MOLECULAR CLOUDS IN THE CENTRAL 100-PC OF THE GALACTIC CENTER

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ABSTRACT. We have observed CS(J=1-0/2-1) lines in a 60'x30'(lxb) area of the Galactic center region. There are two large-scale features with elliptical shape in the position-velocity maps, which suggest shell-like structures in the region. One is the ring with a radius of ∿40 pc in the positive galactic latitude region and another is the shell with a radius of ∿20 pc in the negative galactic longitude region. These could be due to suggest star bursts occurred in the Galactic center region.

1. INTRODUCTION

In the Galactic center region, molecular lines and HI observations have shown some peculiar structures: the 2-pc circumnuclear ring (Becklin et al., 1982, Kaifu et al., 1983, Güsten et al., 1987) and the 230-pc expanding ring (Kaifu et al., 1972, Scoville, 1972). High resolution radio continuum and polarization observations revealed the large scale vertical magnetic field and relativistic electrons in the Galactic center region (Tsuboi et al, 1985, 1986, Seiradakis, 1985). Because the kinetic energy of the molecular clouds is larger than the energy of the magnetic field, the molecular clouds should play a dominant role in the magnetic field. Thus it is important to observe the molecular clouds with high resolution and high sensitivity.

Although CO lines are very strong in the Galactic center region (Burton and Liszt, 1983, Bally et al., 1988), they suffer from strong line-of-sight contamination, especially, for ∿0 km/s components. It is difficult to study the actual structure of molecular clouds in the Galactic center region from these contaminated data. On the other hand, CS lines have large critical density and are free from line-of-sight contamination. In addition, the pair of CS lines is a good tracer of the density of molecular clouds. Thus we have observed CS lines to study the actual structure of the Galactic center. We assume here that the distance to the Galactic center is 8.5 kpc.

2. OBSERVATION

We have made observations of the Galactic center region in the CS(J=1-0) and CS(J=2-1) transition lines from May 1987 till June 1988 with the NRO 45-m telescope. The mapping area contains Sgr A, the Radio Arc, and Sgr C. HPBWs of the telescope at 49 and 98 GHz are 34" and 17", respectively. Observation grids are 15" near the galactic plane and 30" or 45" in the outer region. System temperatures at 20° elevation for

M. Morris (ed.), The Center of the Galaxy, 135–140.

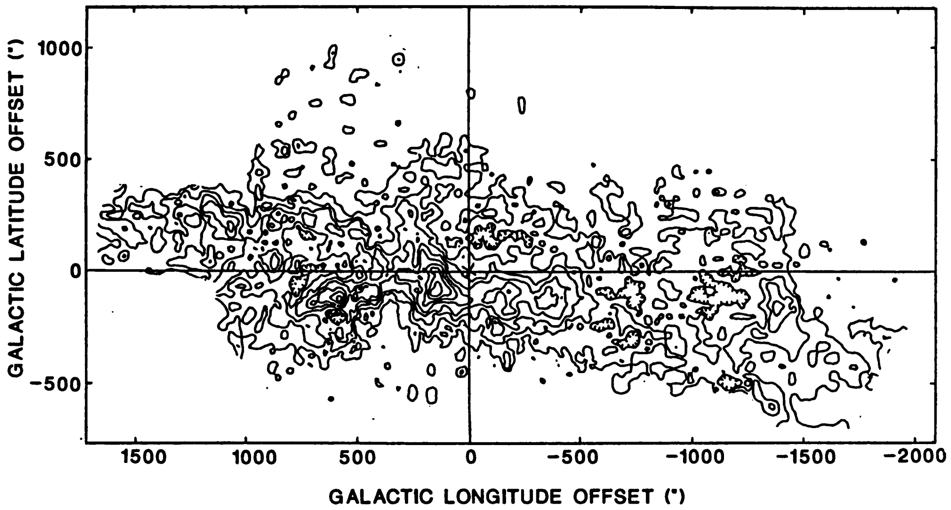

Figure 1:The intensity distribution of CS(J=1-0) emission integrated over the velocity range of -30 to 90 km/s. Contour interval is $\int T_a^* dv$=20 K km/s. The origin of coordinates is $\alpha=17^h42^m29^s.3$, $\delta=-28°59'20''$.

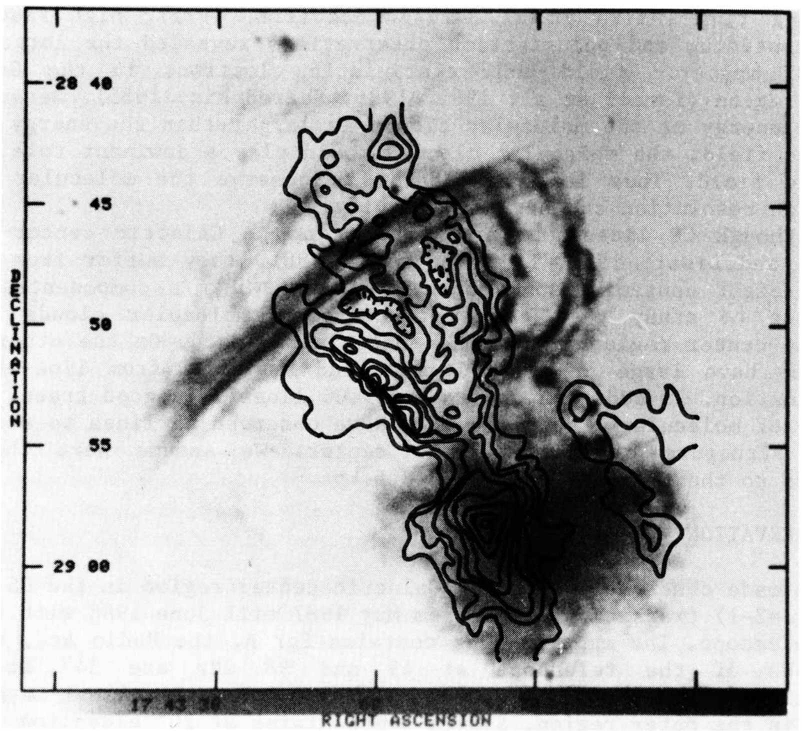

Figure 2:The CS(J=1-0) map in the velocity range of 30 to 90 km/s (contours) and the 1.5-GHz map (gray scale, Yusef-Zadeh & Morris, 1987)

CS(J=1-0) and CS(J=2-1) are 300-600 K and 600-1000 K, respectively. The achieved r.m.s. noise for CS(J=1-0) and CS(J=2-1) are 0.3 K/250 kHz and 0.6 K/250 kHz, respectively. In this observation, ∿6000 CS(J=1-0) spectra and ∿2000 CS(J=2-1) spectra with sufficient S/N are obtained.

3. RESULTS AND DISCUSSION

Figure 1 shows the spatial distribution of CS(J=1-0) emission in the velocity range of -30 to 90 km/s. The appearances of the molecular clouds are filamentary and clumpy. The spatial distributions are asymmetric with respect to Sgr A. The clouds are much more crowded in the positive velocity range than in the negative velocity range. The most prominent cloud is the "50-km/s molecular cloud" which is located on the eastern side of Sgr A. The peak of this cloud has a triangular shape. This cloud extends toward negative galactic longitude and merges with the next prominent cloud, the "20-km/s molecular cloud".

Figure 2 shows the comparison between the CS(J=1-0) map in the velocity range of 30 to 90 km/s and the 1.5-GHz continuum map (Yusef-Zadeh and Morris, 1987). There are three molecular filaments along the galactic plane in the Radio Arc region. The stronger positive galactic molecular (northern) filaments are associated with the weak extended continuum components, which are located near the negative galactic latitude side of the "arched filaments". The negative galactic latitude edge of the weaker positive galactic latitude molecular (southern) filament is also associated with a weak continuum filament. In the negative velocity range, there are three molecular filaments in this region. The edges of two positive galactic latitude filaments are associated with the "arched filaments" (Serabyn and Güsten, 1987). In both velocity ranges, the negative galactic latitude filaments have no strong continuum counterpart.

In the Δl-V_r diagrams of positive galactic latitude regions (see figure 3-a), there is an inclined elliptical feature, which is especially remarkable in the Radio Arc region. The feature suggests the presence of the molecular ring with rotation and radial motion in the Galactic center region. The radius of the ring is about 40 pc. This ring is referred to as the "40-pc molecular ring" here. The rotation velocity and radial velocity of this structure at Δb= 260" are 30 and 60 km/s, respectively. Shaded areas in figure 3-a show the recombination line H76α (Whiteoak and Gardner, 1982). The elliptical feature of the ring is also seen and ionized gas is associated with the "40-pc molecular ring". This shows a physical association between molecular cloud and ionized components mentioned above. The positive velocity portion of the elliptical feature was founded as a high velocity gradient molecular cloud (Burton and Liszt, 1983) and has been identified as a part of a large tilted structure across the Galactic center (Bally et al., 1988).

In the Δb-V_r diagrams (see figure 4), there is a U-shaped feature in the positive galactic latitude region. This feature shows the radial velocity of the ring is increasing with increasing distance from the galactic plane. The number density and the total mass of the ring are estimated from CS observations to be 1×10^4 cm^{-3} and 10^6 Mo, respectively. The kinetic energy of the ring is calculated to be $10^{52\sim53}$ erg. If we assume a point explosion at the Galactic center and a

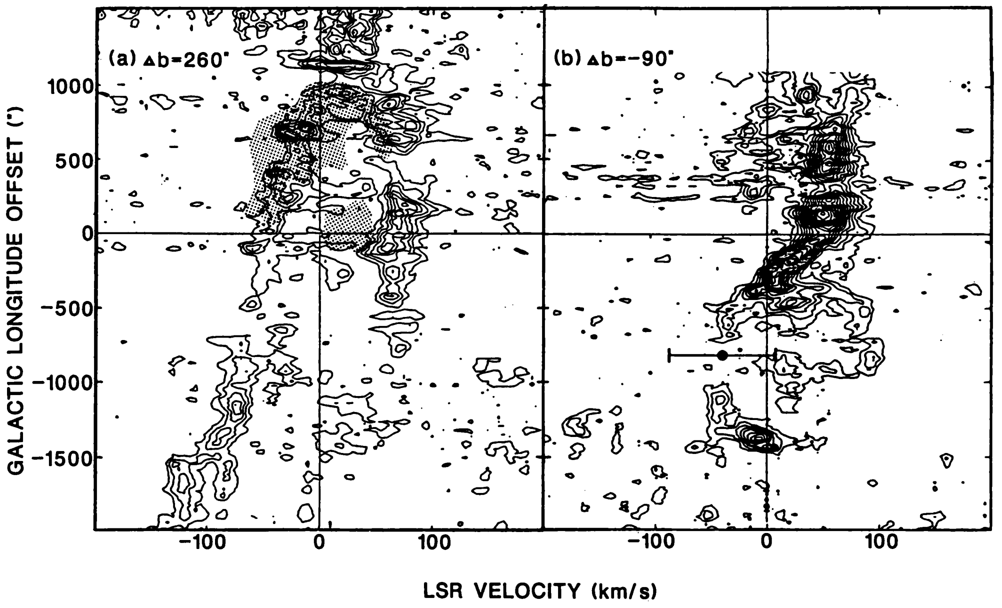

Figure 3:The Δl-V_r diagrams of CS(J=1-0). Contour interval is T_a^*=0.22 K. (a); at Δb=260", the shaded areas show recombination line, H76α (Whiteoak & Gardner, 1982). (b); at Δb=-90", the point with error bar shows recombination line, H109α (Pauls & Mezger, 1975)

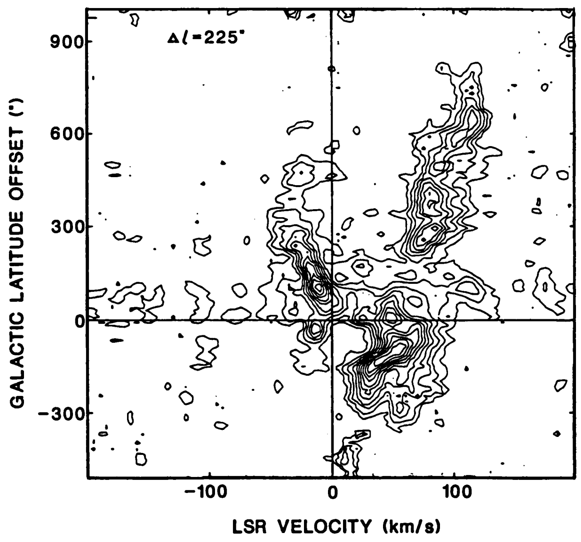

Figure 4:The Δb-V_r diagram of CS(J=1-0) at Δl=225". Contour interval is T_a^*=0.22 K.

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constant expansion velocity of 60 km/s, the age of the ring is estimated to be $8x10^5$ years. Thus this shell-like structure can be accounted for as a remnant of star burst (at least 100 supernovae) in the Galactic center region. If the explosion occurs at the Galactic center, the velocity of the shock should increase with increasing distance from the galactic plane. Thus the Δb-V_r relation of the ring is consistent with an explosion at the Galactic center.

Another shell-like structure of molecular clouds exists in the negative galactic longitude region in the velocity range of -15 to 15 km/s (see figure 5, dotted lines). The radius of the shell-like structure is 20 pc. Here we call this shell-like structure the "barrel". On the Δl-V_r diagram, the west end of the large molecular ridge connects to a new large-scale ring feature which corresponds with the "barrel" (see figure 3-b). The radial and the center velocity is 70 and 20 km/s at Δb=-90", respectively. The total mass of the "barrel" is estimated to be $10^{5\sim6}M_\odot$ from CS(J=1-0/2-1) observations. Thus kinetic energy of the "barrel" is $10^{52\sim53}$ erg. This value is comparable to the kinetic energy of the "40-pc molecular ring". The age of the "barrel" is estimated to be $3x10^5$ years. The "barrel" is probably made by a younger star burst in the Galactic center region than that of the "40-pc molecular ring". Thick contour of figure 5 shows 10-GHz continuum emission distribution (Handa et al., 1987). There is an extended continuum source at 10 GHz in the shell-like structure. The spectral index of this continuum source is α=-0.3 to -0.4 ($S\propto\nu^\alpha$) between 2.7 and 10 GHz (Handa, 1987). Recombination line H109α is detected in this region (Pauls and Mezger, 1975). The central velocity of this ionized component corresponds to that of the "barrel" in the Δl-V_r diagram (see figure 3-b). It is likely that this extended continuum source is an HII region on the shell of the "barrel" induced by the shock of the explosion. These molecular shells in the Galactic center region are displayed schematically in figure 6.

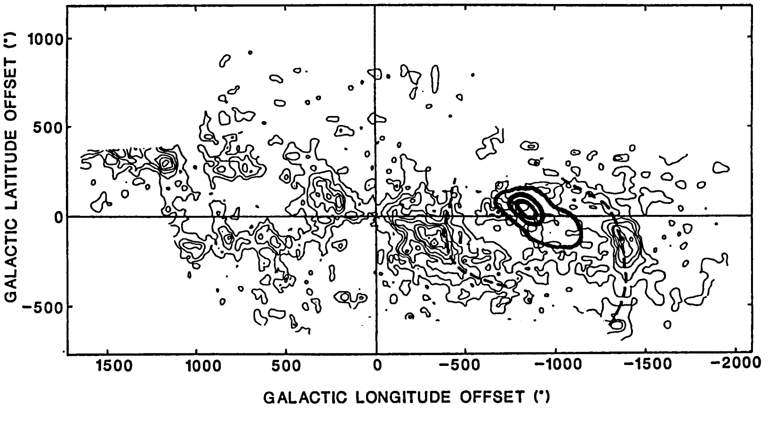

Figure 5:The intensity distribution of CS(J=1-0) emission integrated over the velocity range of -15 to 15 km/s (thin contours). Contour interval is $\int T_A^* dv$=5 K km/s. There is a shell-like source to the west of Sgr A (dotted lines). Thick contours show the 10-GHz continuum emission in the source.

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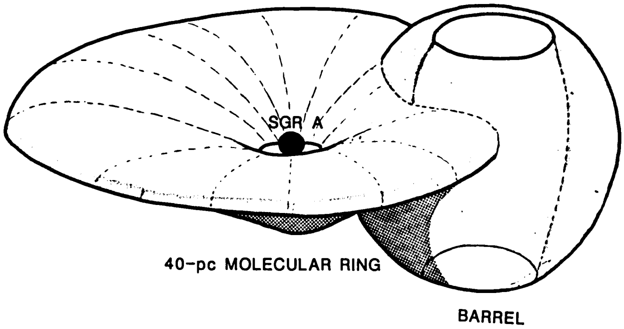

Figure 6 The schematic display of the "40-pc molecular ring" and the "barrel" in the Galactic center region.

4. CONCLUDING REMARKS

We found two large-scale molecular shell-like structures in the Galactic center region. The "40-pc molecular ring" and the "barrel" have the kinetic energy of $10^{52\sim53}$erg and the age of $10^{5\sim6}$ years. These structures suggest star bursts occurred in the Galactic center region.

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