Discovery of a Rich Galaxy Cluster Candidate at $z = 1.52$

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Galaxy environment has strong impacts on galaxy properties. It is well established that high-density environments such as clusters of galaxies are dominated by red passive galaxies, whilst low-density field environments are dominated by blue star-forming galaxies [1]. Distant galaxy clusters are progenitors of local massive clusters, and therefore, they are important targets for studying how the cluster galaxies grow within high-density environments through cosmic time.

Searching distant clusters generally requires a square-degree scale huge area survey as they are rare objects. An alternative, effective way to find galaxy over densities is to investigate the field around high-z radio galaxies. High-z radio galaxies are believed to be progenitors of present-day central cluster galaxies (cD galaxies), and a number of studies have successfully reported "proto-clusters" around high-z radio galaxies (e.g. [2]).

We have completed an imaging survey of a field of the radio galaxy 4C 65.22 (z = 1.52) with Suprime-Cam and MOIRCS on the Subaru Telescope. In addition to the $Br'z'JHK_s$ broad-band photometry, we also used a narrow-band filter NB1657 on MOIRCS ($\lambda_c = 1.657\,\mu$m) which can capture the Hα emission lines at the radio galaxy's redshift [3].

Our data revealed the large-scale distribution of galaxies around the radio galaxy as shown in Fig. 1. In this plot, the black and red symbols represent $z\sim1.5$ galaxies selected with photometric redshift technique, demonstrating a factor of > 10× over-density around the radio galaxy. In particular, the red symbols in the plot denote those having red $z' - J$ colors; they are expected to be quiescent galaxies. It is interesting to point out that the trend that such red (quiescent) galaxies are strongly clustered at the peak of galaxy distribution is qualitatively consistent with the situation in the local universe.

For those having significant excess in the NB1657 photometry, we carefully inspected their broad-band colors to identify the Hα emitters at $z\sim1.52$ (shown with the blue squares in Fig. 1). Clearly, the Hα emitters are distributed in the outskirts of the cluster core (avoiding the highest-density region), which is consistent with our similar Hα study in a $z\sim0.8$ cluster [4]. Therefore we suggest that the newly discovered structure at $z\sim1.5$ reported here is likely a rich galaxy cluster at $z \approx 1.52$.

Interestingly, our recent star-forming galaxy survey in another cluster at a similar redshift [5] reported a high fraction of star-forming galaxies within cluster core environments. Therefore our new data suggest that there is a diversity in the properties of $z\sim1.5$ clusters, and we speculate that the redshift of $z\sim1.5$ is a key epoch for understanding the cluster galaxy evolution.

By comparing the Hα emitters near the central cluster and in the outer fields, we also reported that there is no strong environmental dependence of the star formation rate (SFR) versus stellar mass ($M_\star$) relation at $z\sim1.5$, which is consistent with our recent study [6]. Our study thus demonstrates that the fraction of star-forming galaxies does change with environment (at $z\sim1.5$), but as long as we focus on star-forming galaxies, their properties are not strongly correlated with environment.

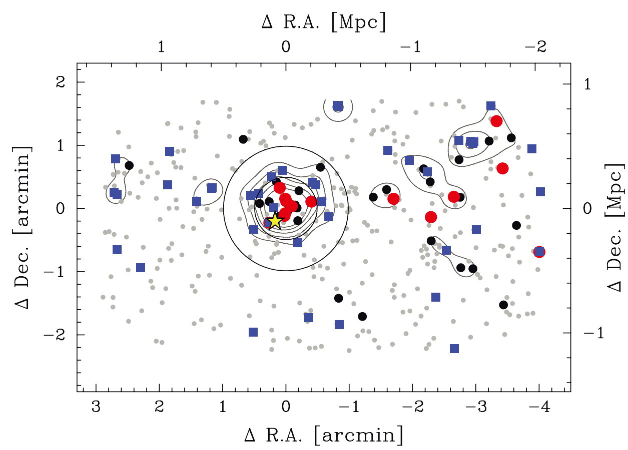

Figure 1: A 2-D map of galaxies around the 4C 65.22 radio galaxy (shown with yellow star). The photo-z selected galaxies with $1.3 < z_{\rm phot} < 1.7$ are shown with black circles (and their density shown with contours), among which red symbols show the location of red (passive) galaxies selected with z'–J colors. The blue squares show Hα emitters at $z = 1.52$. Two large circles show 250 and 500 kpc from the density peak.

References

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