

Observations of the Chemical Complexity at the Edge of our Galaxy

*Takashi Shimonishi¹, Natsuko Izumi², Kenji Furuya³, Chikako Yasui³

1. Niigata University, 2. Institute of Astronomy and Astrophysics, Academia Sinica, 3. National Astronomical Observatory of Japan

Understanding the properties of the interstellar medium at low metallicity is crucial to unveil physical and chemical processes in the past Galactic environment, where the abundance of heavy elements was significantly lower compared to the present-day solar neighborhood. We here report the first detection of a protostar and the surrounding cocoon of complex organic molecules at the edge of our Galaxy, which is known as the extreme outer Galaxy^[1].

It is believed that the far outer part of our Galaxy still harbors a primordial environment that existed in the early epoch of galaxy formation. The environmental characteristics of the extreme outer Galaxy, e.g., low abundance of heavy elements, small or no perturbation from Galactic spiral arms, are very different from those seen in the present-day solar neighborhood. Because of its unique characteristics, the extreme outer Galaxy is believed to be an excellent laboratory to study star formation and the interstellar medium in the past Galactic environment.

In this work, we carried out ALMA observations towards a star-forming region, WB 89-789, which is located at a galactocentric distance of 19 kpc. Our high-sensitivity and high-spatial resolution submillimeter observations detected a variety of carbon-, oxygen-, nitrogen-, sulfur-, and silicon-bearing species, including complex organic molecules containing up to nine atoms (e.g., methanol, ethanol, methyl formate, formamide, etc.), toward a warm (>100 K) and compact (<0.03 pc) region associated with a protostar. Deuterated species such as HDO, HDCO, D_2CO , and CH_2DOH are also detected. A comparison of fractional abundances of complex organic molecules relative to methanol between this outer Galactic protostar and an inner Galactic counterpart shows a remarkable similarity.

The presence of a great chemical complexity in a primordial environment of the extreme outer Galaxy, and its chemical similarity with inner Galactic sources, suggest that the interstellar conditions to form the chemical complexity might have persisted since the early history of the Universe.

[1] T. Shimonishi, N. Izumi, K. Furuya, and C. Yasui, 2021, *ApJ*, 922, 206 (39pp)

Keywords: Interstellar molecules, Protostars, Outer Galaxy, Metallicity, Astrochemistry, Radio Astronomy