Resolving the Rise and Fall of Star Formation in Galaxies
Proceedings IAU Symposium No. 373, 2023
T. Wong & W.-T. Kim, eds.
doi:10.1017/S1743921322004926

Parsec scale CO depletion in KAGONMA 71, or a star-forming filament in CMa OB1

T. Handa[1,2], Y. Hirata[2], T. Murase[2], J. Nishi[2], Y. Shimajiri[3], T. Omodaka[2], M. Nakano[4], K. Sunada[5], T. Ito[1,6] and J. O. Chibueze[7,8]

[1]Amanogawa Galaxy Astronomy Research Center, Kagoshima Univ., 1-21-35 Korimoto, Kagoshima 890-0065, Japan
email: handa@sci.kagoshima-u.ac.jp

[2]Faculty of Science, Kagoshima Univ., 1-21-35 Korimoto, Kagoshima 890-0065, Japan

[3]ALMA project, National Astron. Obs. Japan, 1-21-3 Osawa, Mitaka 181-8588, Japan

[4]Faculty of Education, Oita University, 700 Dannoharu, Oita 870-1192, Japan

[5]Mizusawa VLBI Obs., National Astron. Obs. Japan, Hoshigamine, Oshu-shi 2531, Japan

[6]Kuamoto Univ. Kumamoto, Japan

[7]Centre for Space Research, North-West Univ., Potchefstroom 2531, South Africa

[8] Department of Phys. and Astron., Faculty of Physical Sci., Univ. of Nigeria, Carver Building, University road, Nsukka 410001, Nigeria

Abstract. The depletion of CO molecules is observed in infrared dark clouds. However, only few exsamples are found in pc-scale. An NH_3 emission is one of good counter parts of $C^{18}O$ because of similar effective critical density. Our NH_3 observations of a molecular filament associated with CMa OB1 or KAG 71, which is a target of Kagoshima Galactic Object survey with Nobeyama 45-m telescope by Mapping in Ammonia lines (KAGONMA) project. Although NH_3 data shows similarity in morphology with infrared data suggesting no depletion, $C^{18}O$ in the clumps 4 and 6 are weaker than expected based on NH_3 data. After examining the dissipation of the high-density gas, photodissociation, and depletion, we concluded that CO is depleted at least in the clump 4. It is a new example of depletion in pc-scale.

Keywords. ISM: abundances, ISM: clouds, ISM: molecules

1. Introduction

Although $C^{18}O$ is often used to estimate the column density of dense molecular gas, previous works reported depletion of CO molecules (e.g. Feng et al. 2020; Sabatini et al. 2019). To investigate such depletion in pc scale, a dense gas tracer less depleted, such as NH_3 is helpful. And NH_3 is one of the best counter part of $C^{18}O$ because of the similar effective critical density; both of which are about 2×10^3 cm^{-3}. From 72 objects of KAGONMA (Kagoshima Galactic Object survey with Nobeyama 45-m telescope by Mapping in Ammonia lines) project, we investigate the depletion in KAG 71, or a molecular filament associated with CMa OB1.

2. Observations & data

We made NH_3 observations in $(J, K) = (1, 1), (2, 2), (3, 3)$ transitions as a part of KAGONMA project, simultaneously. The telescope beam size is 75″ and the mapping

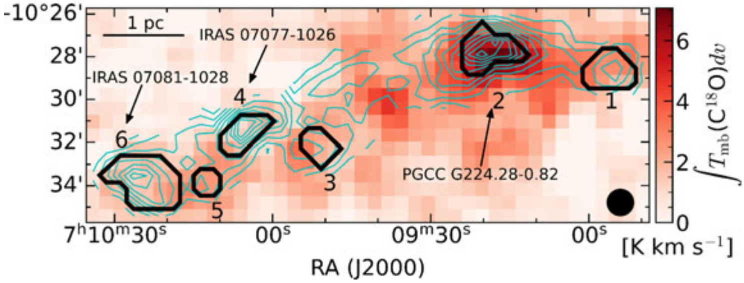

Figure 1. $NH_3(1,1)$ intensity map over FUGIN $C^{18}O$ intensity image smoothed to NH_3 beamsize. Black enclosures are the clumps 1 to 6 from east to west.

area covers about $26' \times 10'$ for the filament. To estimate the intensity distributions of CO, we used ^{12}CO and $C^{18}O$ data from FUGIN (Umemoto et al. 2017) and the map observed with Mopra 22-m telescope (Olmi et al. 2016). The spatial and velocity resolutions of FUGIN are $20''$ and 1.3 km s^{-1}, respectively. Those of Mopra observations are $38''$ and 0.09 km s^{-1}. In many investigations dust continuum flux is used to estimate the gas column density $N(H_2)$. We, therefore, used Hi-GAL data observed with *Herschel* (Molinari et al. 2010). The spatial resolutions are between $12.6''$ and $36.7''$ at 160 and 500 μm.

3. Results

We made the intensity distributions of NH_3 and $C^{18}O$ smoothed to be the same beamsize (fig. 1). Based on DENDROGRAM analysis (Rosolowsky et al. 2008), we identified 6 clumps in NH_3 map. We call the clumps 1 to 6 from east to west. We also made maps of the integrated intensity of $NH_3(1, 1)$ and the H_2 column density, $N(H_2)$, estimated from *Herschel* data (fig. 2(a)). The similarity of NH_3 intensity and $N(H_2)$ distributions suggests both the relative abundance of NH_3, $X(NH_3)$ and gas-to-dust ratio are almost constant in this filament. We made the map of gas kinetic temperature, T_k, from our NH_3 data (fig. 2(b)). It shows $T_k \sim 12$ K and ~ 17 K in the clumps 2 and 4, respectively. We made the distribution of $X(NH_3)$ and it is almost uniform (fig. 2(c)). However, the abundance of $C^{18}O$, $X(C^{18}O)$ estimated from Mopra data is not uniform (fig. 2(d)).

To confirm it we made the correlation plot between the intensities in $NH_3(1, 1)$ and $C^{18}O$ lines from FUGIN (fig. 3). Most plots are along the strait line through the origin. It means $X(C^{18}O)$ is almost constant there. However, in the clumps 4 and 6, $C^{18}O$ intensity does not increase but slightly decreases against NH_3 intensity. In the clump 2, $C^{18}O$ intensity is higher than in the clumps 4 and 6, but smaller than the proportional line expected by overall trend.

4. Discussion

We interpret the weakness of the emission is due to depletion of $C^{18}O$ molecule on dust grains. We considered two other mechanisms shown below, but they are not the case.

(a) low volume density; dense enough to emit the N_2H^+ line (Tatematsu et al. 2017).
(b) destruction of CO molecules by UV radiation; it also destructs NH_3.

Therefore, we conclude that CO molecule is actually depleted on dust grains. The size of our clumps where we found the depletion is in pc scale.

To evaluate the degree of depletion, we define the relative depletion factor, f^{R}_{dep}, by the reciprocal value of the relative abundance of each pixel normalized by the maximum over

https://doi.org/10.1017/S1743921322004926 Published online by Cambridge University Press

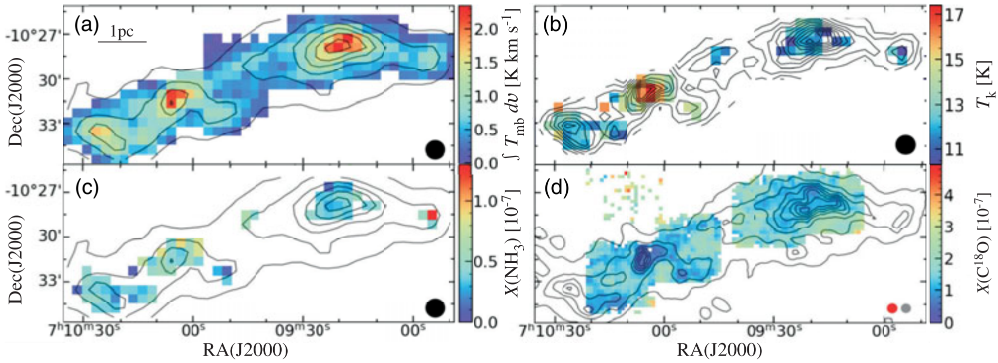

Figure 2. (a) The contour map of the column density, $N(H_2)$, estimated from *Herschel* data smoothed to NH_3 beamsize overlaid on an image of the integrated intensity of $NH_3(1,1)$ line. (b) Gas kinetic temperature image and a contour map of the integrated intensity of $NH_3(1,1)$ line. Clumps 2 is cold & 4 is warm. (c) an relative abundance image of $NH_3(1,1)$. The contour map is the contours in panel (a). (d) relative abundance image of $C^{18}O$ using dust $N(H_2)$ with the contours of $N(H_2)$.

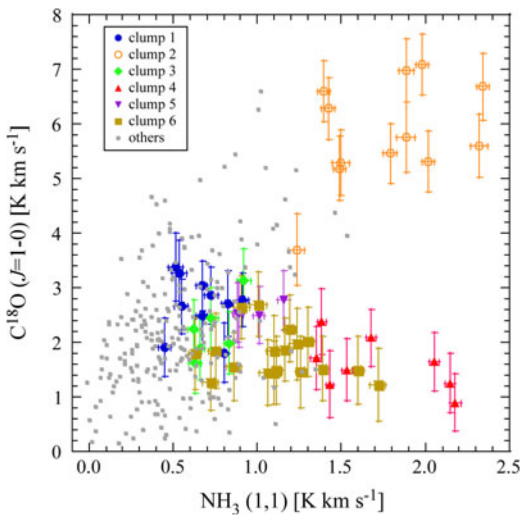

Figure 3. NH_3(1,1) – $C^{18}O$ (J=1–0) integrated intensity correlation plot of the each clump and observed positions.

the filament. In the clump 2, $f^{R}_{dep} \simeq 2$ and in the clump 4, $f^{R}_{dep} \simeq 6$. They are different by a factor of 3. What makes this difference? Both temperature and density are similar; the dust temperatures in the clumps 2 and 4 are about 12 and 16 K, respectively, and the volume densities of H_2 of them using a spherically symmetric clump model are 4×10^4 and 6×10^4 cm^{-3}, respectively. To the contrary, the clump 2 have 3 YSO candidates over 100 $L_\odot$, although the clump 4 has none. Therefore, the photodesorption may prevent to CO depletion on dust.

References

Feng S., Li, D., Caselli P., *et al.* 2020, ApJ 901, 145.

Molinari S., Swinyard B., Bally J., *et al.* 2010, A&A 518, L100.

https://doi.org/10.1017/S1743921322004926 Published online by Cambridge University Press

Olmi L., Cunningham M., Elia D. Jones P. 2016, A&A 594, A58.
Rosolowsky E.W., Pineda J. E., Kauffmann J., Goodman A.A. 2008, ApJ 679, 1338.
Sabatini G., Giannetti A., Bovino S., *et al.* 2019, MNRAS 490, 4489.
Tatematsu K., Liu T.; Ohashi S., *et al.* 2017, ApJS 228, 12.
Umemoto T., Minamidani T., Kuno N., *et al.* 2017, PASJ 69, 78.