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Statistical Study of High-Velocity Compact Clouds Based on the Complete CO Imagings of the Central Molecular Zone

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1. Introduction

High-velocity compact clouds (HVCCs) is one of the populations of peculiar clouds detected in the Central Molecular Zone (CMZ) of our Galaxy. They have compact appearances (< 5 pc) and large velocity widths (> 50 km s^{-1}). Several explanations for the origin of HVCC were proposed; e.g., a series of supernovae (SN) explosions (Oka *et al.* 1999) or a gravitational kick by a point-like gravitational source (Oka *et al.* 2016). To investigate the statistical property of HVCCs, a complete list of them is acutely necessary. However, the previous list is not complete since the identification procedure included automated processes and manual selection (Nagai 2008). Here we developed an automated procedure to identify HVCCs in a spectral line data.

2. Data / Analysis

The ^{12}CO J=1–0 (115.271 GHz) survey has been carried out with the Nobeyama Radio Observatory (NRO) 45 m telescope during the period from 2011 January 19 to 29. We mapped a $\Delta l \times \Delta b = 2^\circ \times 0.5^\circ$ area. The data were resampled onto a $7.5'' \times 7.5'' \times 2$ km s^{-1} grid to obtain the final maps. The HVCC identification procedure consists of three steps: (1) pressing method, (2) unsharp masking, and (3) modified CLUMPFIND. The first step of the procedure, the pressing method, reduces the absorption and contamination of low density gas in the Galactic disk.

The second step is sharpening technique in image processing, which emphasizes spatially compact, broad velocity width features. This process allows the next step to identify HVCCs correctly.

The final step, the modified CLUMPFIND identifies clumps in a data cube. We improved the original CLUMPFIND (Williams, de Geus & Blitz 1994) not to divide each cloud into pieces excessively.

3. Results

We applied this newly-developed identification procedure to the ^{12}CO J=1–0 data cube. Fig.1 shows longitude-velocity diagrams of the CO J=1–0 line before and after the pressing method and the unsharp masking. We identified 116 HVCCs by this procedure. Fig. 2 shows the positions of HVCCs in the l-b plane superposed on the map of velocity-integrated ^{12}CO J=1–0 emission. We found that about 90 % of HVCCs have kinetic energies exceeding 10^{50} erg, which corresponds to the energy injected to the interstellar medium by a SN explosion. This means, if HVCCs have been formed by SN explosions, most of them are associated with massive star clusters. We plotted the velocity dispersion against the size of HVCCs, Galactic center clouds and Galactic disk clouds in Fig. 3 left. This figure clearly demonstrates that HVCCs belong to a population of molecular clouds heretofore unrecognized. Fig. 3 right shows the plot of virial theorem mass ($M_{\rm VT}$) against the LTE Mass ($M_{\rm LTE}$) of HVCCs. The large virial parameter ($\alpha = M_{\rm VT}/M_{\rm LTE}$) of HVCCs indicates that they are definitely not bound by self-gravity.

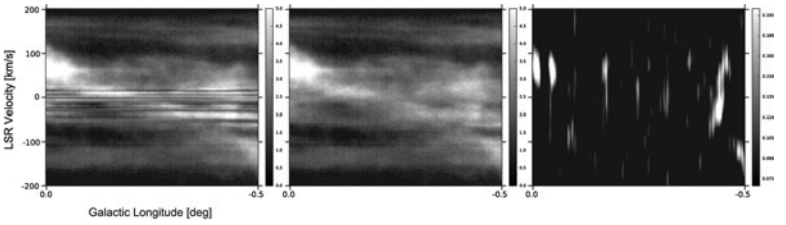

Figure 1. These figures are (l, V) diagrams (l: $-0.5^\circ \sim 0^\circ$, V: $-200 \sim 200$ km s^{-1}). Left figure is the original data. Center figure is applied pressing method 30 times. Right figure is applied unsharp masking. From center figure, We can find that the effects of Galactic disk clouds at near 0 km s^{-1} have been removed. Right figure shows that large velocity widths and compactness are emphasized.

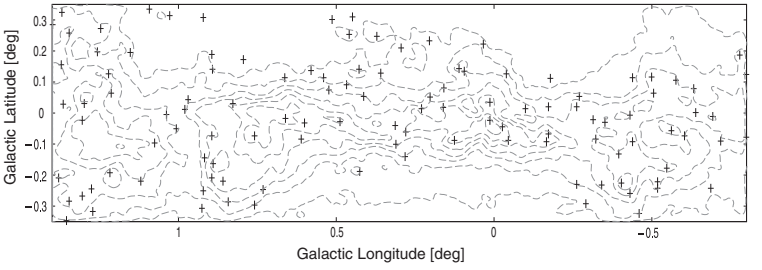

Figure 2. This is the (l, b) diagram of ^{12}CO J=1–0 line emission integrated over $V_{\rm LSR} = -200 \sim 200$ km s^{-1}. Contours are drawn at every 400 K km s^{-1} from 400 K km s^{-1} to 4000 K km s^{-1}. Crosses are HVCCs we identified.

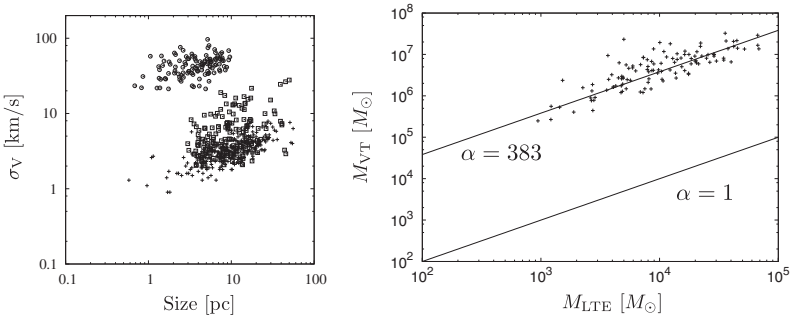

Figure 3. Left figure is the plot of the velocity width against the size. Crosses are the Galactic disk clouds (Solomon *et al.* 1987). Filled squares are the Galactic center clouds (Oka *et al.* 2001b). Open circles are the HVCCs we identified. Right figure is the relations of HVCCs between LTE Mass and virial theorem Mass. The $\alpha = M_{\rm VT}/M_{\rm LTE}$.

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