SE-17P A new hot core in the outer Galaxy: testing the universality of star formation across the Galaxy

(Ikeda et al. 2025a, 25b in prep.)

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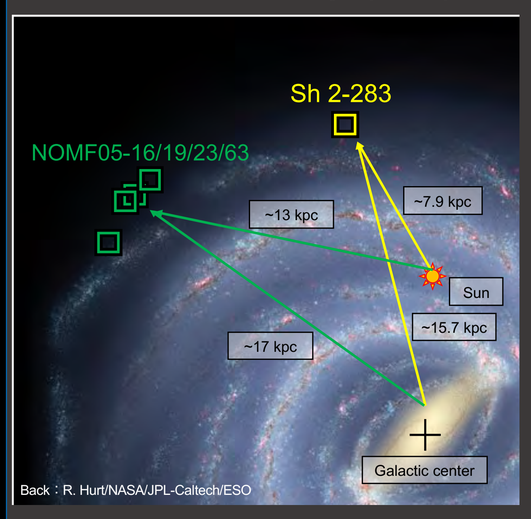
Introduction

Protostar survey was conducted toward the 5 star-forming regions in the outer Galaxy

Problem:

Are star formation and chemical evolution processes uniform in the different environment from the solar neighborhood?

The outer Galaxy (OG):



The outer Galaxy (galactocentric distance >13.5 kpc), characterized by lower metallicity and gas density, serves as a unique laboratory to test the universality of star formation and chemical evolution.

Molecular line surveys were conducted toward the 5 star-forming regions (Sh 2-283, NOMF05-16/19/23/63) located in the OG (galactocentric distance = 15.7-17.4 kpc, ~1/3-1/4 $Z_\odot$) with ALMA (Table 1).

Results & Discussion

- 5 out of 16 targets harbor molecular outflows (Figure 1, [1]).
- Detected outflow sources show the bipolar structures, and for Sh 2-283-1a SMM1, their knotty jet components are also detected (emission intervals of 900-4000 yrs)

  →Comparable to the inner Galactic sources, indicating the uniform star formation processes in OG.
- Toward Sh 2-283-1a SMM1, hot core with a variety of molecular emission lines were detected (Figure 2, 3).
- The CH_3OH & SO_2 abundances of OG & LMC/SMC hot cores show different trend (CH_3OH is low in LMC/SMC, while SO_2 is low in OG)

  → Reflecting the environmental difference of these low-metallicity regions? (e.g. Dust temperature, UV strength, and freeze-out timescales).
- The COMs abundances show similarity among the 3 regions (Figure 5).

  →The formation efficiency & processes of COMs (starting from CH_3OH) are consistent once CH_3OH is formed?

Observations

ALMA Cycle 9, 12m array [PI: T. Shimonishi]

— Spectral coverage: 340-360 GHz

— Velocity, spatial resolution: ~0.9 km s^{-1}, ~0.7” (~5000 au)

Table 1. Target Information

Source Name	RA (J2000.0)	Dec. (J2000.0)	D (kpc)	D_{GC} (kpc)	$[K]$ (mag)	$[H]$-$[K]$ (mag)	V_{sys} (km s^{-1})	Outflow (Y/N)	Submm. Cont. (Y/N)
Sh 2–283–1a SMM1	06:38:29.66	0:44:40.73	7.9	15.7	15.6	1.9	53.2	Y	Y
Sh 2–283–1b	06:38:29.60	0:44:41.25	7.9	15.7	15.9	1.7	53.2	N	N
Sh 2–283–1c	06:38:29.38	0:44:36.25	7.9	15.7	15.2	1.5	53.2	N	N
Sh 2–283–2	06:38:30.14	0:44:57.95	7.9	15.7	16.4	1.5	51.9	N	Y
Sh 2–283–3	06:38:27.83	0:44:42.20	7.9	15.7	14.0	0.7	47.5	N	Y
Sh 2–283–4	06:38:27.83	0:44:42.25	7.9	15.7	12.7	0.5	47.5	N	Y
Sh 2–283–5	06:38:28.60	0:44:25.00	7.9	15.7	14.7	1.1	45.4	N	Y
NOMF05-16–1	08:03:37.95	-37:08:06.38	12.8	17.3	–	–	107.4	Y	N
NOMF05-19–1	08:06:31.80	-37:29:52.43	12.7	17.1	16.3	1.4	39.5	N	Y
NOMF05-19–2	08:06:33.78	-37:30:14.27	12.7	17.1	14.7	2.9	38.1	N	N
NOMF05-19–3	08:06:33.17	-37:29:49.40	12.7	17.1	15.3	2.3	35.5	N	Y
NOMF05-19–4	08:06:31.80	-37:29:52.57	12.7	17.1	11.5	0.8	36.6	N	Y
NOMF05-23–1	08:05:33.01	-39:09:24.61	13.2	17.4	14.4	1.4	106.8	Y	Y
NOMF05-23–2	08:05:33.87	-39:09:24.97	13.2	17.4	14.1	1.7	109.0	N	N
NOMF05-23–3	08:05:34.81	-39:09:16.85	13.2	17.4	15.6	1.3	105.7	Y	Y
NOMF05-63–1	08:29:53.20	-45:55:09.63	14.1	17.3	10.3	1.7	110.3	Y	Y

Figure 1. Summary of outflows/jets

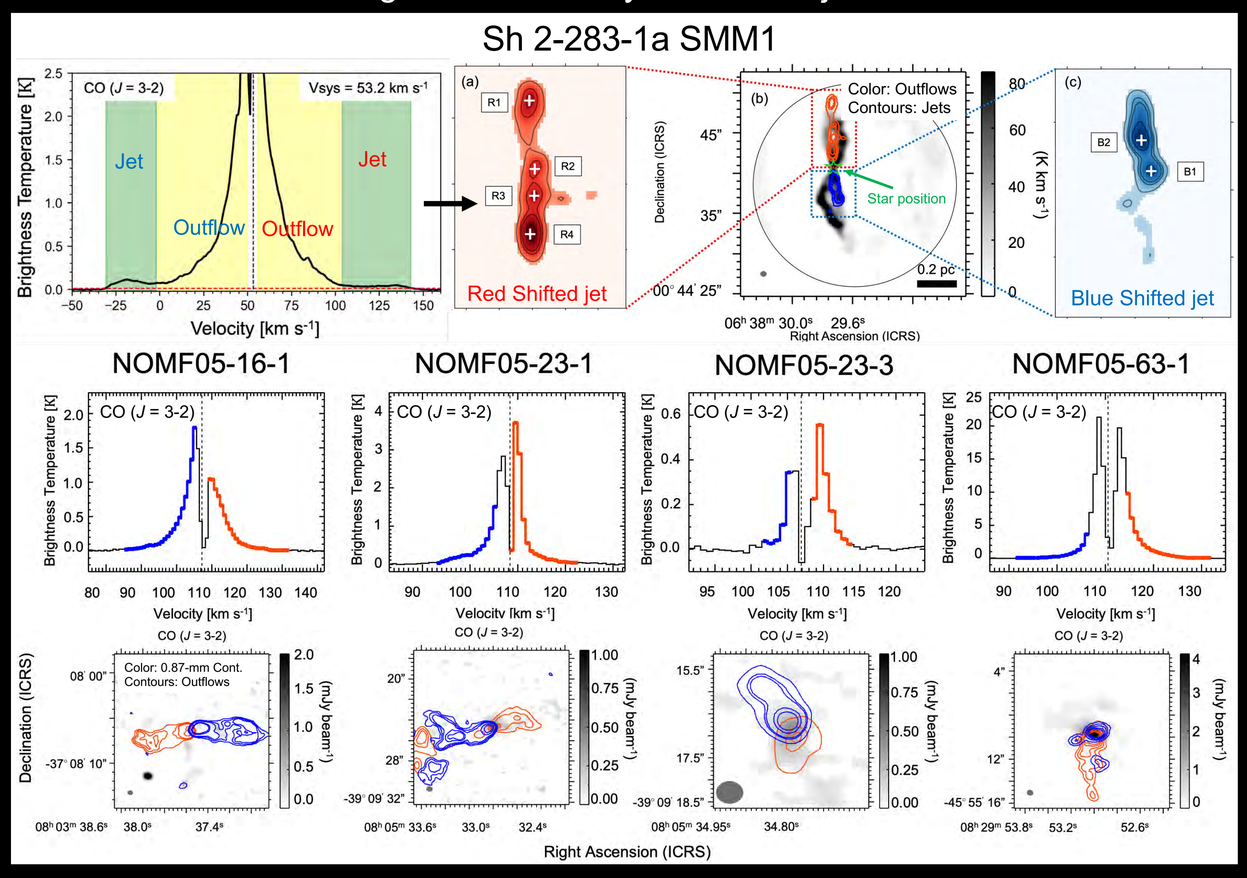


Figure 2. Moment 0 maps of hot gas (left) & Spectra of Sh 2-283-1a SMM1 (right)

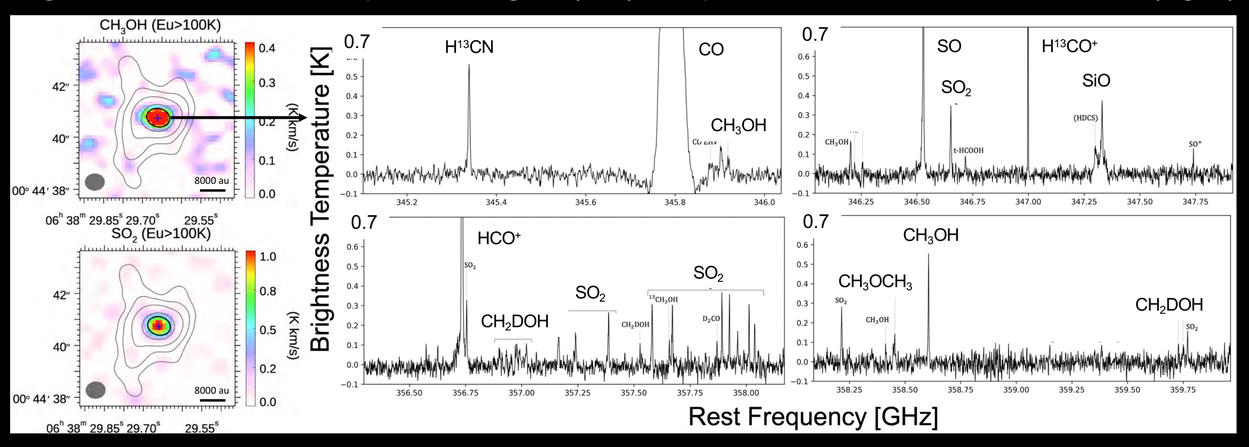


Figure 3. Rotational diagram analysis

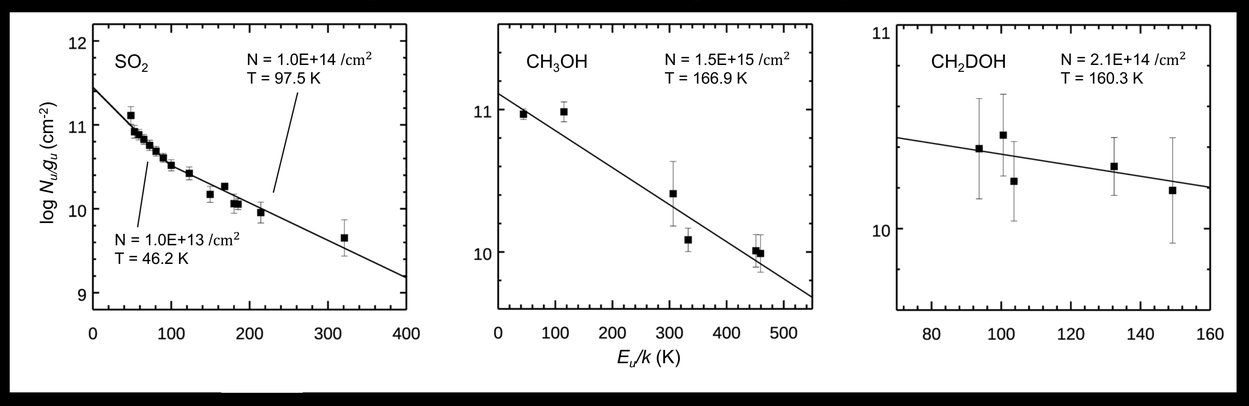
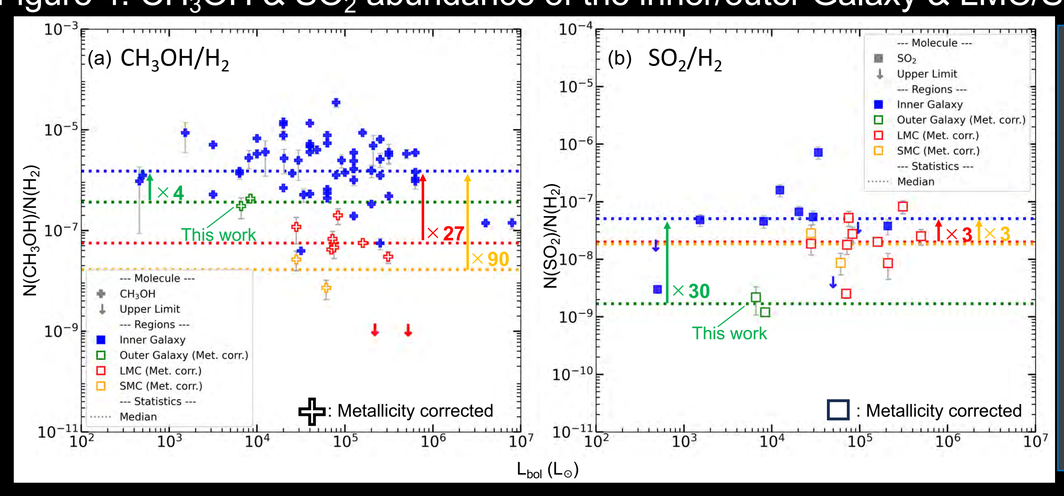


Figure 4. CH_3OH & SO_2 abundance of the inner/outer Galaxy & LMC/SMC hot cores



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Inner hot cores:

- Fuente+ 2014
- ATOMS survey (Liu+ 2020; Qin+ 2022; Chen+ 2025)
- Li +2025
- ALMAGAL survey (Santos +2024, for SO_2 data)

Outer hot core:

Shimonishi+ 2021

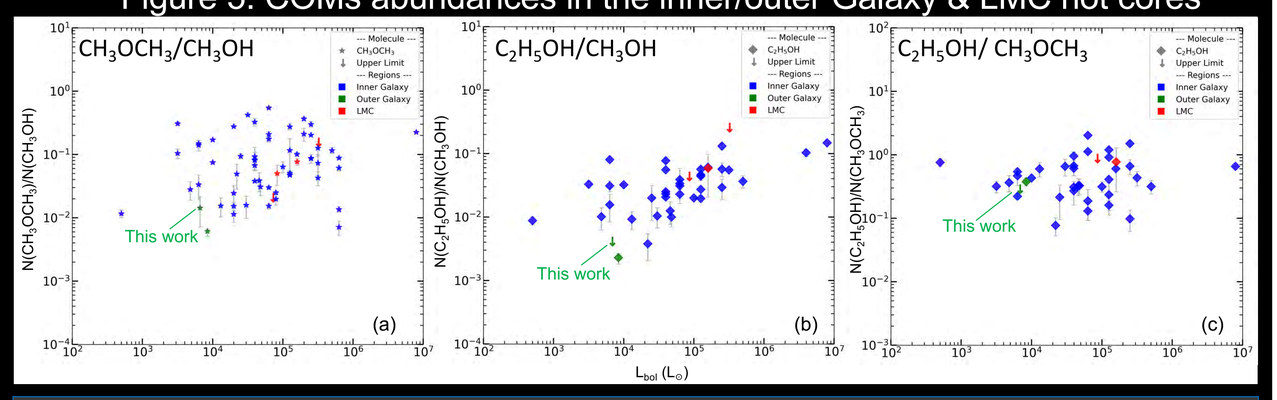
LMC hot cores:

Shimonishi+ 2016; 2020; Broadmeadow+ 2025; Shimonishi+ in prep.

SMC hot cores:

Shimonishi+ 2023

Figure 5. COMs abundances in the inner/outer Galaxy & LMC hot cores



Future Works

- Follow-up observations with broader spectral coverage (molecular line survey, PI: T. Shimonishi), higher spatial resolution (internal structures, PI: Y. Cheng).
- Additional survey of the outer Galactic protostars (PI: T. Ikeda).

Reference: [1] Ikeda et al., 2025, ApJ, 988, 111