Discovery of Star Formation in the Extreme Outer Galaxy Possibly Induced by a High-Velocity Cloud Impact [1]

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The extreme outer galaxy (EOG), which we define as the region with a Galactocentric radius (R_G) of more than 18 kpc [2], has a very different environment from the solar neighborhood with a much lower gas density (< 1/10) [3], lower metallicity (~1/10) [4], and little or no perturbation from the spiral arms. Such a region not only defines the size and shape of our Galaxy, but it also serves as an excellent laboratory for studying the star-forming process in low-density and low-metallicity environments. Because such environments may have similar characteristics that existed in the early phase of Galaxy formation [2], we might be able to directly observe the galaxy formation processes in unprecedented detail at a much closer distance than distant galaxies.

Digel Clouds, which are composed of eight molecular clouds (Cloud1-8), were discovered by the very first survey of molecular clouds in EOG [5]. We observed Cloud1, which has the largest dynamical mass among all of the Digel Clouds and perhaps the largest Galactocentric radius (R_G = 22 kpc; kinematic distance) among all known clouds in the Galaxy, at CO lines with NRO 45 m telescope as well as NIR wavelengths (J, H, K_S bands) with Subaru 8.2 m telescope, and discovered star forming regions (Figure 1).

Using the cluster member, we estimated the photometric distance of the clusters to be $R_G \geq 19$ kpc, which is consistent with the kinematic distance. We also derived the age of the clusters to be less than 1 Myr, using the disk fraction of the clusters, which is the percentage of cluster members with a optically thick circumstellar dust disk [6,7]. The clusters have lower star formation efficiency (~1 %) than in the solar neighborhood, which might suggest some environmental dependence.

Because of the low-density, triggered formation as opposed to spontaneous formation may play a crucial role in the EOG [8,9]. On the sky, Cloud 1 is located very close to the HI peak of high-velocity cloud (HVC). [10,11] suggested the interaction between the HVC and the Galactic disk, and there are some HI intermediate velocity structures between the HVC and the Galactic disk, which indicates an interaction between them. We suggest the possibility that the HVC impacting on the Galactic disk has triggered star formation in Cloud 1. Such process may have occurred frequently in the early phase of the formation of the Galaxy.

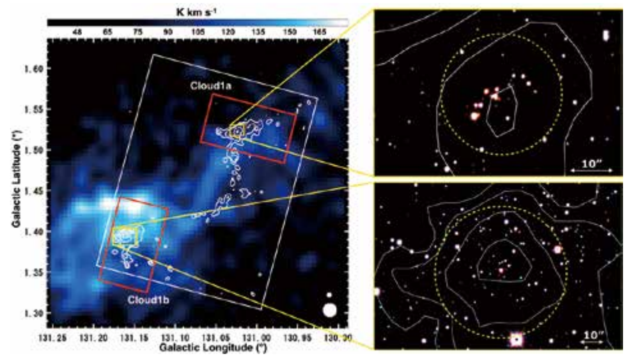

Figure 1: Left) HI map around Cloud 1 (from DRAO data: v_{LSR} = −104.5 ~ −99.6 km s^{-1}). The white contours show the integrated ^{12}CO(1–0) map of Cloud 1 (from our NRO 45 m telescope data: v_{LSR} = −104.1 ~ −99.1 km s^{-1}), and contour levels are at 2σ, 3σ, 5σ, 7σ (1σ = 0.5 K km s^{-1}). The white and red boxes show the mapping size of the NRO 45 m observation and the field of view of the Subaru (4′ × 7′; MOIRCS), respectively. The large and small white filled circles at the lower right corner show the resolution of the DRAO (~58″) and NRO 45 m telescope (~17″), respectively. Right) *JHK* pseudo color images of the Cloud 1 clusters from our Subaru data. The white contours show the same as the ^{12}CO map as in the left panel. The yellow dotted circles show the defined cluster regions (radius of Cloud 1a circle: 14″, Cloud 1b: 28″).

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