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Physical Contact between the +20 km s^{-1} Cloud and the Galactic Circumnuclear Disk

Shunya Takekawa[1], Tomoharu Oka[1,2] and Kunihiko Tanaka[2]

[1]School of Fundamental Science and Technology, Graduate School of Science and Technology, Keio University, 3-14-1 Hiyoshi, Yokohama, Kanagawa 223-8522, Japan
email: shunya@z2.keio.jp

[2]Department of Physics, Institute of Science and Technology, Keio University, 3-14-1 Hiyoshi, Yokohama, Kanagawa 223-8522, Japan

Abstract. We report the discovery of physical contact between the Galactic circumnuclear disk (CND) and an adjacent giant molecular cloud. The central 10 pc of our Galaxy has been imaged in molecular lines at millimeter wavelength using the Nobeyama Radio Observatory 45 m radio telescope. In the position-velocity maps of several high-density probe lines, we have found an emission "bridge" connecting the +20 km s^{-1} cloud (M–0.13–0.08) and the negative longitude extension of the CND. The collision between the +20 km s^{-1} cloud and the CND may be responsible for the formation of the bridge. This event can promote mass accretion onto the CND and/or into the inner cavity.

Keywords. Galaxy: center, galaxies: nuclei, ISM: molecules, radio lines: ISM

1. Introduction

The Galactic nucleus, Sgr A*, is encompassed by a dense molecular gas ring, i.e., the "circumnuclear disk" (CND). The CND has an inner radius of ~ 2 pc, is inclined $\sim 20°$ to the Galactic plane, and has a rotational velocity of ~ 110 km s^{-1} (e.g., Genzel *et al.* 1985). The CND extends up to ~ 7 pc from the center toward negative Galactic longitude and up to ~ 3 pc toward positive longitude (e.g., Oka *et al.* 2011).

The CND is considered to be the mass reservoir for the central activities, and may have been formed by the tidal capture and disruption of a giant molecular cloud (GMC) by the central SMBH within 10^6 yr (Wardle & Yusef-Zadeh 2008). Indeed, two GMCs, M–0.13–0.08 and M–0.02–0.07 (+20 and +50 km s^{-1} clouds, respectively), are located on both sides of the CND. Although several authors have suggested the possibility of interaction between the +20 km s^{-1} cloud and the CND, no direct connection has been detected yet (Herrnstein & Ho 2005). Here, we report the discovery of an emission feature that bridges the +20 km s^{-1} cloud and the CND in b–V maps of molecular lines.

2. Observations and Results

On-the-fly (OTF) mapping observations were performed with the Nobeyama Radio Observatory (NRO) 45 m radio telescope during February 5–12 and March 28–30, 2014. The mapping area was $6' \times 6'$ ($-0.11° \leqslant l \leqslant -0.01°$ and $-0.11° \leqslant b \leqslant -0.01°$), covering the entire CND. Target lines were HCN J=1–0, H^{13}CN J=1–0, HCO$^+$ J=1–0, CS J=2–1, SiO J=2–1, SO N_J=2_3–1_2, and HC$_3$N J=11–10, which were selected based on our previous 3 mm band line surveys (Takekawa *et al.* 2014). The half-power beamwidth (HPBW) at 86 GHz was 20″. The rms noise level of the resultant maps was 0.1 K in $T_{\rm MB}$.

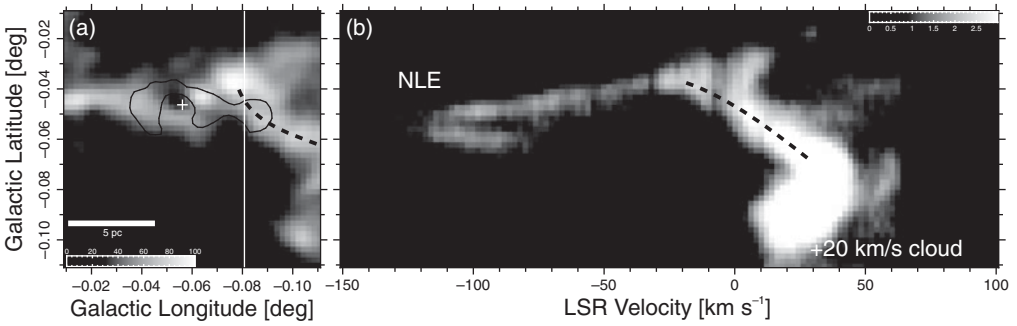

Figure 1. (a) Velocity-integrated intensity map of the CS J=2–1 line. The integration velocity ranges from −40 to +10 km s^{-1}. The "+" indicates the location of Sgr A*. The dashed line traces the "bridge". The black contour shows where the HCN J=1–0 velocity-integrated intensity is 350 K km s^{-1}, drawn to indicate the distribution of the CND. (b) Latitude-velocity map along the vertical line in (a). The dashed line traces the "bridge".

In these data, we noticed a "bridge" of emission that connects the +20 km s^{-1} cloud with the negative longitude extension (NLE) of the CND in l–b–V space. Figure 1(a) is a map of CS J=2–1 line emission integrated over the velocity from −40 to +10 km s^{-1}, and Figure 1(b) is the latitude-velocity (b–V) map at the Galactic longitude indicated by the vertical line in Figure 1(a). The bridge extends from $l \sim -0.11°$ to $-0.08°$. In the b–V map, the bridge originates from the +20 km s^{-1} cloud at $(b, V_{\rm LSR}) \simeq (-0.06°, +30\,{\rm km\ s^{-1}})$, moves upward with decreasing velocity, and then joins the NLE at $(b, V_{\rm LSR}) \simeq (-0.04°, -20\,{\rm km\ s^{-1}})$. The bridge appears also in the $H^{13}CN$, SiO, SO, and HC_3N maps but is less prominent in the HCN and HCO^+ maps, presumably because of the strong foreground absorption. Because these lines have high critical densities, the bridge probably consists of dense $[n({\rm H_2}) \gtrsim 10^5\ {\rm cm^{-3}}]$ molecular gas.

The continuity of the +20 km s^{-1} cloud and the CND indicates the physical contact between them. Because it is known that the +20 km s^{-1} cloud is in front of the Galactic nucleus (e.g., Güsten & Henkel 1983), the bridge may be thought of as a streamer from the +20 km s^{-1} cloud toward the nucleus. However, the upper part of the +20 km s^{-1} cloud seems to be accelerating toward us, which is incompatible with the streamer interpretation of the bridge. This invokes the cloud-plunging scenario, i.e., a cloud has plunged into the +20 km s^{-1} cloud. The NLE, which is the asymmetric part of the CND, may have plunged into the northern part of the +20 km s^{-1} cloud. It compressed, accelerated, and swept up molecular gas in the +20 km s^{-1} cloud, which had been just in front of the NLE, to form the connecting bridge.

The collision between the +20 km s^{-1} cloud and the NLE cancels out their angular momentum and they lose kinetic energy with dissipation of the shock. As a result, some part of the NLE may accrete inward along highly eccentric orbits, and part of the +20 km s^{-1} cloud may move inward as well. These processes may lead to growth of the 2-pc ring and possibly feed the inner cavity.

References

Genzel, R., Crawford, M. K., Townes., C. H., & Watson, D. M. 1985, *ApJ*, 297, 766
Güsten, R. & Henkel, C. 1983, *A&A*, 125, 136
Herrnstein, R. M. & Ho, P. T. P. 2005, *ApJ*, 620, 287
Oka, T., Nagai, M., Kamegai, K., & Tanaka, K. 2011, *ApJ*, 732, 120
Takekawa, S., Oka, T., Tanaka, K., *et al.* 2014, *ApJS*, 214, 2
Wardle, M. & Yusef-Zadeh, F. 2008, *ApJ*, 683, L37