Large Variety of the velocity profile of C^+, C, and CO and their column densities in N159

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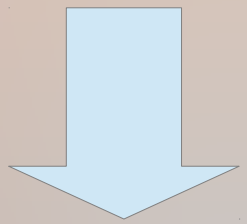
1. Background

- [CII]/CO is expected to be higher in low metallicity environment
- The line profile of [CII] 158μm is often very different from that of CO lines → complex origin of the line emission



Spatially and velocity-resolved mapping observations in star-forming regions LMC

2. Observations

- OTF mapping with 6” step size, 4'x(3'-4') area covering N159 W and E
- SOFIA/GREAT + APEX/FLASH^{+}&CHAMP^{+}

Line	Frequency [GHz]	Instrument	η_f^a	η_{mb}^b	HPBW^c [″]
^{13}CO(3-2)	330.5879653	FLASH^{+}	0.95	0.69	19.0
CO(3-2)	345.7959899	FLASH^{+}	0.95	0.69	18.2
CO(4-3)	461.0407682	FLASH^{+}	0.95	0.61	13.6
[C I] $^3P_1$-$^3P_0$	492.1606510	FLASH^{+}	0.95	0.6	12.8
CO(6-5)	691.4730763	CHAMP^{+} LFA	0.95	0.42	8.8
[C I] $^3P_2$-$^3P_1$	809.3419700	CHAMP^{+} HFA	0.95	0.38	7.7
[N II]	1461.1338000	GREAT L1	0.97	0.67	18.3
[C II]	1900.5369000	GREAT L2	0.97	0.67	14.1

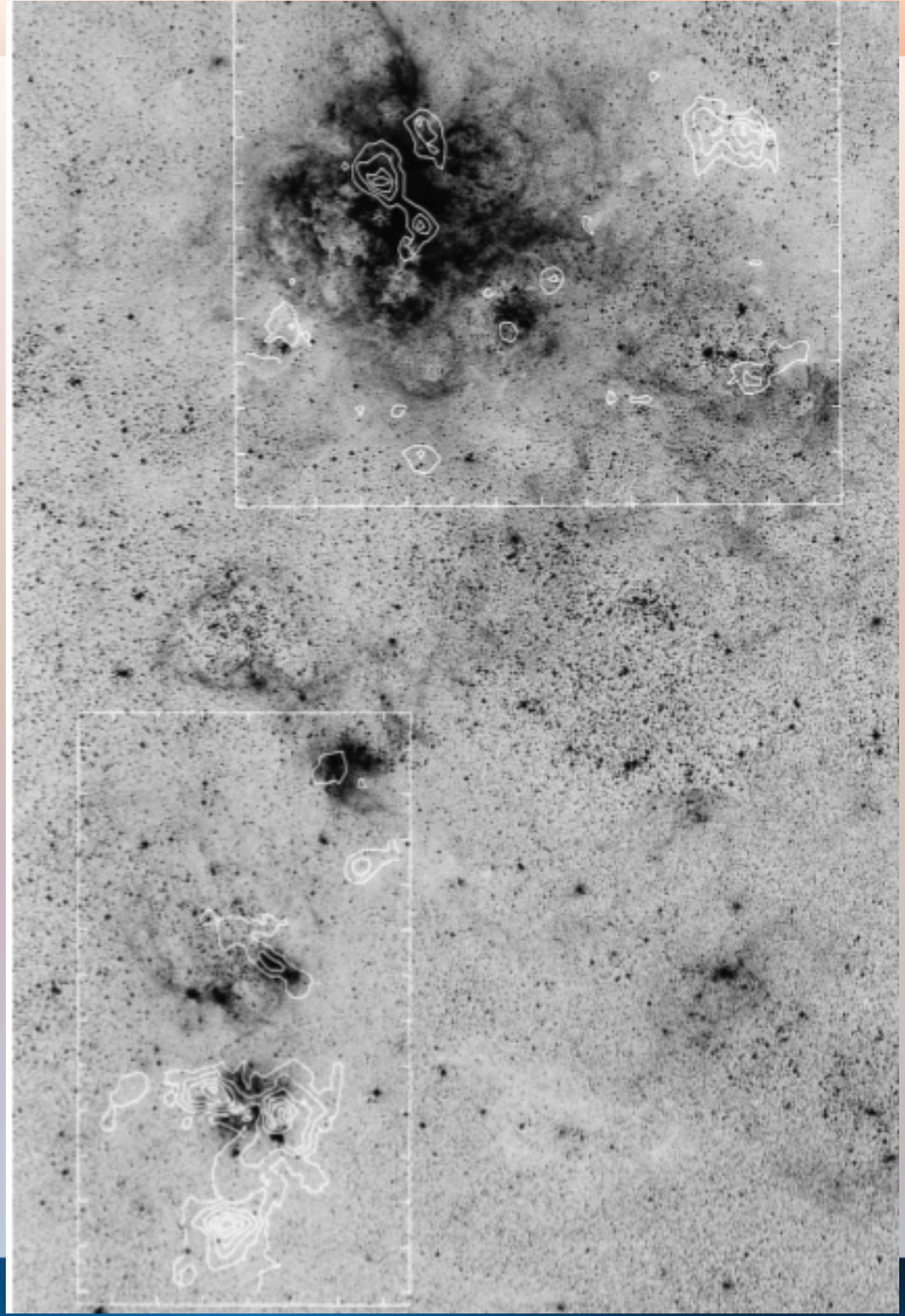


Image : blue
Contour : CO(1-0)

Johansson et al. (1998)

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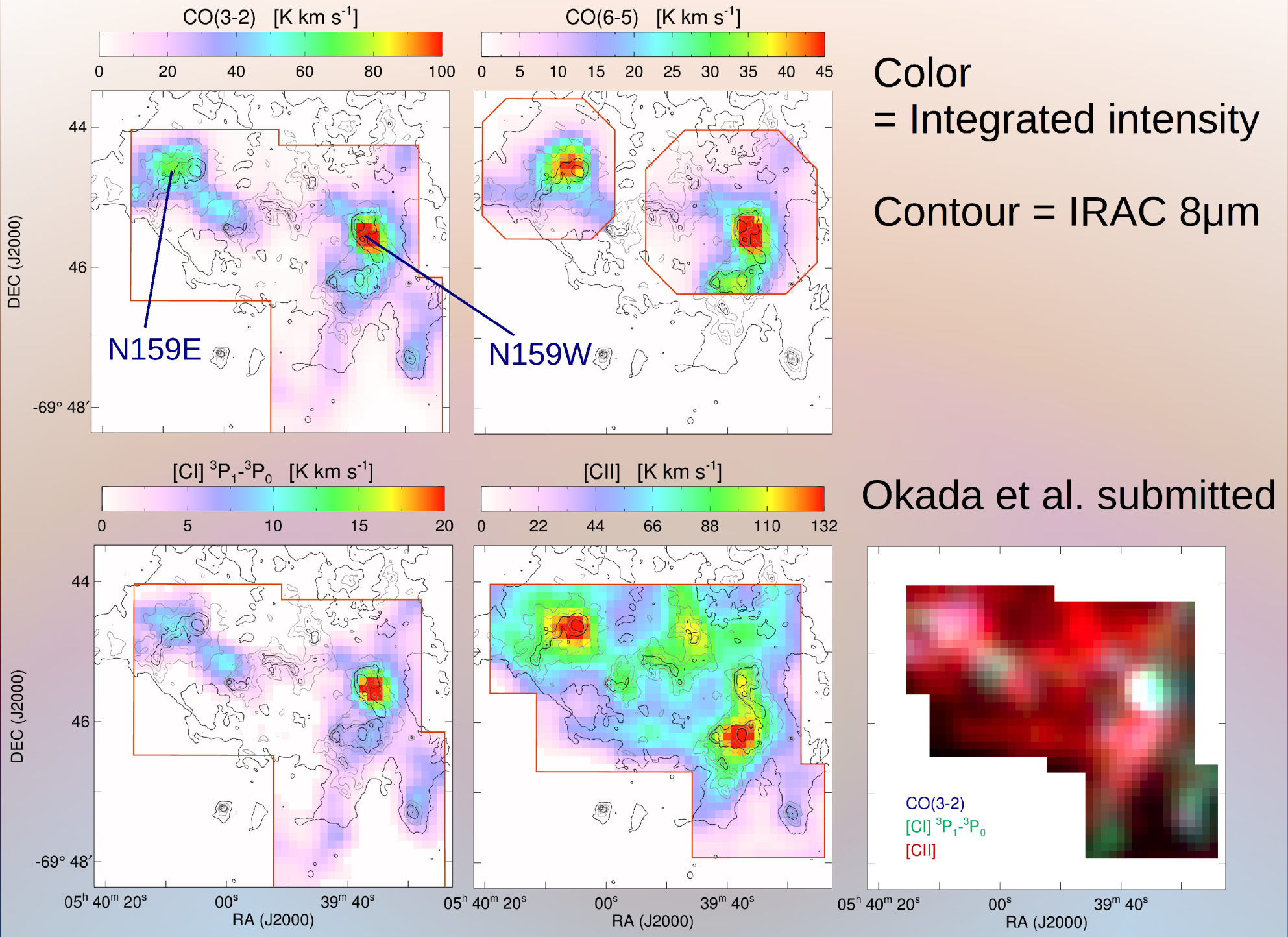
GREAT observations

- New Zealand deployment (2013)
- [CII] : 4 flights (1.5h+2h+0.3h+0.2h)
- [NII] : first 2 flights
- XFFTS (2.5GHz bandwidth, 44kHz resolution)

3. Results

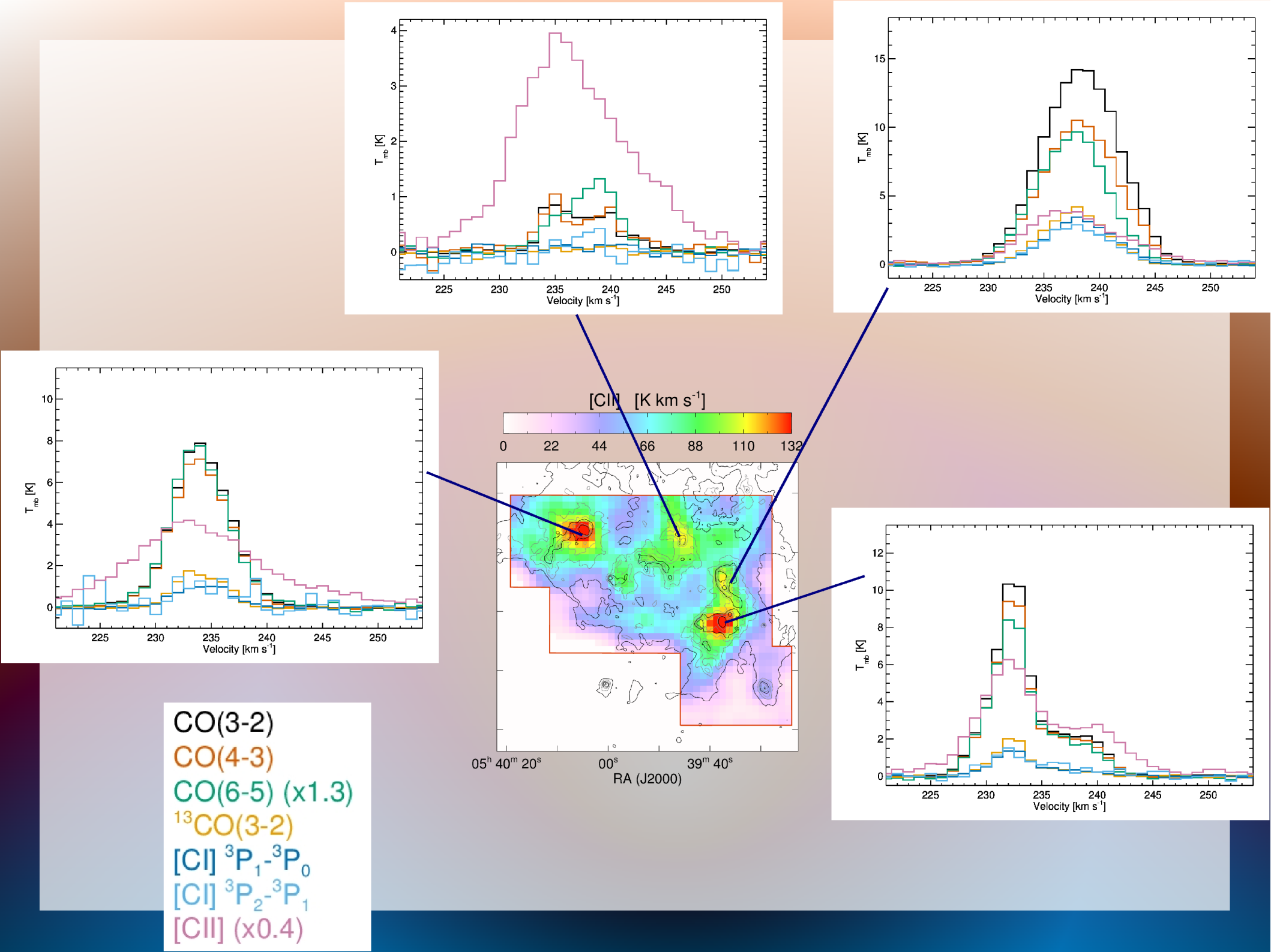
- Convolved to 1 km/s velocity resolution and 20” spatial resolution



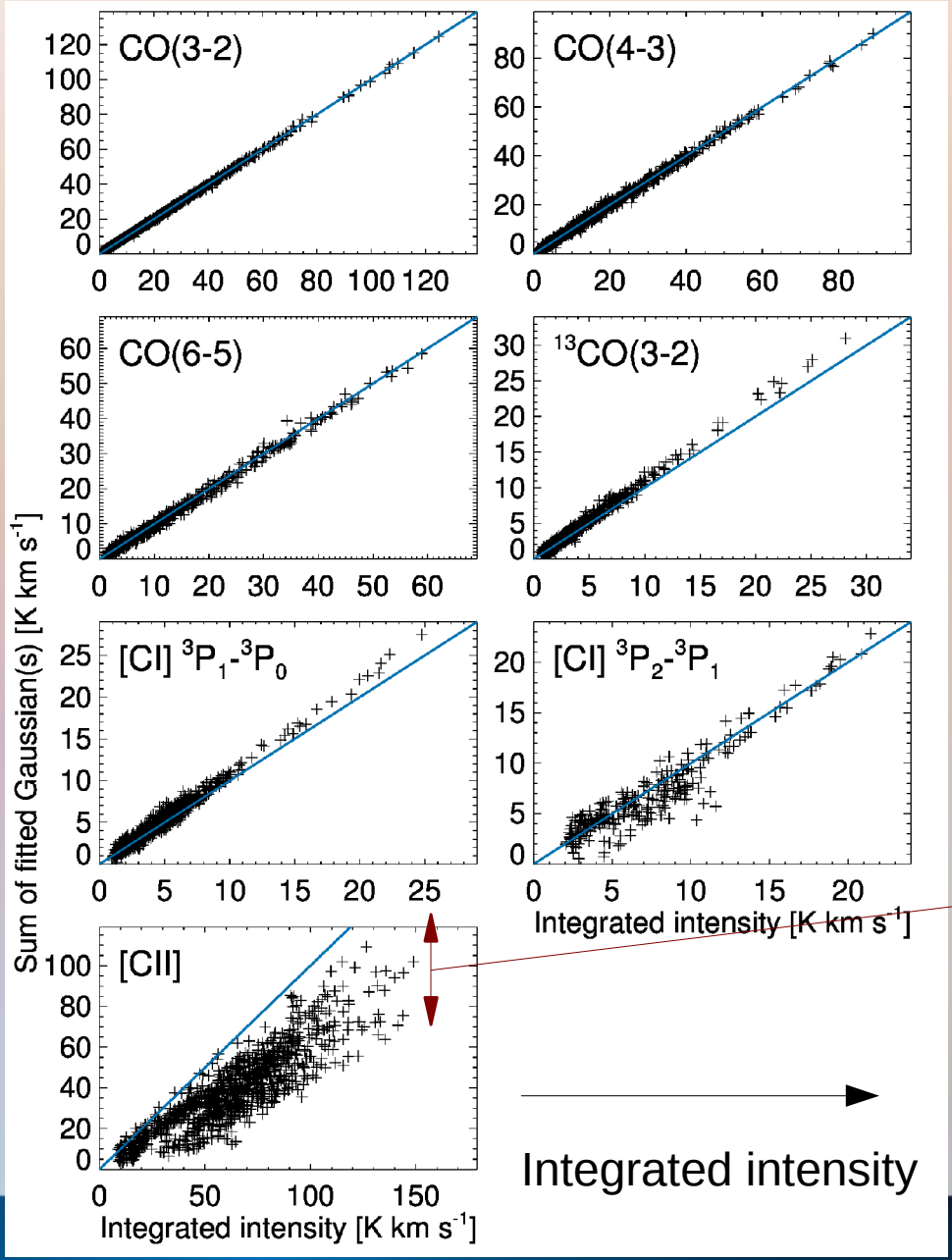
Color
= Integrated intensity

Contour = IRAC 8μm

Okada et al. submitted


[CII] [K km s-1]
0 22 44 66 88 110 132
05h 40m 20s 00s 39m 40s
RA (J2000)
Tmb [K]
Velocity [km s-1]
CO(3-2)
CO(4-3)
CO(6-5) (x1.3)
13CO(3-2)
[CI] 3P1-3P0
[CI] 3P2-3P1
[CII] (x0.4)

Result 1 – Line profile



Sum of fitted Gaussians

Integrated intensity

Gaussian fit to CO(3-2)
1 or 2 Gaussians

Use the center and width to fit the other emission lines

Spatial variation
20-50%

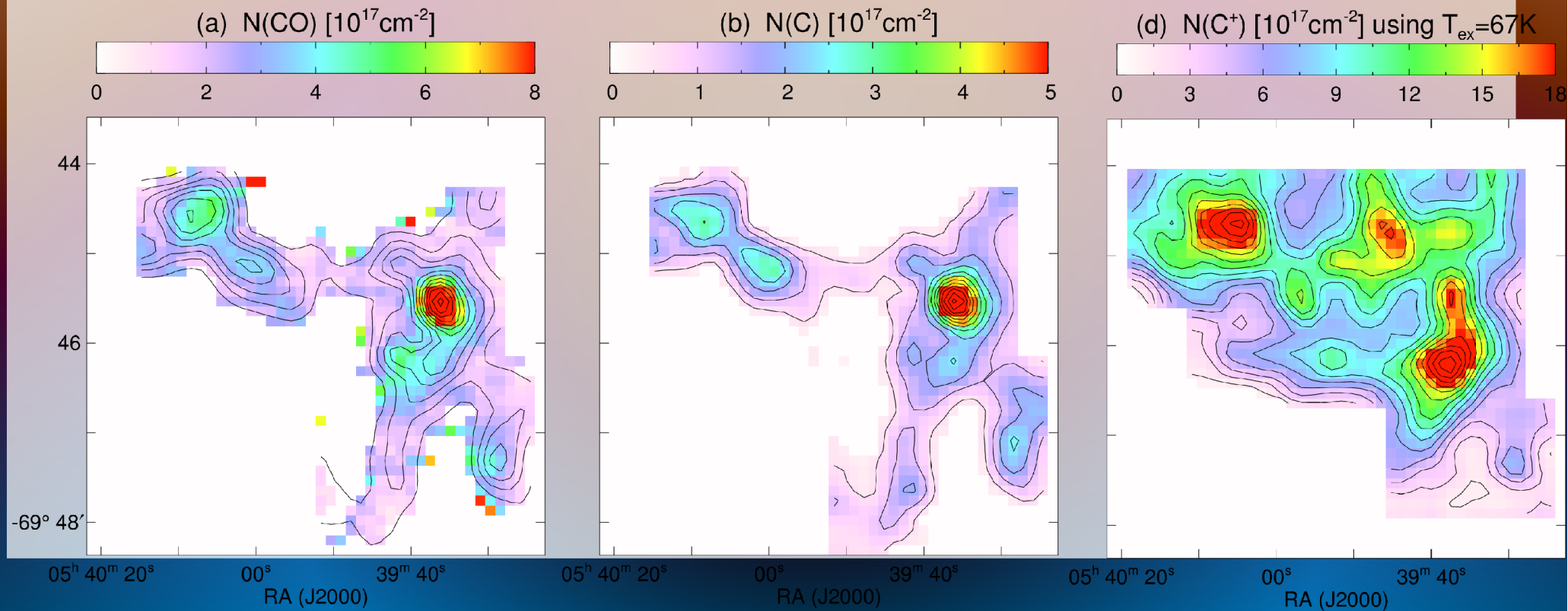
Result 2 – Column density fraction

CO : $^{12}CO(3\text{-}2)/^{13}CO(3\text{-}2) \rightarrow \tau \rightarrow T_{ex}$

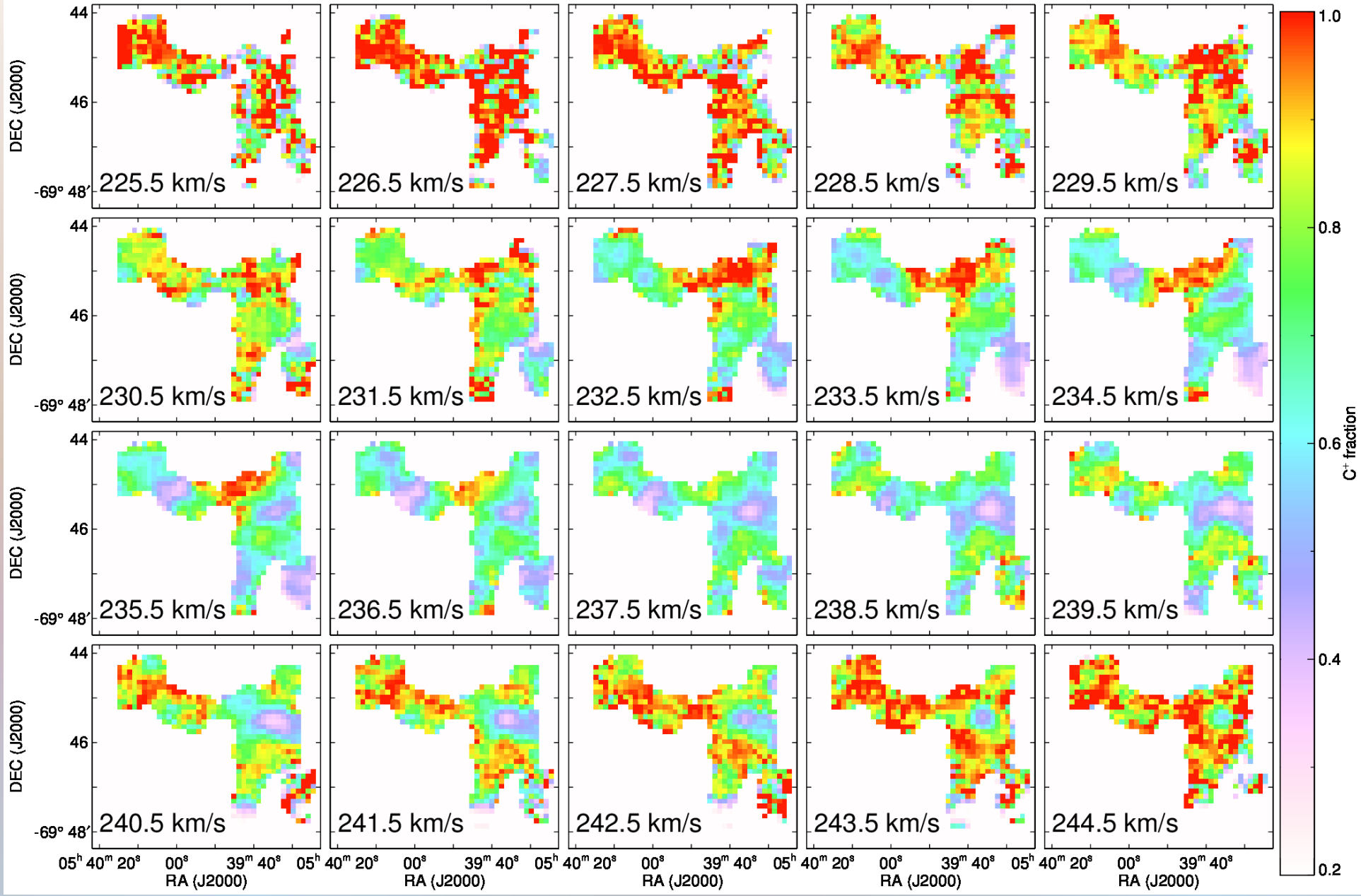
C : Constant T_{ex} (consistent with $[CI]^3P_2\text{-}^3P_1/^3P_1\text{-}^3P_0$)

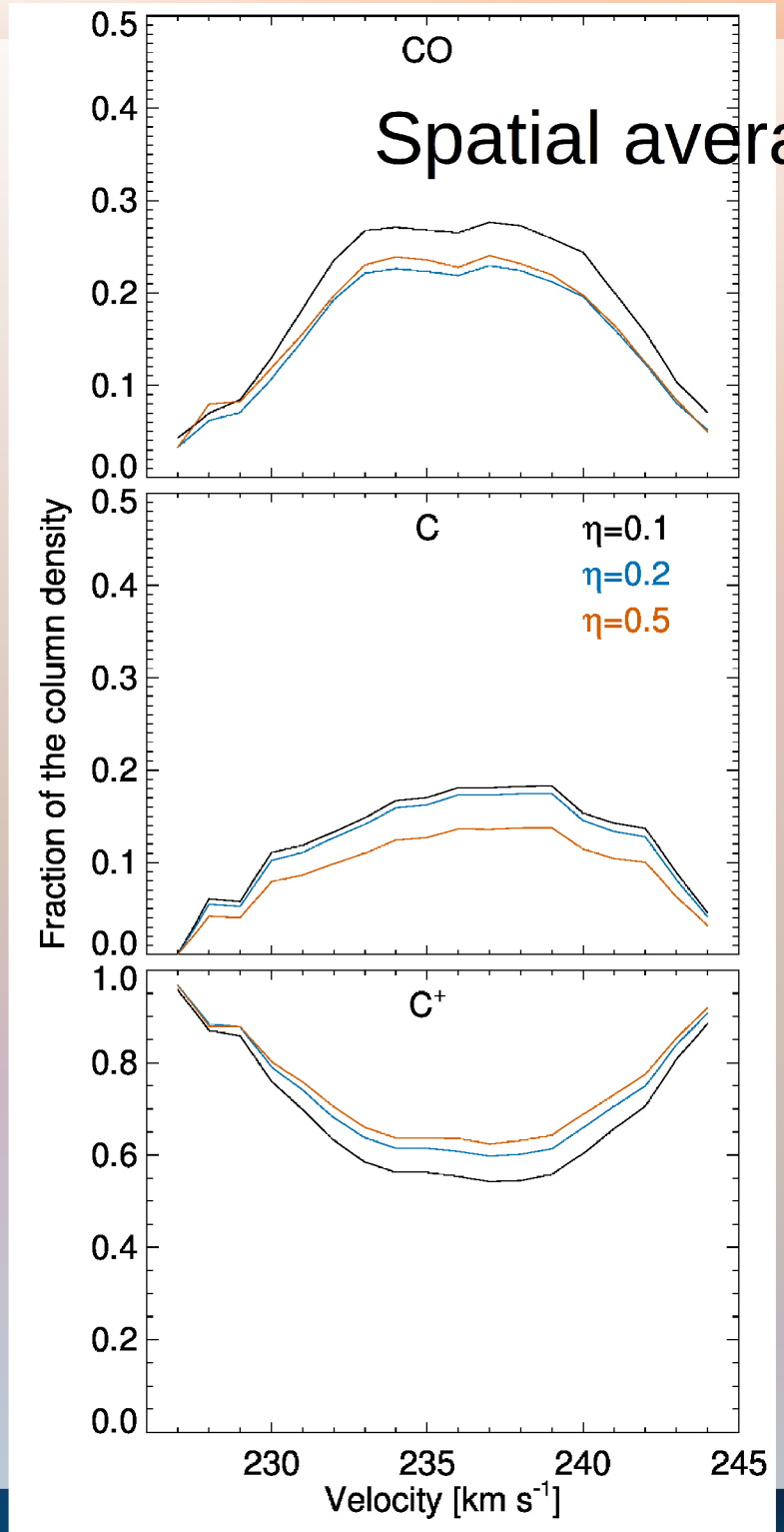
C^+ : Constant T_{ex} (optically thick at the peak positions)

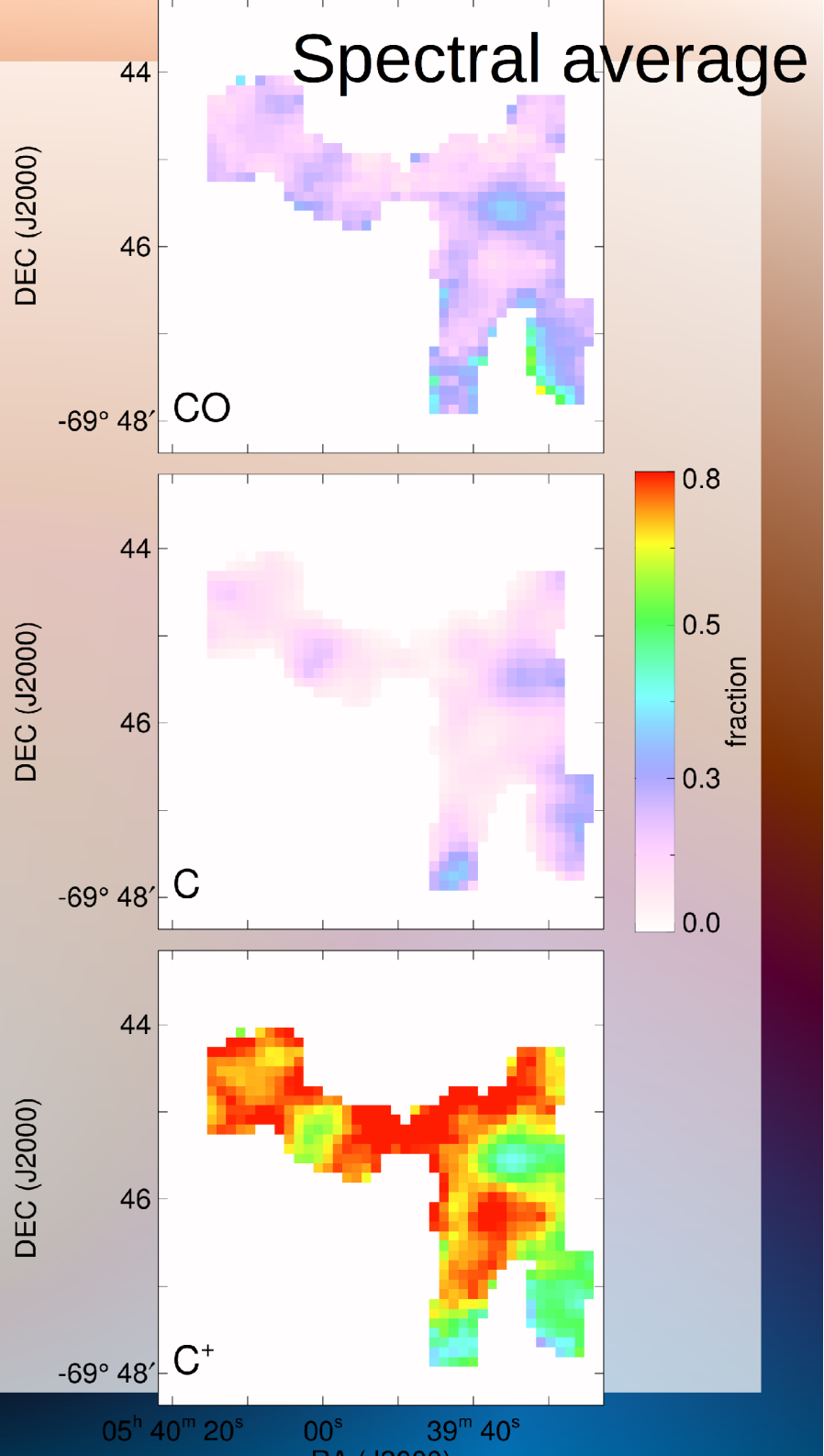
N(CO), N(C), N(C^+) for each velocity bin!



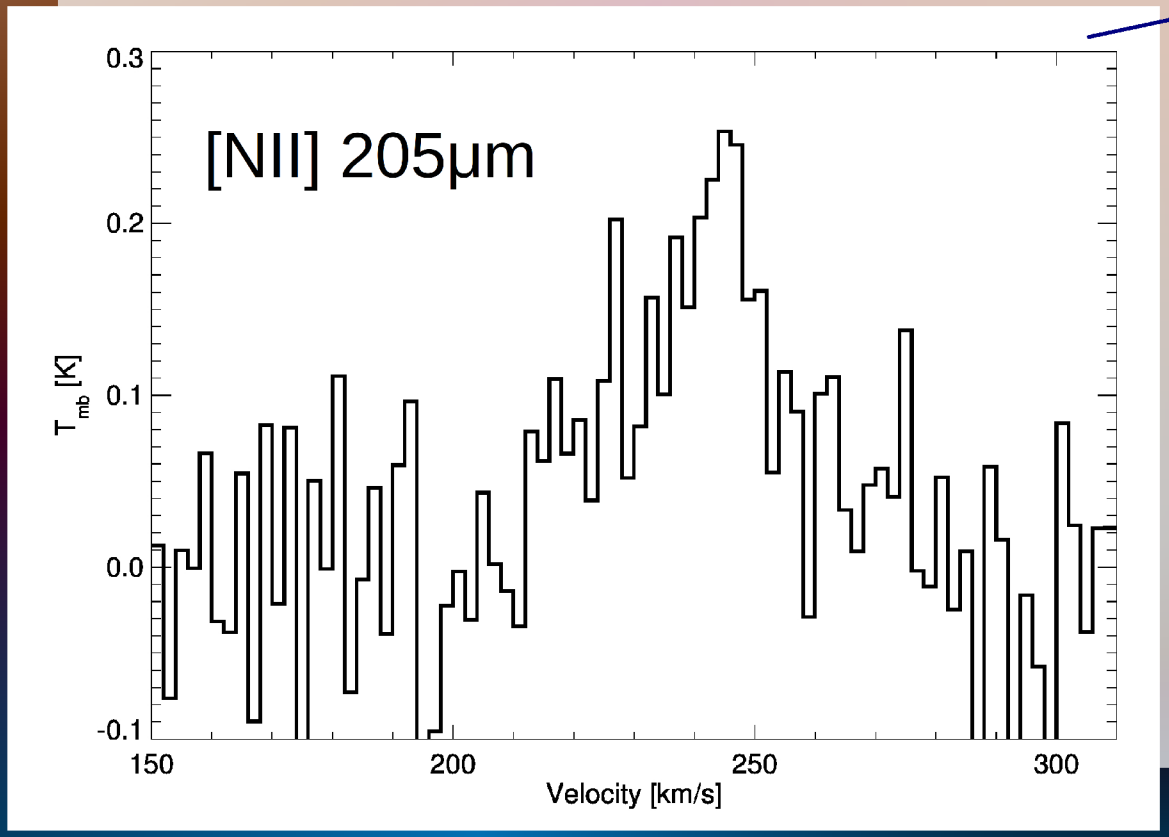
Channel map of $N(C^+)/(N(CO)+N(C)+N(C+))$

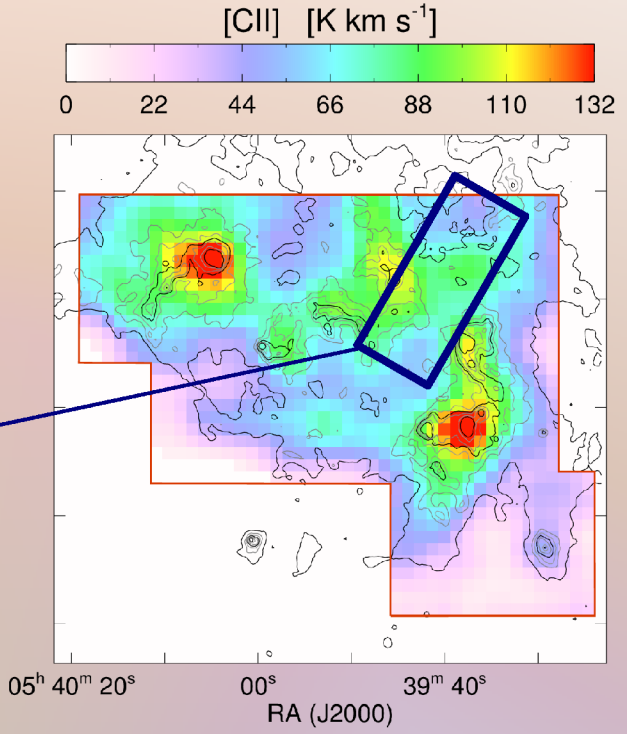


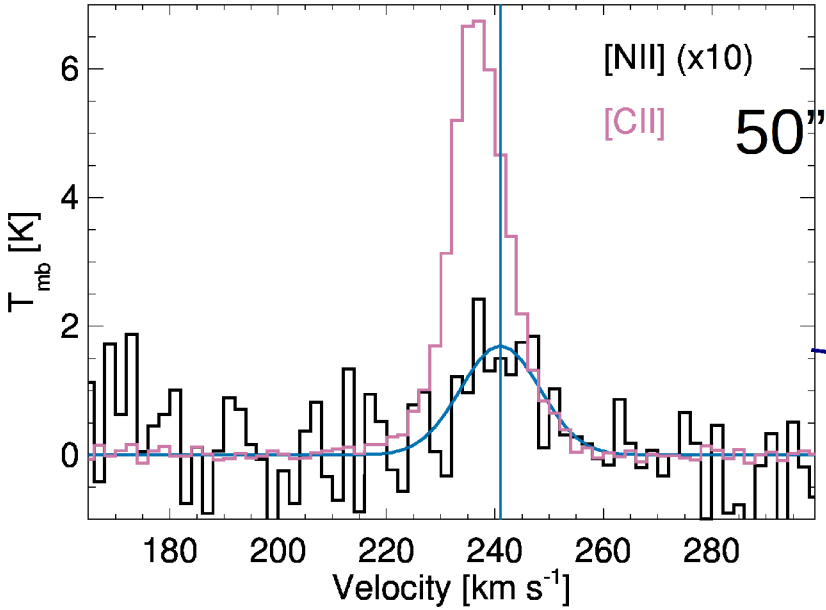

Spatial average
CO
C
C+
η=0.1
η=0.2
η=0.5
Fraction of the column density
Velocity [km s-1]
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.8
1.0
230
235
240
245


Spectral average
CO
C
C+
DEC (J2000)
-69° 48′
44
46
05h 40m 20s
00s
39m 40s
fraction
0.0
0.3
0.5
0.8

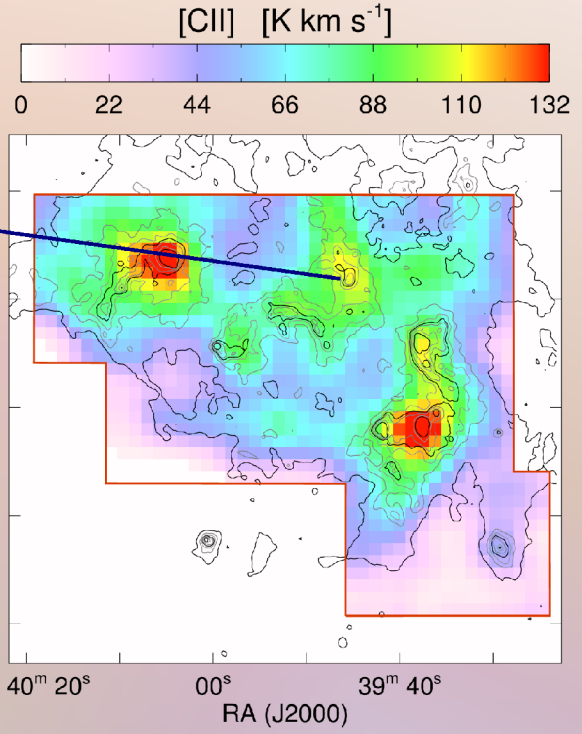
Result 3 – the ionized gas contribution to [CII]



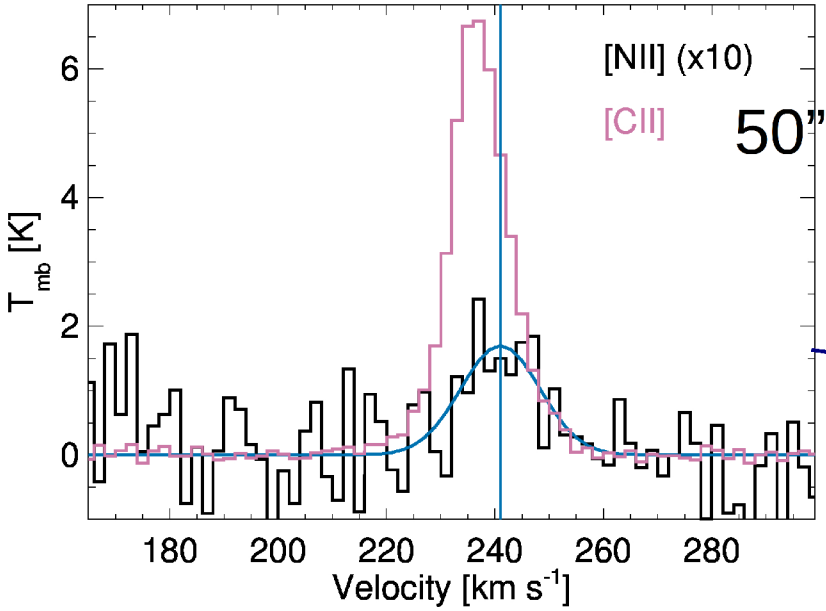




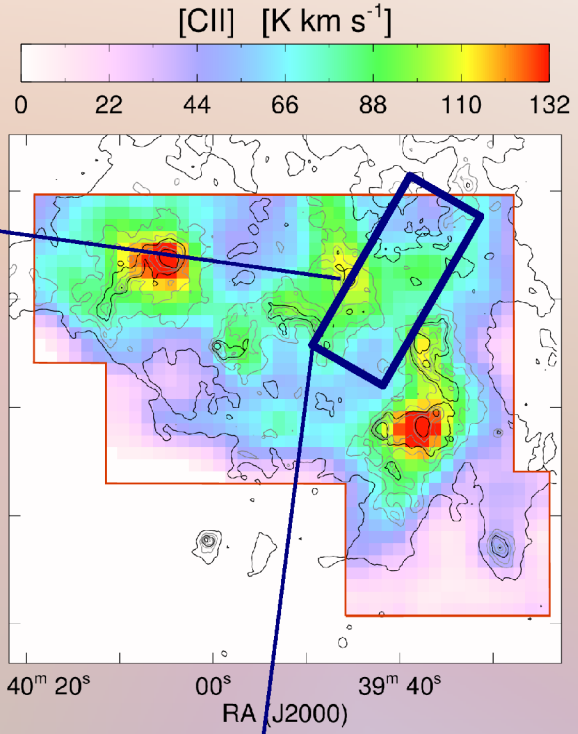
50”, 2km/s resolution



[NII]/[CII] = 0.014
Maximum possible contribution of the ionized gas to the [CII] emission = 19%



50”, 2km/s resolution



[NII]/[CII] = 0.014
Maximum possible contribution of the ionized gas to the [CII] emission = 19%

[NII]/[CII] = 0.02
Maximum possible contribution of the ionized gas to the [CII] emission = 30%

Summary

- Observations : Velocity resolved mapping observations of [CII], [NII], CO, [CI] in LMC/N159

- Line profile : 20-50% of [CII] emission cannot be fitted by the CO line profile → ablating from the dense cores or additional gas component
- Column density in each velocity bin : C^+ dominates the velocity range far from the line center / the region located between the CO cores
- The ionized gas contribution to [CII] : [NII]/[CII] suggests ≤ 19% at [CII] peak, ≤ 30% where [NII] is detected, ≤ 15% over the whole observed region