R04a ALMA deep $^{12}C^{17}O(1–0)$ and $^{12}C^{18}O(1–0)$ imaging reveals hidden, short time-scale star formation in the Seyfert galaxy NGC 1068

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We report the first mapping of $^{12}C^{18}O(1–0)/^{12}C^{17}O(1–0)$ intensity ratio of the starburst (SB) ring in NGC 1068 using ALMA. In theory, intensity ratio of $^{12}C^{18}O/^{12}C^{17}O$ is thought to evolve during star formation with a time scale of $\sim$100 Myr. Then the ratio can trace star formation activity with a short time scale hidden by dust. However, while $^{12}C^{16}O$, $^{13}C^{16}O$, and $^{12}C^{18}O$ lines have been investigated for galaxies in the local and distant Universe, $^{12}C^{17}O$ has not been studied well yet because of its faint brightness.

Combining all available ALMA Band-3 spectral data for NGC 1068, we obtain the high quality $^{12}C^{18}O(1–0)/^{12}C^{17}O(1–0)$ ratio map of the SB-ring with a spatial resolution of 60 pc. Then, we study the $^{12}C^{18}O(1–0)/^{12}C^{17}O(1–0)$ ratio in relation to ALMA $^{13}C^{16}O(1–0)/^{12}C^{18}O(1–0)$ intensity ratio, a metallicity indicator O3N2, and surface star formation rate density (Σ_{SFR}) derived from MUSE optical spectral cube data, aiming to investigate the nature of $^{12}C^{17}O$. We obtain the following results. (1) The $^{12}C^{18}O(1–0)/^{12}C^{17}O(1–0)$ ratio distribution is characterized by a median of $2.2^{+0.4}_{-0.3}$ with a 16–84 percentile from $0.89^{+0.14}_{-0.11}$ to $4.2^{+0.5}_{-0.4}$, which is inconsistent with that of the Galaxy. It also shows a different behavior from the $^{13}C^{16}O(1–0)/^{12}C^{18}O(1–0)$ intensity ratio. (2) The O3N2 and Σ_{SFR} evolves with the $^{12}C^{18}O(1–0)/^{12}C^{17}O(1–0)$ ratio. These facts suggest that the observed variation of $^{12}C^{18}O(1–0)/^{12}C^{17}O(1–0)$ ratio traces the dynamical local star formation activity.