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Molecular clouds in the Extreme Outer Galaxy

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Abstract. More than 200 molecular clouds were newly found distributed beyond the Outer arm in the extreme outer Galaxy (EOG) region by MWISP. Those MCs roughly following the HI′s distribution well delineate the outermost spiral structure (the Outer Scutum-Centaurus arm) and warp of our Galaxy. Besides, those MCs show different σ_v-Radius relation and exhibit higher value of $\alpha_{\rm vir}$ than MCs in the inner Galaxy.

Keywords. Galaxy: structure – ISM: molecules – radio lines: ISM

1. Introduction

Molecular cloud (MC) in the Extreme Outer Galaxy (EOG) not only delineates the spiral structure and warping of our Galaxy, but it also serves as an excellent laboratory for studying the star-formation process in a physical environment that is very different from that of the solar neighborhood. However, because of the far distances involved and the lack of high-sensitivity observations in the past, the MCs detected in the EOG regions is less than 30, and even more the star-formation signature is only revealed in few of these dense cores. The Milky Way Imaging Scroll Painting (MWISP) project is a high resolution (50″) J=1-0 ^{12}CO, ^{13}CO, and C^{18}O survey of the northern Galactic Plane, performed with the Purple Mountain Observatory Delingha 13.7 m telescope. The survey started in 2011, and will cover Galactic longitudes from l=-10.25° to 250.25° and latitudes from b=-5.25° to 5.25° over a period of ∼10 years. The nominal sensitivities in the survey are set for 0.3 K in ^{13}CO/C^{18}O at the resolution of 0.17 km s^{-1}, and 0.5 K in CO at the resolution of 0.16 km s^{-1}. The high-sensitivity data from MWISP survey will provide us a unique opportunity to study the spiral structure and star-formation activity at the edge of the Milky Way.

2. Overview

The spiral arm traced by the EOG clouds. Using our new CO data of the MWISP, we have found a total of 72 EOG clouds in Galactic range of 100° < l <150°, which delineate a new segment of a spiral arm between Galactocentric radii of 15 and 19 kpc in the second Galactic quadrant (Sun *et al.* 2015). The new arm appears to be the extension of the distant arm discovered by Dame & Thaddeus as well as the Outer Scutum−Centaurus (OSC) arm into the outer second quadrant. And a total of 168 EOG clouds were identified in Galactic longitude range of 34.75° ⩽L⩽45.25° (Sun *et al.* 2017), which in roughly following the OSC arm. All these may provide a robust evidence for the existence of the OSC arm. Figure 1a shows their locations.

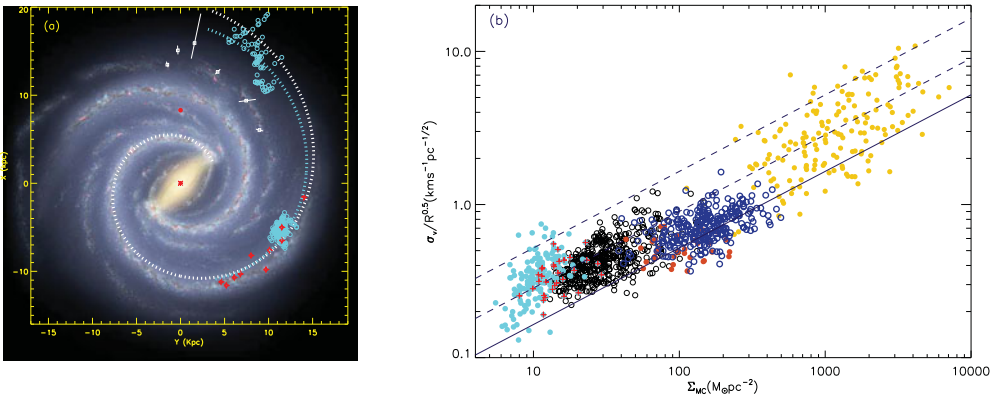

Figure 1. (a) Locations of the EOG clouds superposed on an artist's conception of the Milky Way (R. Hurt: NASA/JPL-Caltech/SSC). Note that the distances are derived from the rotaion curve of Reid *et al.* (2014). (b) Scaling coefficient, $\sigma_v/R^{1/2}$, as a function of the mass surface density for clouds located in EOG region (cyan, from MWISP), Galactic Center (gold, Oka *et al.* 2001), Galactic ring (red and blue, Solomon *et al.* 1987; Dame *et al.* 1986), and outer Galaxy (black, Heyer *et al.* 2001). The solid line and two dashed lines show the loci for α_{vir}=1 (lower), 3 (middle) and 10 (upper), respectively. The pluses mark the EOG clouds with ^{13}CO detections.

The warp of the Galactic disk. The Galactic warp structure traced by CO emission of the OSC arm was discussed. Both of the effects of the warp and the tilted plane (because of the Sun's offset from the physical mid-plane) were considered. We find that the slope of the two warp models are very close to that of the observations, especially the gaseous warp model from the HI data. Generally, the Z scale heights of the OSC arm is increased with the increasing of the Galactocentric radii.

Properties of the EOG clouds. Similar to Heyer & Dame (2015), the revised scaling Larson relations were examined and compared across a wide range of Galactic environments in Figure 1b. We find that the EOG clouds are well displaced below the scaling relationship defined by the inner Galaxy MCs. The results are similar to the finding in the outer Galaxy clouds (Heyer & Dame 2015). Interestingly, most of the EOG clouds have a virial ratio $\alpha_{\rm vir}$ >3.

Acknowledgements

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Top: Mareki Honma
Bottom: Christian Henkel animating the discussion

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