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Dense Molecular Gas and H_2O Maser Emission in Galaxies

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Abstract. Extragalactic H_2O masers have been found in dense gas circumstance in off-nuclear star formation regions or within parsecs of Active Galactic Nuclei (AGNs). HCN molecular (one of the best dense gas tracers) Emission has been detected in more than 60 galaxies. For HCN-detected galaxy sample, the relation of maser and gas emission was investigated here to identify physical observable properties that differentiate maser and non-maser galaxies. Our analysis results show that there is no significant difference on the infrared and gas emission between maser galaxies and galaxies without maser detection. For maser host HCN-galaxies, maser luminosity is found to be correlated to CO luminosity (a proxy of the total molecular gas) and HCN luminosity, i.e., kilomasers ($L_{H_2O} < 10L_\odot$) with low maser luminosity having low gas emission luminosity, with respect to megamasers ($L_{H_2O} > 10L_\odot$). For normalized maser and HCN luminosity (for removing distance effect), the correlation is still apparent. However, for normalized maser and CO luminosity, the correlation disappeared completely. Thus one proposition that the amount of dense molecular gas should be a good tracer of H_2O maser emission can be made.

Key words. Maser—dense gas—tracer.

1. Introduction

Since H_2O masers were found to be originated in dense gas circumstance, dense gas may be a good tracer of H_2O maser formation (e.g., Lo 2005; Zhang *et al.* 2010). HCN is one of the best tracers of dense gas, since it is one of the most abundant high dipole-moment molecules, which requires about 2 orders of magnitude higher densities for collisional excitation than CO (Gao & Solomon 2004). The largest and the most sensitive HCN survey (complemented with CO observations) to date was performed by Gao & Solomon (2004) and HCN $J = 1-0$ emission was detected from 52 galaxies. Before that, there are just 12 detections. For all HCN-detected galaxies, we identify three types of H_2O line emission: H_2O megamasers, H_2O kilomasers and H_2O non-detections. Here gas properties of these three types were analysed and compared.

2. Sample and analysis

All 62 HCN-detected galaxies with their corresponding data were collected, including luminosity distance, infrared luminosities, HCN emission luminosities, and the isotropic maser luminosities. We also checked their observations for searching H_2O maser line emission ($J_{K_aK_c} = 6_{16} - 5_{23}$, $\lambda \sim$1.3 cm). All 62 sources have been observed and there were 7 megamasers, 7 kilomasers, and 48 non-detections.

2.1 *Dense gas emission of H_2O maser and non-maser galaxies*

Figure 1 shows the correlations for L_{IR} with L_{CO} (left panel) and L_{HCN} (middle) for HCN galaxy sample and we sort the samples by H_2O type: megamasers, kilomasers and non-detections. No obvious difference on gas emission could be found between maser and non-maser galaxies, which show similar distributions of HCN and CO emission luminosities. To remove distance effect, both L_{IR} and L_{HCN} normalized by L_{CO} were plotted (right panel of Fig. 1). The results were similar and there were no significant difference between maser galaxies and galaxies without maser detection. However, kilomaser sources (empty squares) tend to locate at regime with lower gas emission luminosity, relative to megamaser sources.

2.2 *Dense gas vs. maser emission*

As analysed above, the kilomaser galaxies tend to have low gas emission than megamasers. To analyse it further, we plotted H_2O maser isotropic luminosity and CO (left panel of Fig. 2) and HCN luminosity (middle) for HCN galaxy sample with maser detection. The correlation is significant for both figures, i.e., rising maser luminosity with increasing gas luminosity. Megamasers tend to have stronger gas emission than kilomasers. To remove distance effect on the correlation, both $L_{\mathrm{H_2O}}$ and L_{HCN} normalized by L_{CO} and $L_{\mathrm{H_2O}}/L_{\mathrm{CO}}$ was plotted against $L_{\mathrm{HCN}}/L_{\mathrm{CO}}$ (dense gas fraction)

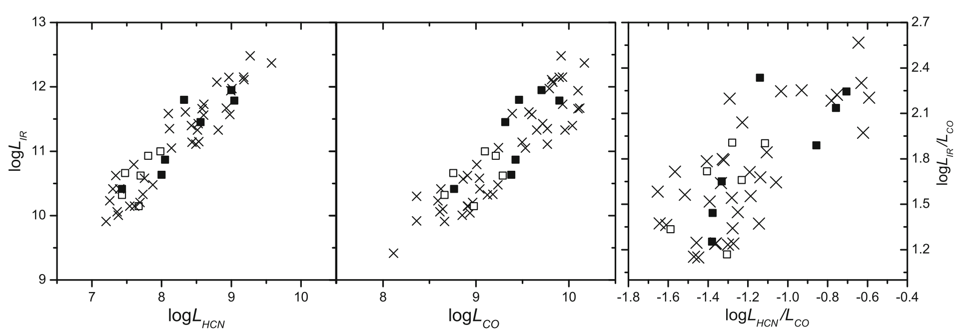

Figure 1. *Left*: L_{IR} vs. L_{HCN}; *Middle*: L_{IR} vs. L_{CO} (logarithm scale, in $L_\odot$); *Right*: $L_{\mathrm{IR}}/L_{\mathrm{CO}}$ (a proxy for star formation efficiency) vs. $L_{\mathrm{HCN}}/L_{\mathrm{CO}}$ (dense gas fraction) in HCN-detected galaxies with known H_2O properties. Megamasers, kilomasers and non-detections are denoted by filled squares, empty squares and cross symbols, respectively.

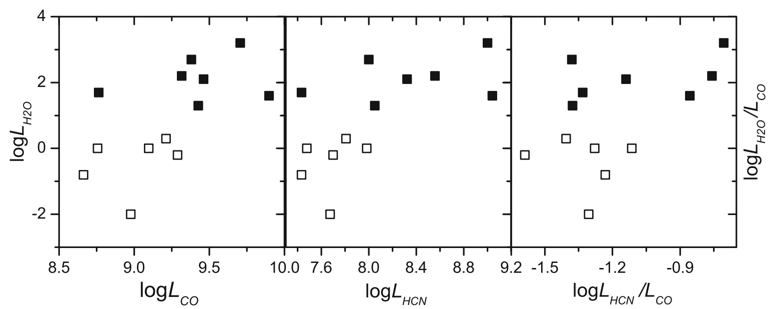

Figure 2. *Left*: H_2O maser vs. CO luminosity. *Middle*: H_2O maser vs. HCN luminosity (logarithm scale). *Right*: Normalized maser luminosity (L_{H_2O}/L_{CO}) vs. dense gas emission (L_{HCN}/L_{CO}). Symbols are identical to those used in Fig. 1.

in Fig. 2(right). Similar trend is still apparent, i.e., kilomasers tend to have lower dense gas emission than megamasers. However, for normalized maser and CO luminosity, the correlation disappeared completely. Thus, we propose that one good tracer of H_2O maser emission is the amount of dense gas, instead of the total molecular gas in maser host galaxy.

3. Summary

All HCN-detected galaxies with H_2O maser properties are investigated here. Our analysis results show: (1) No significant difference in the infrared and gas emission between maser and non-maser galaxies; (2) We proposed that H_2O maser emission is physically related to the amount of dense gas, instead of the total molecular gas in the maser host galaxy. Larger sample is helpful to confirm it.

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