Ammonia mapping observations of star forming filament in the CMa OB1

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Introductions
“KAGONMA” project

- **KAgoshima Galactic Object survey with Nobeyama 45-Meter telescope in Ammonia lines**

- **Goal**
  - Understanding the physical process from diffuse interstellar gas to dense molecular cores
  
  → **Mapping observations in molecular lines around molecular clouds**

- **Survey**
  - Mapping observations in Ammonia lines using Nobeyama 45m telescope

- **Target selection**
  - Total 72 molecular clouds are determined by the C$^{18}$O(J=1-0) map of FUGIN (Umemoto et al. 2017)
Introductions: Why ammonia?

- High critical density (> $10^4$ /cc)
  - They can trace just star forming regions.

- Hyperfine structure
  - They can calculate optical depth without abundance assumption.

- The inversion lines of metastable ammonia
  - We can calculate temperature, easily.

- Ammonia doesn’t freeze-out onto dust grains.
  - Ammonia can trace very cold and high density region that C$^{18}$O can’t trace.
Star forming filament that belong to CMa OB1 (Distance: 1 kpc, Gregorio-Hetem 2008).

The distance of this filament is 900 pc (Elia et al. 2013).

It contains a large concentration of sources associated with extended 4.5 \( \mu \)m emission (Sewiło et al. 2019).

These resemble the extended green objects (EGOs) identified by Cyganowski et al. (2008).
Introduction
YSOs distribution

YSO candidates were identified by Sewiło et al. (2019).

Color: Herschel 250 \(\mu\)m map
Red cross: Possible YSO candidates
Pink circle: YSO candidates (envelope only)
Red circle: YSO candidates (envelope + disk)
Black circle: YSO candidates (Disk only)
Observations

- Telescope: The 45 m telescope at Nobeyama Radio Observatory (NRO)
- lines: NH$_3$ (1,1), (2,2), (3,3), H$_2$O maser
- Total obs. points: 295
- HPBW : 75"
- Grid spacing: 37.5"
- Velocity resolution: 0.19 km/s (NH$_3$), 0.21 km/s (H$_2$O maser)
- RMS noise level: 0.04 K ($T_a^*$)
Results: clump identification

Clump identification criteria

1. There is one intensity peak at the peak intensity of ammonia for each clump.

2. Clump size is determined by FWHM.

3. Intensity of main line and satellite lines is should be $3\sigma$ or more.
Color: Rotational temperature map
Contours: Integrated intensity map of NH$_3$(1,1)

Average 15.1 K

Average 11.5 K

Average 12.1 K

Clump 5 have highest temperature.
Comparing NH$_3$(1,1) with C$^{18}$O(1-0)

Integrated intensity map

There is a possible correlation and a negative correlation.

Clump 5 & 8a have weaker C$^{18}$O intensity toward NH$_3$ intensity.
Is $\text{C}^{18}\text{O}$ selectively photo-dissociated?

If the massive star exists, $\text{C}^{18}\text{O}$ is selectively dissociated by ultraviolet radiation.

Most luminous YSO candidate in this filament has 126 $L_\odot$.

This is not massive (young) star.

HD54662 exists outside the filament.

If it is nearby, clump 2 will be affected by massive star.

It will not be near the filament.

$\text{C}^{18}\text{O}$ is not selective photo-dissociated.
Does $^{18}$O freeze-onto dust grains?

CO adsorbed on dust at $T < 20$ K (Aikawa+2008).

NH$_3$ is observed in dense regions. The rotation temperature of each clump is 16 K or less.

**Possible!**

Existing observations and theories indicate that typical molecular depletion occurs on a scale of about 0.05 pc.

**Does molecular depletion at this spatial scale?**

- We proposed two models.
  - Cluster of normal size depleting cores
  - IRDCs

Black solid contours: $^{18}$O intensity
Black dashed contours: 200$\mu$m
Blue dashed contours: NH$_3$ intensity
This figure made from Willacy et al. (1998).
Model 1. Cluster of normal size depleting cores

C$^{18}$O depletion on 1 pc scale

Many normal size depletion cores.

Green contour: C$^{18}$O (1-0) integrated intensity map
Blue contour: NH$_3$ (1,1) integrated intensity map
Red crosses: Possible YSO Candidates
Red circles: YSO candidates (envelope + disk)
Magenta circles: YSO candidates (envelope only)

YSO candidates are referred from Sewiło et al. (2019).
Model 2 Infrared dark cloud (IRDC)

- Figure show that the timescale of molecular freeze-out onto dust grains become faster than the physical evolution timescale of the core as the density increases.

If a region with high initial density spreads over a wide area, molecular depletion should be observable over a wide area.

Comparing timescales between depletion and free-fall at 10 K. The orange and blue line represent depletion timescale and free-fall timescale, respectively. This figure made from Bergin & Tafalla (2007).

Are these clumps IRDC?
Summary

- Ammonia mapping observations were performed toward star forming filament at CMa OB1.

- We obtained 9 NH$_3$ clumps in this filament from NH$_3$(1,1) line.

- As a result of comparing NH$_3$(1,1) and C$^{18}$O(1-0), the intensity of C$^{18}$O(1-0) is less than the intensity of NH$_3$(1,1) in two of the 1 pc scale clumps.

- The cause of the lack of C$^{18}$O(1-0) intensity on the 1 pc scale is the large scale molecular depletion.