URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

Molecular gas physical conditions in the central kpc of M 83

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Molecular gas plays an important role in galaxy evolution because it fuels the formation of stars, which is an essential process in the evolution of galaxies. Thus, deciphering how the physical conditions of molecular gas, such as volume density ($n_{\mathrm{H_2}}$) and kinetic temperature (T_{k}), regulate star formation is crucial for a better understanding of galaxy evolution. The region of interest is the central kpc of a nearby, face-on, barred-spiral galaxy M 83 ($r \lesssim 500$ pc). Active star formation has been reported in the northwestern orbit intersection where the northern dust lane joins the circumnuclear ring, while the southeastern orbit intersection has almost no sign of star formation. CO multi-line excitation analysis is performed within the region to probe the physical conditions of the gas, and investigate whether the variation in star formation is an effect of physical conditions. We used the archival data of $\mathrm{CO}(J=1-0)$, $\mathrm{CO}(J=2-1)$, and $^{13}\mathrm{CO}(J=1-0)$ lines observed by the Atacama Large Millimeter/submillimeter Array (ALMA) at the resolution of $2''$, corresponding to ~ 40 pc at the distance of the galaxy. Two intensity ratios: $I_{^{12}\mathrm{CO}(J=2-1)}/I_{^{12}\mathrm{CO}(J=1-0)}$ $(\equiv R_{21})$ and $I_{^{13}\mathrm{CO}(J=1-0)}/I_{^{12}\mathrm{CO}(J=1-0)}$ $\left(\equiv R_{13/12}\right)$ are then compared with non-local thermodynamic equilibrium (non-LTE) radiative transfer models computed using `RADEX` software [1] to probe the best-fitting $n_{\mathrm{H_2}}$ and T_{k} which satisfies the observed intensity ratios.

We found the typical pressure $P/k\ (= n_{\mathrm{H_2}} T_{\mathrm{k}}) \sim 10^5\,\mathrm{K\,cm^{-3}}$ for clouds in this region, and no significant difference in $n_{\mathrm{H_2}}$, T_{k} between locations with active star formation and no star formation as traced by H41α emission. A previous study [2] suggested that the star formation activity near the northwestern orbit intersection is mainly induced by cloud-cloud collision rather than self-gravity. Meanwhile, the southeastern orbit intersection lacks star formation because there may be less gas supply and less frequent cloud collisions, making it difficult for stars to form. Our results then support the abovementioned scenario, in which cloud-cloud collisions compress the gas, form filamentary structures and further lead to star formation [3]. Filamentary structures form at a small spatial scale, which is unlikely to be observable at the adopted resolution. In the southeastern orbit intersection and the southern dust lane, we found that some clouds are denser although there is no trace of star formation. We conclude that the star formation in the northwestern orbit intersection is collision induced, and at this resolution, the variation in physical conditions of the gas related to star formation cannot be found.

References

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