

The results of the protostar survey toward the outer Galaxy with ALMA: Detection of the protostellar outflows/jets and a hot molecular core

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The outer Galaxy (galactocentric distance (D_{GC}) >13.5 kpc) exhibits distinctive characteristics compared to the inner Galaxy, including low metallicity, reduced-gas density, and minimal perturbation from spiral arms and supernova explosions. These environmental conditions make it a crucial region for investigating the universality of star formation and chemical evolution across the Galaxy. Until recently, molecular detections of protostars in the outer Galaxy remained sparse, with only one reported (WB89-789 SMM1; [1]). Increasing the sample size of outer Galactic protostars is essential for unveiling the universality of physical and chemical properties of star-forming regions.

In this work, we carried out the protostar survey toward the 16 protostar candidates located in the five star-forming regions in the outer Galaxy (Sh 2-283/NOMF05-16/19/23/63; Z~1/3-1/4 Z_{Sun}) at the D_{GC} of 15.7-17.4 kpc with ALMA.

As a result, we newly detected 5 protostellar outflow sources with CO(3-2) emission, one of which exhibits jet components with bullet structures [2]. The morphological properties of these outflows and jets are similar to those observed in nearby sources, indicating the universality of star formation processes even in the outer Galaxy.

Moreover, we identified one protostar associated with a hot molecular core, in which high-excitation transitions ($E_u > 100$ K) of complex organic molecules such as CH₃OH and CH₃OCH₃ were detected. A comparison of the fractional abundances relative to CH₃OH between this protostar and WB89-789 SMM1 shows a remarkable similarity within a factor of ~2, and this result supports the idea that such chemical richness may be a common feature of hot cores, even in the outer Galaxy.

We will present a more detailed discussion of the physical and chemical properties of these sources.

References

- [1] T. Shimonishi et al., 2021, ApJ, 922, 206
- [2] T. Ikeda et al., 2025, ApJ, 988, 111