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Jansky VLA S-band view of Hα emitters (HAEs) associated with a protocluster 4C23.56 at z = 2.5

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Abstract. We present recent results on Karl Jansky Very Large Array (JVLA) deep S-band (2-4 GHz) observation towards a protocluster 4C23.56 at redshift z ∼ 2.5. The protocluster 4C23.56 is known to have a significant over density (∼ 5 times) of star-burst galaxies selected to be Hα line-bright by a Subaru narrow band imaging. Now we have found 25 HAEs associated with the protocluster. These starburst HAEs are likely to become massive ellipticals at z = 0 in a cluster. Various other galaxy populations also reside in this field and the fact makes the field very unique as a tool to understand galaxy formation in a over dense region. Subsequent deep 1100-μm continuum surveys by the ASTE 10-m dish have discovered that several submillimeter bright galaxies (SMGs) coincide with HAEs, suggesting HAEs undergoing dusty starbursts. As star formation rates (SFRs) of HAEs might have been underestimated, we use radio being resistant to dust extinction. We investigate the correlation between $SFR_{1.4GHz}$ and $SFR_{H\alpha}$ for radio index $\alpha = 0.8$ to see if the correlation holds for the sources and to check the number of dusty star forming galaxies. Our final results will allow us to evaluate quantitatively how the galaxy formation channel may be different under the condition of over-densities.

Keywords. galaxies: active – galaxies: clusters: general –surveys – galaxies: evolution – galaxies: formation – galaxies: high-redshift – radio continuum: galaxies – galaxies: starburst

1. Introduction

Clusters of galaxies, being the most massive structures bounded with gravity in the Universe, provide us an exclusive window to investigate the galaxy formation and evolution in the over-dense region. The progenitors of clusters, protoclusters, are unsettled systems having over-densities than the fields, which is becoming present-day clusters, perhaps by merging and intense star formation, although only a handful to them are identified up to now. A protocluster 4C23.56 is at redshift z = 2.48, where a group of HAEs are found from the Subaru narrow band (NB) survey (MAHALO; MApping HAlpha and Lines of Oxygen with Subaru). The total number of the detected HAEs is 25 up to now (Tanaka *et al.*, in prep; Tanaka *et al.* (2011)). The protocluster is very unique in that it has various galaxy populations in addition to HAEs, e.g. distant red

galaxies (DRGs; Kajisawa *et al.* (2006)), extremely red objects (EROs; Knopp & Chambers (1997)), mid-infrared sources (Galametz *et al.* (2012), Mayo *et al.* (2012)) and that there are multi-wavelength ancillary data sets available. Sub-mm single dish telescope ASTE/AzTEC revealed that four of SMGs were overlapped with some HAEs (Suzuki *et al.* in prep; Zeballos *et al.* in prep). However, we could barely pin down the counterparts of SMGs at other wavelengths due to the coarse resolution with ASTE compared to other optical/NIR surveys as well as their redshifts. The overlap of SMGs suggests that dusty star bursts may be onset in HAEs making even the Hα emissions be diminished, leading the underestimation of SFRs. So, we targeted a protocluster associated to the radio galaxy 4C23.56 with Karl Jansky Very Large Array (JVLA) at S-band (2-4 GHz).

2. Results and conclusions

We have reached the r.m.s. level to detect HAEs having SFR $>$ 100 - 400 $M_{\odot}yr^{-1}$ (3σ) and, as a result, the detection number of JVLA counterparts was seven out of 25. We have also applied stacking analysis to reveal the averaged properties of undetected sources but no the features detected at 3σ. The figure 1 shows the correlation between 1.4 GHz radio continuum and Hα emission which was derived from JVLA 3 GHz (this work) and Subaru NB observations where we assumed radio spectral index $\alpha = 0.8$ to convert 3 GHz information to 1.4 GHz luminosity. We speculate five HAEs among the rest are undergoing dusty starbursts, of which SFRs have been underestimated. Otherwise, these would represent AGN. Adding the Spitzer/MIPS 24μm data and PdBI CO(5-4) observation, one HAE is likely to be undergoing a merger with a heavily obscured starburst. Differentiating the (dusty) starburst and the AGN for the rest will be remained as future works by doing SED fittings and comparison with X-ray observation (Lee *et al.* in prep). Further follow-up observations with ALMA/JVLA will provide more information on the physical properties on each galaxy in this protocluster and illuminate the processes how massive galaxy formation and evolution is affected by its surrounding environment.

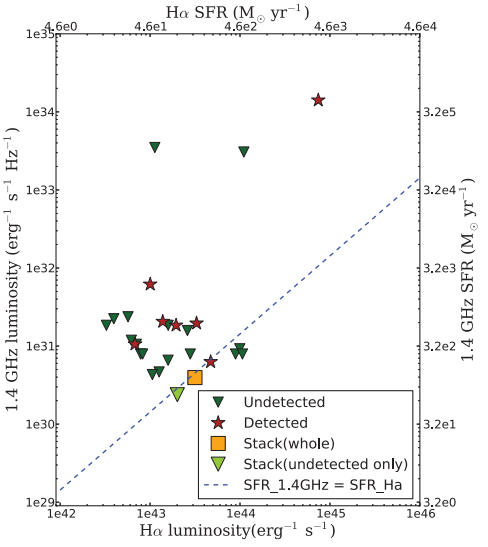

Figure 1. Radio and Hα emission corrleation of a protocluster associated with 4C23.56. The detection rate of HAE counterparts in radio is $\sim$30%. The radio galaxy 4C23.56 itself is on top right of this figure and well-above the correlation representing a radio excess by AGN. All JVLA detections of HAE counterparts, except for one is above the correlation which suggests dusty starbursts of HAEs and/or AGN.

References

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