# Ammonia mapping observations of star forming filament in the CMa OB1

Yushi Hirata, Toshihiro Handa, Omodaka Toshihiro, Yoshito Shimajiri, Takeru Murase, Koya Ishizaki, Junya Nishi, Takumi Ito(Kagoshima Univ.)
Makoto Nakano (Oita Univ.) Kazuyoshi Sunada (NROJ)

NRO 45 m telescope
Image credit　NAOJ

# Introductions

## "KAGONMA" project

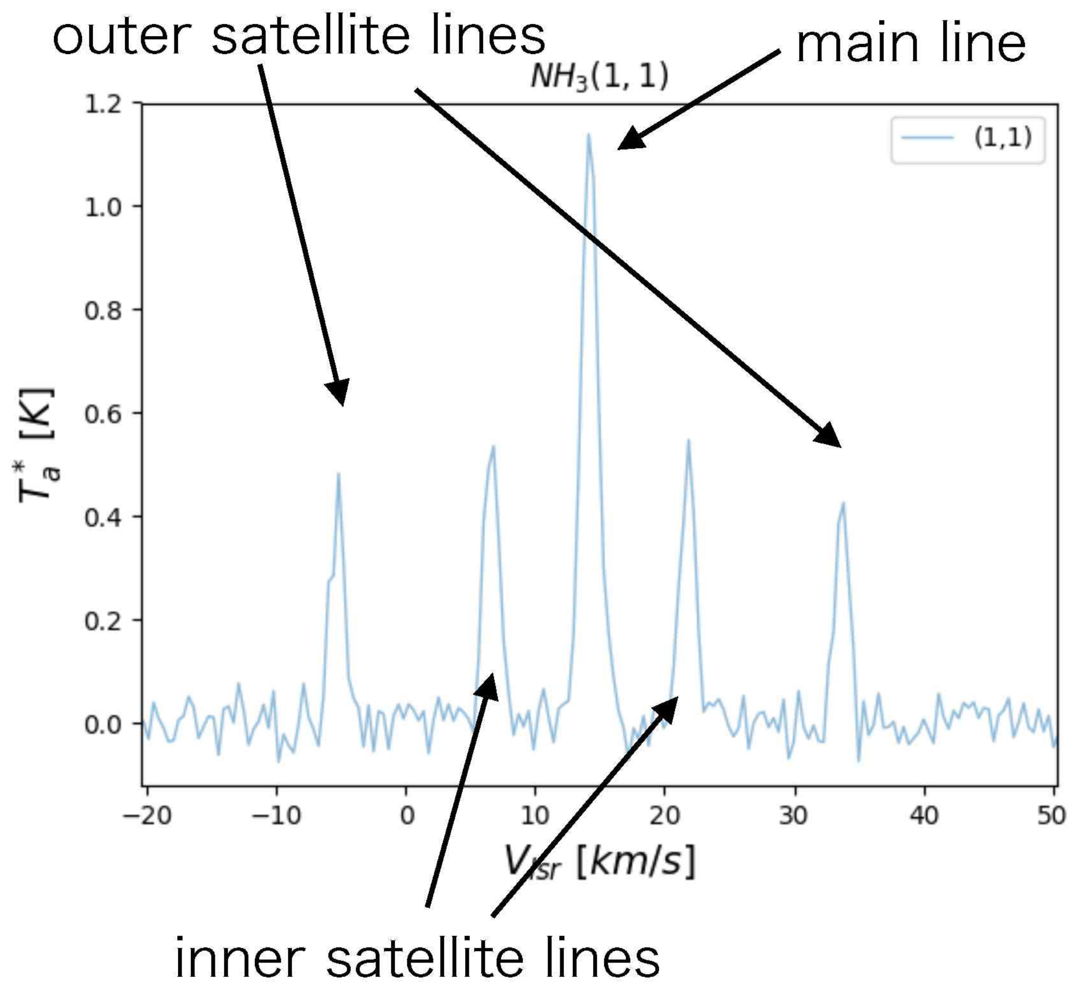
- **KAgoshima Galactic Object survey with Nobeyama 45-Meter telescope in Ammonia lines**

- **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.

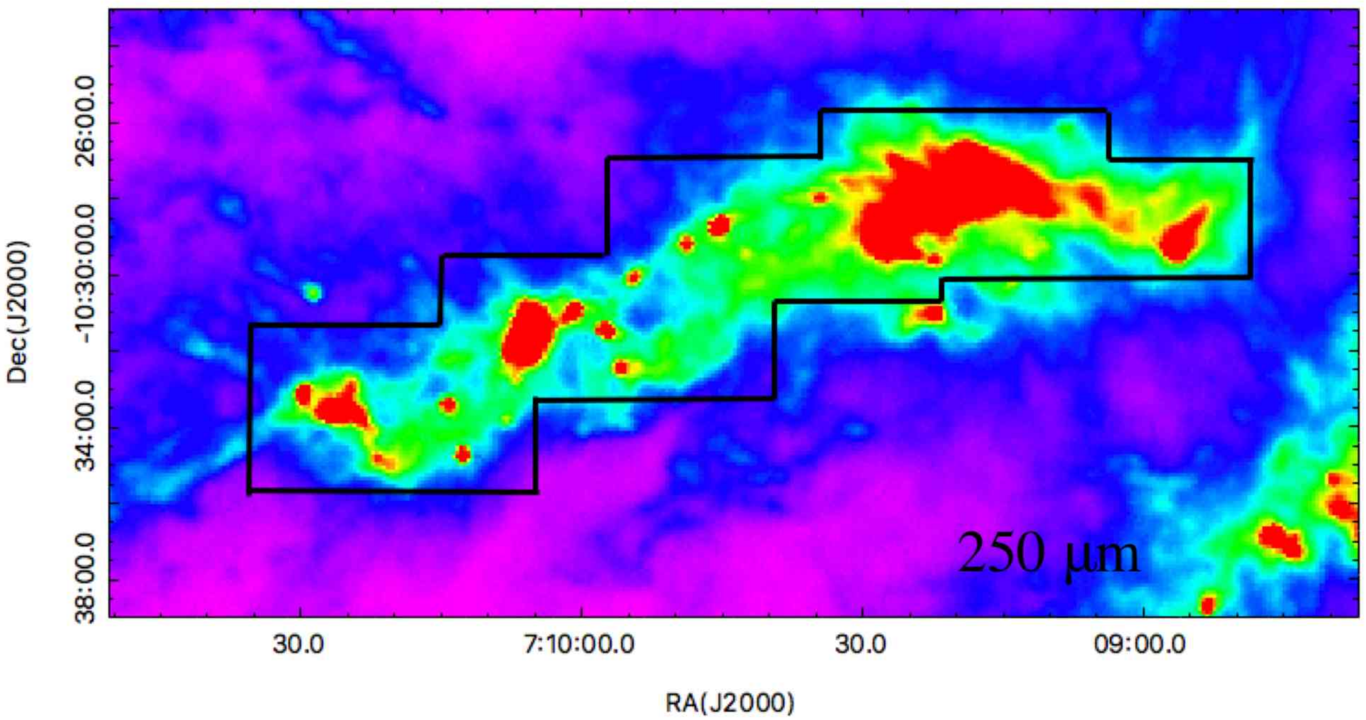
The inversion lines of metastable ammonia

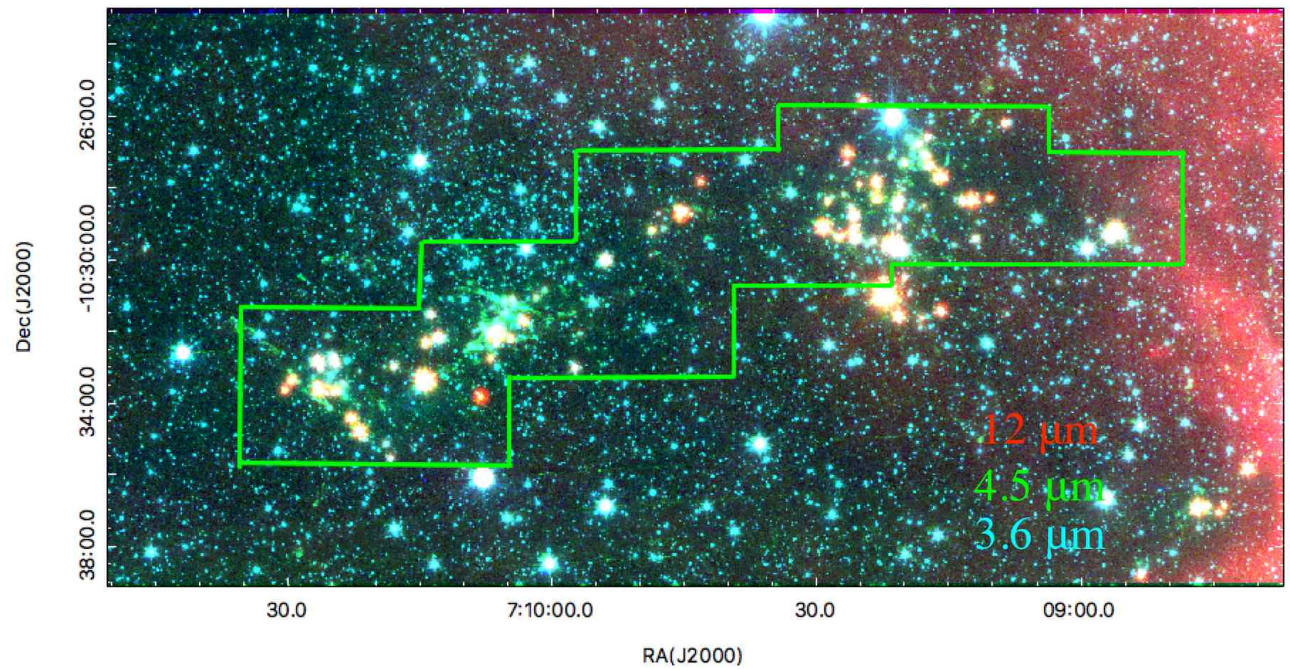
→ We can calculate temperature, easily.

Ammonia doesn't freeze-out onto dust grains.

→ Ammonia can trace very cold and high density region that $C^{18}O$ can't trace.

# Introduction -objects-



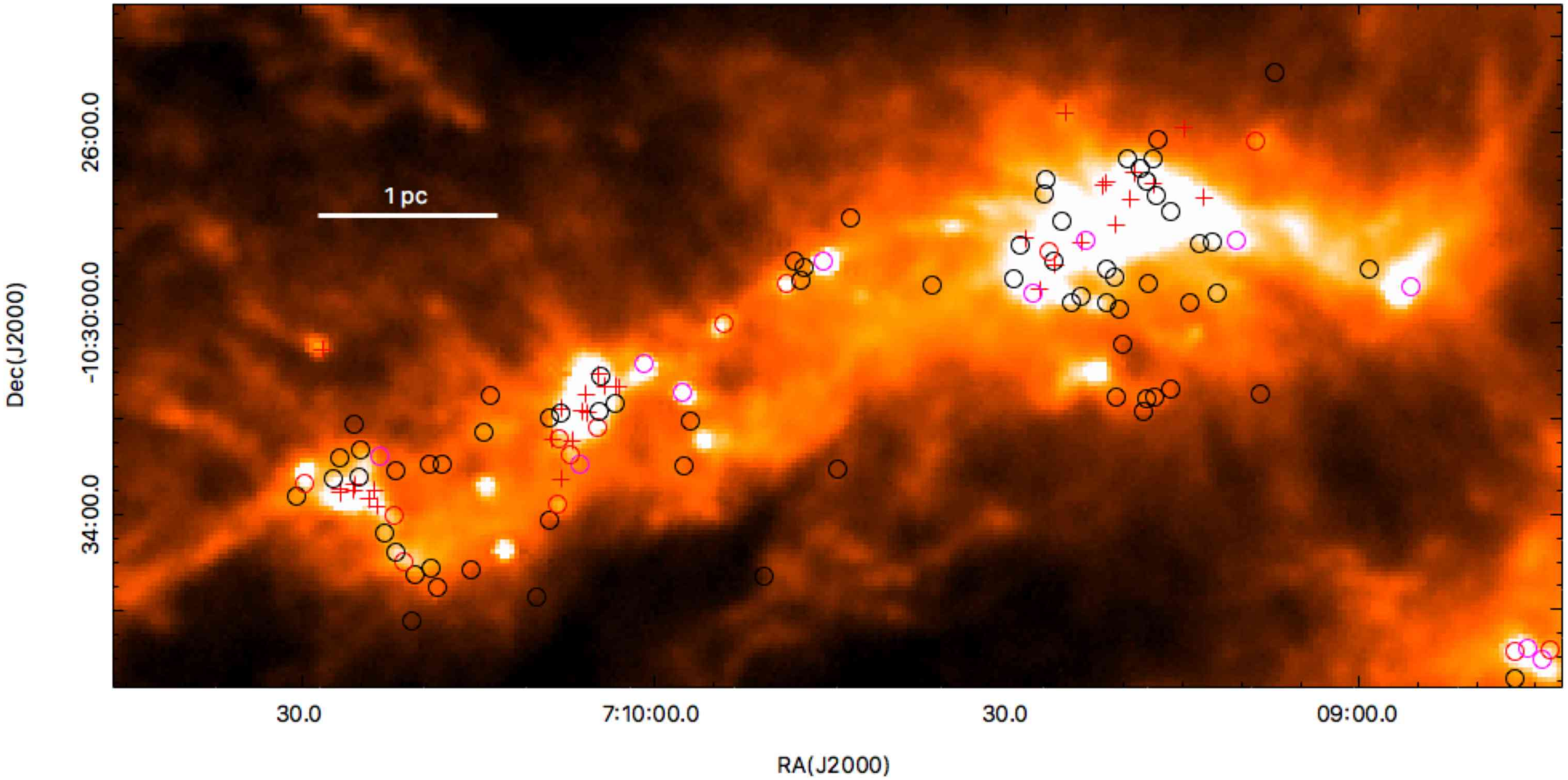

Star forming filament that belong to CMa OB1 (Distance:1 kpc, Gregorio-Hetem 2008).

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

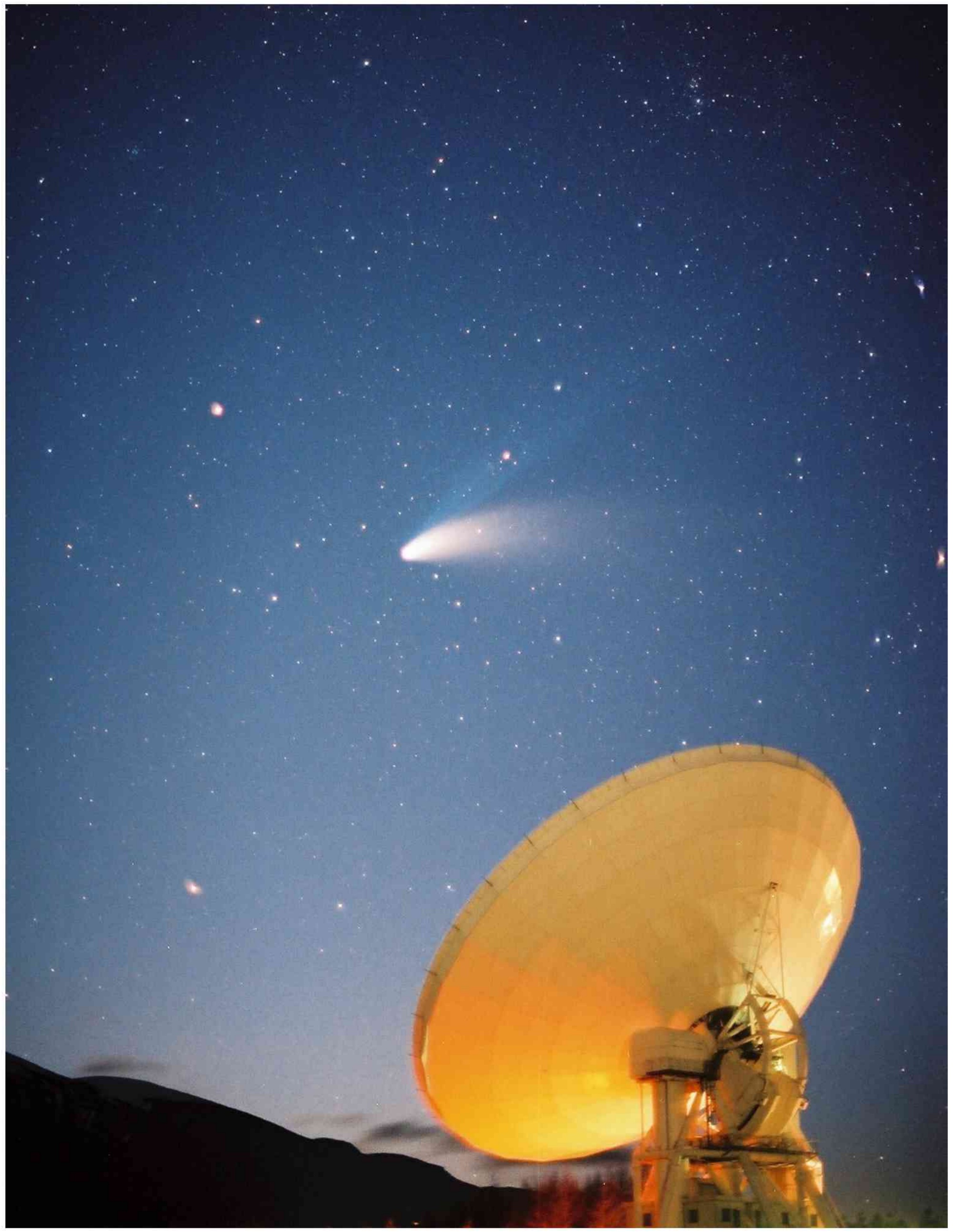
Red cross : Possible YSO candidates

Pink circle : YSO candidates (envelope only)

Red circle : YSO candidates (envelope + disk)

Black circle : YSO candidates (Disk only)

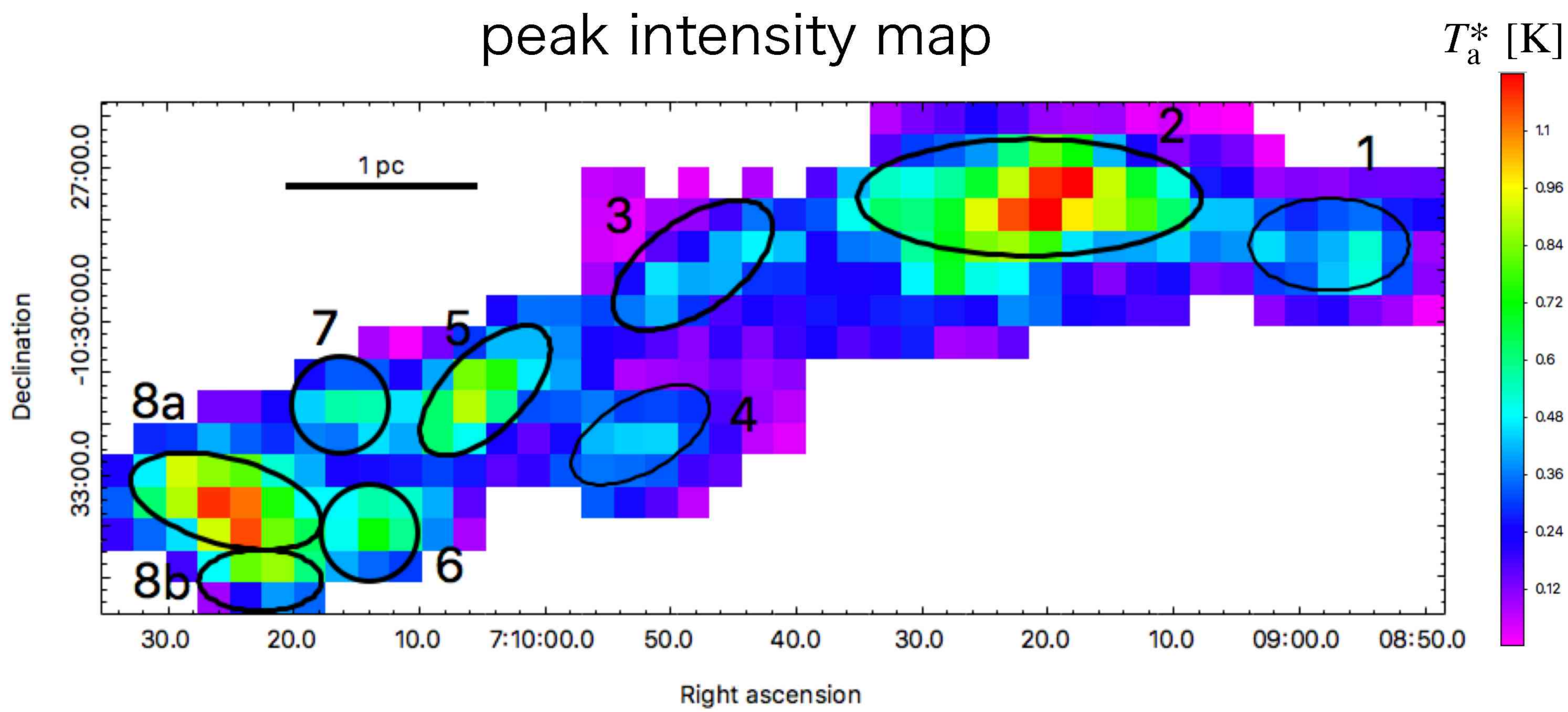
# Observations



NRO 45 m telescope
Image credit　NAOJ

- Telescope: The 45 m telescope at Nobeyama Radio Observatory (NRO)
- lines:$NH_3$(1,1),(2,2),(3,3), $H_2O$ maser
- Total obs. points: 295
- HPBW : 75”
- Grid spacing: 37.5”
- Velocity resolution : 0.19 km/s ($NH_3$),0.21 km/s ($H_2O$ maser)
- RMS noise level: 0.04 K ($T_a^*$)

# Results : clump identification



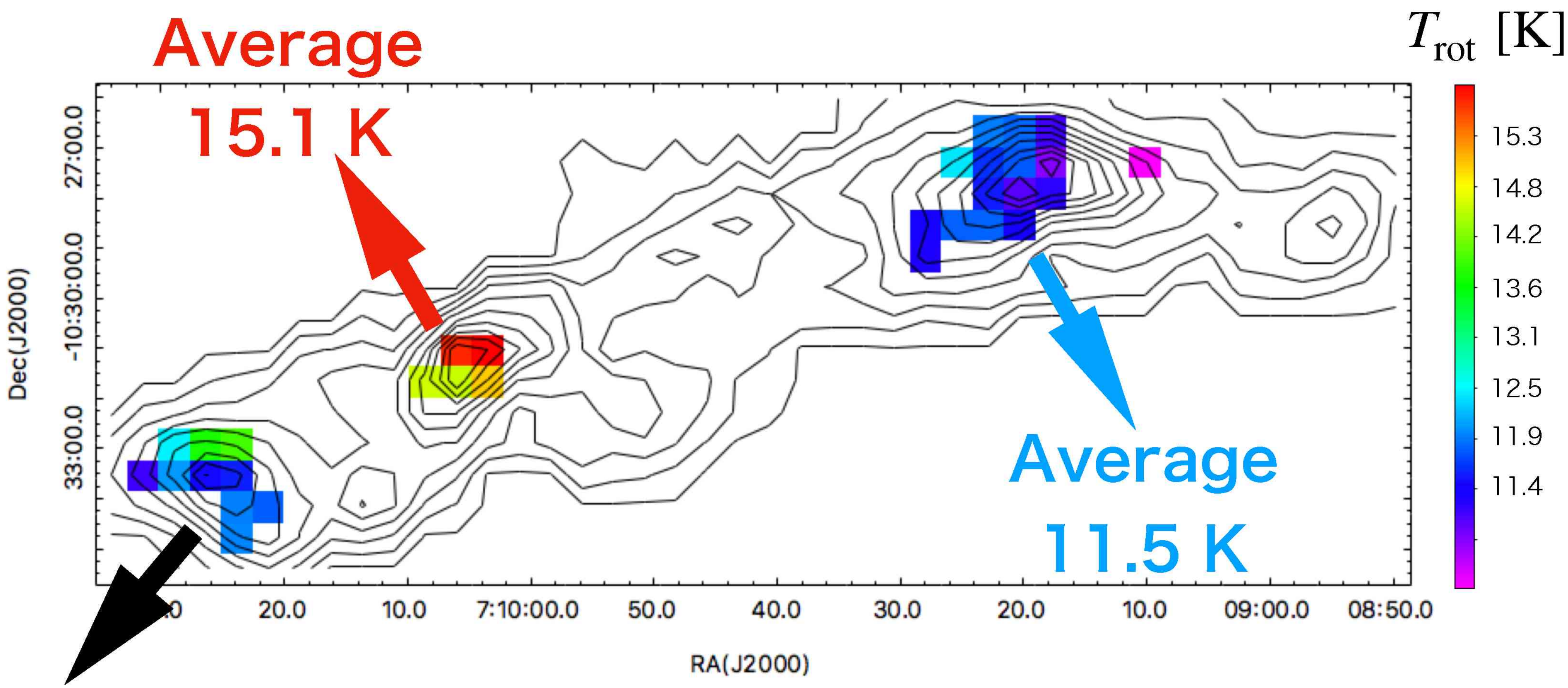

## Clump identification criteria

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 3σ or more.

# Temperature




**Average**
**12.1 K**

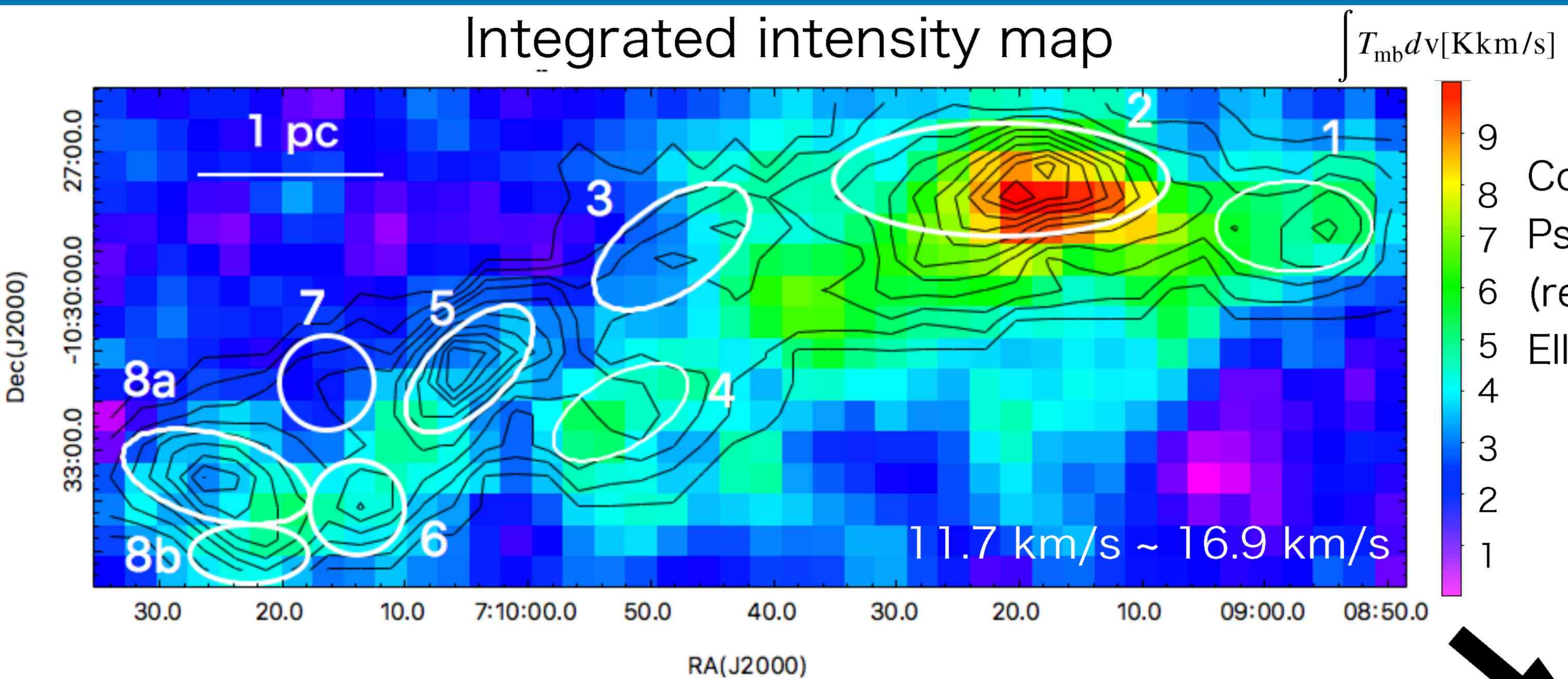
Color : Rotational temperature map

Contours : Integrated intensity map of $NH_3(1,1)$

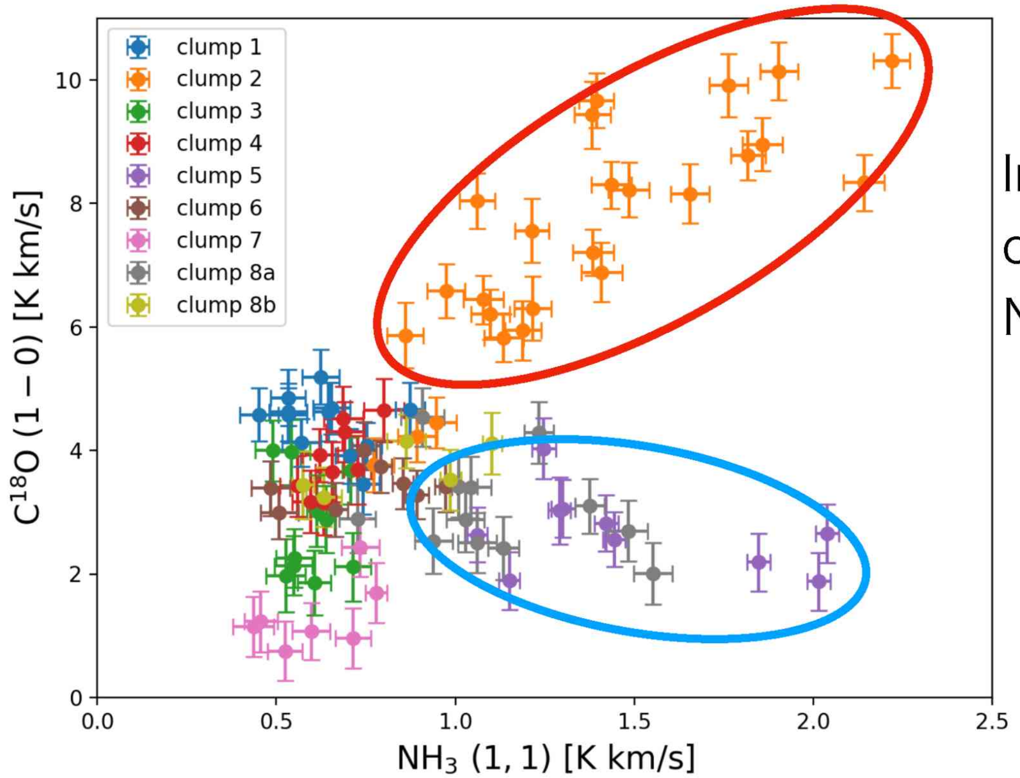
**Clump 5 have highest temperature.**

# Comparing $NH_3$(1,1) with $C^{18}O$(1-0)

Integrated intensity map




Contour : $NH_3$(1,1)
Pseudo-color : $C^{18}O$(1-0)
(resolution 75")
Ellipses : Clumps




Intensity correlation $NH_3$ vs $C^{18}O$

**There is a possible correlation and a negative correlation.**

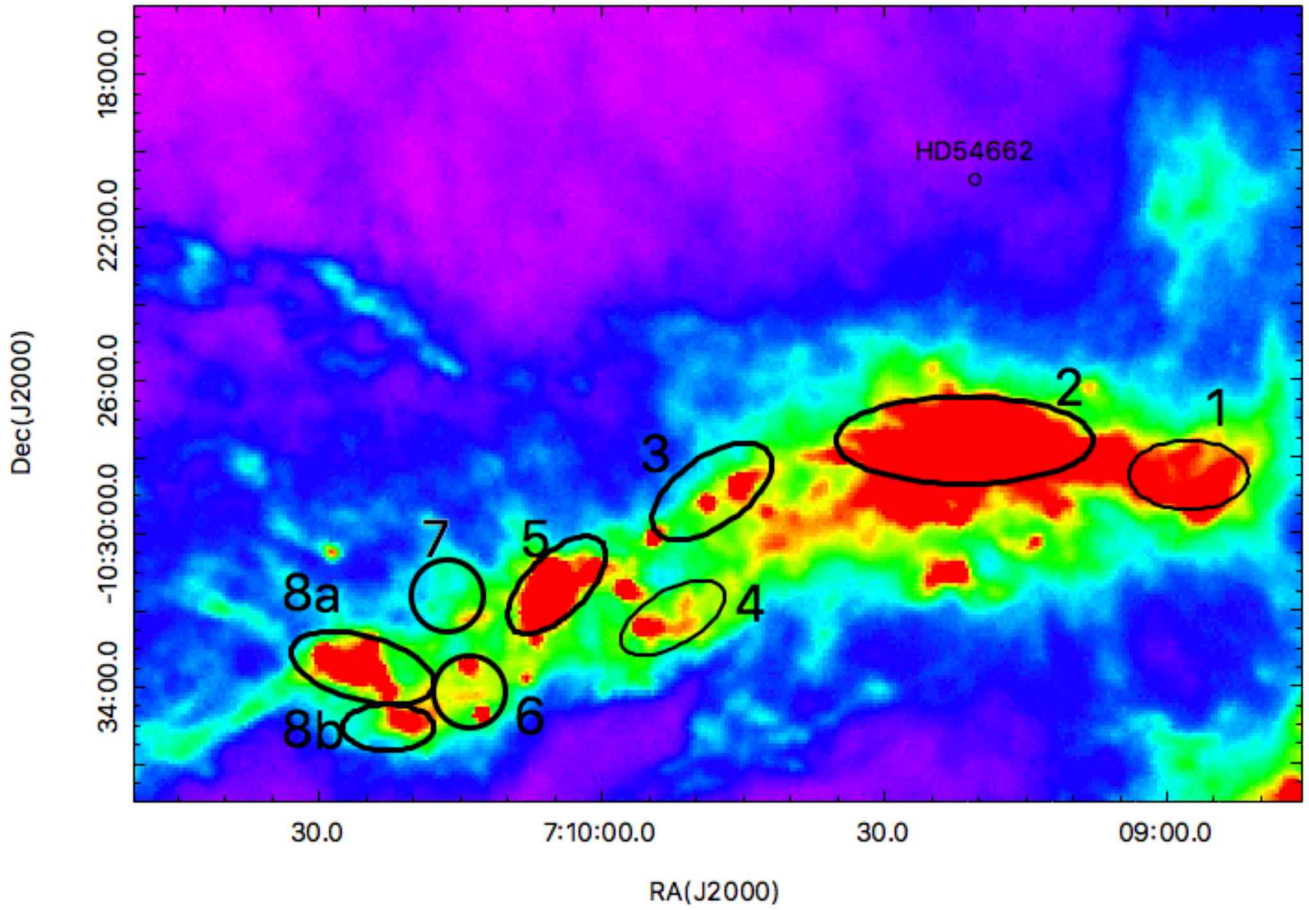
**Clump 5 & 8a have weaker $C^{18}O$ intensity toward $NH_3$ intensity.**

# Is $C^{18}O$ selectively photo-dissociated?

If the massive star exists, $C^{18}O$ 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.

↓

$C^{18}O$ is not selective photo-dissociated.

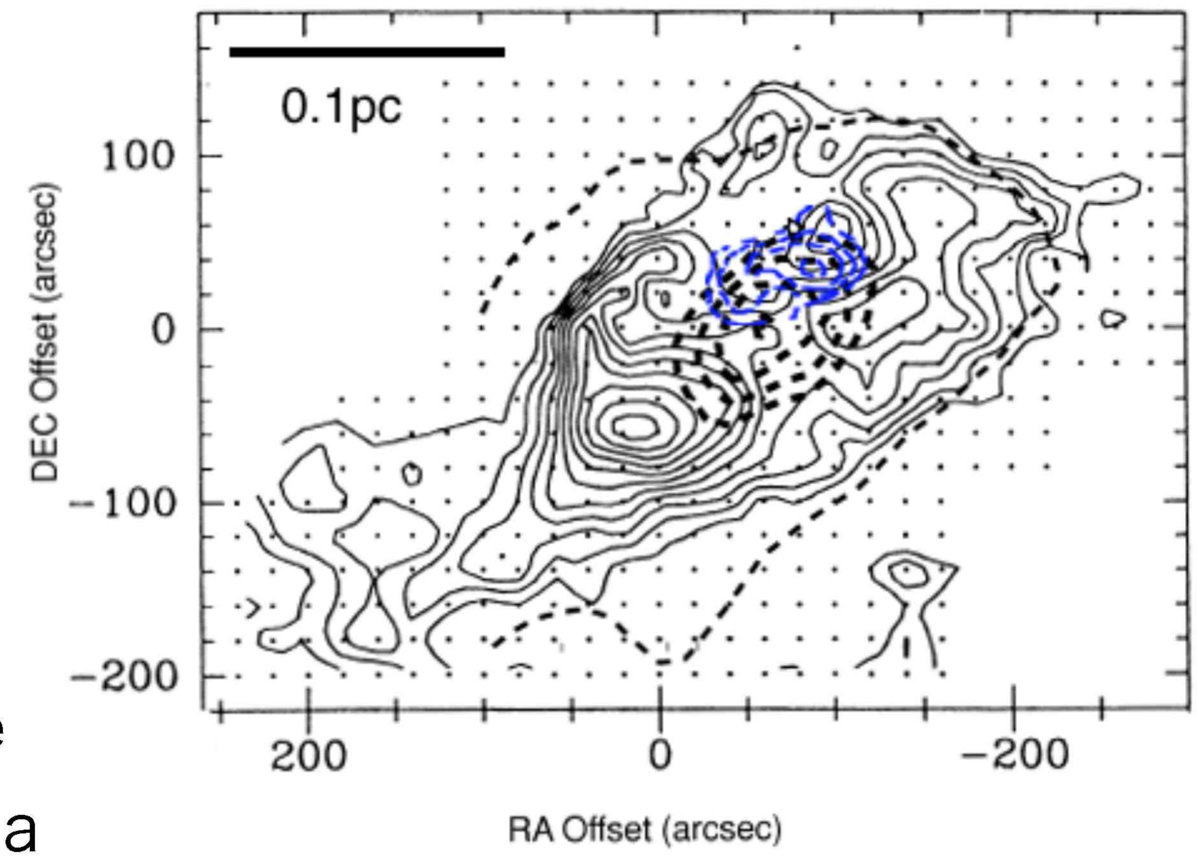
# Does $C^{18}O$ freeze-onto dust grains?

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

NH3 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.

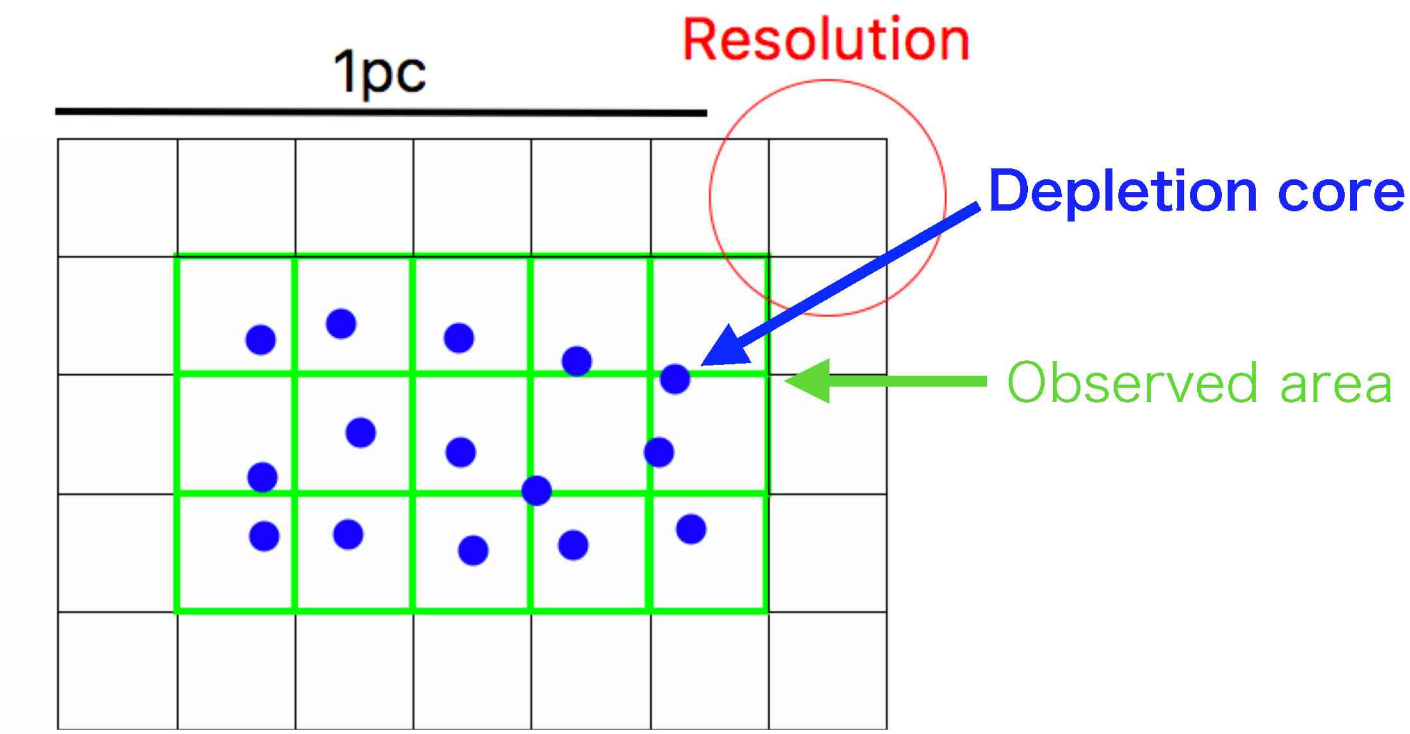



Black solid contours:$C^{18}O$ intensity
Black dashed contours:200 $\mu$m
Blue dashed contours:$NH_3$ intensity
This figure made from
Willacy et al. (1998).

**Does molecular depletion at this spatial scale?**
**We proposed two models.**

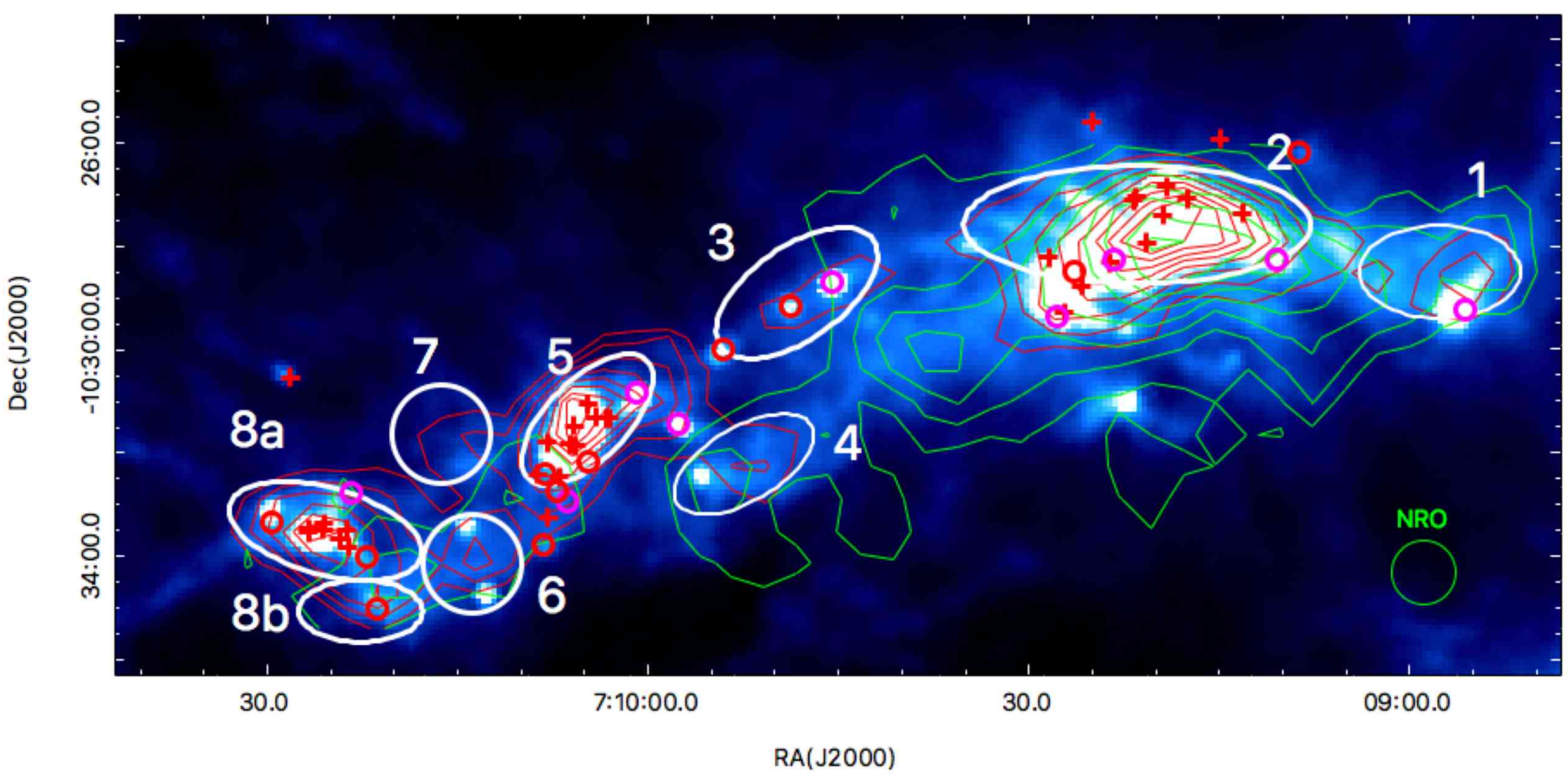
- **Cluster of normal size depleting cores**
- **IRDCs**

# 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)

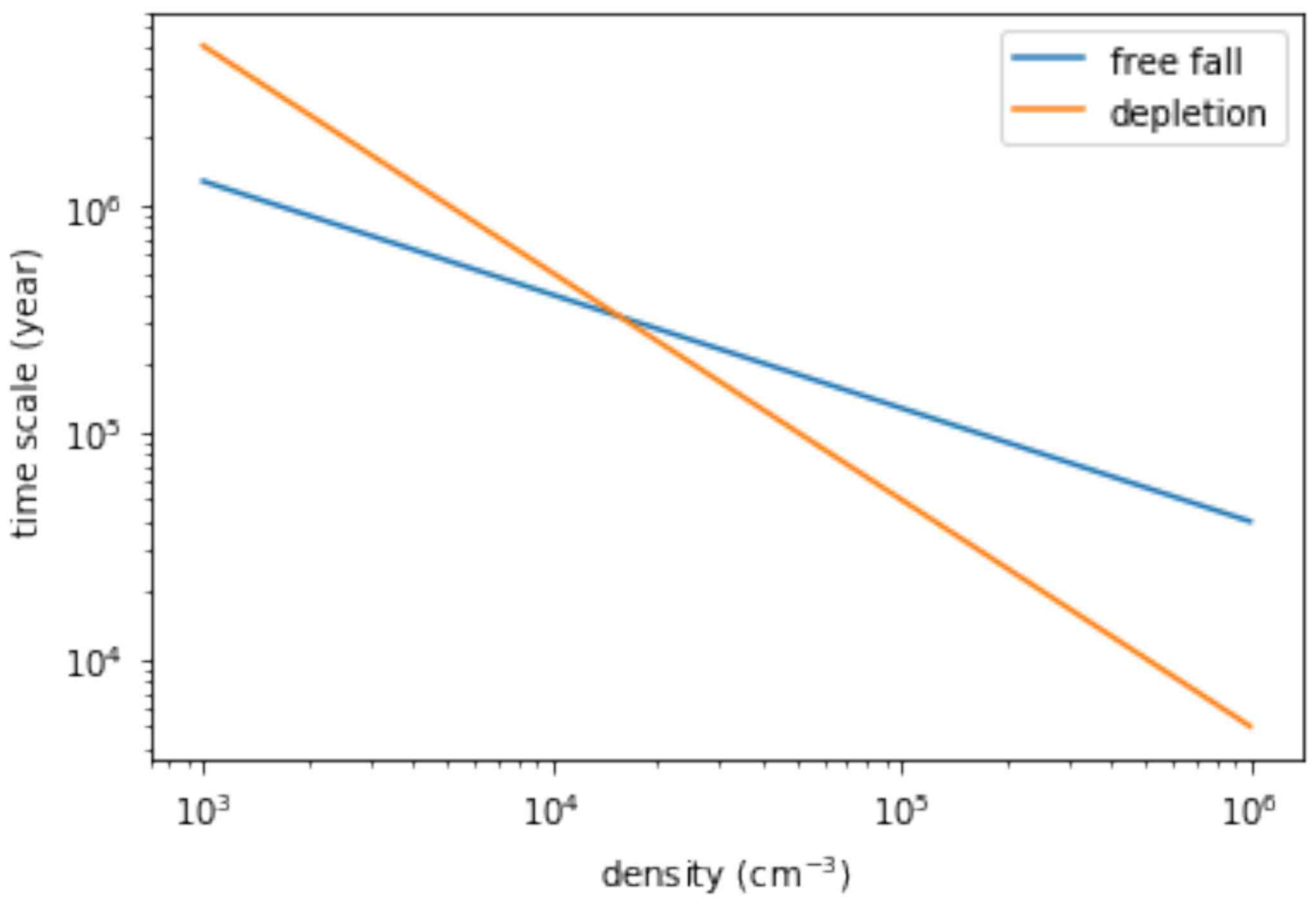
YSO candidates are referred from Sewiło et al. (2019).

# 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.

**Are these clumps IRDC?**




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).

# Summary

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

- We obtained 9 $NH_3$ clumps in this filament from NH3(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.