NRO M33 All-Disk Survey of Giant Molecular Clouds (NRO MAGiC): II. Dense Gas Formation within Giant Molecular Clouds in M33

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We have conducted observations of the ^{12}CO(J=1–0) and ^{12}CO(J=3–2) line emission of 74 major giant molecular clouds (GMCs) within the galactocentric distance of 5.1 kpc in the Local Group galaxy M33 [1]. The observations are part of the Nobeyama Radio Observatory M33 All-disk survey of Giant Molecular Clouds project (NRO MAGiC [2]). The spatial resolution is 100 pc.

We detect ^{12}CO(J=3–2) emission of 65 GMCs successfully. The ^{12}CO(J=1–0) and ^{12}CO(J=3–2) integrated intensity ratio $R_{3-2/1-0}$ is spread over a wide range from less than 0.1 to 0.74, having a weighted mean of $R_{3-2/1-0}$ = 0.26. This weighted mean is slightly smaller than that of the quiescent disk region of the Milky Way. Furthermore, we find that the correlation between the surface density of the star formation rate (Σ_{SFR}), which is derived from a linear combination of Hα and 24 μm emissions, and the ^{12}CO(J=3–2) integrated intensity still holds at the scale of 100 pc (Figure 1), although the correlation between $I_{CO(1-0)}$ and Σ_{SFR} is not obvious, as we have already shown in the preceding paper [3]. This result show that the star-forming activity is closely associated with warm and dense gases that are traced with the ^{12}CO(J=3–2) line, even in the scale of GMCs.

We also find that the GMCs with a high star-forming activity tend to show a high value of $R_{3-2/1-0}$. Moreover, we also observe a mass-dependent trend of $R_{3-2/1-0}$ for the GMCs with a low star-forming activity (Figure 2). From these results, we speculate that the $R_{3-2/1-0}$ values of the GMCs with a low star-forming activity mainly depend on the dense gas fraction and not on the temperature, and therefore, the dense gas fraction increases with the mass of GMCs, at least in the GMCs with a low star-forming activity.

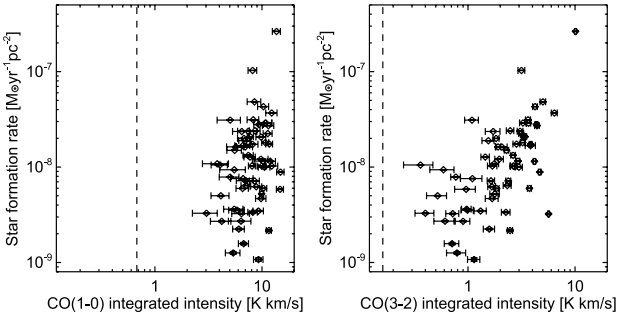

Figure 1: The surface density of SFR (Σ_{SFR}) versus $I_{CO(1-0)}$ and $I_{CO(3-2)}$ at the $T_{CO(1-0)}$ peak position in each GMC. The dashed lines indicate the sensitivity limits for each CO line. Correlation coefficients are 0.22 and 0.68, respectively.

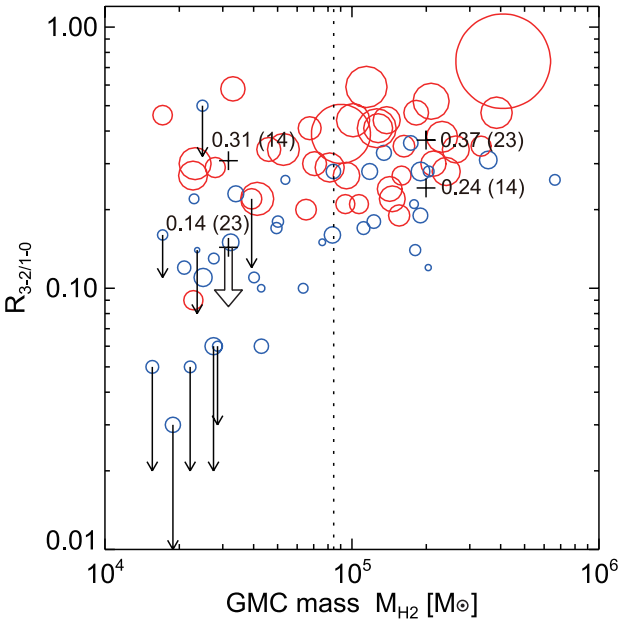

Figure 2: GMC mass versus $R_{3-2/1-0}$. The area of the circles is set proportionally to Σ_{SFR} at the $T_{CO(1-0)}$ peak position of each GMC. The red circles represent GMCs with $\Sigma_{SFR} > 1\times10^{-8}\,M_\odot\,pc^{-2}$, and the blue ones indicate those with $\Sigma_{SFR} < 1\times10^{-8}\,M_\odot\,pc^{-2}$. The dotted line indicates the criterion of $M_{H2} = 8.4\times10^4\,M_\odot$. The black crosses and the numbers next to them stand for the averaged $R_{3-2/1-0}$ values in each mass-bin, which are taken for GMCs with higher and lower star-forming activity, respectively. The numbers in the bracket are the numbers of the GMCs used for averaging. For GMCs whose ^{12}CO(J=3–2) emissions are not detected, $R_{3-2/1-0}$ is shown as the upper limit, with an arrow whose length is the rms value of $R_{3-2/1-0}$.

References

[1] Onodera, S., et al.: 2012, *PASJ*, **64**, 15.
[2] Tosaki, T., et al.: 2011, *PASJ*, **63**, 1171.
[3] Onodera, S., et al.: 2010, *ApJ*, **722**, L127.