

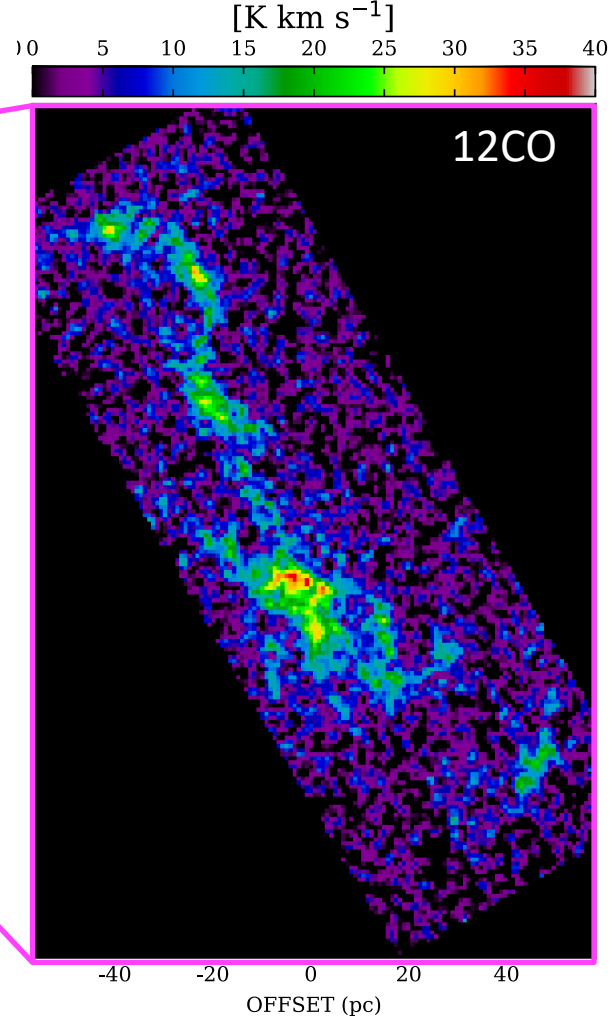
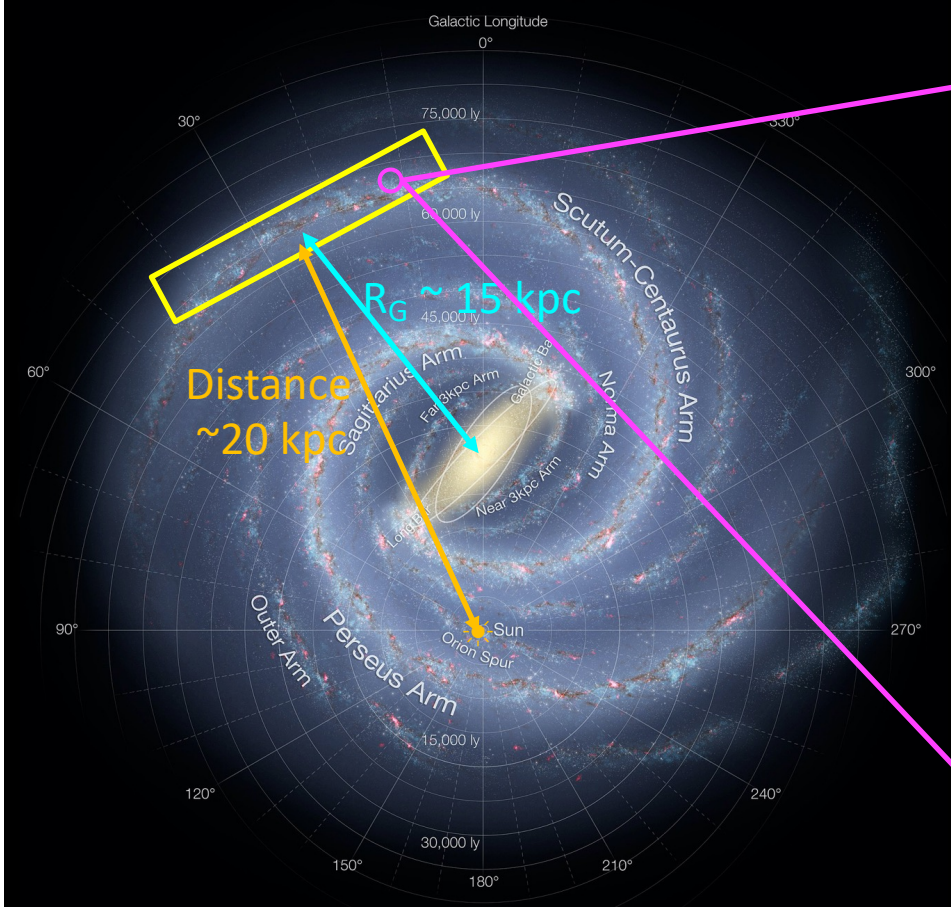
Investigating **Extreme Outer Galaxy** Molecular Clouds in the First Galactic Quadrant

K. Tokuda (Osaka Prefecture University/ NAOJ), **A. Konishi (M1)**, et al.

Telescope/instrument : NRO 45m/FOREST

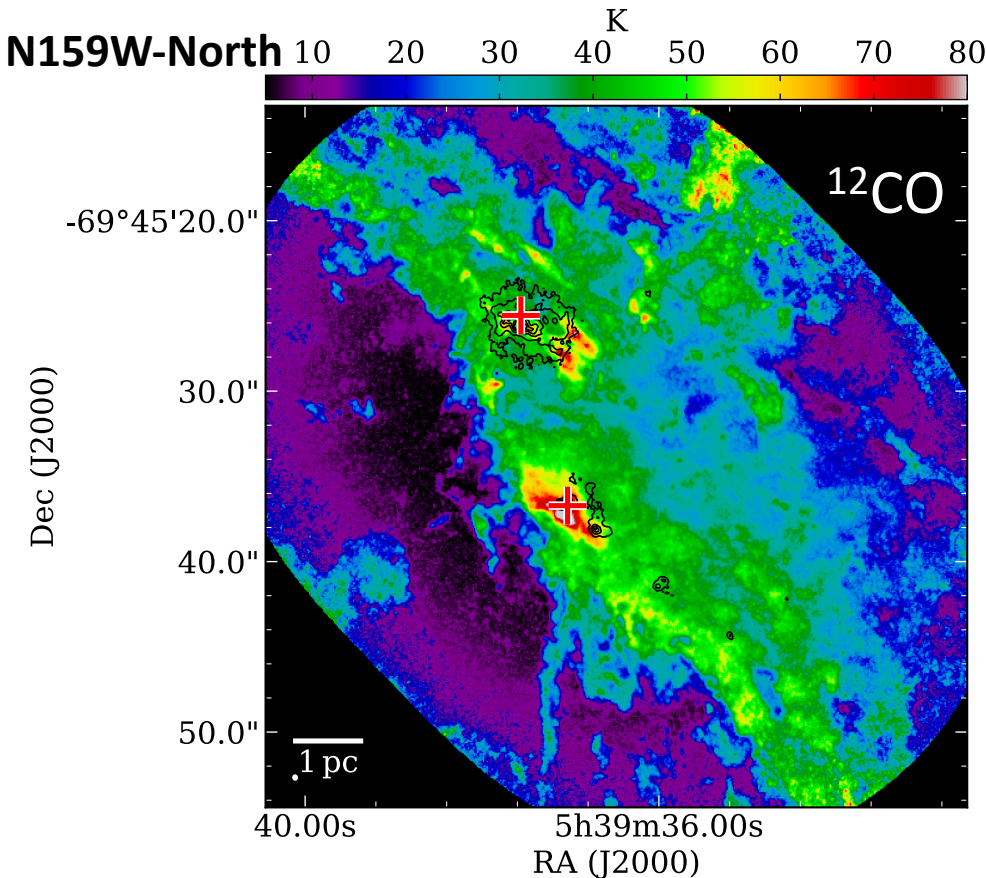
Obs. line : CO(1-0), ^{13}CO , C^{18}O , Angular resolution: $15''$ (~ 2 pc at 20 kpc)

Obs. period : 2021/Feb. \sim April

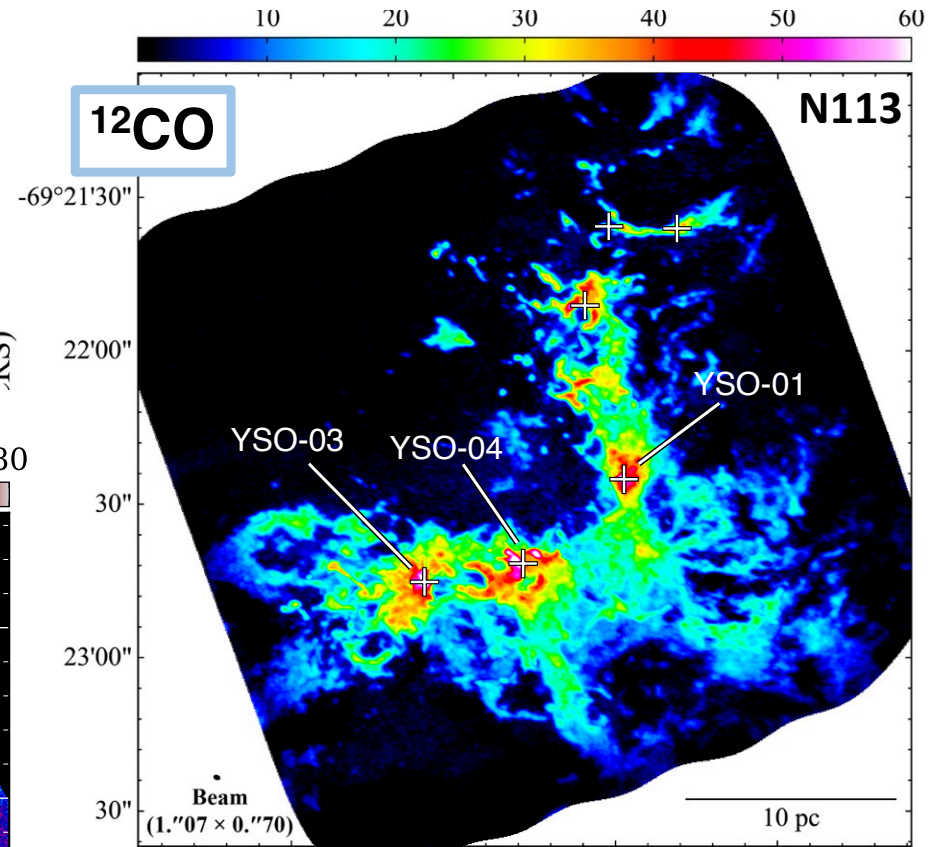


Motivation: Understanding star formation in low-metallicity

- High-resolution (~ 0.1 pc) molecular cloud views in the Large Magellanic Cloud ($Z \sim 0.5 Z_{\odot}$)



(see Minami-san's poster P07)



(see Nishioka-san's poster P11)

Large-scale colliding flows created complex filamentary clouds and promoted subsequent massive cluster formation (see also Fukui+19; Tokuda+19).

An Unbiased CO Survey toward the Northern Region of the SMC ($Z \sim 0.2 Z_{\odot}$) with the Atacama Compact Array

● ACA 1 filed

Red: $H\alpha$
Green: CO(2-1)

Obs. field $\sim 0.26 \text{ deg}^2$
Mosaicing No. ~ 8000



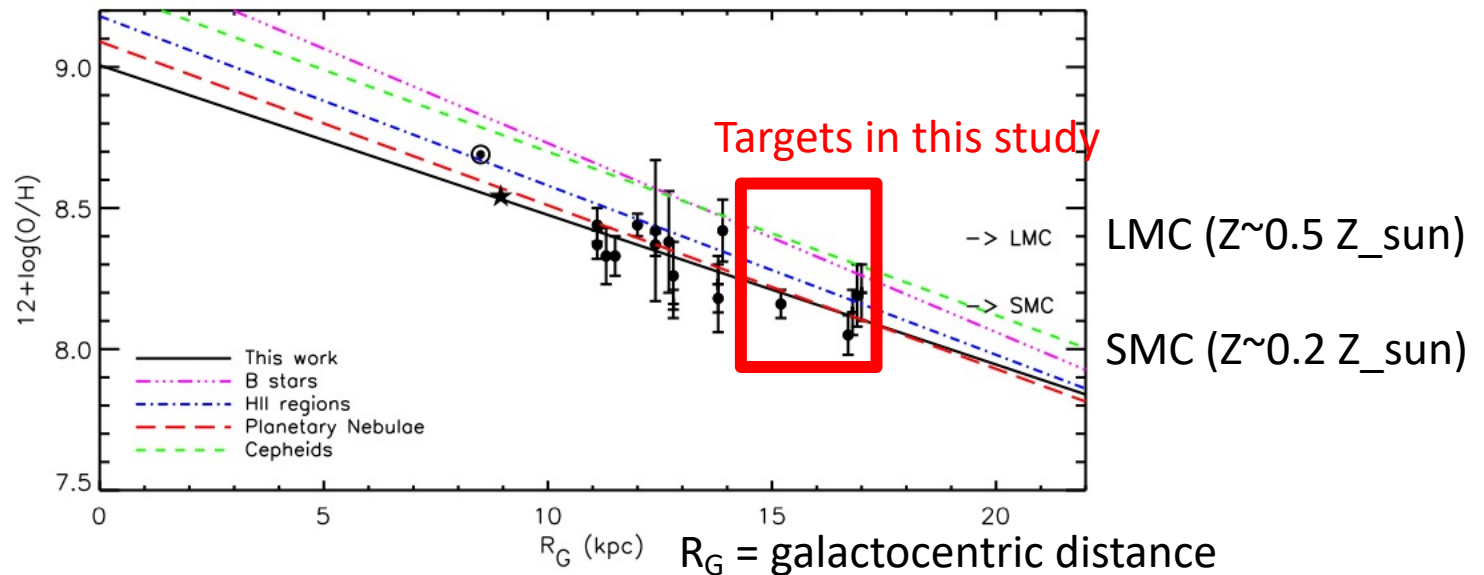
Kazuki Tokuda

(Osaka Pref. Univ./NAOJ), and many others

100 pc

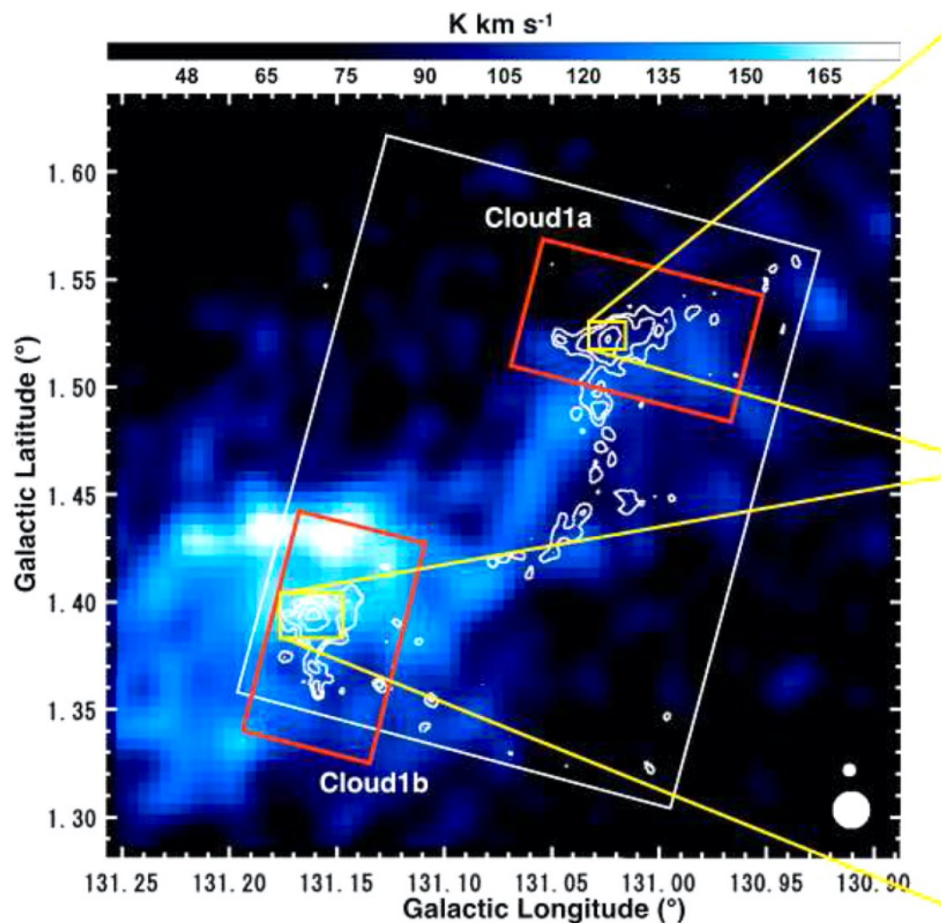
Outer MW survey with NRO45m

Investigating Extreme Outer Galaxy Molecular Clouds in the First Galactic Quadrant



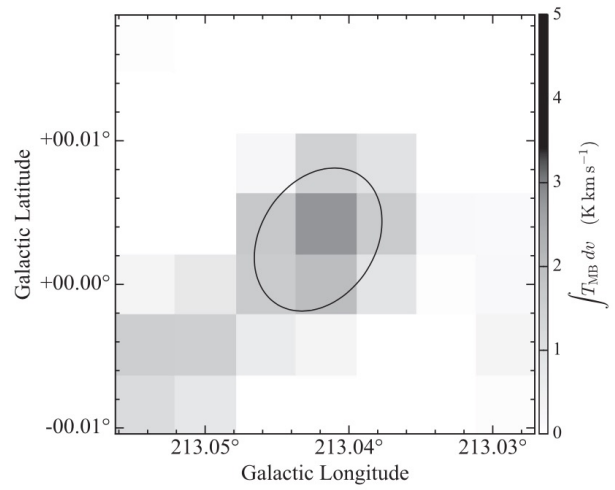
Fernández-Martín et al. 2017

Molecular line observations toward the 2nd/3rd quad.

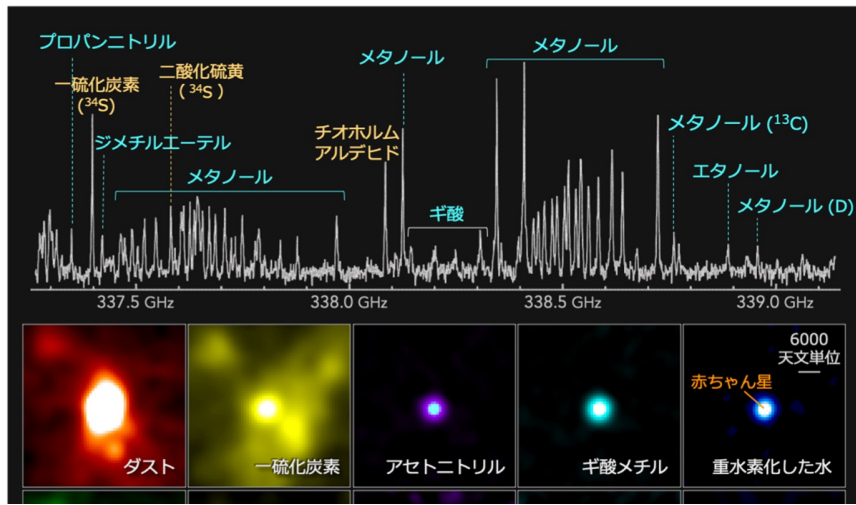


ContourCO, Color HI (Izumi+14)

Distance from sun: 16 kpc
 R_G : 22 kpc



Distance: 21 kpc CO (Matsuo+14)
 R_G : 29 kpc



クレジット:ALMA (ESO/NAOJ/NRAO), 下西隆/新潟大学

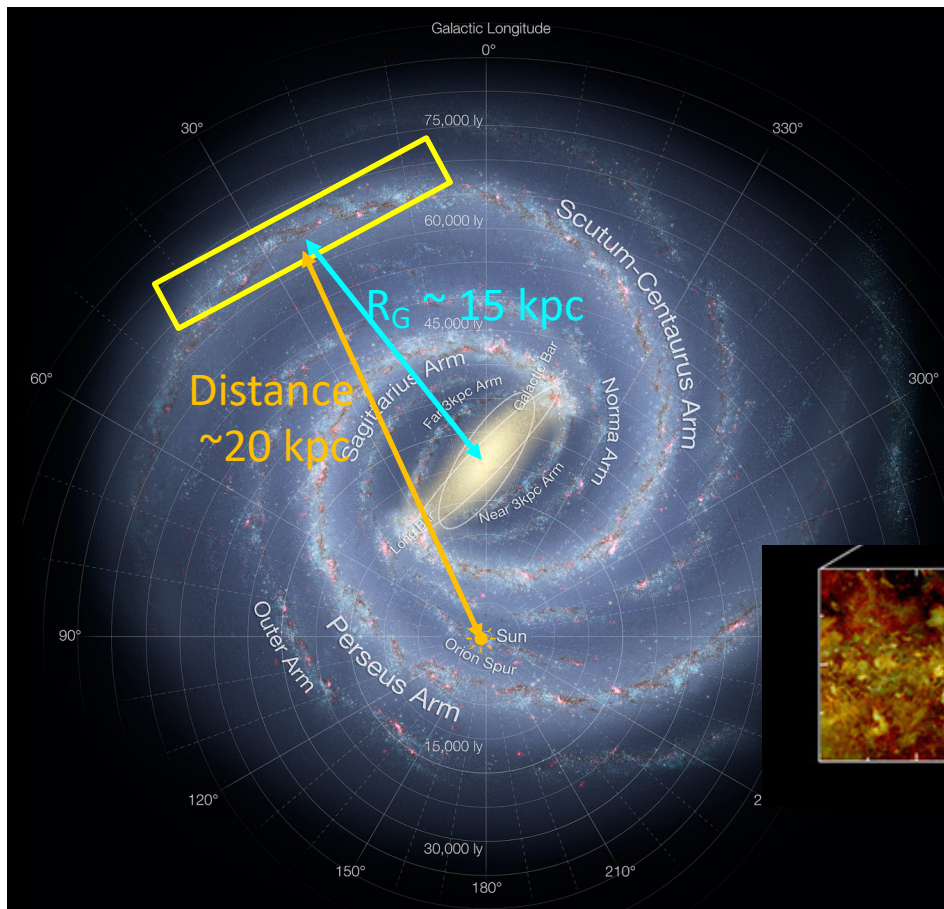
Obs. targets

PI : K., Tokuda

Telescope/instrument : NRO 45m/FOREST

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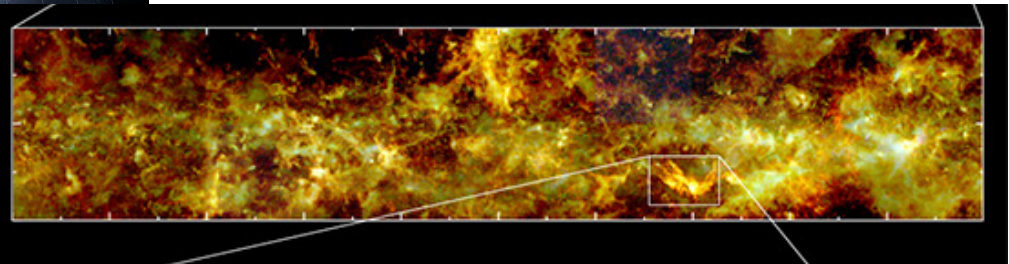
Obs. priod : 2021/Feb. \sim April



This will allow us to prove

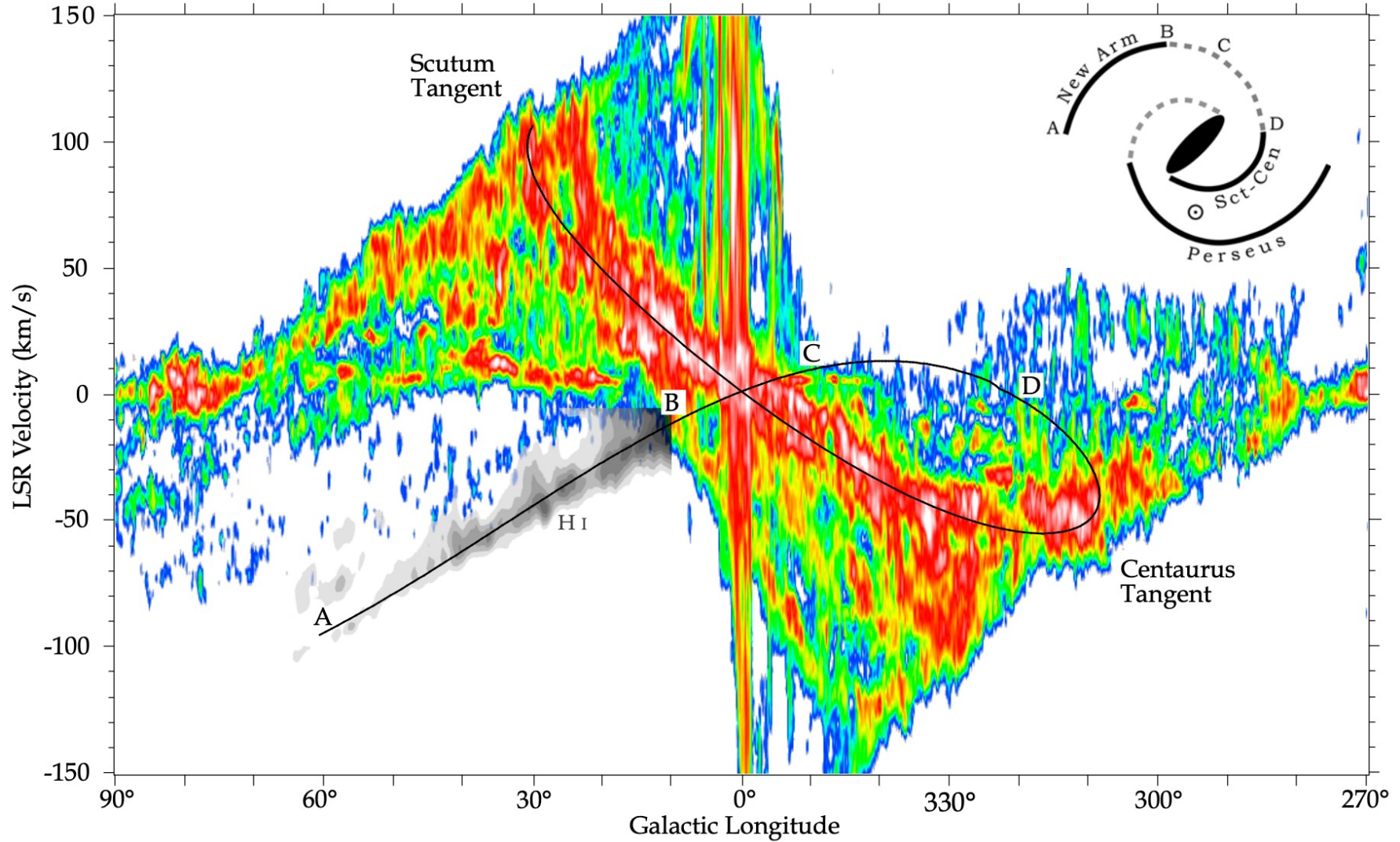
- Star formation in the outer MW
- Galactic structure details

First galactic quadrant
 \Rightarrow Very contaminated region



Molecular cloud view, FUGIN survey
(Umemoto+17, Torii+19)

Extremely outer galaxy in the first galactic quadrant



CO LV diagram and new arm (Dame+11)

Searching for distant (>20kpc) clouds

Dame et al. 2011

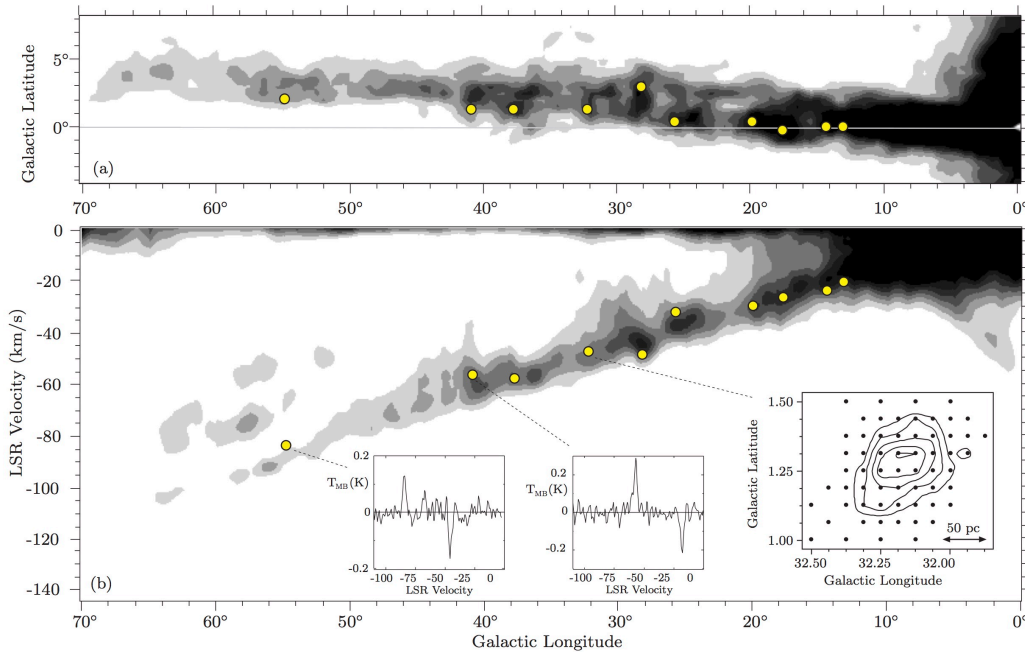


Table : New arm clouds

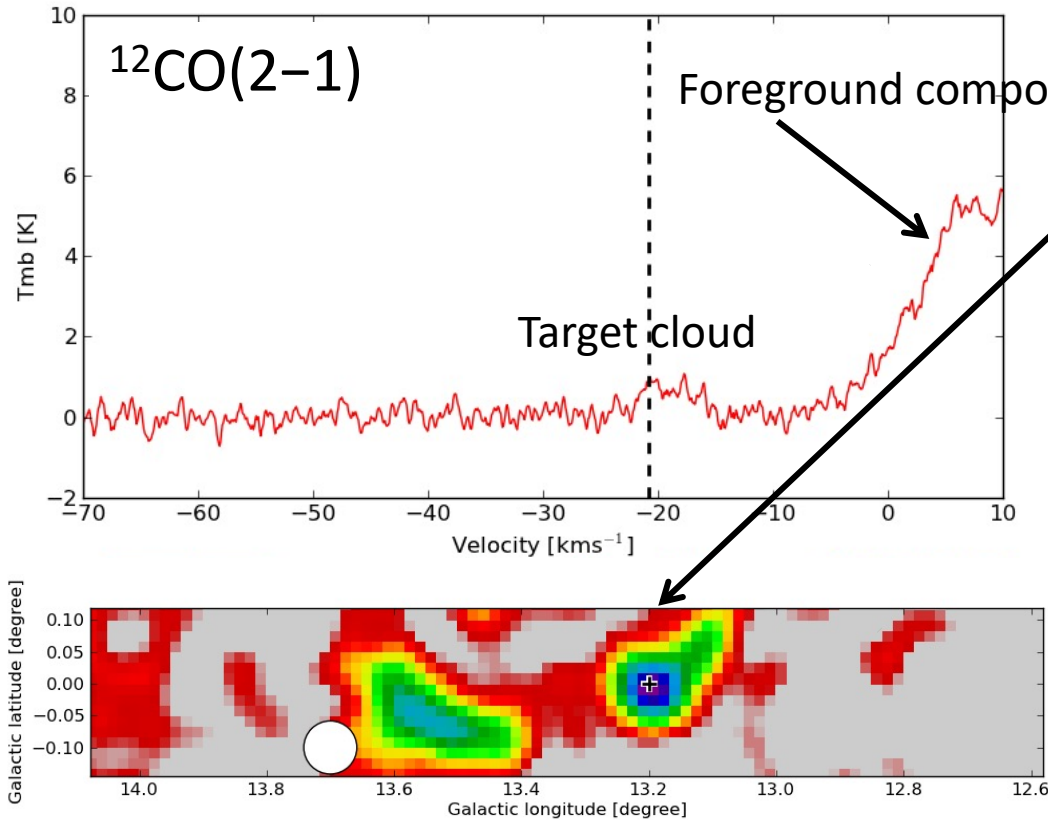
l ($^{\circ}$)	b ($^{\circ}$)	v_{LSR}^a	d^d
13.250	0.000	-20.9	22.7
14.500	0.000	-24.4	23.3
17.750	-0.250	-27.3	22.2
20.000	0.375	-30.4	21.9
25.750	0.375	-32.2	19.9
28.250	2.875	-49.2	23.1
32.250	1.250	-47.6	20.8
37.750	1.250	-58.7	20.9
40.875	1.250	-57.0	19.4
54.750	2.000	-84.4	19.4

Gray : HI (LAB survey), ● : CO detected spots with the CfA 1.2m telescope

Searching for distant (>20kpc) clouds

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40.875			.4
54.750			.4



Survey-type observations with the Osaka 1.85m telescope can detect distant clouds



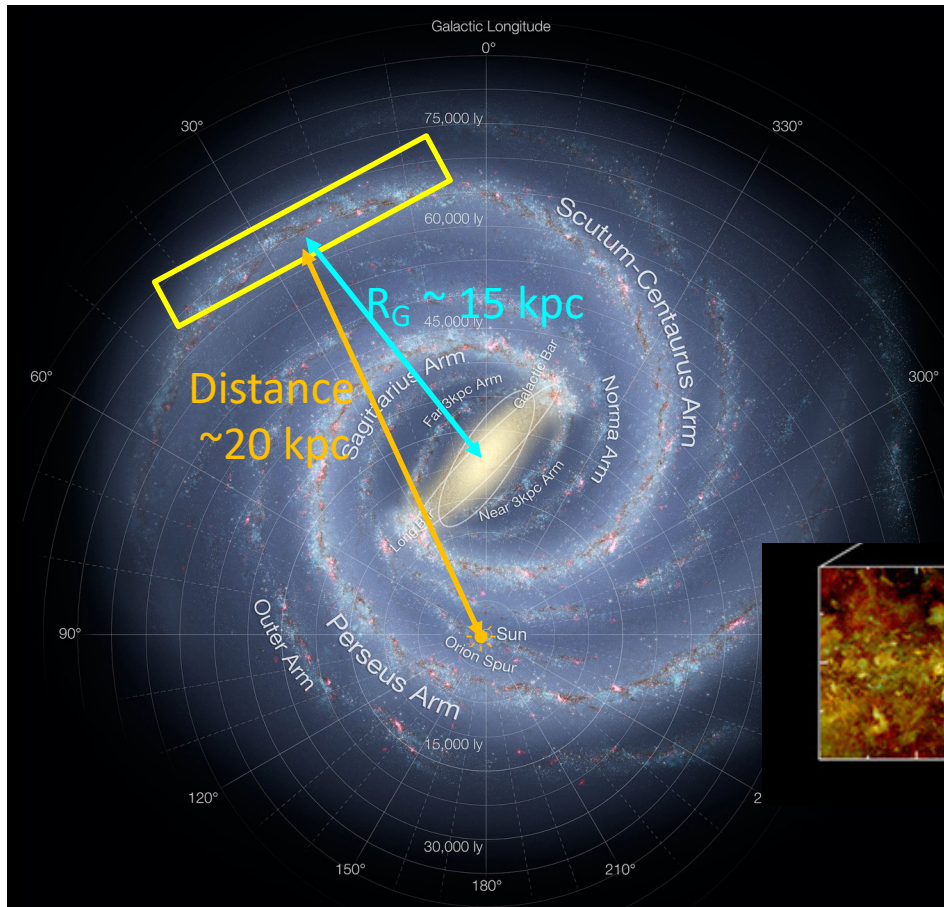
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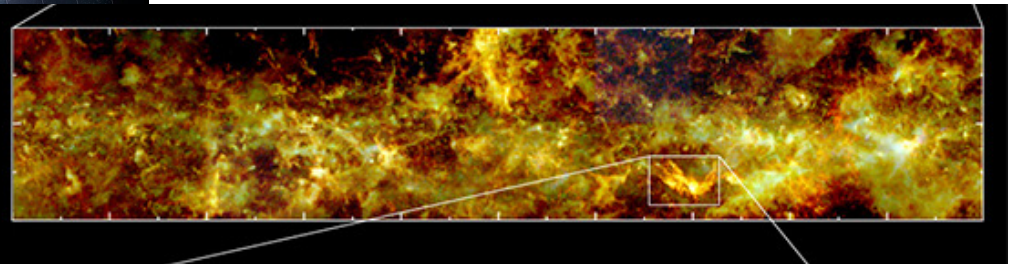
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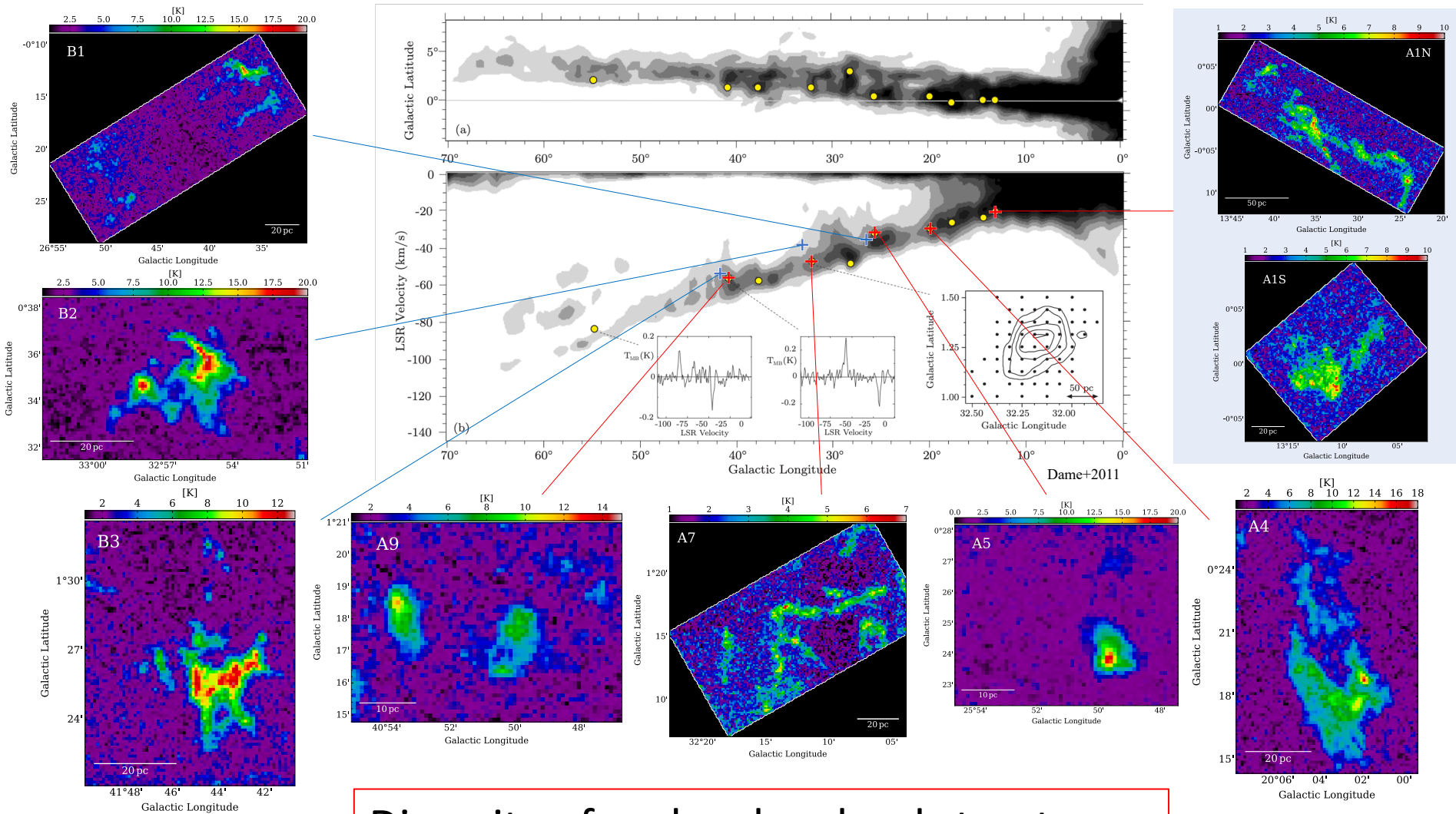
- Star formation in the outer MW
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First galactic quadrant
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Molecular cloud view, FUGIN survey
(Umemoto+17, Torii+19)

Preliminary results: 12CO maps

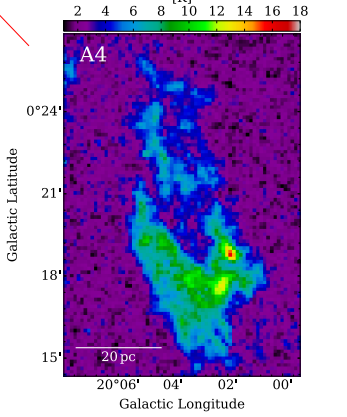
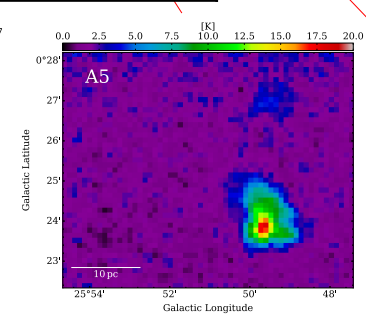
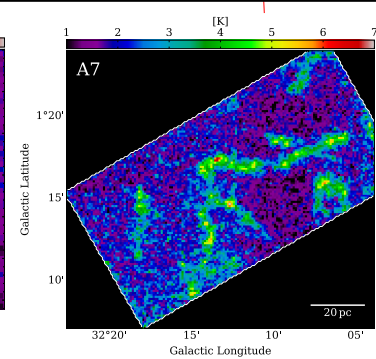
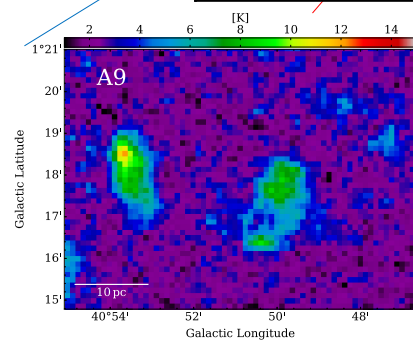
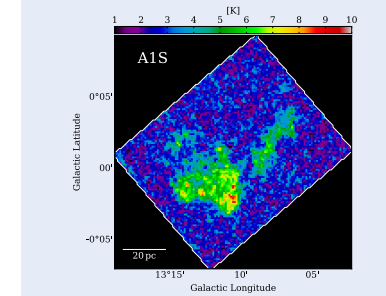
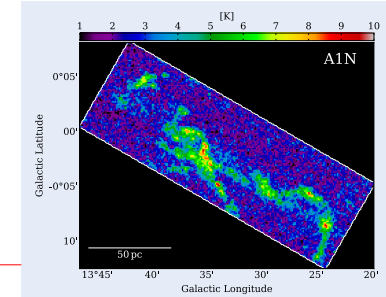
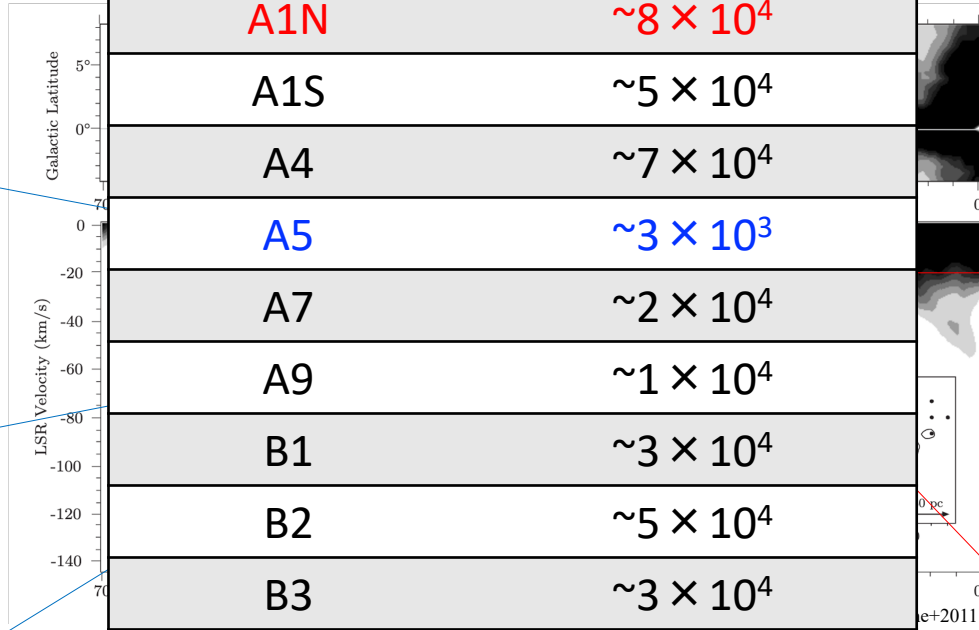
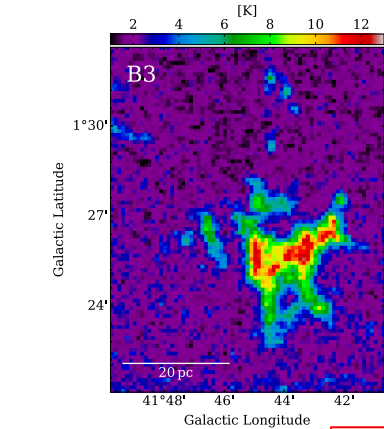
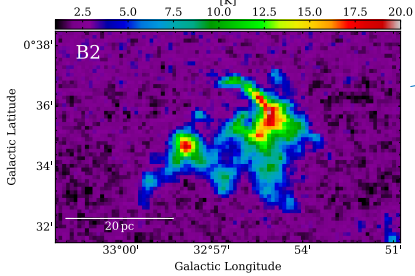
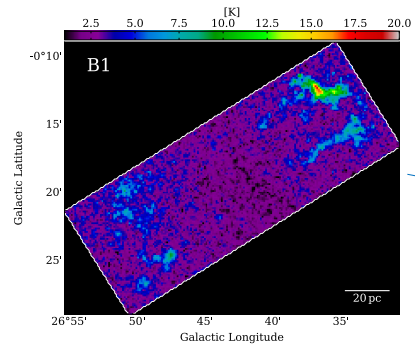


Diversity of molecular cloud structures
Filaments, blobs, and clump

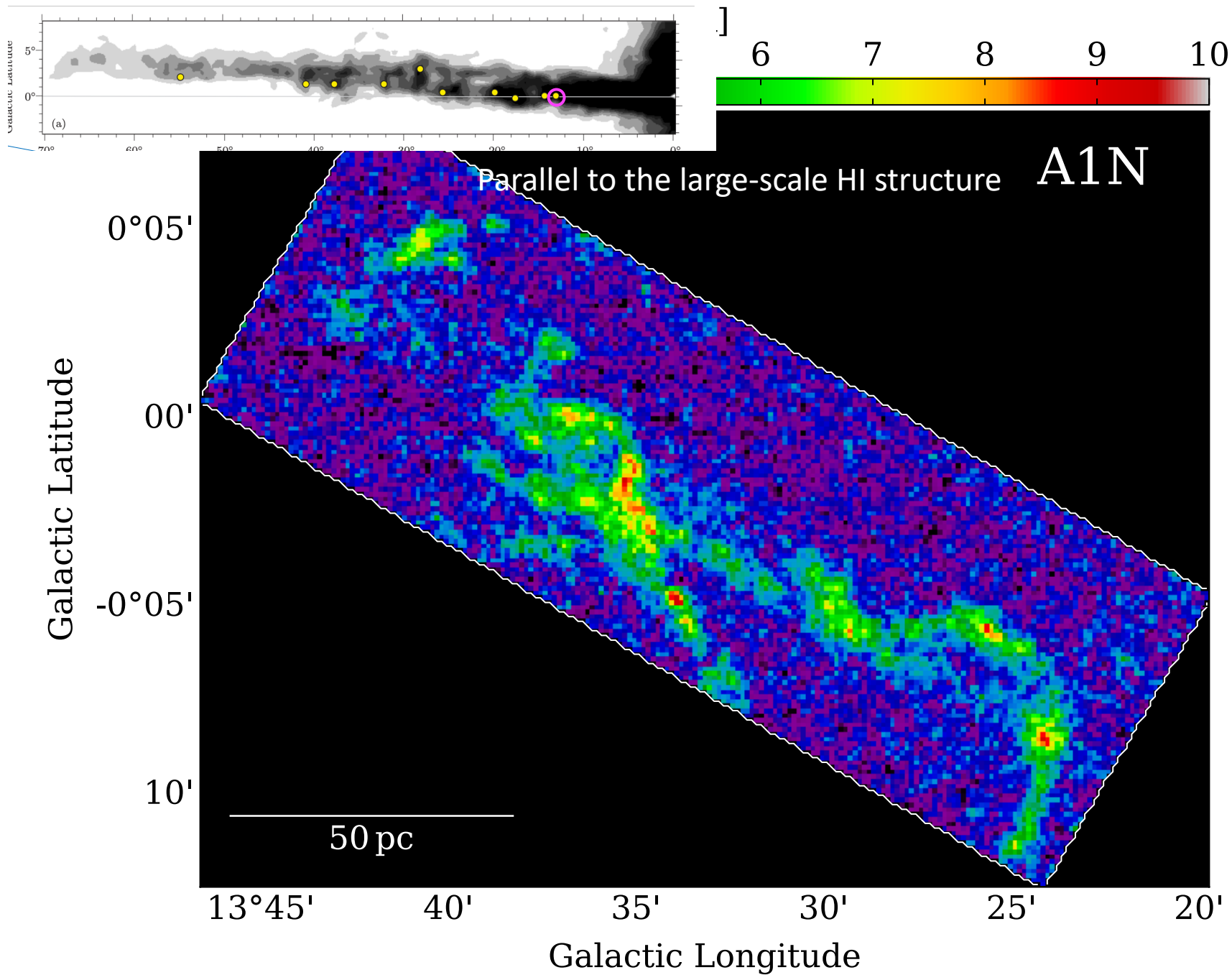
Xco factor = 2×10^{20} [cm⁻²]

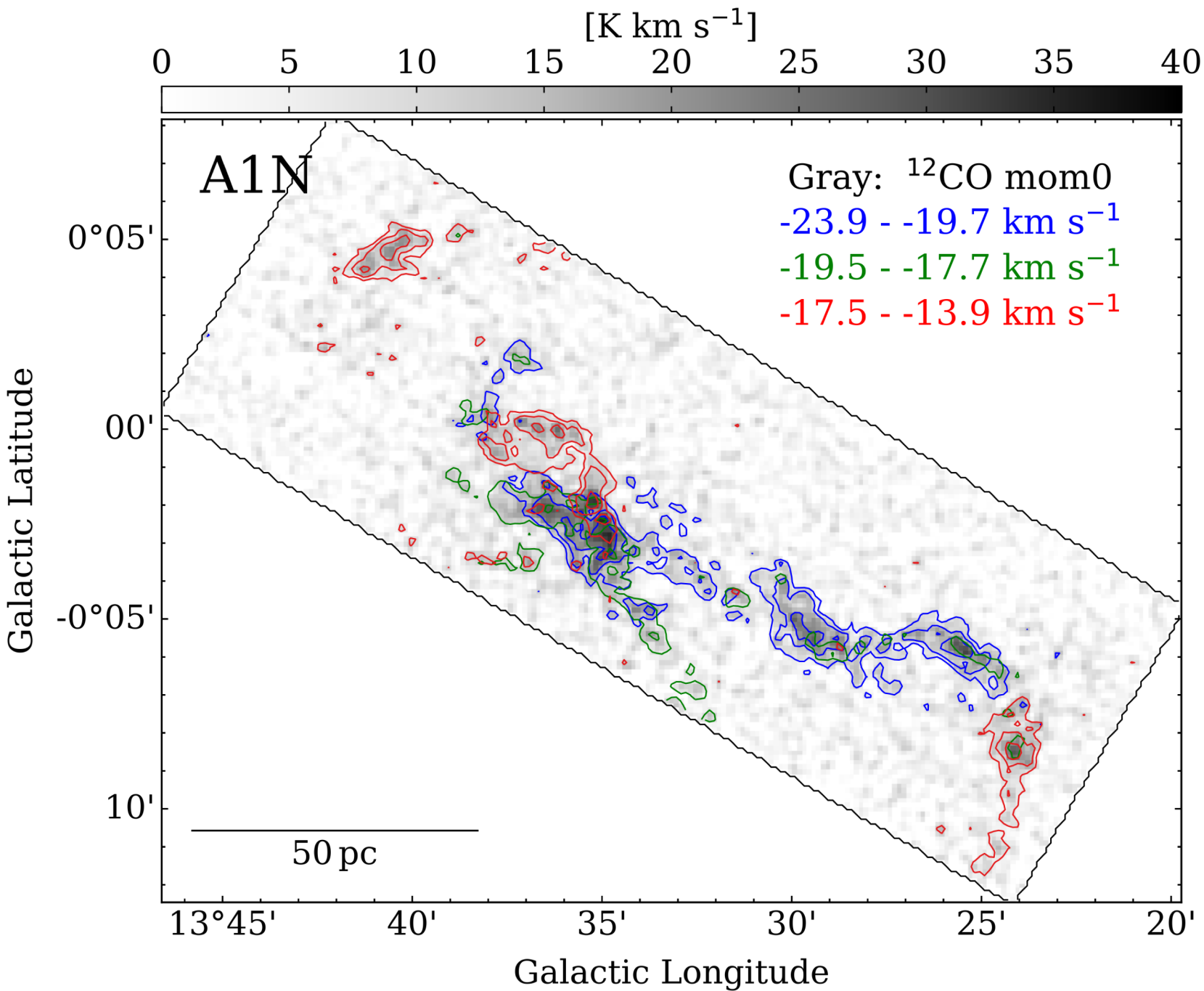
Preliminary results

Name	Mass [M_{sun}]
A1N	$\sim 8 \times 10^4$
A1S	$\sim 5 \times 10^4$
A4	$\sim 7 \times 10^4$
A5	$\sim 3 \times 10^3$
A7	$\sim 2 \times 10^4$
A9	$\sim 1 \times 10^4$
B1	$\sim 3 \times 10^4$
B2	$\sim 5 \times 10^4$
B3	$\sim 3 \times 10^4$



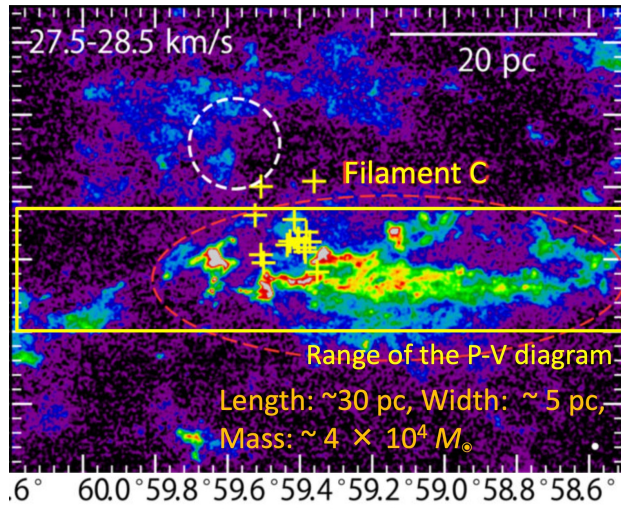
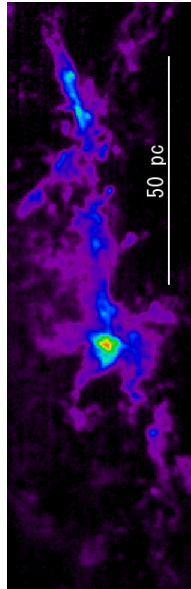
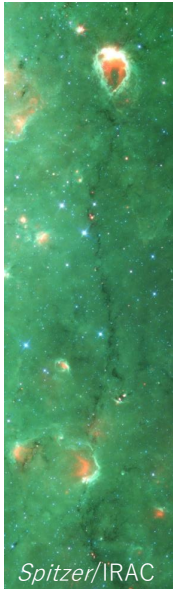
The molecular mass is similar to well-know GMCs.
e.g., Orion A $\sim 7 \times 10^4$ Mo (Nishimura+15)



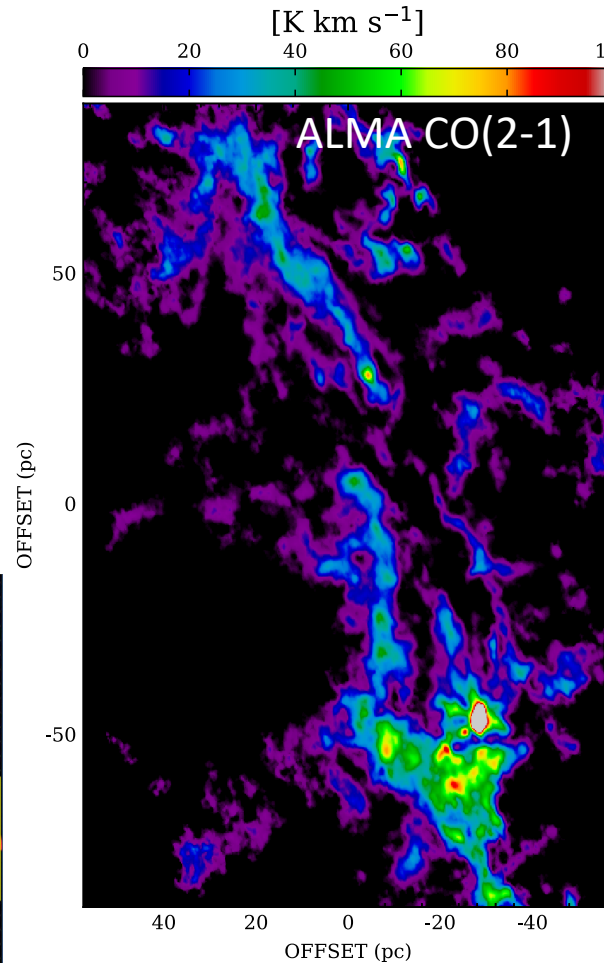


Giant molecular Filaments in the extremely outer MW

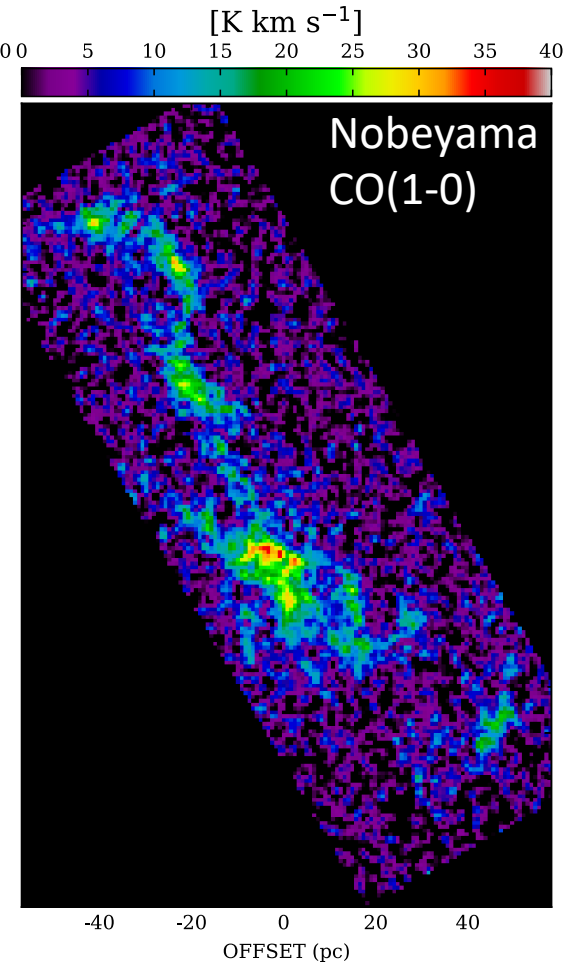
Nessie nebula W51 (Bieging+10)



(see Kohno-san's poster P12)



GMF in M33 ($R_G \sim 2$ kpc)
(Tokuda+20)



MW/A1N ($R_G \sim 15$ kpc)
(This work)

Summary : Outer MW survey with NRO45m

- NRO45m survey toward outer MW
 - Spatially resolved view with a fine velocity resolution
 - Diversity: filaments/clumps/isolated blobs
 - Giant molecular filaments at $R_G \sim 15$ kpc

Future works

- Revising galactic plane CO survey data (e.g, NRO, NANTEN2, OPU1.85m, PMO)
- ALMA follow up studies
- Searching for the star formation activities in the detected clouds
- Comparing various molecular clouds in different environments (in LMC/SMC and inner and outer MW)