Dense Molecular Gas Emission and Infrared Radiative Pumping in the Ultraluminous Infrared Galaxy IRAS 20551−4250

IMANISHI, Masatoshi, NAKANISHI, Kouichiro (NAOJ)
IZUMI, Takuma (University of Tokyo)

Ultraluminous infrared galaxies (ULIRGs) which emit huge infrared luminosity with $L_{IR} > 10^{12} L_{\odot}$ are usually produced by gas-rich galaxy mergers and are shining brightly due to dust thermal radiation heated by starburst and/or AGN activity hidden behind dust. Distinguishing the hidden energy sources of the ULIRG population is closely related to understand how stars are formed and supermassive blackholes grow in mass during gas-rich galaxy mergers in the universe. Since the compact AGN can easily be embedded in dust, we need to observe at the wavelengths where dust extinction effects are small. (Sub) millimeter is one such wavelength and molecular line flux ratios in this wavelength can be a good tool to probe the highly embedded energy sources in ULIRGs, because the ratios are expected to be different between AGNs and starbursts, due to different physical/chemical effects to the surrounding molecular gas, coming from different amount of hot dust and X-ray radiation. Molecular gas observations, such as HCN, HCO^+, and HNC have been conducted for nearby ULIRGs, and it has been argued that elevated HCN emission can be a good AGN indicator.

Possible explanations for the enhanced HCN emission in AGNs include (1) higher HCN abundance in molecular gas largely influenced by AGN radiation, and (2) higher HCN excitation in AGNs. Additionally, it was proposed that an infrared radiative pumping can contribute. Namely, HCN is vibrationally excited by absorbing infrared 14 μm photons, and through the decay back to the vibrational ground level, HCN rotational J-transition line fluxes can be higher. Since an AGN can emit the infrared 14 μm photons more strongly than a starburst, due to AGN-heated hot dust emission, this mechanism is expected to work more efficiently in an AGN. However, HCO^+ and HNC can also be vibrationally excited by absorbing infrared 12 μm and 22 μm photons, respectively. We need to investigate the strengths of vibrationally excited emission lines for all of HCN, HCO^+, and HNC, if we are to confirm if this mechanism is indeed responsible for elevated HCN emission in AGNs.

We have observed the ULIRG, IRAS 20551–4250, using ALMA (Figure 1), and detected vibrationally excited (v_2=1f) J=3–2 emission lines for HCN and HNC, but did not for HCO^+ (Figure 2). We calculated an infrared radiative pumping rate for HCN, HCO^+, and HNC, by using the available Spitzer IRS 5–35 μm infrared spectrum, and found that observational results can be explained if HCN abundance is higher than HCO^+ and HNC by a factor of at least a few. Based on the vibrational excitation temperature and Einstein A coefficients for vibrational and rotational transitions, we estimated that the infrared radiative pumping plays a role for rotational level population at least for HCN and HNC [1]. It is demonstrated that including the infrared radiative pumping, in addition to the widely assumed collisional excitation, is needed to understand molecular gas emission in AGNs.

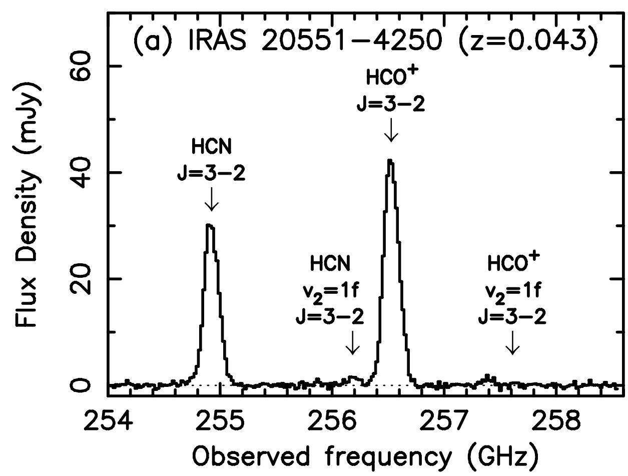

Figure 1: Spectrum of IRAS 20551–4250 obtained with ALMA [1]. Although the HCN-to-HCO^+ J=3–2 flux ratio is slightly less than unity, it is still higher than starburst galaxies.

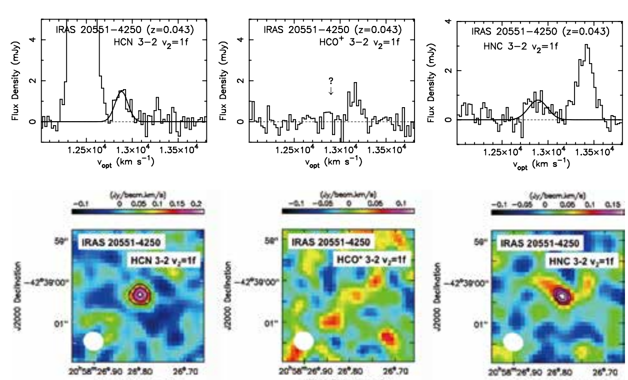

Figure 2: Spectra and integrated intensity maps of vibrationally excited (v_2=1f) J=3–2 emission lines of HCN (Left), HCO^+ (Middle), and HNC (Right) [1].

Reference

[1] Imanishi, M., et al.: 2016, *ApJ*, **825**, 44.