Energy Diagnostics of Nearby Luminous Infrared Galaxies Using ALMA

IMANISHI, Masatoshi, NAKANISHI, Kouichiro
(NAOJ)

Luminous infrared galaxies (LIRGs) are formed by gas-rich galaxy mergers. Their large infrared luminosities are powered by starburst and/or supermassive-blackhole-driven, active galactic nucleus (AGN) activity in dust-obscured regions. To investigate the nature of these dust-obscured energy sources of LIRGs, observations at the wavelengths of low dust extinction are crucial. An AGN has two important different properties, when compared to starburst activity. First, an AGN has much higher emission surface brightness, and so produces a larger amount of hot (several 100 K) dust, than a starburst. Second, the X-ray to UV luminosity ratio is higher in an AGN than a starburst. Due to these different properties, AGN and starburst can have different physical/chemical effects to the surrounding molecular gas, and so can produce different molecular line flux ratios. Since rotational transition lines of molecules are found at the almost dust-extinction-free (sub)millimeter wavelength, emission line flux ratios of multiple molecules could be a powerful tool to scrutinize dust-obscured energy sources of LIRGs. Since molecular gas in LIRGs is usually at high density, observations of molecules with high dipole moments, such as HCN, HCO^+, and HNC, are useful to investigate the physical properties of LIRGs. We have conducted HCN, HCO^+, HNC J = 4–3 observations, at the submillimeter 350 GHz range, of six LIRGs whose energy sources were diagnosed based on previously obtained infrared spectra [1]. Our primary aim is to confirm the dichotomy of molecular line flux ratios as a function of primary energy source (i.e., AGN or starburst), and to investigate if this method is effective to scrutinize unknown dust-obscured energy sources of distant LIRGs.

Figure 1 shows an example of ALMA data. Figure 2 plots the observed molecular line flux ratios. Among five sources marked with filled stars, four (except IR22491) were diagnosed to be buried-AGN important, and tend to show higher HCN/HCO^+ J = 4–3 flux ratios than starburst-dominated regions in the LIRG, NGC 1614 (marked with filled circles). This HCN flux enhancement in AGNs could be qualitatively explained by widely proposed scenarios of (1) HCN abundance enhancement, relative to HCO^+, in an AGN, (2) HCN J = 4–3 flux enhancement by infrared radiative pumping, in addition to collisional excitation, and (3) more HCN J = 4–3 excitation (higher critical density than HCO^+ J = 4–3) in an AGN than a starburst. The energy source of the remaining one LIRG (IR22491) is still uncertain. In this LIRG, further investigations are required, because its molecular line flux ratio could be largely affected by galaxy-wide turbulence, as inferred from its large molecular line width [1]. Future ALMA observations of other LIRGs with known energy sources at other rotational transition lines are needed to confirm the effectiveness of molecular line flux ratios as the method of energy diagnostics of LIRGs and to understand the physical origin of the observed molecular line flux ratios.

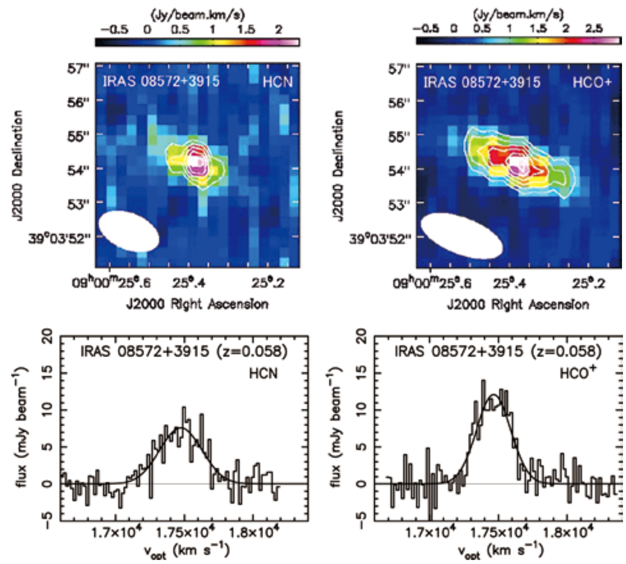

Figure 1: Integrated intensity maps (Top) and spectra (Bottom) of the LIRG, IRAS 08572+3915. (Left): HCN J = 4–3, (Right): HCO^+ J = 4–3. In the integrated intensity maps, the filled elliptical circles at the lower-left parts represent ALMA beam sizes. In the spectra, the ordinate is flux (mJy beam^{-1}) and the abscissa is optical velocity (km s^{-1}).

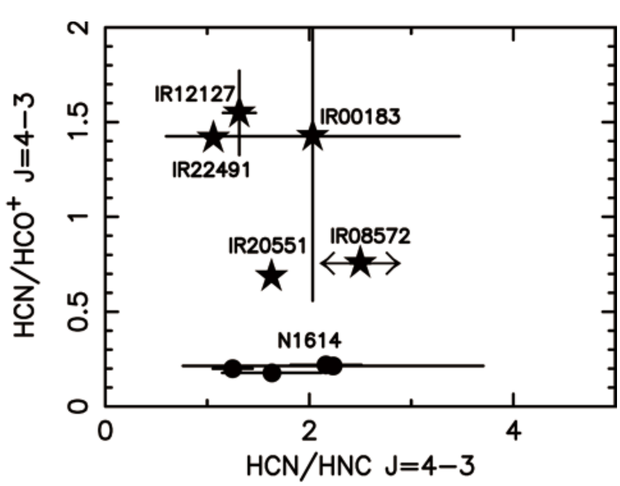

Figure 2: Molecular line flux ratios of LIRGs obtained in our ALMA Cycle 0 data. The abscissa is HCN/HNC J=4–3 flux ratio, and the ordinate is HCN/HCO^+ J=4–3 flux ratio.

Reference

[1] Imanishi, M., Nakanishi, K.: 2014, *AJ*, **148**, 9.