A Universal Correlation between Star Formation Activity and Molecular Gas Properties across Environments

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In the local universe, it is well known that the fraction of early-type galaxies increases with local galaxy density, while that of late-type galaxies decreases [1]. This strong correlation between galaxy properties and environment suggests that the environment plays an important role in shaping the nature of individual galaxies. It is believed that accelerated galaxy growth and/or efficient quenching of star formation in high-density environments could explain the environmental difference, but the physical causes (or mechanisms) responsible for the environmental effects are still unclear.

In this study, we focused on the environmental impacts on molecular gas properties as the origin of environmental effect, and investigated the environmental dependence of the relation between star formation activity and molecular gas content. The galaxy sample were selected from SDSS DR7 spectroscopic data. We defined the galaxy environment based on the local number density of galaxies, which is expressed as

$$\Sigma_5 = \frac{5}{\pi D_{p,5}^2}\ [\mathrm{Mpc}^2] \qquad (1)$$

$$\rho_5 = \frac{\Sigma_5}{\langle \Sigma_5 \rangle} \qquad (2)$$

where $D_{p,5}$ is the projected comoving distance to the fifth-nearest neighbor galaxy within a redshift slice of $\Delta z = \pm 0.003$, and $\langle \Sigma_5 \rangle$ is the median density measured within the same redshift slice. As shown in Figure 1, we divided the sample into five environmental bins (D1–D5). We selected six to seven galaxies uniformly from D1–D5 and estimated the molecular gas mass by the CO(1–0) observations with NRO 45 m telescope. Further, by combining our sample and the COLDGASS data [2], which is the extragalactic CO survey with IRAM 30 m telescope, we could construct the CO catalog to cover a wide range in environment.

This allows us to conduct the first systematic study of environmental dependence of molecular gas properties in galaxies from the lowest- to the highest-density environments in the local universe. As a result, we confirmed that $f_{\mathrm{H_2}}$ have strong positive correlation with the SFR offset from the star-forming main sequence (ΔMS) and, most importantly, we found that these correlations are universal across all environments (Figure 2). This result demonstrated that star formation activity within individual galaxies is primarily controlled by their molecular gas content, regardless of their global environment [3].

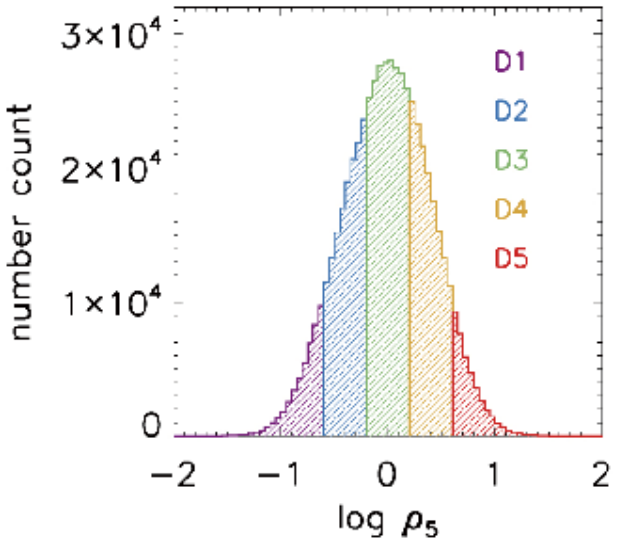

Figure 1: The distribution of ρ_5 for SDSS sample. Our definition of D1–D5 environment bins are shown with different color shades.

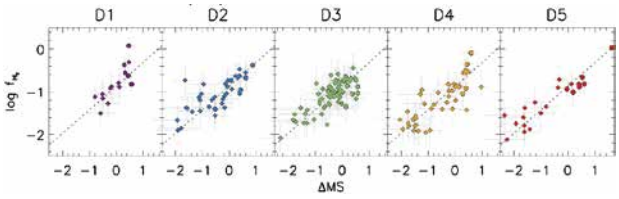

Figure 2: ΔMS–$f_{\mathrm{H_2}}$ relation for each environmental bin. For comparison, we show the best-fitting result for D3 bin as gray dotted lines in all of the panels.

References

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