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# Searching for methylamine in Orion-KL using ALMA archival data

**Harumi Minamoto**[1], **Yoko Oya**[2], **Hirota Tomoya**[3] **and Hideko Nomura**[1]

[1]Department of Earth and Planetary Sciences, Tokyo Institute of Technology,
2-12-1 Ookayama, Meguro-ku, Tokyo 152-8551, Japan,
email: minamoto.h@eps.sci.titech.ac.jp

[2]Department of Physics, The University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, email: oya@taurus.phys.s.u-tokyo.ac.jp

[3]National Astronomical Observatory of Japan,
2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan, email: tomoya.hirota@nao.ac.jp

**Abstract.** Methylamine ($CH_3NH_2$) is the simplest amine and thought to be a potential interstellar precursor to the amino acid glycine ($NH_2CH_2COOH$). It is confirmed by the experimental work and in terms of exploration in the Solar system, $CH_3NH_2$ has been detected in two comets. However, in molecular clouds, a robust detection of $CH_3NH_2$ has been reported only for Sgr B2(N) so far, while a variety of complex organic molecules have been detected by radio observations in many star-forming regions. To search for $CH_3NH_2$, we used the ALMA Cycle 2 archival data toward Orion Kleinmann-Low nebula (Orion-KL) at Band 6 and found 5 candidate emission at the hot core region. By using the rotation diagram method, we evaluated its tentative column density and rotational temperature to be $4.9\times10^{14}$ cm$^{-2}$ and 102 K, respectively.

**Keywords.** astrobiology, astrochemistry, ISM: individual (Orion-KL)

## 1. Introduction

The simplest amine methylamine ($CH_3NH_2$) has been suggested as a precursor to the amino acid glycine ($NH_2CH_2COOH$). Theoretical and laboratory studies have demonstrated that glycine is formed on icy grain surfaces from $CH_3NH_2$ and $CO_2$ under UV irradiation (Holtom *et al.* 2005). However, in molecular clouds, a robust detection of $CH_3NH_2$ has been reported only for Sgr B2(N) (Halfen *et al.* 2013) so far, while a variety of complex organic molecules have been detected by radio observations.

Orion Kleinmann-Low nebula (Orion-KL) is known as the nearest high-mass star-forming region (at $d = 388 \pm 5$ pc, Kounkel *et al.* 2017) and one of the most prolific sources of line emission of a variety of complex organic molecules. Because of its richness in chemical composition, it has also been regarded as a suitable target for molecular line survey in the interstellar medium. Although there is a report of tentative detection of $CH_3NH_2$ (Pagani *et al.* 2017), detailed analysis has not been carried out, and so we conducted further verification of this species.

## 2. Results

We used the ALMA Cycle 2 archival data toward Orion-KL (#2013.1.00533.S) in Band 6. In Orion-KL, we found 5 candidate features (Table 1) of $CH_3NH_2$ lines in Hot core. Figure 1(a) shows one example of the intensity distribution maps. We extracted the spectrum from Hot core and show it in Figure 1(b).

**Table 1.** Observed rotational transitions of $CH_3NH_2$ in Orion-KL.

| Fequency [GHz] | S$\mu^2$ [D$^2$] | E$_u$ [K] | Transition ($J$, $K_a$, $\Gamma$) | Comments |
|---|---|---|---|---|
| 215.670 | 53.92 | 111.48 | 9, 2, $E_{1-1}$ $\rightarrow$ 9, 1, $E_{1+1}$ | Partially blended |
| 217.758 | 129.88 | 182.05 | 12, 2, $B_2$ $\rightarrow$ 12, 1, $B_1$ | |
| 229.908 | 27.37 | 92.71 | 8, 2, $A_2$ $\rightarrow$ 8, 1, $A_1$ | |
| 235.735 | 82.06 | 92.76 | 8, 2, $B_2$ $\rightarrow$ 8, 1, $B_1$ | |
| 244.887 | 49.54 | 48.09 | 5, 2, $B_1$ $\rightarrow$ 5, 1, $B_2$ | |

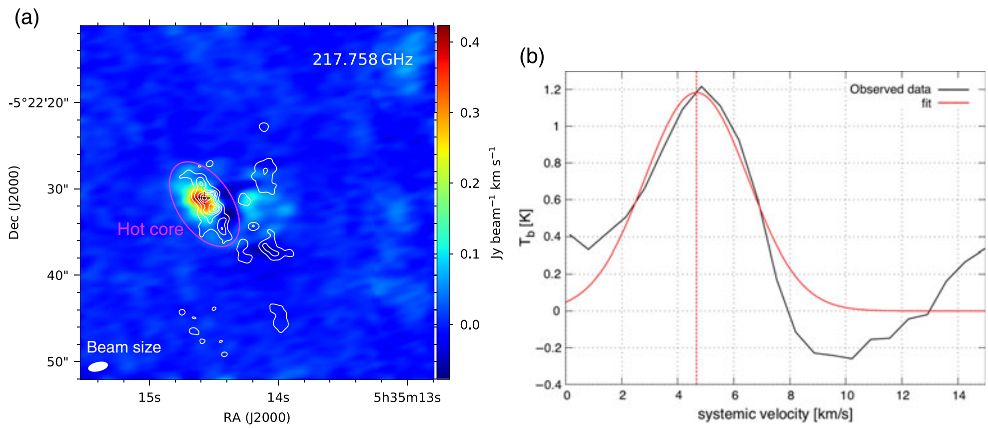


**Figure 1.** (a) Intergrated intensity map of the line at 217.758 GHz. The white contour represents the 1.3 mm continuum map (Hitota *et al.* 2015) and the black cross marks Hot core center where the spectrum analyzed in this work are extracted. (b) Spectrum of the $CH_3NH_2$ line at 218.758 GHz observed in Hot core center (black) and the result of the Gaussian fitting (red).

The systemic velocity ($V_{LSR}$) and the width (FWHM, $\Delta V$) of the line in Figure 1(b) are derived by Gaussian fitting as $V_{LSR} = 4.7 \pm 0.1$ km s$^{-1}$ and $\Delta V = 4.2 \pm 0.2$ km s$^{-1}$. Since the typical values of Hot core are $V_{LSR}$ of 4$\sim$ 6 km s$^{-1}$ and $\Delta V$ of 5$\sim$15 km s$^{-1}$ (Favre *et al.* 2011a), our results are consistent within the range of errors.

Assuming the local thermodynamic equilibrium (LTE) condition and optically thin emission, we plotted the rotation diagram using the observed lines in Table 1. The 215.670 GHz transition seems to be contaminated by other molecular line emission, and so we used the other 4 lines for the rotation diagram analysis.

We derived a rotational temperature of $T_{rot} = 102^{+26}_{-17}$ K with a column density of $N_{tot} = 4.9^{+3.7}_{-19} \times 10^{14}$ cm$^{-2}$ tentatively. For more robust detection, it is necessary to identify more emission lines by the observation with high sensitivity.

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