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ALMA view of the massive dense clump in the Galactic center 50 km s^{-1} molecular cloud

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Abstract. We observed the 50 km s^{-1} molecular cloud with a high angular resolution ($\sim 1\farcs5$) using ALMA in the $H^{13}CO^{+}$ $J = 1-0$, $C^{34}S$ $J = 2-1$, CS $J = 2-1$ and SiO $v = 0$ $J = 2-1$ emission lines. This cloud is a candidate for the massive star forming region induced by cloud-cloud collision (CCC). We newly found a massive dense clump (DC1) with a size of ~ 0.3 pc in the CCC region of the cloud in the $H^{13}CO^{+}$ $J = 1-0$ map. The DC1 seems to be located on a line where the four H_{II} regions line up. Furthermore, the DC1 has a broad velocity width covering ~ 30 km s^{-1} and ~ 60 km s^{-1} components in the CS $J = 2-1$ map; the 30 km s^{-1} component has filamentary structures and the 60 km s^{-1} one a sheet-like structure. From the position-velocity diagrams of the $H^{13}CO^{+}$ $J = 1-0$ and CS $J = 2-1$ lines and the intensity ratio of $T(\mathrm{SiO}\ v = 0\ J = 2-1)/T(\mathrm{H^{13}CO^{+}}\ J = 1-0)$, i.e., a shock tracer, we consider that the DC1 has formed by the CCC between the filaments and the sheet-like gas. The LTE mass and virial parameter of the DC1 is estimated to be $\sim 1.3 \times 10^{4}\ M_{\odot}$ and ~ 5, respectively. These facts suggest that the DC1 is likely in a gravitationally bound state and may start massive star formation. We propose a scenario that the CCC induced the massive star formation in the H_{II} region A $\sim 10^{5}$ years ago and now causes the formation and collapse of the DC1; the clump would evolve to an H_{II} region within $\sim 10^{5}$ years.

1. Introduction

The 50 km s^{-1} molecular cloud (50MC) is one of the remarkable molecular clouds in the Sagittarius A (Sgr A) region. Therefore, the 50MC is thought to be a massive star forming region (SFR) induced by the cloud-cloud collision (CCC) (Tsuboi et al. 2015). Figure 1-A shows the $H^{13}CO^{+}$ $J = 1-0$ integrated intensity map in the range of $V_{\mathrm{LSR}} = 25-55$ km s^{-1} (pseudo color). The four compact H_{II} regions A-D are clearly seen in the integrated intensity map of the H42α recombination line (contours). In Figure 1-A, we newly found a distinct dense clump with a size of $\sim$ 0.1 pc, called DC1 hereafter, toward the cloud center. It should be noted that the DC1 seems located on a line where the four H_{II} regions A to D line up. Figure 1-B shows a closeup view of the $H^{13}CO^{+}$ integrated intensity map toward the DC1 in the dashed rectangular region of the panel A. Fitting a 2-dimensional Gaussian function to the DC1 map, the DC1 has a beam-deconvolved radius, R, of $7\farcs8$ ($\sim$ 0.3 pc). The size of the best-fit Gaussian function in FWHM

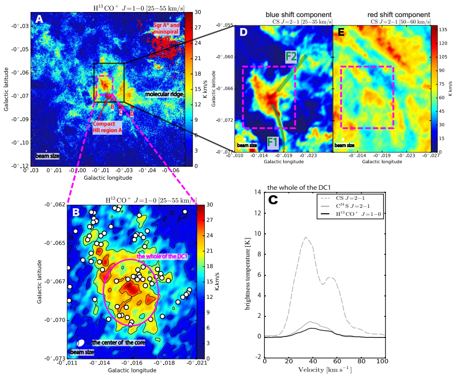

Fig. 1. [A] Integrated intensity map of the $H^{13}CO^+$ $J = 1-0$ emission line. [B] The closeup view of the dashed rectangular region of the panel-A with the integrated intensity map of the $H^{13}CO^+$ $J = 1-0$ emission line with black contours. [C] The velocity profiles of the whole of the core indicated by the open circle in the panel B. [D, E] The closeup view of the black rectangular region of the panel-A with the integrated intensity map of the CS $J = 2-1$ emission line.

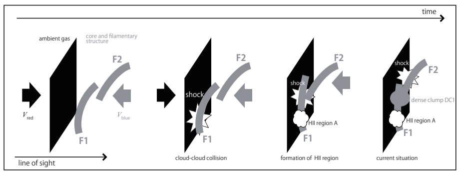

Fig. 2. Schematic illustration for the possible time evolution of the collision between the filaments and the sheet in the central region of the 50MC.

is shown in Figure 1-B by the open ellipse. The LTE mass, virial mass, virial parameter, mean number density and free fall time of the DC1 become $\sim 1.3 \times 10^4\ M_\odot$, $\sim 5.67 \times 10^4\ M_\odot$, ~ 5, 2×10^6 cm^{-3} and 2.4×10^4 years, respectively.

The structure of the ambient gas around the DC1 is traced by the CS $J = 2-1$ emission line in Figure 1-D and E.

The blueshifted component of the double peaks corresponds to the structure in Figure 1-D, while the redshifted one in Figure 1-E. There exist two distinct filamentary structures, referred to as "F1" and "F2" hereafter, which cross each other at the position of the DC1. The H_{II} region A and the DC1 are located on the same filament. Based on the above results and the position-velocity diagrams (not shown here), we propose a possible scenario for the massive star formation triggered by the CCC in the 50MC. Figure 2 shows a schematic illustration for the time evolution of the massive star formation triggered by the CCC in the central dense region of the 50MC. The sheet-like gas is moving fast along the line of sight with the velocity of $V_{sheet} \sim 55$ km s^{-1}, whereas the filaments F1 and F2 are moving slowly with the velocity of $V_{filament} \sim 35$ km s^{-1}, as shown in the leftmost panel of Figure 2. After a while, the lower part of the filament F1 collided with the sheet at the relative velocity of $V_{col} = V_{sheet} - V_{filament} \sim 20$ km s^{-1} (see the middle left panel in Figuure 2). The shock caused by the collision produced shock-compressed dense gas to likely trigger the star formation in the shock-compressed gas, leading to the compact H_{II} region A with an age of $\sim 10^5$ years (Yusef-Zadeh et al. 2010), as shown in the right panel of Figure 2. After $\sim 10^5$ years, the sheet-like gas collided the upper part of the F1 and the lower part of the F2 as shown in the middle right panel of Figure 2. This collision with shock is generating the massive dense clump DC1 in $\sim 10^5$ years. Note that the low-mass star formation is progressing in and around the DC1 because the 44GHz class I methanol masers (McEwen et al. 2016) are located in and around the DC1 shown in Figure 1-E by black open circles. It is likely that the central massive region of the DC1 will evolve into an H_{II} region within $\sim 10^4$ years. After the next 10^5 years, the sheet will collide with the upper part of F2 to make another dense clump, as shown in the rightmost panel of Figure 2.

References

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