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3 mm band line survey toward the high-velocity compact cloud CO−0.40−0.22

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Abstract. High-velocity compact clouds (HVCCs) are a population of molecular clouds which have compact appearance ($d < 10$ pc) and large velocity width ($\Delta V > 50$ km s^{-1}), and are found in the central molecular zone of our Galaxy. We performed a 3 mm band line survey toward CO−0.40−0.22, a spatially unresolved HVCC with an extremely large velocity width ($\Delta V \simeq 90$ km s^{-1}), using the Mopra 22 m telescope. We surveyed the frequency range between 76 GHz and 116 GHz with a 0.27 MHz frequency resolution. We detect at least 54 lines from 32 molecules. Many line profiles show a prominent peak at $v_{\rm LSR} \sim 70$ km s^{-1} with very large velocity width, indicating they are emitted by the HVCC. Detections of largish molecules are indicative of non-equilibrium chemistry. We extracted some prominent lines based on velocity structure, intensity ratios, and PCA analyses. Shock diagnostic lines (SiO, SO, CH_3OH, HNCO) and dense gas probes (HCN, HCO^+) appear to be prominent. Excitation analysis of CH_3OH lines show an enhancement in $T_{\rm rot}$ in the negative high-velocity end of the profile. These results suggest that CO−0.40−0.22 has experienced a shock, acceleration, compression, and heating in the recent past.

Keywords. Galaxy: center — ISM: clouds — ISM: molecules — radio lines: ISM

1. Introduction

The large-scale CO surveys of the central molecular zone (CMZ) of our Galaxy have revealed a highly complex distribution and kinematics of molecular gas, including many expanding shells/arcs and filaments, along with a number of compact clouds exhibiting large velocity widths (Oka *et al.* 1998; 2012). This population of high-velocity compact clouds (HVCCs) is unique in the CMZ. Some of them are associated with expanding shells/arcs and hints of massive stellar clusters (Oka *et al.* 1999; 2001; 2008; Tanaka *et al.* 2007), suggesting that local explosive events such as supernova explosions may be responsible for the origin of HVCCs. Thus, they might be related to the origin of high gas temperature (e.g., Morris *et al.* 1983), widespread shock-probe molecules (Martín-Pintado *et al.* 1997; Hüttemeister *et al.* 1998), and the boisterous gas kinematics there.

CO−0.40−0.22 is one such HVCC, being centered at $(l, b) = (-0\overset{\circ}{.}40, -0\overset{\circ}{.}22)$, having a very compact appearance ($d \simeq 4$ pc) and extremely broad velocity width ($\Delta V \simeq 90$ km s^{-1}). This HVCC especially stands out in the HCN $J = (4-3)$ map, indicating high temperature and very high density (Tanaka *et al.* 2013). Neither of clumpy structure nor expanding shell/arc have been detected in this HVCC, while it shows a hint of a velocity gradient. To understand the nature of this HVCC, an unbiased spectral line survey as well as high-resolution imaging are essential.

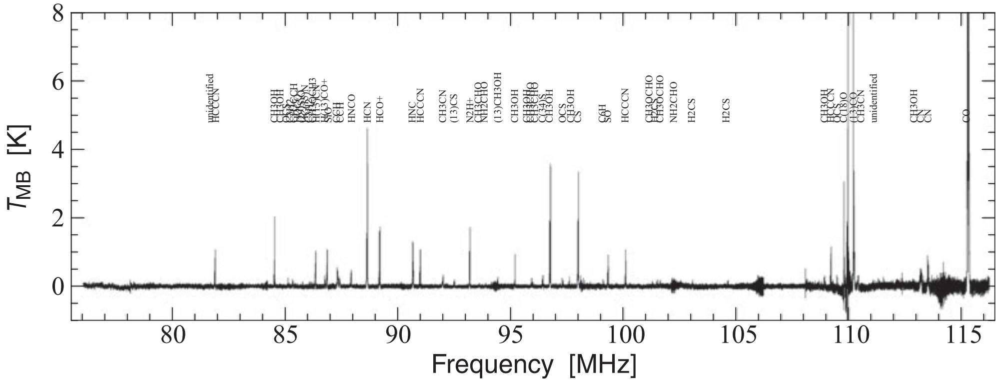

Figure 1. A wide band spectrum of CO−0.40−0.22 obtained with the Mopra 22 m telescope.

2. Observations and results

We performed a spectral line survey in the 3 mm band toward CO−0.40−0.22 using the Mopra 22 m radio telescope. The observations were made 2013 June 6–9. MOPS was used as a receiver backend in the 8.3 GHz bandwidth, 0.27 MHz resolution mode. We covered a frequency range from 76 GHz to 117 GHz. The primary beam of the telescope had sizes of 38″ and 30″ in diameter (HPBW) at 90 GHz and 115 GHz, respectively. The main-beam efficiency was 0.5 at 90 GHz and 0.4 at 115 GHz. The RMS noise of the resultant spectra was $\Delta T_{\rm MB} \sim 30$ mK (1σ) in frequencies less than 110 GHz and $\Delta T_{\rm MB} \sim 90$ mK around 115 GHz.

We detect at least 54 lines from 32 molecules from CO−0.40−0.22. A number of lines from largish molecules were detected, suggesting non-equilibrium chemistry. Most detected lines show profiles which peak at $v_{\rm LSR} \sim -70$ km s^{-1} with linewidths of $\Delta V \sim 50$ km s^{-1}. Two lines, c-C_3H_2 2(1,2)–1(0,1) and $H^{13}CO^+$ $J = (1-0)$, show broad triangular profiles. To extract spectral lines which probe this HVCC well, we define the following groups; **V**: $V_{\rm av} < 30$ km s^{-1} and $\sigma_{\rm V} > 10$ km s^{-1}, **R**: $T_{\rm MB}^{\rm HVCC} > 0.3$ K and $T_{\rm MB}^{\rm HVCC}/T_{\rm MB}^{\rm CMZ} > 1$, **C**: $R_{\rm X/C18O}^{\rm HVCC}/R_{\rm X/C18O}^{\rm CMZ} > 10$, **PC1**: main sequence in the PC1-PC2 plot, **PC2**: main sequence in the PC1-PC3 plot, **PC3**: main sequence in the PC2-PC3 plot. Taking the intersection, $\mathbf{V} \cap \mathbf{R} \cap \mathbf{C} \cap \mathbf{PC1} \cap \mathbf{PC2} \cap \mathbf{PC3}$, we conclude that HC_3N, CH_3OH, SiO, HNCO, c-C_3H_2 and $H^{13}CO^+$ lines are prominent probes of this HVCC. We also calculate rotation temperature ($T_{\rm rot}$) profiles using CH_3OH lines, and find that $T_{\rm rot}$ is enhanced in the negative high-velocity end of the line. These results suggest that CO−0.40−0.22 has experienced a shock, acceleration, compression, and heating in the recent past.

We are also conducting high-resolution imaging of CO−0.40−0.22 using ALMA, which will reveal the kinematics of this anomalous high-velocity feature.

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