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Difference of the Gas Density Histograms in and out of spiral arms in Milky Way Galaxy

Toshihiro Handa[1], Miru Maebata[1], Takeru Murase[1], Shinji Fujita[2], Mikito Kohno[2], Nario Kuno[3], Mika Kuriki[3], Mitsuhiro Matsuo[4], Tetsuhiro Minamidani[4], Atsushi Nishimura[2], Kazufumi Torii[4], Yuya Tsuda[5] and Tomofumi Umemoto[4]

[1]School of Science & Engineering, Kagoshima university,
Korimoto 1-21-35, Kagoshima, Kagoshima 890-0065, Japan,
email: handa@sci.kagoshima-u.ac.jp

[2]Department of Astrophysics, Nagoya University,
Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8602, Japan.

[3]Graduate School of Pure and Applied Sciences, University of Tsukuba,
Tennodai 1-1-1, Tsukuba, Ibaraki 305-8571, Japan.

[4]Nobeyama Radio Observatory, National Astronomical Observatory of Japan,
Minamimaki 462-2, Minamisaku, Nagano 384-1305, Japan.

[5]Meisei University,
Hodokubo, Hino, Tokyo 191-0042, Japan.

Abstract. "Gas Density Histogram (GDH)" is an observational counterpart of the probability density function (PDF) of the gas density of interstellar medium (ISM). We used ^{12}CO data in $(l, b) = (29^\circ, 0)$ region from "FOREST unbiased galactic imaging survey with Nobeyama 45-m telescope (FUGIN)", which is a large coverage survey in three CO (1-0) lines. Using the kinetic distance, we estimated the volume density of the voxel from the observed column density. The resultant GDHs of the inter-arm regions show lognormal or lognormal-like, but those in the spiral arm regions show flat-top shape.

Keywords. ISM: evolution, radio lines: ISM

1. Introduction

To address the density structure of ISM we investigate the GDH in the Milky Way. It is cumulative volumes as a function of gas density in an assigned region and an observational counterpart of PDF, if the density structure is steady. Although observational PDF is estimated for some galactic objects, they are 2 dimensional, *i.e.* sky coverage vs column density. Here, we show a 3D study in the galactic scale using the kinetic distance.

2. Data & Method

We investigate a $2^\circ \times 2^\circ$ region around $(l, b) = (29^\circ, 0^\circ)$ from the ^{12}CO (1-0) data of FUGIN survey (Umemoto *et al.* 2017). The spatial and velocity resolutions are $20''$ and 1.3 km s^{-1}, respectively. The grid spacing is $8.5''$. The typical noise level is 0.44 K in $T_{\rm mb}$. To reduce the noise level we integrated the data over 8 velocity channels before making GDHs; the velocity range we used is $26.75 \leqslant v_{\rm LSR} \leqslant 99.55$ km s^{-1} by every 5.2 km s^{-1}. The number of voxels we used is, therefore, $481 \times 481 \times 15$.

The column density of ISM is derived from ^{12}CO (1-0) intensity using the conversion factor $X_{\rm CO}$. We used $X_{\rm CO} = 1.8 \times 10^{20}$ cm^{-2} (K km s^{-1})$^{-1}$ (Dame *et al.* 2001). The

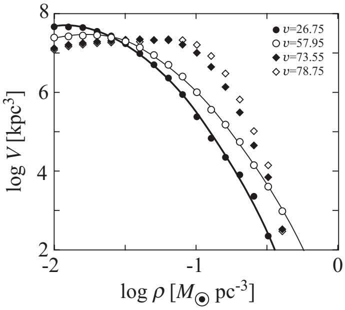

Figure 1. Gas Density Histograms from ^{12}CO (1-0) data around $(l, b) = (29°, 0°)$. Four different symbols show the GDHs at a different LSR velocity *i.e.* distance from the Sun. GDHs at $v_{\rm LSR} = 26.75$ and 57.95 km s^{-1} show lognormal (parabolic in this space), and two solid lines are the best fit curves. The others are flat-top and rapidly decrease in the denser end.

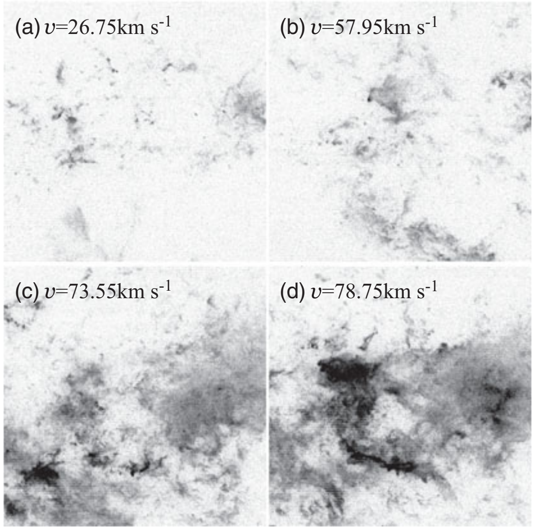

Figure 2. Four typical chanel maps in ^{12}CO (1-0). The area is 2° square centered at $(l, b) = (29°, 0°)$. The LSR velocity is shown in each panel. The GDHs at velocity shown in panels (a) and (b) are type A, and those in panels (c) and (d) are type B.

line-of-sight (LoS) depth of a voxel is derived using kinetic distance based on the flat rotation model with $R_0 = 8.5$ kpc and $V_0 = 220$ km s^{-1} (Kerr & Lynden-Bell 1986). The volume density of each voxel is the column density derived by this LoS depth, and the volume of each voxel is calculated using this LoS depth and the observed solid angle. For each velocity channel map we accumulate the volume for each volume density range, which gives the GDH at the corresponding distance, although it is an average of near and far locations. The low density limit is given by the noise level and LoS depth correspondent velocity range. It is about $10^{-2} M_\odot$ pc^{-3} for this region.

3. Results & Discussion

Out of 15 channels 3 GDHs are lognormal-like (type A), but the others are flat top or with a bump beyond the peak (type B). The typical GDHs at 4 velocities are shown in Fig. 1. Type A is expected for turbulence dominated region where gas density is randomly fluctuated (Vazquez-Semadeni 1994). Type A is found at the inter-arm regions in the $l - v$ diagram, where only few small molecular clouds are found (Fig. 2). Type B is found at the spiral-arm regions, where many dense cores and extended gas with filamentary structure are found. This suggests that molecular gas density is controlled by different mechanism in and out of the spiral arm. In the arm cloud-cloud collision and/or gravitational collapse may work to make dense clouds. We will apply this method for other regions.

References

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