The Gas Inflow and Outflow Rate in Star-Forming Galaxies at $z \sim 1.4$

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The gas flow into and out of galaxies have a significant impact on the formation and evolution of galaxies. The outflow of enriched gas causes the decrease of the gas metallicity (hereafter metallicity) of galaxies and results in a presence of the stellar mass-metallicity relation of galaxies. Feedback from outflows plays an important role for the star-formation activity and the structure formation of a galaxy. On the other hand, the inflow of gas into galaxies is relatively difficult to observe. In this work, we try to constrain the gas inflow and outflow rate of star-forming galaxies at $z \sim 1.4$ by employing a simple analytic model for the chemical evolution of galaxies. The sample is constructed based on a large near-infrared (NIR) spectroscopic sample observed with Subaru/FMOS [1].

The sample used in this work is originated from the K-band selected galaxy sample in the Subaru XMM-Newton Deep Survey and UKIDSS Ultra Deep Survey field (SXDS/UDS). We selected galaxies with $K \leq 23.9$ mag, phot-z of $1.2 \leq z_{ph} \leq 1.6$, the stellar mass of $M_* \geq 10^{9.5}\,M_\odot$, and the expected H$\alpha$ flux of $F(\mathrm{H}\alpha) \geq 5\times10^{-17}$ erg s^{-1} cm^{-2}. During the FMOS/GTOs, engineering runs, and open-use observations, ~1200 objects were observed by using FMOS with low resolution mode with the typical on-source exposure time of 3 – 4 hours. In total, significant Hα emission lines with signal-to noise ratio (S/N) $\geq$ 3 are detected from 343 objects [2,3].

The metallicity is derived from the [N II] λ6584/Hα emission line ratio. We use the calibration of N2 method [4]. The resulting metallicity ranges widely from ~0.3 to ~1.4 $Z_\odot$. The gas mass is estimated from the observed Hα luminosity by assuming the Kennicutt-Schmidt (K-S) law [5], where the SFR surface density (Σ_{SFR}) is calculated from the intrinsic Hα luminosity corrected for the dust extinction and r_{50} derived from the image in B-band as the galaxy size. The gas mass fraction (μ) is defined as $\mu = M_{gas}/(M_* + M_{gas})$, where M_{gas} and M_* are gas mass and stellar mass, respectively. The resulting gas mass fraction is widely distributed from ~0.2 to ~0.8 with the median value of 0.47.

We employ the least-χ^2 fittings for the observed gas mass fraction, stellar mass, and metallicity with a simple analytic model of chemical evolution of galaxies:

$$Z = \frac{y_Z}{f_i}\,\{1 - [(f_i - f_o) - (f_i - f_o - 1)\mu^{-1}]^{\frac{f_i}{f_i - f_o - 1}}\}, \quad (1)$$

where y_Z is a true yield, and f_i and f_o are infall and outflow rate which are normalized by the SFR, respectively, and

$$\mu = \frac{M^0_{gas} + (f_i - f_o - 1)M_*}{M^0_{gas} + (f_i - f_o)M_*}, \quad (2)$$

where M^0_{gas} is the initial primordial gas mass. The joint χ^2 fitting shows the best-fit inflow rate is ~1.8 and the outflow rate is ~0.6 in unit of star-formation rate (SFR).

By applying the same analysis to the previous studies at $z \sim 0$ and $z \sim 2.2$, it is shown that the both inflow rate and outflow rate decrease with decreasing redshift, which implies the higher activity of gas flow process at higher redshift. The decreasing trend of the inflow rate from $z \sim 2.2$ to $z \sim 0$ agrees with that seen in the previous observational and theoretical works with different methods, though the absolute value is generally larger than the previous works. The outflow rate and its evolution from $z \sim 2.2$ to $z \sim 0$ obtained in this work agree well with the independent estimations in the previous observational works.

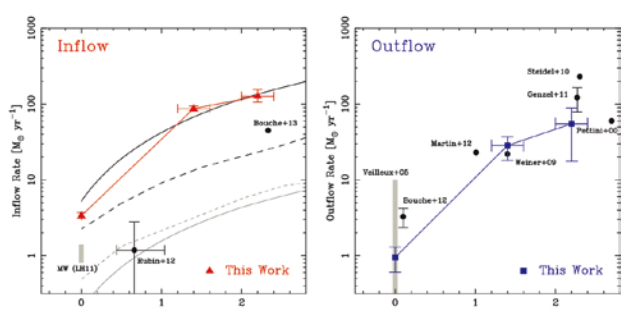

Figure 1: The best-fit inflow rate (left) and outflow rate (right) in unit of $M_\odot\,\mathrm{yr}^{-1}$ as a function of redshift. The results are compared to the previous results at various redshifts in theoretical and observational works.

References

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* belonged to NAOJ when the paper was published.