2026 ALMA Summer School - Group 1 (Spectral line)

Spectral line Analysis in 30 Doradus

Mentors

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Contents

Target source - 30 Doradus in LMC

30 Doradus (Tarantula Nebula)

- An extreme starburst H II region
- Distance ~ 50 kpc
- Size ~ 200 pc
- 1pc ~ 4 arcsec
- Hosts ~1000 massive stars

Ideal laboratory to study the structure, dynamics, and distribution of stellar populations, gas, and dust across the multi-wavelength range.

Scientific Goal

1. Determine whether the CO emission toward 30 Dor falls within the systemic velocity range of the LMC.

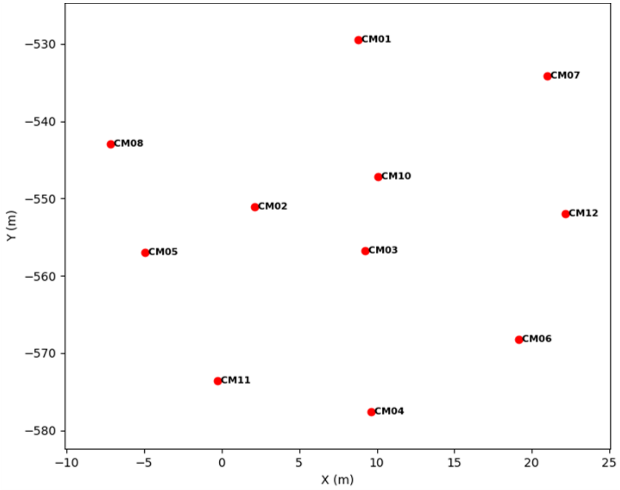
1. Compare the spatial distributions of 12CO and 13CO
   after matching them to the same angular resolution.

1. Estimate the H2 column density
   in regions where both 12CO and 13CO are detected.

Informations of Observation

- Target : 30 Doradus
- Array : 7m dish
- Mode : Mosaic

  (to cover the extended target region)



Antenna configuration

- Obs date : 2019.10.1. - 2019.11.14.

Weighting Parameters

Beam size (arcsec)

high resolution ←

		Uniform	Briggs (0.5)	Natural
12CO	Bmaj	6.51	6.74	7.1
	Bmin	5.28	5.41	5.81
13CO	Bmaj	6.49	7.0	7.36
	Bmin	5.58	5.7	6.11

Weighting Parameters

RMS value (after tclean)

high sensitivity

	Uniform	Briggs (0.5)	Natural
12CO	0.06144 Jy	0.05551 Jy	0.05508 Jy
13CO	0.06027 Jy	0.05134 Jy	0.0474 Jy

CLEAN Parameters

```
tclean(
        ⋮
        specmode='cube',
        gridder='mosaic',
        deconvolver='multiscale',
        scales=[0, 1, 2, 5],
        weighting='briggs',
        robust=0.5,
        ⋮
        phasecenter='~',
        nchan=41,
        start='210km/s',
        width='2km/s',
        ⋮
        niter=10000,
        threshold='33mJy * 3.',
        usemask = 'auto-multithresh',
        ⋮
    )
```

CLEAN Parameters

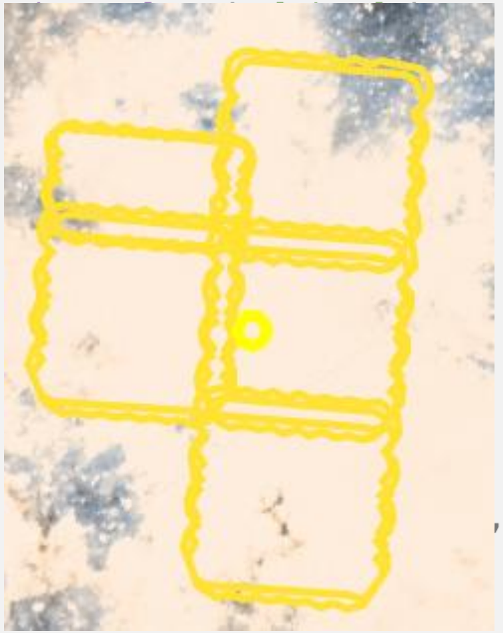
```
tclean(
    ⋮
    specmode='cube',
    gridder='mosaic',
    deconvolver='multiscale',
    scales=[0, 1, 2, 5],
    weighting='briggs',
    robust=0.5,
    ⋮
    phasecenter='~',
    nchan=41,
    start='210km/s',
    width='2km/s',
    ⋮
    niter=10000,
    threshold='33mJy * 3.',
    usemask = 'auto-multithresh',
    ⋮
)
```

A separate 2D intensity map generated for each velocity channel.

RA * Dec * Velocity

CLEAN Parameters

```
tclean(
      ⋮
      specmode='cube',
      gridder='mosaic',
)
```



Combining multiple pointings into a single mosaic to cover sky areas much larger than the telescope’s primary beam.

```
Pointing 1  ┐
Pointing 2  │
Pointing 3  ├─ Primary-beam weighted combination → Single mosaic image
...         │
Pointing n  ┘
```

CLEAN Parameters

```
tclean(
        ⋮
        specmode='cube',
        gridder='mosaic',
        deconvolver='multiscale',
        scales=[0, 1, 2, 5],
        weighting='briggs',
        robust=0.5,
        ⋮
        phasecenter='~',
        nchan=41,
        start='210km/s',
        width='2km/s',
        ⋮
        niter=10000,
        threshold='33mJy * 3.',
        usemask = 'auto-multithresh',
        ⋮
    )
```

Instead of point source,
we used "multiscale" CLEAN to
capture extended gas structure.

scale unit : pixel
calculating : scale * cell

CLEAN Parameters

```
tclean(
        ⋮
        specmode='cube',
        gridder='mosaic',
        deconvolver='multiscale',
        scales=[0, 1, 2, 5],
        weighting='briggs',
        robust=0.5,
        ⋮
        phasecenter='~',
        nchan=41,
        start='210km/s',
        width='2km/s',
        ⋮
        niter=10000,
        threshold='33mJy * 3.',
        usemask = 'auto-multithresh',
        ⋮
   )
```

We selected ‘briggs’.

Robust = 0.5

provides a good compromise between angular resolution and image sensitivity, making it a popular choice for many ALMA imaging applications.

CLEAN Parameters

```
tclean(
        ⋮
        specmode='cube',
        gridder='mosaic',
        deconvolver='multiscale',
        scales=[0, 1, 2, 5],
        weighting='briggs',
        robust=0.5,
        ⋮
        phasecenter='~',
        nchan=41,
        start='210km/s',
        width='2km/s',
        ⋮
        niter=10000,
        threshold='33mJy * 3.',
        usemask = 'auto-multithresh',
        ⋮
   )
```

Number of velocity channels : 41

Center of first channel: 210 km/s

Velocity channel spacing: 2 km/s

Velocity range: 210–290 km/s

velocity range was set

to include the line - free channel.

(restfreq='230.538GHz')

CLEAN Parameters

```
tclean(
        ⋮
        specmode='cube',
        gridder='mosaic',
        deconvolver='multiscale',
        scales=[0, 1, 2, 5],
        weighting='briggs',
        robust=0.5,
        ⋮
        phasecenter='~',
        nchan=41,
        start='210km/s',
        width='2km/s',
        ⋮
        niter=10000,
        threshold='33mJy * 3.',
        usemask = 'auto-multithresh'
        ⋮
  )
```

CLEAN threshold
&
Auto masking

Smoothing

Why did we apply smoothing? (10 arcsec)

- 12 CO map & 13 CO maps have different beam sizes.
- To ensure consistent analysis conditions => smoothing

CASA "imsmooth" task

```
imsmooth(
    imagename=item['imagename'],
    outfile=item['outfile'],
    kernel='gauss',
    targetres=True,
    major='10arcsec',
    minor='10arcsec',
    pa='0deg'
)
```

		Briggs (0.5)
12CO	Bmaj	6.74
	Bmin	5.41
13CO	Bmaj	7.0
	Bmin	5.7

Smoothing

targetres = **True** or **False** ?

```
imsmooth(
    imagename=item['imagename'],
    outfile=item['outfile'],
    kernel='gauss',
    targetres=True,
    major='10arcsec',
    minor='10arcsec',
    pa='0deg'
)
```

```
imsmooth(
    imagename=item['imagename'],
    outfile=item['outfile'],
    kernel='gauss',
    targetres=False,
    major='10arcsec',
    minor='10arcsec',
    pa='0deg'
)
```

Smoothing

targetres = **False**

We directly specify the value for θ_{kernel} .

```
imsmooth(
    imagename=item['imagename'],
    outfile=item['outfile'],
    kernel='gauss',
    targetres=False,
    major='10arcsec',
    minor='10arcsec',
    pa='0deg'
)
```

$$\theta_{\mathrm{out}} = \sqrt{\theta_{\mathrm{in}}^2 + \boxed{\theta_{\mathrm{kernel}}^2}}$$

Smoothing

targetres = **True**

We set the final target beam size after smoothing.

(automatically calculates θ_{kernel})

```
imsmooth(
    imagename=item['imagename'],
    outfile=item['outfile'],
    kernel='gauss',
    targetres=True,
    major='10arcsec',
    minor='10arcsec',
    pa='0deg'
)
```

$$\boxed{\theta_{\mathrm{out}}} = \sqrt{\theta_{\mathrm{in}}^2 + \theta_{\mathrm{kernel}}^2}$$

Smoothing

We used **targetres = True**

```
imsmooth(
    imagename=item['imagename'],
    outfile=item['outfile'],
    kernel='gauss',
    targetres=True,
    major='10arcsec',
    minor='10arcsec',
    pa='0deg'
)
```

$$\boxed{\theta_{\rm out}} = \sqrt{\theta_{\rm in}^2 + \theta_{\rm kernel}^2}$$

		Before	After
12CO	Bmaj	6.74	**10**
	Bmin	5.41	
13CO	Bmaj	7.0	
	Bmin	5.7	

Background

Use 12CO, 13CO emission as a tracer of molecular gas H2

- 30Dor: Giant H II region complex hosting a large stellar population and embedded within a giant molecular cloud

- Cold H II is difficult to observe directly, so use the bright rotational emission lines of 12CO and 13CO to trace gas

Property	12CO	13CO
population	more abundant	less abundant
emission	brighter	fainter
optical depth	optically thick	optically thin
Main application	excitation temperature	optical depth column density

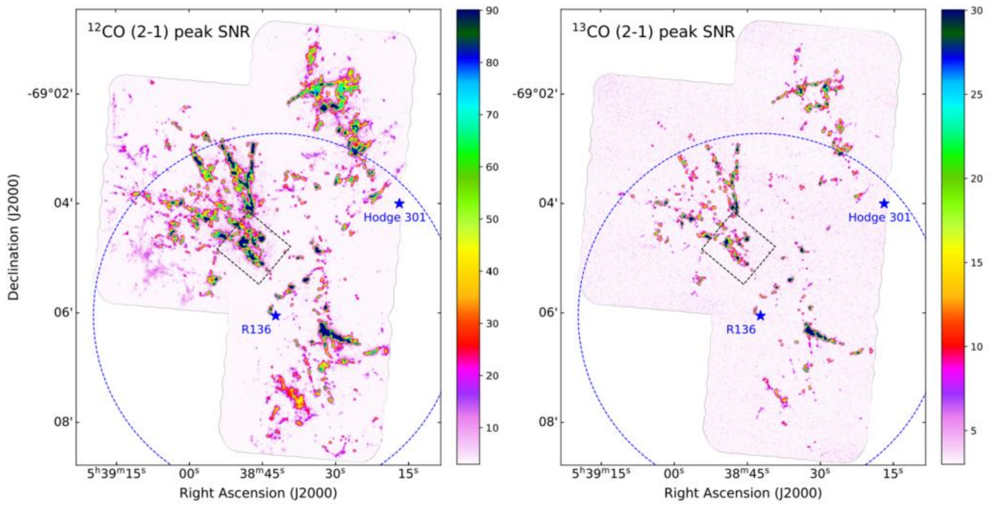
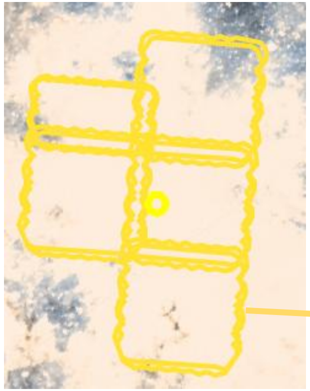
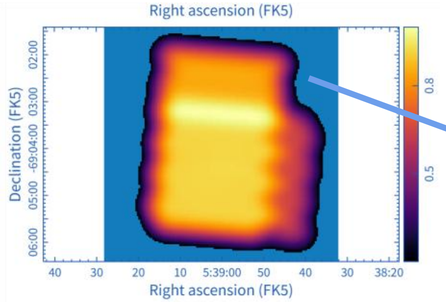


Figure 2. Peak SNR images for the CO (left) and ^{13}CO (right) cubes. The dashed circle represents a projected distance of 200″ (48 pc) from the center of the R136 cluster, for ease of comparison with Fig. 11. The dashed rectangle has a linear dimension of ~12 pc and denotes the region mapped in ALMA Cycle 0 (Indebetouw et al. 2013). The central position of the more evolved Hodge 301 cluster is also indicated.

Background

Small Data Coverage Due to Computing Limitations





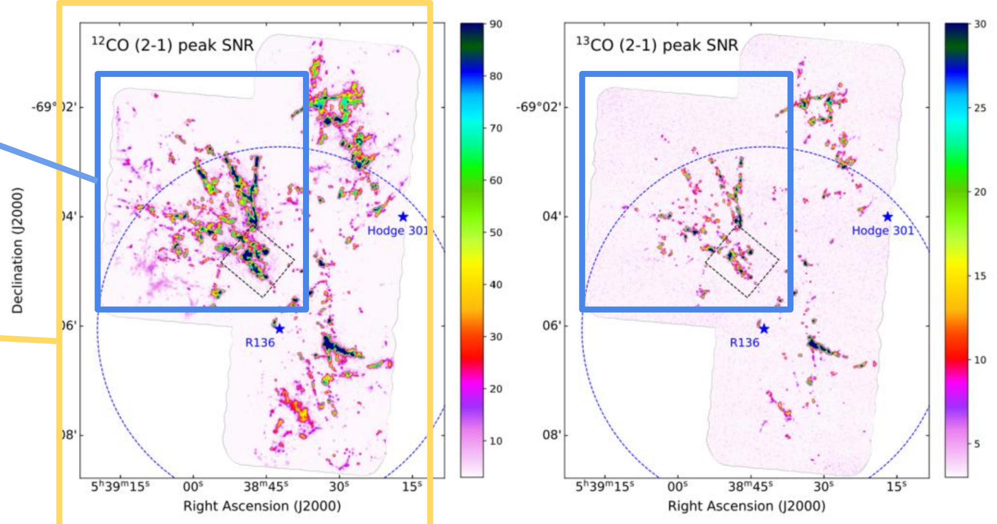


Figure 2. Peak SNR images for the CO (left) and ^{13}CO (right) cubes. The dashed circle represents a projected distance of 200″ (48 pc) from the center of the R136 cluster, for ease of comparison with Fig. 11. The dashed rectangle has a linear dimension of ~12 pc and denotes the region mapped in ALMA Cycle 0 (Indebetouw et al. 2013). The central position of the more evolved Hodge 301 cluster is also indicated.

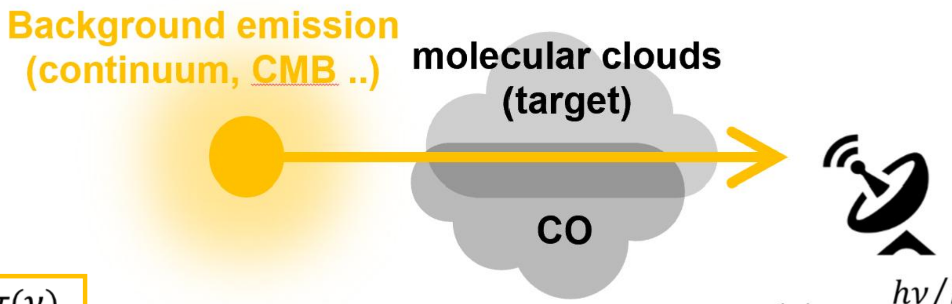
Consideration

- Focus on a smaller subregion, not the entire field

- Only use 7-m array data and did not include Total Power (TP) or 12-m array data

- Limited by missing total flux from extended emission and insufficient angular diameter resolution to resolve compact source

Scientific goal



Radiative transfer equation

$$T_B(\nu) = \boxed{J(T_{exc})\left(1 - e^{-\tau(\nu)}\right)} + \boxed{J(T_{BG})e^{-\tau(\nu)}}$$

CO cloud emission

background emission
due to absorption from the CO cloud

$$J(T) = \frac{h\nu/k}{e^{h\nu/kT} - 1}$$

$$T_{\mathrm{B,line+base}}(v) = J(T_{\mathrm{exc}})\left(1 - e^{-\tau(v)}\right) + J(T_{\mathrm{BG}})e^{-\tau(v)}$$

$$T_{\mathrm{B,base}}(v) = J(T_{\mathrm{BG}})$$ → background baseline

$$T_{\mathrm{MB}}(v) = T_{\mathrm{B,line+base}}(v) - T_{\mathrm{B,base}}(v)$$

$$T_{\mathrm{MB}}(v) = \left(J(T_{\mathrm{exc}}) - J(T_{\mathrm{BG}})\right)\left(1 - e^{-\tau(v)}\right)$$

T_{B}: observed brightness temperature
T_{exc}: excitation temperature of CO
T_{BG}: background radiation temperature (e.g., the CMB and continuum emission)
$J(T)$: radiation temperature
τ: optical depth (measures how opaque the cloud is to radiation)

Scientific goal: estimating H2 Column density

Analysis Workflow

1. Excitation Temperature T_{exc}
2. 13CO Optical depth $\tau_{13}(\nu)$
3. 13CO column density $\mathrm{N(13CO)}$
4. 12CO, H2 column density $\mathrm{N(12CO), N(H_2)}$

Under LTE(Local thermal equilibrium), both isotopologues are assumed to share the same excitation temperature. Therefore, T_{exc} can derived from the optically thick 12CO(2-1) emission can be applied to 13CO(2-1):

$$T_{\mathrm{MB}}(\nu) = (J(T_{\mathrm{exc}}) - J(T_{\mathrm{BG}}))\left(1 - e^{-\tau(\nu)}\right)$$

$$\tau_{12CO} \gg 1, T_{\mathrm{BG}} = 2.73\ \mathrm{K},\ \nu_{12CO} = 230.538\ \mathrm{GHz}$$

$$T_{\mathrm{exc}} = 11.06 \left\{\ln\left[1 + \frac{11.06}{T_{12} + 0.19}\right]\right\}^{-1}$$

Scientific goal: estimating H2 Column density

Analysis Workflow

1. Excitation Temperature T_{exc}
2. 13CO Optical depth $\tau_{13}(\nu)$
3. 13CO column density $\mathrm{N(13CO)}$
4. 12CO, H2 column density $\mathrm{N(12CO), N(H_2)}$

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$$T_{\mathrm{exc}} = 11.06 \left\{\ln\left[1 + \frac{11.06}{T_{12} + 0.19}\right]\right\}^{-1}$$

$$\tau_{13}(\nu) = -\ln\left[1 - \frac{T_{13}(\nu)}{\frac{10.58}{e^{10.58/T_{\mathrm{exc}}} - 1} - 0.22}\right]$$

Scientific goal: estimating H2 Column density

Analysis Workflow

1. Excitation Temperature T_{exc}

2. 13CO Optical depth $\tau_{13}(\nu)$

3. 13CO column density $\mathrm{N(13CO)}$

4. 12CO, H2 column density
   $\mathrm{N(12CO)}, \mathrm{N(H_2)}$

A Spectroscopic Study of the DR 21 Outflow Source. III. The CO Line Emission, Garden R.P, 1991

$$T_{\mathrm{MB}}(\nu) = \left(J(T_{\mathrm{exc}}) - J(T_{\mathrm{BG}})\right)\left(1 - e^{-\tau(\nu)}\right)$$

$$\tau_{12CO} \gg 1, T_{\mathrm{BG}} = 2.73\ \mathrm{K},\ \nu_{12CO} = 230.538\ \mathrm{GHz}$$

$$T_{\mathrm{exc}} = 11.06\left\{\ln\left[1 + \frac{11.06}{T_{12} + 0.19}\right]\right\}^{-1}$$

$$\tau_{13}(\nu) = -\ln\left[1 - \frac{T_{13}(\nu)}{\frac{10.58}{e^{10.58/T_{\mathrm{exc}}} - 1} - 0.22}\right]$$

$$\mathrm{N(13CO)[cm^{-2}]} = 1.21 \times 10^{14}\,\frac{(T_{exc} + 0.88)\,e^{5.29/T_{exc}}}{1 - e^{-10.58/T_{exc}}}\int \tau_{13}(\nu)\,d\nu$$

$$2\mathrm{N(H_2)} = \left(6 \times 10^6\right) \times N(\mathrm{13CO})$$

Scientific goal: estimating H2 Column density

Analysis Workflow

1. Excitation Temperature T_{exc}
2. 13CO Optical depth $\tau_{13}(\nu)$
3. 13CO column density $\mathrm{N(13CO)}$
4. 12CO, H2 column density $\mathrm{N(12CO)}, \mathrm{N(H_2)}$

$$\left[\frac{\mathrm{12CO}}{\mathrm{H_2}}\right] \sim 1.6 \times 10^{-5} \ \& \ \left[\frac{\mathrm{12CO}}{\mathrm{13CO}}\right] \sim 50$$

(Heikkila+99; Mizuno+10,fujii+14),

$$\left[\frac{\mathrm{12CO}}{\mathrm{H_2}}\right]^{-1} \times \left[\frac{\mathrm{12CO}}{\mathrm{13CO}}\right] \approx \frac{N(\mathrm{H_2})}{N(\mathrm{13CO})} = 3 \times 10^6 \text{ (Wong+22).}$$

$$T_{\mathrm{MB}}(\nu) = \left(J(T_{\mathrm{exc}}) - J(T_{\mathrm{BG}})\right)\left(1 - e^{-\tau(\nu)}\right)$$

$$\tau_{12CO} \gg 1, T_{\mathrm{BG}} = 2.73 \text{ K}, \nu_{12CO} = 230.538 \text{ GHz}$$

$$T_{\mathrm{exc}} = 11.06 \left\{\ln\left[1 + \frac{11.06}{T_{12} + 0.19}\right]\right\}^{-1}$$

$$\tau_{13}(\nu) = -\ln\left[1 - \frac{T_{13}(\nu)}{\frac{10.58}{e^{10.58/T_{\mathrm{exc}}} - 1} - 0.22}\right]$$

$$\mathrm{N(13CO)[cm^{-2}]} = 1.21 \times 10^{14} \frac{(T_{exc} + 0.88)\, e^{5.29/T_{exc}}}{1 - e^{-10.58/T_{exc}}} \int \tau_{13}(\nu)\, d\nu$$

$$2\mathrm{N(H_2)} = \left(6 \times 10^6\right) \times N(\mathrm{13CO})$$

Does CO emission toward 30 Dor falls within the systematic velocity range of the LMC ?

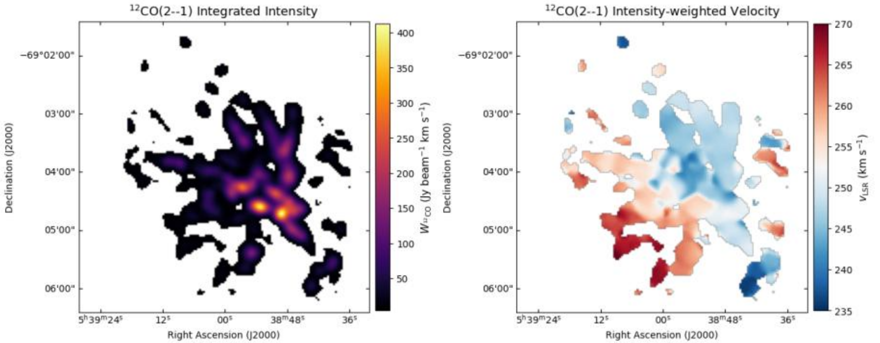
- **Moment 0 — Integrated intensity:** $M_0 = \int I(v)\,dv$ — measures the **total CO line emission along each line of sight**, tracing the spatial distribution of molecular gas.

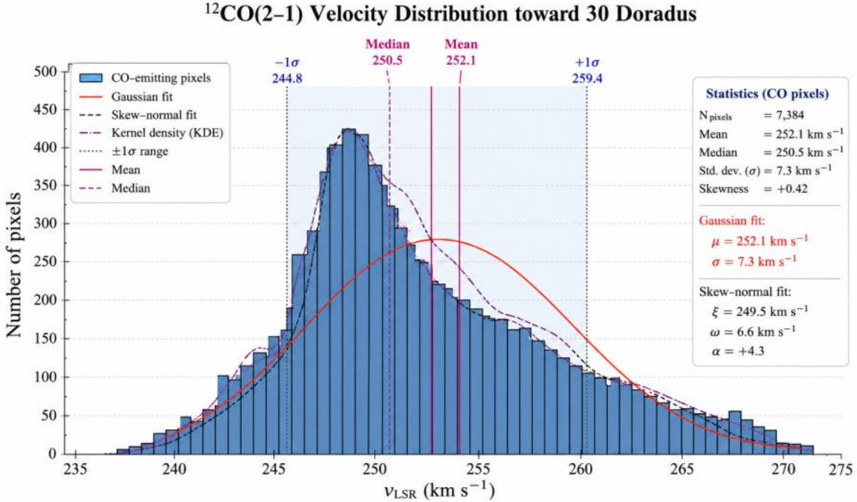
- **Moment 1 — Intensity-weighted velocity:** $M_1 = \frac{\int v\, I(v)\,dv}{\int I(v)\,dv}$ — gives the **characteristic LOS velocity of the CO gas**, used here to check whether it is kinematically consistent with the LMC.

- moment maps are masked below 3σ, [where $\sigma =$ rms of moment 0 map -- we also applied threshold $T_{ex} < 3K$ masking]

- We generally consider the $V_{sys|LMC} \sim 265$ km/s

- The measured CO velocities fall in the expected velocity regime of LMC gas toward the 30 Dor region. Therefore, the detected CO emission is kinematically consistent with being associated with the LMC.



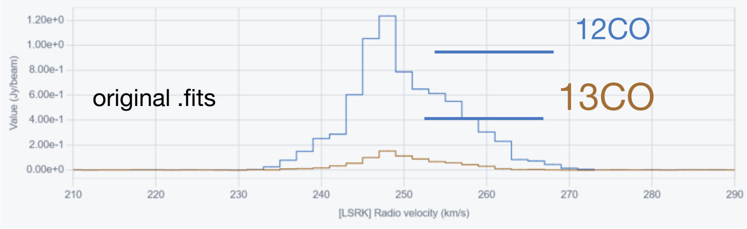


Summary: The ^{12}CO(2–1) emission toward 30 Doradus peaks at $v_{LSR} \approx 250$–252 km s^{-1} and shows a slightly positively skewed distribution (skewness = +0.42). Most CO emission lies within 244.8 – 259.4 km s^{-1} (±1σ), consistent with the systemic velocity range of the LMC.

Scientific goal

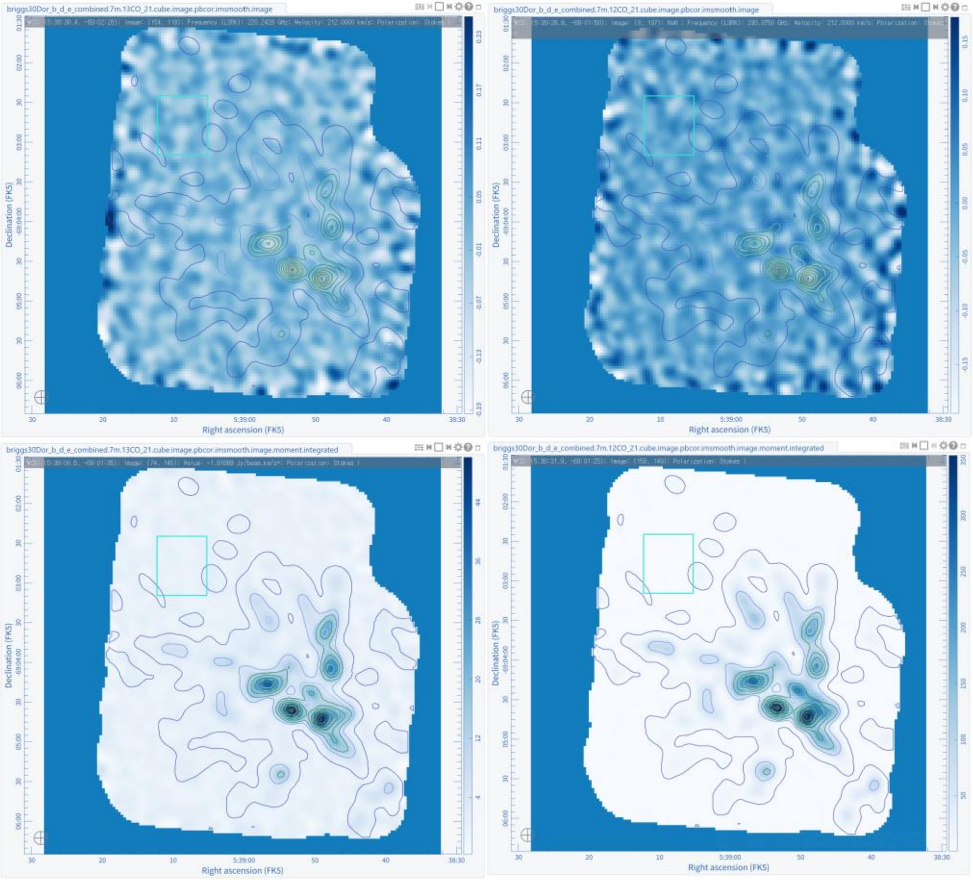
Checking 12CO, 13CO
Intergated moment0 map with CARTA

Integrated moment0 map
- imsmooth image 10”
- channel range: 10~30 (total 40)
- threshold: none
- Integrated 12CO rms: 1.18 Jy/beam.km/s



	CO13	CO12
emission	faint	bright
features	same	

- main body structure and spatial distribution are similar, same underlying molecular cloud structure



contour configuration: 12CO 3sigma rms

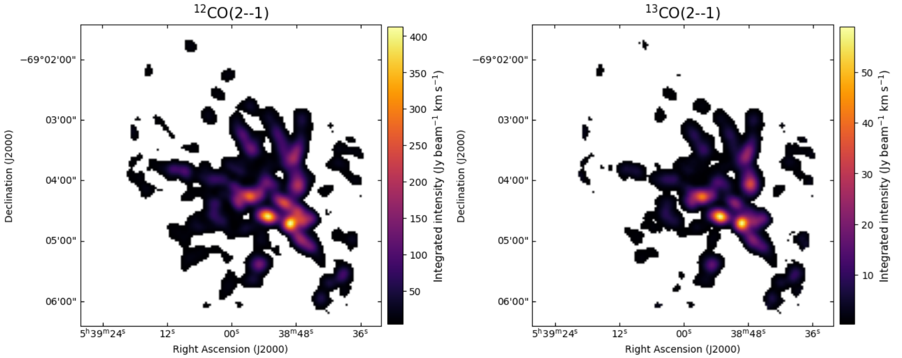
Comparison of the spatial distributions of ^{12}CO and ^{13}CO

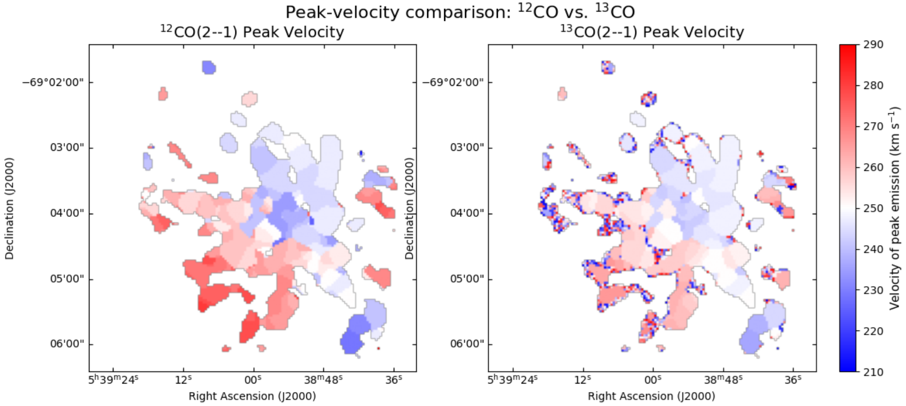
- **Matched resolution:** ^{12}CO(2–1) and ^{13}CO(2–1) moment-0 maps were compared at the **same angular resolution (10'')**.

- **Strong morphological correspondence:** The main clumps and elongated structures are spatially coincident in both isotopologues, indicating that they trace the **same underlying molecular-cloud structures**.

- **Different intensity/extent:** ^{12}CO is substantially brighter and appears somewhat more extended, whereas ^{13}CO emission is more concentrated toward the prominent molecular structures.

- **Physical interpretation:** The difference is consistent with the higher abundance and optical depth of ^{12}CO; ^{13}CO is less opaque and therefore provides better leverage on **column density**, although sensitivity also affects its apparent extent.



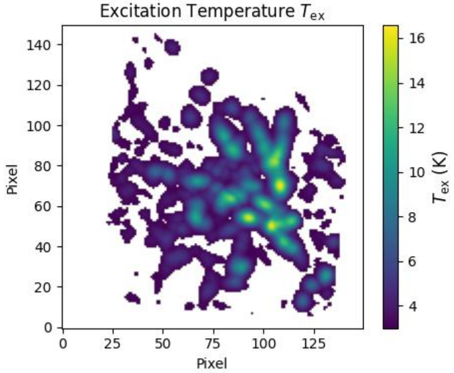


Estimation the H_2 column density in regions where both ^{12}CO and ^{13}CO are detected.

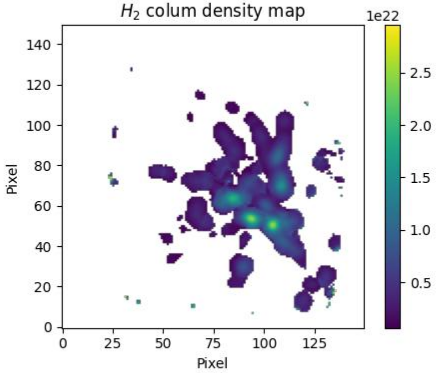
- Jy/beam → Kelvin scale to compute the excitation temperature of ^{12}CO →

$$T = 1.222 \times 10^3 \frac{I}{\nu^2\, \theta_{maj}\, \theta_{min}}$$

- Applied rms threshold = 5σ and $T_{ex} > 3K$ for both ^{12}CO and ^{13}CO cubes respectively for peak detection with moment-8 maps
- $M_8\,(x,y) \;=\; \max_{\vartheta}[\,I\,(x,y,\vartheta)]$
- $\sigma_{^{12}CO}$ = 0.055 Jy/beam, $\sigma_{^{13}CO}$ = 0.051 Jy/beam
- We made optical depth cube with only detected-peak pixels
- $N(H_2) = 3 \times 10^6 \times N(^{13}CO)$
- The LTE-derived $N(\mathrm{H_2})$map reveals a highly structured molecular cloud, with the largest molecular-gas columns concentrated in the central CO-bright structures and peak $N(\mathrm{H_2}) \sim 3{\times}10^{22}\ \mathrm{cm^{-2}}$.



Mean = 4.93 K
Median = 3.97 K
Std. dev. = 2.37 K
Max = 16.56 K
Min = 3.00 K



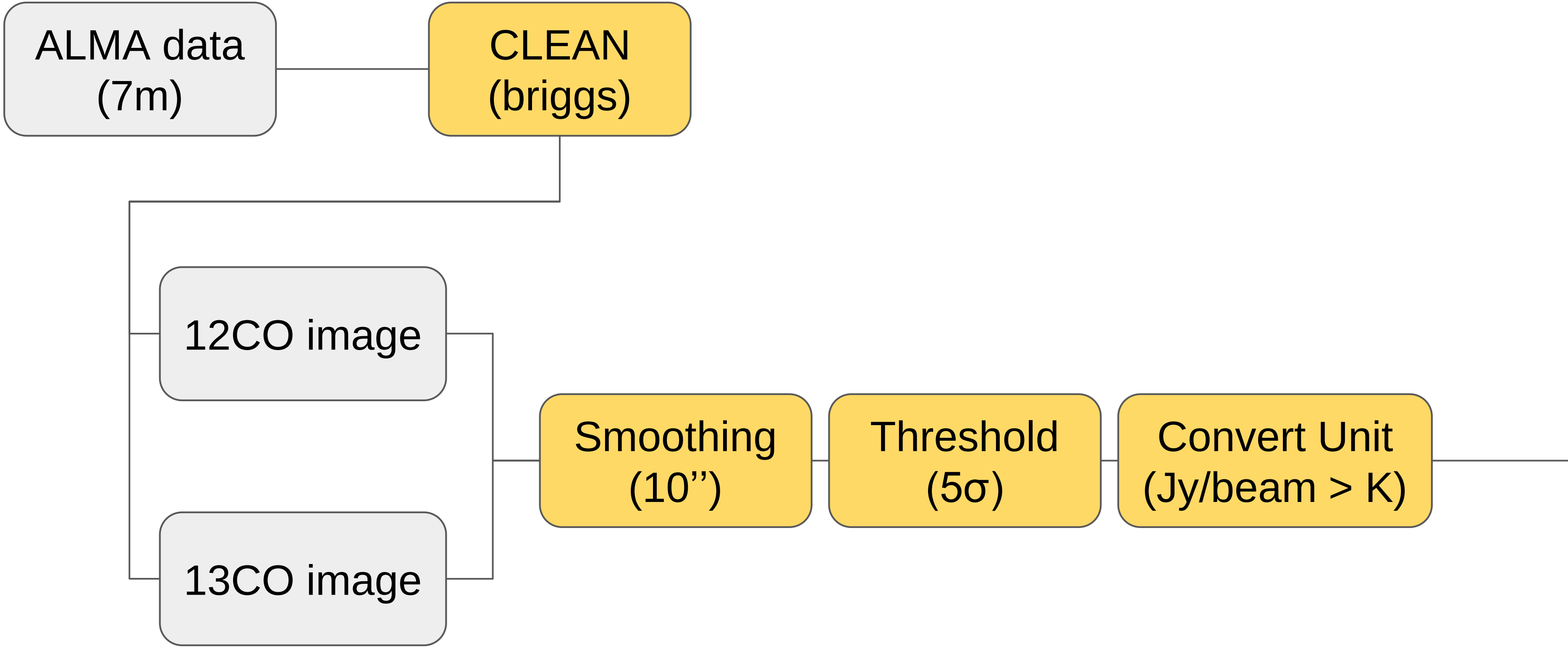
Mean = 4.76e+21 cm^{-2}
Median = 3.62e+21 cm^{-2}
Std. dev. = 3.77e+21 cm^{-2}
Max = 2.95e+22 cm^{-2}
Min = 6.74e+20 cm^{-2}

$$T_{exc} = 11.06 \left\{ \ln\left[1 + \frac{11.06}{T_{12} + 0.19}\right]\right\}^{-1}$$

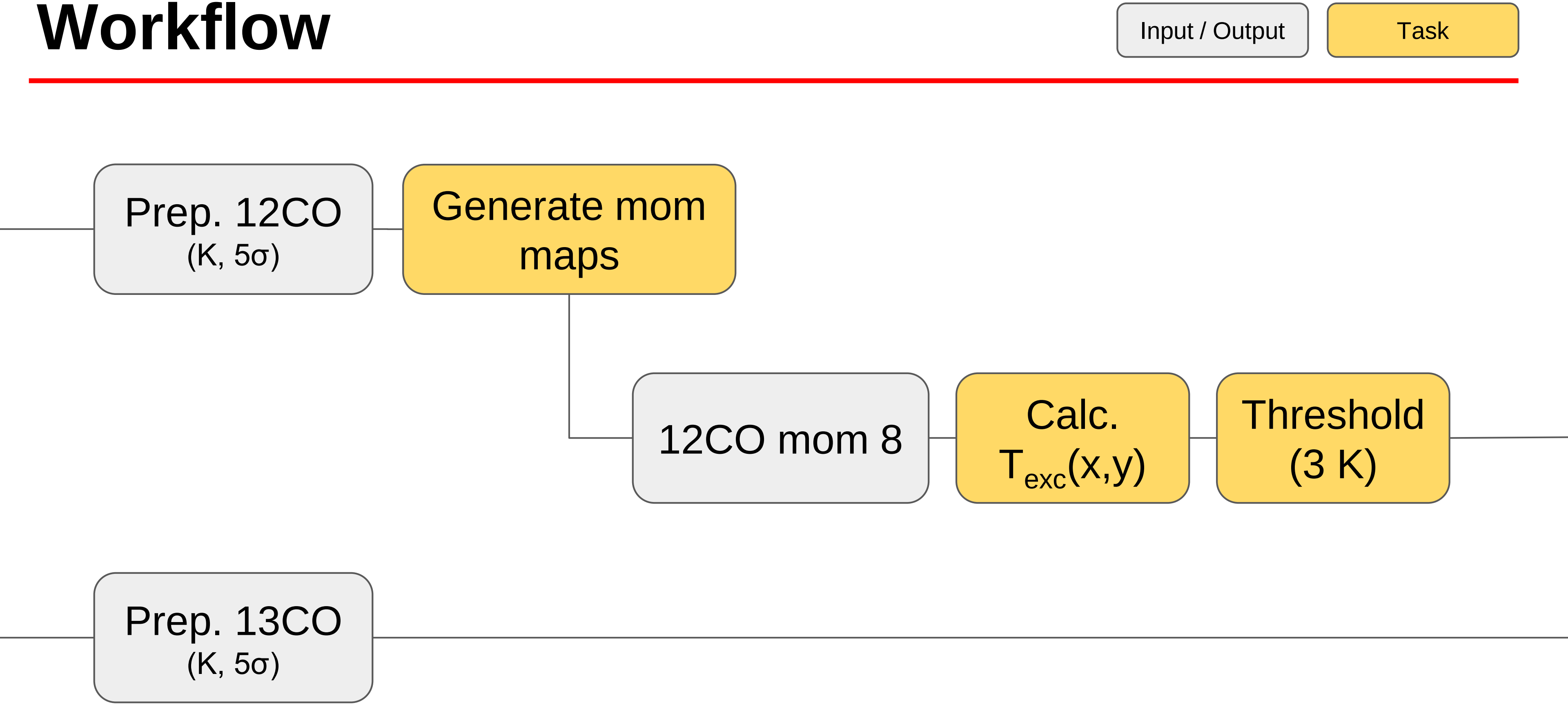
$$N(13CO)\ [\mathrm{cm^{-2}}] = 1.21 \times 10^{14} \frac{(T_{exc} + 0.88)e^{5.29/T_{exc}}}{1 - e^{-10.58/T_{exc}}} \int \tau_{13}(v)\, dv$$

Workflow

Input / Output
Task

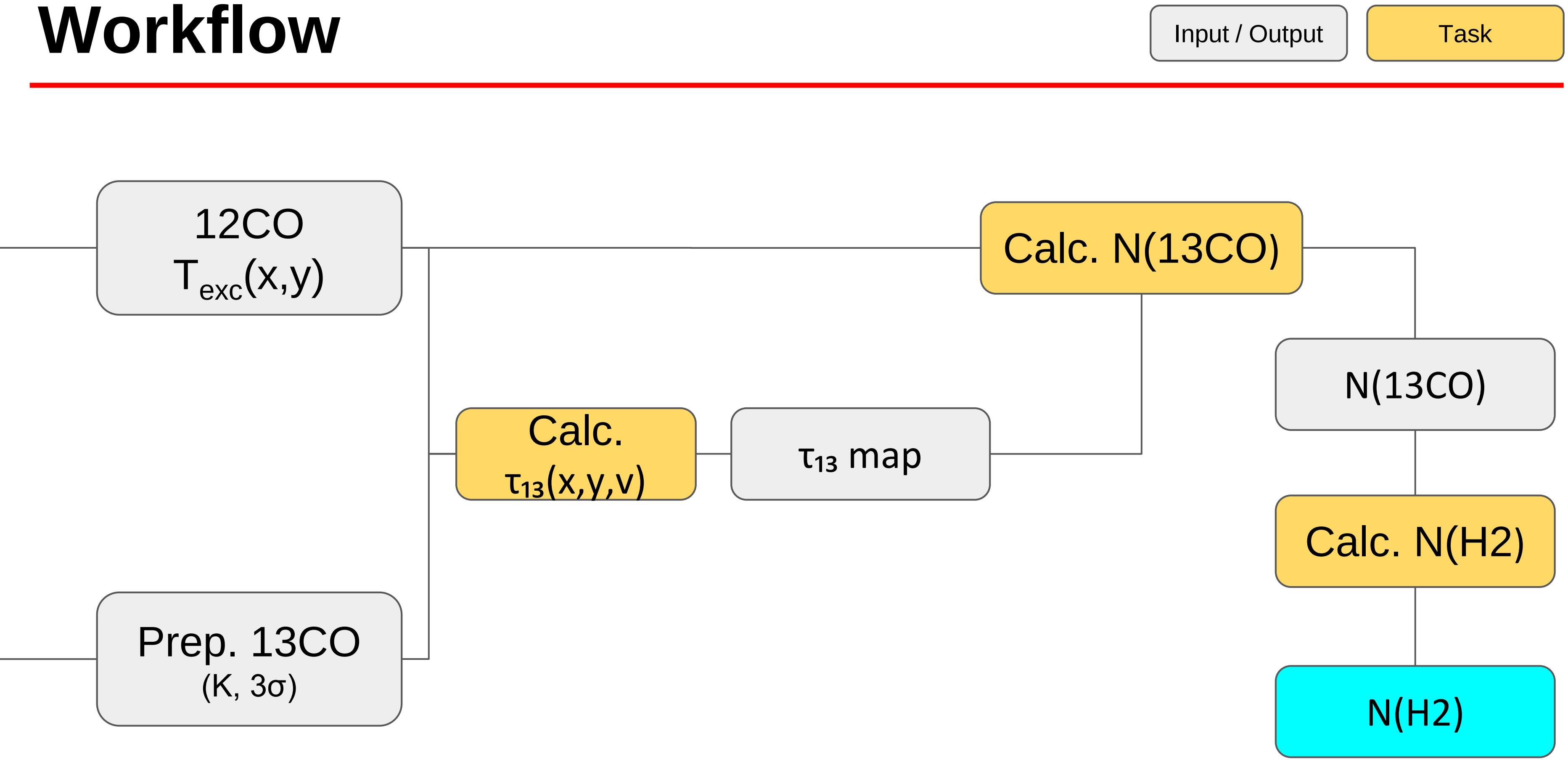


Workflow

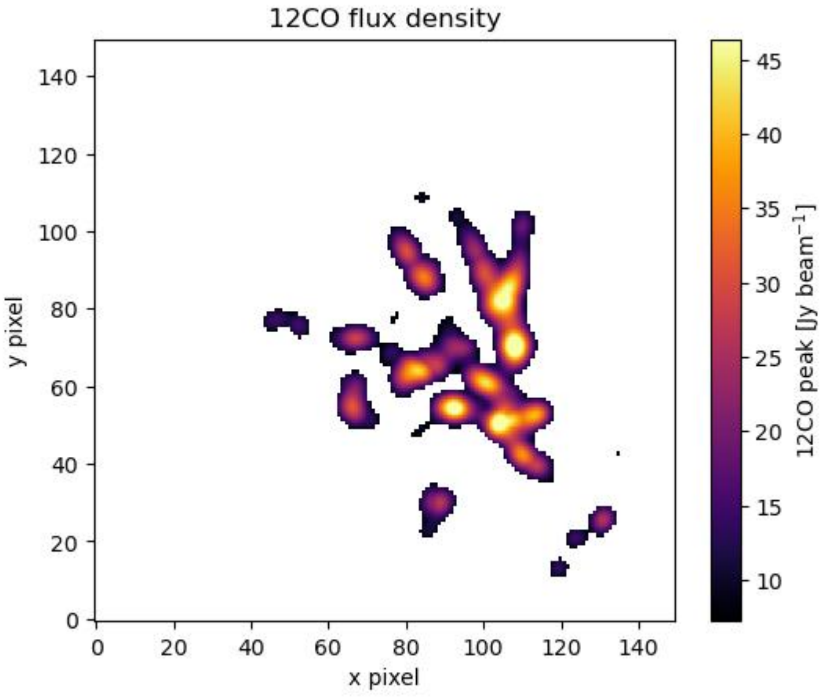


Input / Output
Task
Prep. 12CO
(K, 5σ)
Generate mom maps
12CO mom 8
Calc.
$T_{exc}(x,y)$
Threshold
(3 K)
Prep. 13CO
(K, 5σ)

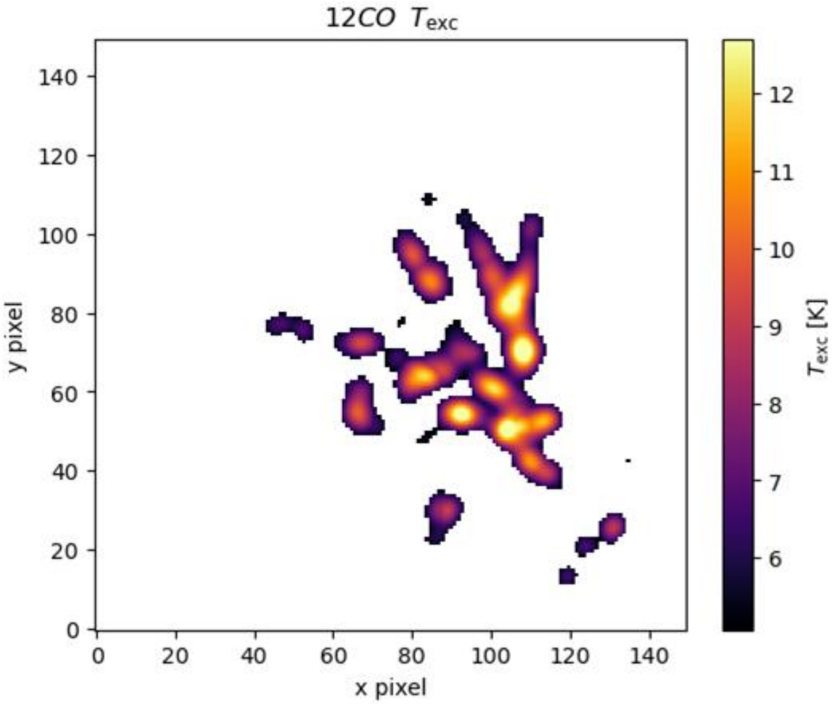
Workflow


Input / Output
Task
12CO
$T_{exc}(x,y)$
Prep. 13CO
(K, 3σ)
Calc.
$\tau_{13}(x,y,v)$
τ_{13} map
Calc. N(13CO)
N(13CO)
Calc. N(H2)
N(H2)

Results - 12CO Excitation Temperature

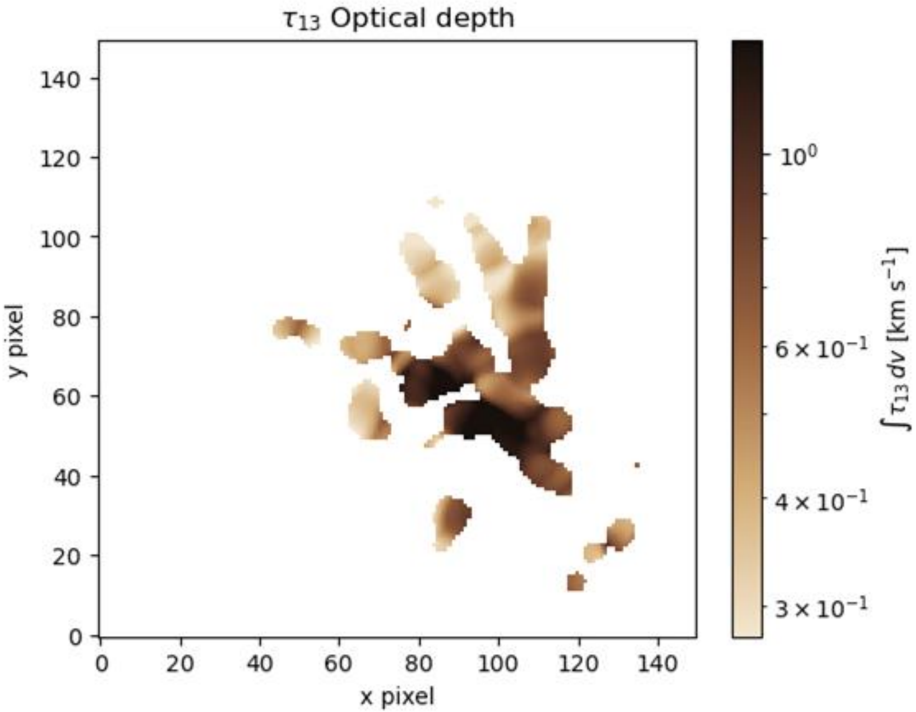


S_min = 7.24 Jy/beam, S_max = 46.36 Jy/beam

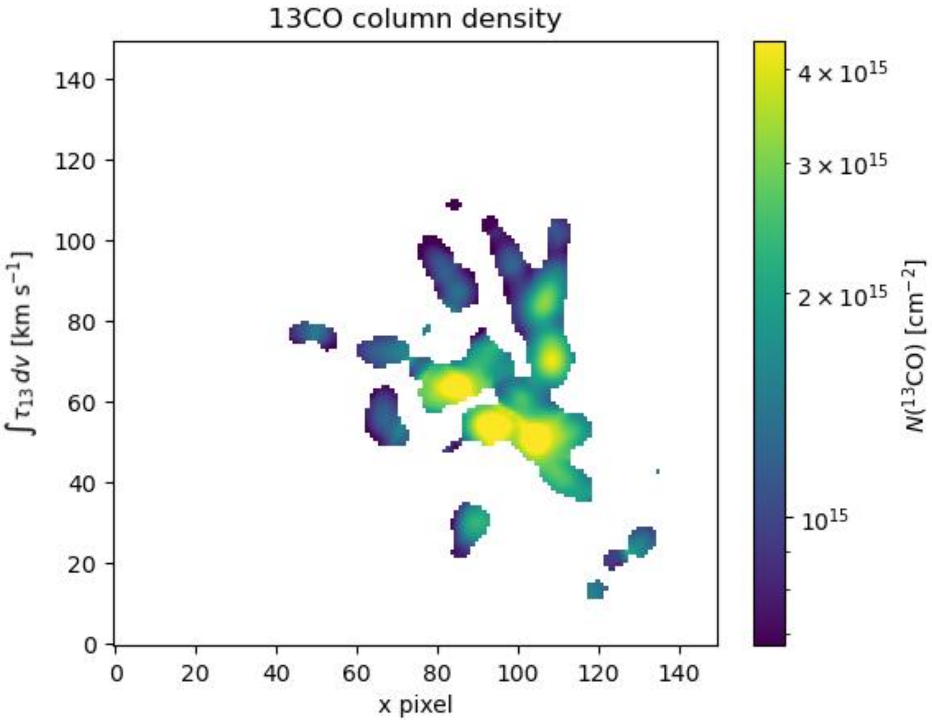


T_min = 5.06 K, T_max = 12.71 K

Results - 13CO optical depth ~ column density

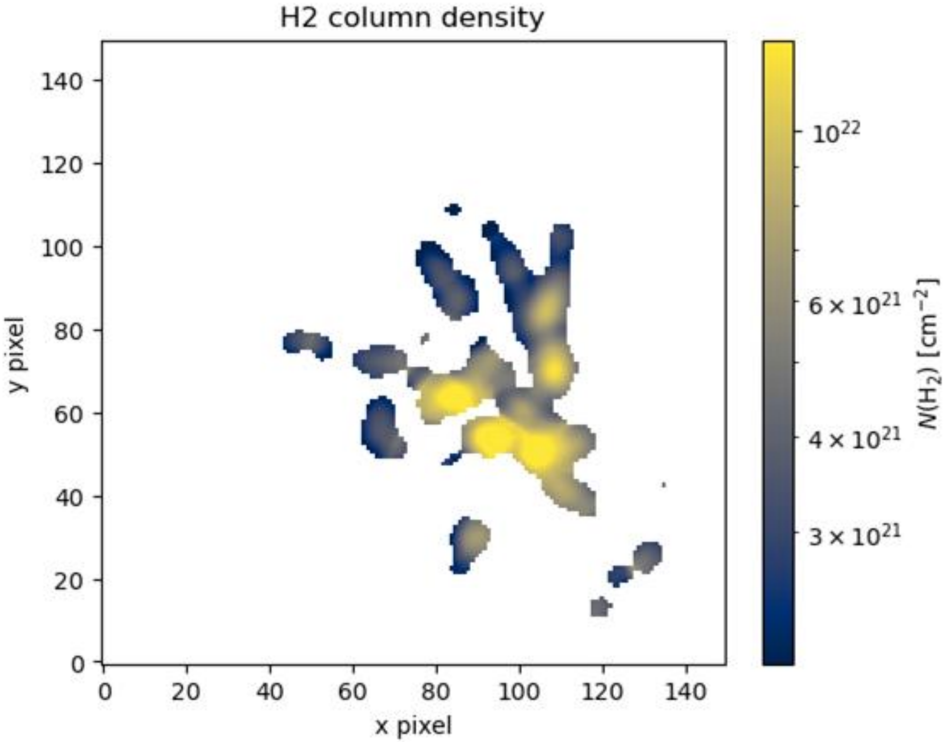


(integ) tau_min = 0.11 km/s, tau_max = 2.08 km/s



N(13CO)_min = 2.56 e+14 /cm^2
N(13CO)_max = 4.37 e+15 /cm^2

Results

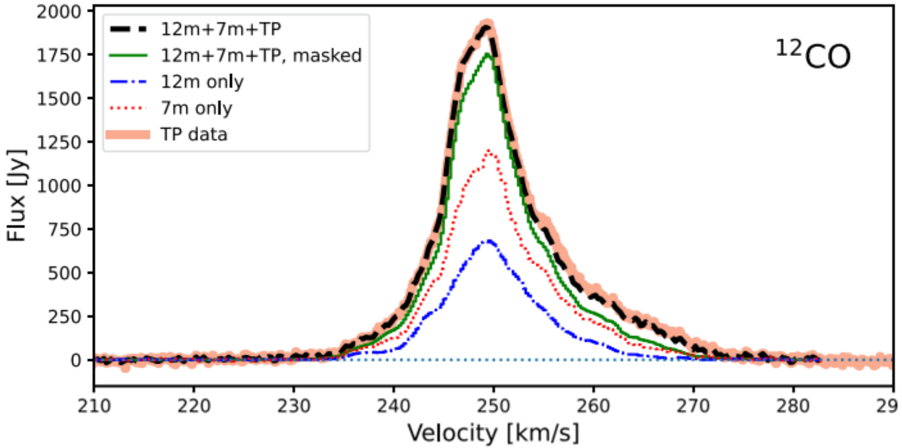


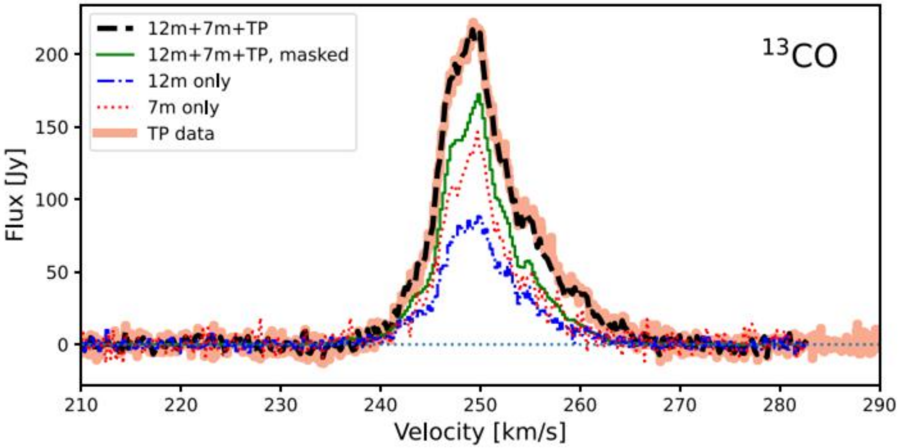
$N(H2)_{med}$ = 4.58 e+21 /cm^2

ref N(H2) ~ 6 e+21 /cm^2

Limitation

Comparing gained flux across configurations





Limitation

Main difference with the original data

	Wong et al. 2022	Us
ALMA observation	12m + 7m + TP	7m
FoV	5 mosaic field	part of 5 (2)

Absence of 12m: low resolution ignored small scale structures

Absence of TP: Ignored extended gas structures and its physical parameters

Part of field may not represent the whole source

APPENDIX

Detail equations

1. Excitation Temperature T_{exc}

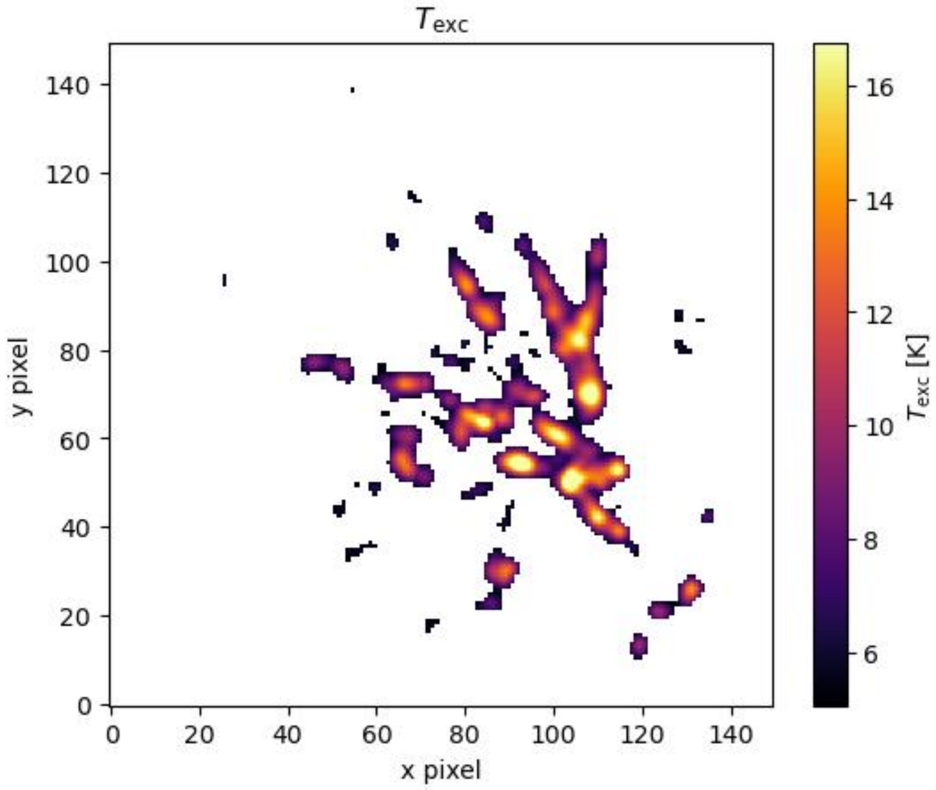
$$T_{\mathrm{MB}}(v) = (J(T_{\mathrm{exc}}) - J(T_{\mathrm{BG}}))\left(1 - e^{-\tau(v)}\right)$$

$$T_{\mathrm{MB}}\,(v) = \frac{h\nu}{k}\left(\frac{1}{e^{h\nu/kT_{\mathrm{exc}}} - 1} - \frac{1}{e^{h\nu/kT_{\mathrm{BG}}} - 1}\right)\left(1 - e^{-\tau(v)}\right)$$

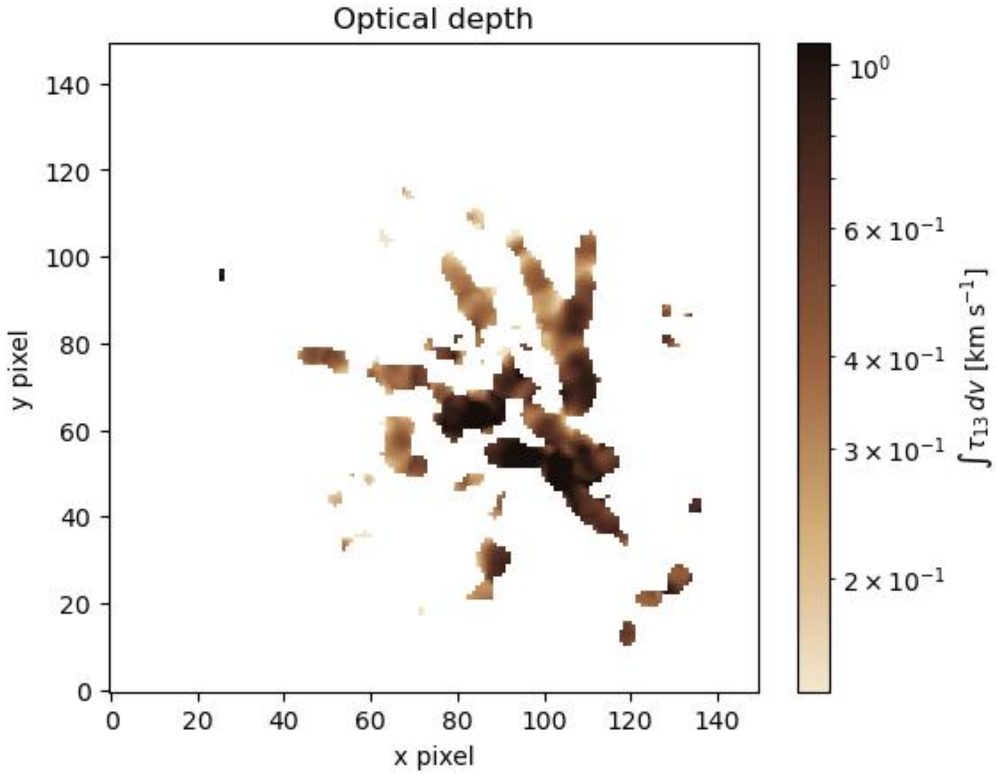
$$T_{12}(v) = \frac{h\nu_{12}}{k}\left(\frac{1}{e^{h\nu_{12}/kT_{\mathrm{exc}}} - 1} - \frac{1}{e^{h\nu_{12}/kT_{\mathrm{BG}}} - 1}\right)$$

$$T_{\mathrm{exc}} = 11.06\left\{\ln\left[1 + \frac{11.06}{T_{12} + 0.19}\right]\right\}^{-1}$$

7.1 arcsec

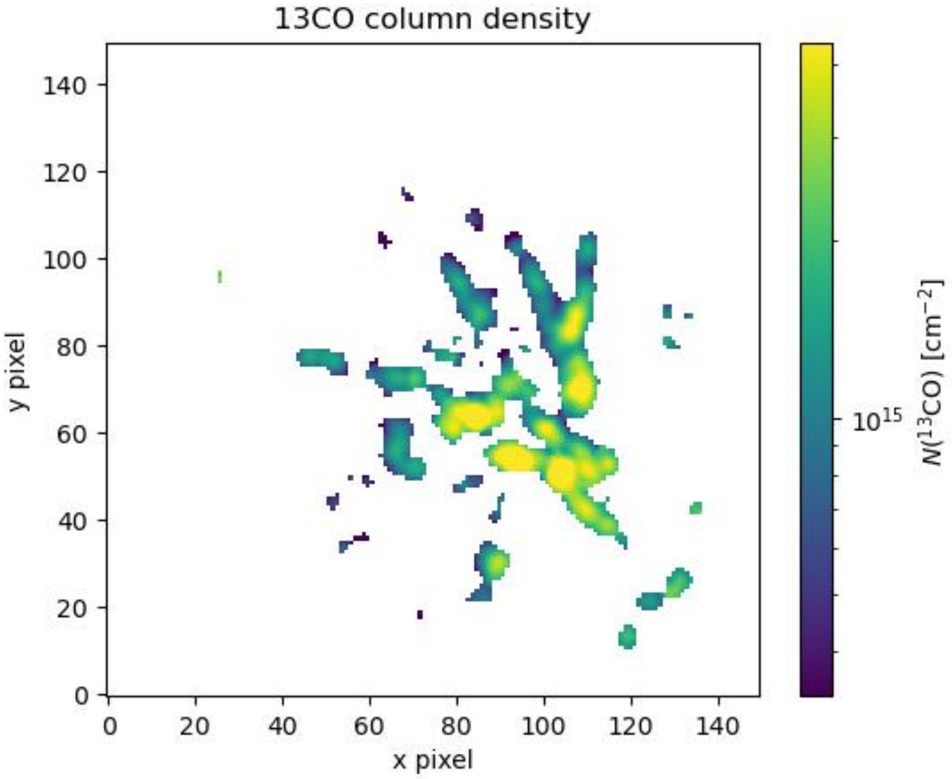


7.1 arcsec

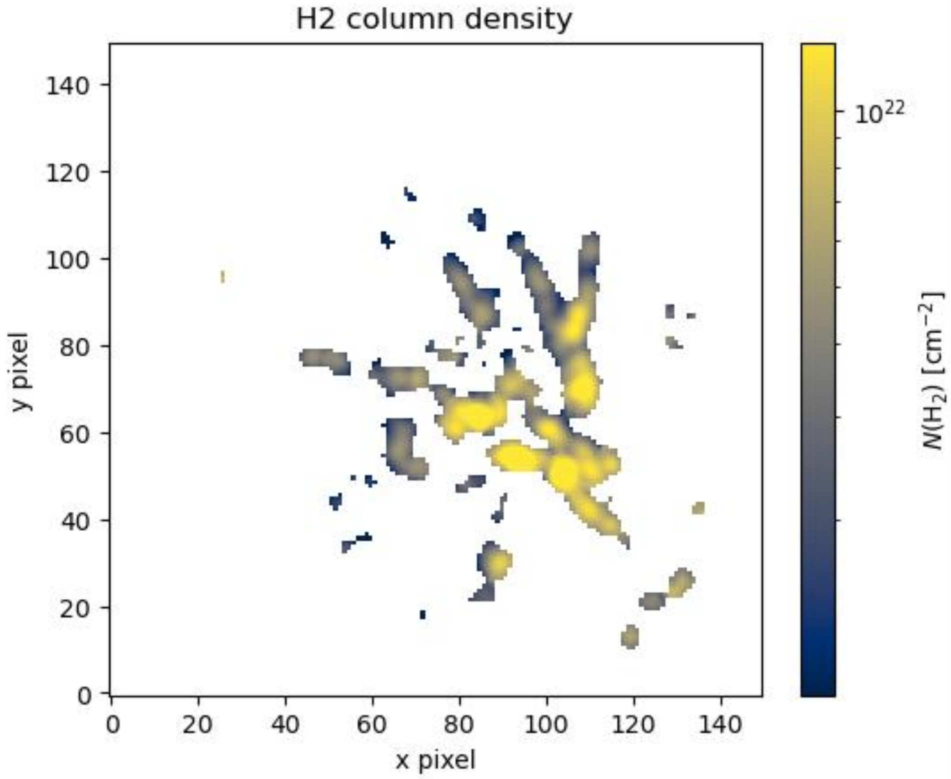


Optical depth
y pixel
x pixel
0
20
40
60
80
100
120
140
10^0
6×10^{-1}
4×10^{-1}
3×10^{-1}
2×10^{-1}
$\int \tau_{13}\, dv$ [km s^{-1}]

7.1 arcsec


13CO column density
y pixel
x pixel
0
20
40
60
80
100
120
140
10^{15}
$N(^{13}CO)$ [cm^{-2}]

7.1 arcsec


H2 column density
y pixel
x pixel
0
20
40
60
80
100
120
140
10^{22}
$N(H_2)$ [cm^{-2}]

Full CLEAN parameter

```
tclean(
        vis=vis,
        imagename=image_name,

        specmode='cube',
        gridder='mosaic',

        deconvolver='multiscale',   # extended source
        scales=[0, 1, 2, 5], # pixel unit  (scale * cell)

        weighting='briggs',
        robust=0.5,

        imsize=[150, 150],
        cell='2arcsec',
        phasecenter='J2000 84.75deg -69.065deg',

        nchan=41,
        start='210km/s',
        width='2km/s',
```

```
        restfreq='230.538GHz',  # (12CO)
        outframe='LSRK',
        veltype='radio',

        niter=10000, # zero iteration for dirty map
        threshold='33mJy * 3.',

        usemask = 'auto-multithresh',
        #sidelobethreshold = 3.0, # standard value
        #noisethreshold = 5.0, # standard value
        #minbeamfrac = 0.3, # standard value
        #lownoisethreshold = 1.5, # standard value
        #negativethreshold = 0.0, # standard value

        interactive=False,
        parallel=False, # True for mpi mode
        pbcor=True,
        restoringbeam='common'
)
```

plotms:
12CO(2-1) & 13CO(2-1) velocity range in the *.ms data