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Mass–metallicity relation for AKARI-FMOS infrared luminous galaxies at $z \sim 0.9$

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Abstract. We study the mass–metallicity relation and fundamental relation (FMR) for infrared bright galaxies (IR galaxies) at $z \sim 0.9$ discovered by AKARI NEP-Deep survey. The main result of this work is that metallicity of IR galaxies surprisingly match optical selected galaxies at a given mass even their star formation rates are different, which may imply that optical and IR selected galaxies follow similar star formation histories, and the starbursts in the IR galaxies do not give a strong impact in changing metallicity because of the short duration time.

Keywords. galaxies: evolution, galaxies: fundamental parameter (metallicity), infrared: galaxies

1. introduction

Heavy elements are synthesized in stars and return into the interstellar medium reflecting the results of the past star formation activity in a galaxy. Thus, the gas phase metallicity (Z) is a key parameter in understanding the processes of the formation and the evolution of a galaxy. Many investigations of stellar mass M_* and Z relation (MZ relation) and a relation among M_*, Z and Star Formation Rate (SFR) called a fundamental relation (FMR) have done up to $z \sim 3.3$. However, these relations only hold true to ultraviolet, optical, or near-IR selected star forming galaxies. Since most of star formations at high-z universe are hidden by dust, studying dusty galaxies is critical to fully understand the MZ relation and its evolution. Here, we investigate the MZ relation and FMR for IR galaxies at $z \sim 0.9$ discovered by AKARI NEP-Deep survey (NEPD).

2. Data and physical quantity

For selecting IR galaxies at $z \sim 0.9$, we started with the NEPD catalog (Murata *et al.*2013), which contains 11349 mid-IR sources with multiple wavelength (X-ray to far-IR) data with photometric redshift z_p calculated by Oi *et al.*(2014). We selected mid-IR sources detected at >2 of the three 11, 15, and 18μm AKARI bands and observed their Hα and [N II]λ6563 emission lines using Subaru/FMOS. The observation was carried out on June 20th and 21st, 2012. 354 sources were observed and Hα emission lines were identified from 25 sources. 17 of the sources show $>3\sigma$ [N II] emission line in their spectra.

We estimated M_* and IR luminosity (L_{IR}) by spectral energy distribution fitting with Chabrier (2003) IMF. SFR was calculated using a relationship with an intrinsic Hα luminosity (Kennicutt 1998) estimated with a linear combination of observed Hα luminosity and L_{IR} (Kennicutt *et al.*2009), and were converted to that using Chabrier IMF. Metallicity was determined from an empirical relation, $12+\log(O/H) = 8.90+0.57\log([N\,II]/H\alpha)$ calibrated by Pettini & Pagel 2004. Metallicity for the sources with $<3\sigma$ [N II] detection were calculated with values corresponding to 3σ as the upper limits.

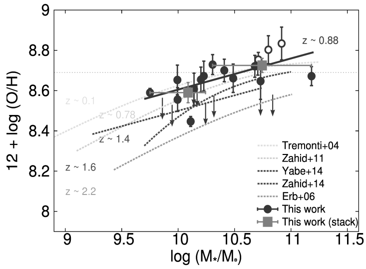

Figure 1. The MZ relation for 25 IR galaxies. Circles and arrows show individual sources in our sample and squares represent stacking results. Dashed lines are the MZ relations at various redshifts.

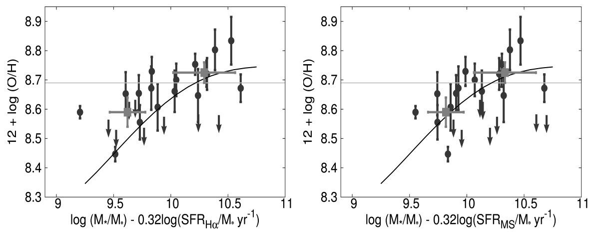

Figure 2. The Z vs. log(M_*)−0.32log(SFR). SFRs in the left are measured with observed Hα luminosity and L_{IR}, while the values in the right are estimated using a relation with M_* at $z \sim 0.78$ by Zahid *et al.*(2012).

3. MZ relation and FMR

We plotted Z against M_* of our sample with relations of normal galaxies at various redshifts as comparison (Fig. 1). The metallicity measured sources (>3σ) show a clear trend between M_* and Z (thick solid line). We found that the relation is consistent with the normal galaxies at $z \sim 0.1$, suggesting that these IR galaxies are already chemically evolved to the local galaxy level. By contrast, average metallicities of our sample (results of stacking analysis) are rather consistent with that of $z \sim 0.78$ (Zahid *et al.*2012) which is the closest to the redshift of this work among the other data in the literature.

In the left panel of Fig. 2, we plotted our data on the FMR (solid line). There is a discrepancy between the IR galaxies with their SFRs and the FMR. On the other hand, when SFRs of the main-sequence galaxies are used, our sample surprisingly matches with the FMR (right panel of Fig. 2). Thus, the IR galaxies have similar metallicities at a given M_* even their SFRs are significantly higher compared with those of optical selected normal galaxies. The results might indicate that optical and IR selected galaxies follow similar star formation histories, and since the starbursts in the IR galaxies are temporal phenomena, these star-formation do not give a strong impact in changing galaxies' properties such as Z and M_*.

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