. Finally, 1,675 candidate galaxy cluster galaxies were found in ELAIS-N1 and N2 fields at $0.8 < z < 1.8$. We checked SWIRE photometric redshifts (Rowan-Robinson et al. 2007) data and there was photometric redshift information for 1,087 of the galaxy candidates ($\sim 0.47$). Of the galaxies, 788 candidate galaxies satisfy $z > 1$ ($\sim 0.75$).

5. CONCLUSIONS

Galaxy clusters at $z > 1$ are important objects to study galaxy evolution and the evolution of the universe. We found 1,675 candidate galaxy cluster galaxies in ELAIS-N1/N2 fields using multi-wavelength data. Furthermore, we suggested a new color-cut technique which is effective for detecting galaxies at $z > 1$ without any dependence on population. Details of this work will appear in Hyun et al. (in preparation).

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