NH_3 OBSERVATIONS OF THE SGR A COMPLEX REGION WITH THE NOBEYAMA MILLIMETER ARRAY

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ABSTRACT. We report NH_3 observations of the Sgr A complex region including Sgr A West and the 20 km/s and 50 km/s molecular clouds (M-0.13-0.08 and M-0.02-0.07) using the Nobeyama Millimeter Array and the 45m telescope. NH_3(1,1) and (2,2) lines were simultaneously observed to estimate the kinetic temperature. Our results suggest strong interaction between the molecular clouds and the continuum sources in the Sgr A complex. The interaction with continuum sources might be an important factor in determining the physical conditions of molecular gas in the galactic center region.

1. Introduction

The conspicuous molecular clouds apparently close to the galactic center are labelled (according to their galactic coordinates) M-0.13-0.08 and M-0.02-0.07, or the 20 km/s and 50 km/s clouds, respectively. The entire system of clouds exhibits different properties from the local clouds in the galactic disk with their broad linewidth ($\gtrsim$ 15 km/s) and the high kinetic temperature (30-40K) (ex., Güsten and Henkel 1983; Armstrong et al. 1985). Recent radio continuum observations in the Sgr A complex region including the two clouds imply activities within our galactic nucleus (Yusef-Zadeh and Morris 1987). Thus the relationship between the molecular clouds and continuum sources in the Sgr A complex would yield a clue to the nature of the activities of the galactic center region.

2. Results

2.1. SPATIAL DISTRIBUTION OF NH_3 EMISSION

The parameters of the observations and data reduction are summarized in the table. Figure 1 shows a CLEAN map and an integrated intensity map of NH_3 (2,2) emission averaged over the velocity ranges $-5.8 < V_{lsr} < 55.4$ km/s. The CLEAN map was made using natural weighting and convolving the

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TABLE OBSERVATIONAL PARAMETERS OF NH_3 (1,1) AND (2,2) LINES

Source		M-0.13-0.08*	Sgr A West & M-0.02-0.07**
Baselines		20 m - 469 m 76 baselines	20 m - 469 m 60 baselines
Visibility calibrator		NRAO530 (7.0 ± 1.0 Jy)	
Bandpass calibrator		3C273	
Bandwidth		80 MHz	
Synthesized beam(")	(1,1)	24.3x12.7	19.5x9.8
	(2,2)	24.0x12.6	19.5x9.8
Velocity coverage	(1,1)	-35.6 ~ 57.4 km/s	-36.6 ~ 99.9 km/s
of CLEAN maps	(2,2)	-33.5 ~ 59.4 km/s	-35.5 ~100.9 km/s
Velocity resolution		2 km/s	
S r.m.s. (mJy/beam)		46	48
Tb r.m.s. (K)		0.32	0.52

* Field center R.A.(1950)=17h42m28.0s DEC.(1950)=-29°04'01.1"
** 17h42m29.335s -28°59'18.6"

(u,v) data with a Gaussian taper of 25kλ. Primary beam correction has not been applied. The eastern half of M-0.02-0.07 was out of the primary beam. One-third of the total single-dish NH_3 flux was detected with the interferometer. There are many continuum sources as shown in Figure 1(a). SgrA-A to D and SgrA-G are compact HII regions (Ekers et al. 1983; Ho et al. 1985). The "wisp"(SgrA-E) and SgrA-F show non-thermal spectra (Ho et al. 1985). Intense emission is confined to the areas surrounded by the continuum sources, i.e., SgrA-A to D (Ekers et al. 1983) and Sgr A East in M-0.02-0.07, and the "wisp" and SgrA-F (Ho et al. 1985) in M-0.13-0.08. We have found a new H_2O maser spot near SgrA-F (Fig.1(a)). A part of emission from M-0.13-0.08 extends to the north with $\lesssim$ 1pc width and reaches to the place immediately next to Sgr A West.

2.2. KINEMATIC STRUCTURE

<M-0.13-0.08> A uniform velocity gradient (~ 10 km/s/arcmin) can be seen till the end of the northern extension in Figure 2(a) along A-A'. This velocity gradient almost agrees with that reported by Gusten et al. (1980,1981). Thus the uniform gradient indicates that the extension is a part of the M-0.13-0.08 cloud. Figure 2(b) and (c)(B-B'and C-C') show a complex velocity structure with a relatively large linewidth (~ 12 km/s) in (l,b)=(359°52.5'~54',-00°04'~05'). A feature like an arc can be seen in both diagrams. It implies a radial motion (~ 7 km/s) of gas from the velocity gradient. This region having the complex velocity structure is located in the area surrounded by the "wisp" and SgrA-F.

<M-0.02-0.07> The velocity field in the western half of M-0.02-0.07 is fairly constant with 40-50 km/s. However, the peak velocity becomes slightly larger in the north-west and smaller in the south. Typical line profiles with peak velocities and linewidths are presented in Figure 3.

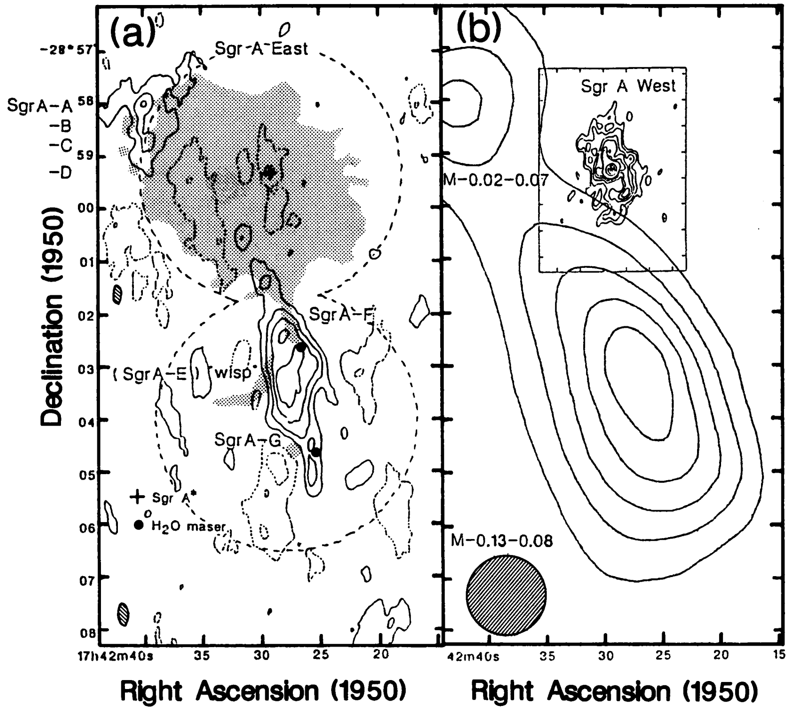


Fig. 1. (a) NH_3 (2,2) emission averaged over the velocity range −5.8 < Vlsr < 55.4 km/s, with continuum emission subtracted. The contour levels are −84, −42, 42, 84, 126, 168 mJy/beam. The field of view of the interferometer is denoted by a dashed line. The 6cm continuum emission is superposed on it (Ho et al. 1985). The position of Sgr A^* is marked by a cross, and the positions of H_2O masers are marked by filled circles. A new one is located near SgrA-F. (b) A total $T_A^*(NH_3(2,2))$ integrated intensity obtained by the 45m telescope with the same velocity range. The contour levels are spaced at 20 K*km/s intervals. The 1.3cm continuum emission observed with the interferometer is superposed on it. Its contour levels are −2,2,4,8,12,16,20,40,60,and 80% of 1.917 Jy/beam.

The most remarkable property of the gas is its large linewidth (>13 km/s). It is larger than that in M-0.13-0.08.

2.3. THE STRUCTURE OF GAS KINETIC TEMPERATURE

We have summarized the spatial distribution of rotation temperatures and linewidths in Figure 4. The detailed procedure to derive rotation temperatures using (1,1) and (2,2) lines will be described in Okumura et al.(1988). In M-0.13-0.08, the positions with both higher rotation temperatures and broader linewidths seem to be located in the northern half of the cloud. On the other hand, we could find no variation of rotation

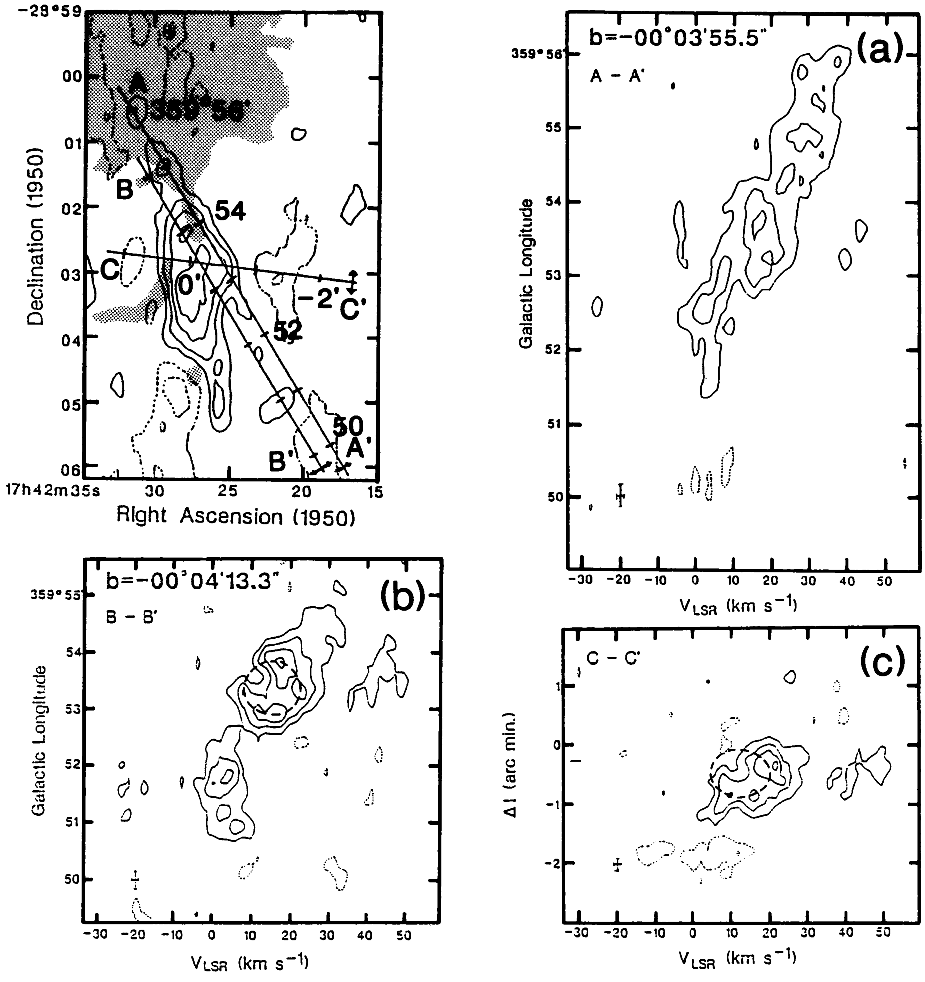


Fig. 2. Three position-velocity diagrams of NH_3 (2,2) emission. The positions and the averaged spatial widths of the cuts are shown in a top-left panel. (a) A longitude-velocity diagram along the northern extension of M-0.13-0.08(A-A'). The velocity resolution is 2.0 km/s. The contour levels are -280, -140, 140, 280, 420, 560 mJy/beam. (b) A longitude-velocity diagram through the area surrounded by the "wisp" and SgrA-F(B-B'). The other parameters are as Fig.2.(a). (c) A position - velocity diagram whose cut is approximately perpendicular to a northern part of the "wisp"(C-C'). The other parameters are as Fig.2.(a). Position offsets are in arc min. from (l,b) = (359°53'30", -00°04'33.8").

temperature and linewidth in M-0.02-0.07, although they are higher and broader than those in M-0.13-0.08. The rotation temperature is a lower limit to the kinetic temperature. According to Walmsley and Ungerechts

(1983), 20(30)K in rotation temperature using (1,1) and (2,2) lines corresponds to 30(>50)K in the kinetic temperature.

4. Discussion - The Association between Molecular Gas and the Continuum Sources in the Sgr A Complex

We suggest strong interaction between the molecular clouds and the continuum sources in the Sgr A complex. This might be an important process to determine the physical properties of molecular gas in the galactic center region.

<M-0.13-0.08> Our results show high kinetic temperature (>50K), broad linewidth (>10 km/s), and a complex velocity structure (Fig. 2(b) and (c)) in the northern half of M-0.13-0.08. They seem to be due to the interaction between the molecular gas and the continuum sources which probably come from an explosive event like a supernova remnant. Ho et al. (1985) suggest that the "wisp" may be a part of a supernova remnant because of its shape, spectral index, and polarization vectors. They inferred that its higher brightness on the side of M-0.13-0.08 may be due to the interaction with the molecular material. Our molecular line observations support their conclusion. Input of turbulence could account for broad linewidth (ex., IC443; White et al. 1987). A new H_2O maser spot might imply that low-mass star formation is triggered by the turbulence. Compression of molecular gas and the dissipation of turbulent energy (Mauerberger et al. 1986) appear to be important to heat molecular gas. The radial motion can be interpreted as a local expansion due to the impact of an explosive event. The detailed properties of molecular gas will be discussed by Okumura et al. (1988). At this meeting, Szczepanski et al. (1988) have proposed that maser activity of methanol (CH_3OH) adjacent to SgrA-F may be due to the impact of a SNR and the resulting shock of the molecular material in the M-0.13-0.08 cloud.

<M-0.02-0.07> Many radio observers of M-0.02-0.07 have discussed the relationship among the compact HII regions, Sgr A East (shell), and the molecular clouds (Güsten et al. 1980, 1983; Liszt et al. 1983; Brown and Liszt 1984; Ho et al. 1985; Goss et al. 1985; Yusef-Zadeh and Morris 1987). They argued the possibility of interaction between the continuum sources and the molecular gas. The brightness temperature of the Sgr A East shell at 23.7GHz is much lower than the excitation temperature of NH_3 emission. Since we can exclude the effect of absorption, the shape of observed emission toward the shell indicates the actual distribution of hot and dense molecular gas. Radio recombination line emission from the compact HII regions was observed by Goss et al. (1985) to have radial velocities from 43 to 52 km/s. This almost agrees with that of NH_3 emission shown in Figure 3, confirming the association between the compact HII regions and the 50 km/s cloud (M-0.02-0.07) argued by Goss et al. (1985). Thus the molecular gas in the western half of M-0.02-0.07 seems to be physically close to both the compact HII regions and the Sgr A East shell. High kinetic temperature (>>50K) and broad linewidth (>13 km/s) also suggest strong interaction with the Sgr A East shell which is considered to be a supernova remnant (ex., Goss et al. 1983). Compared

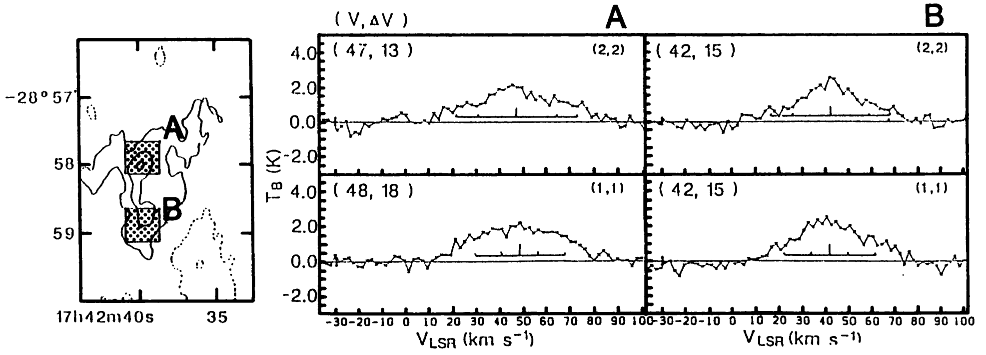
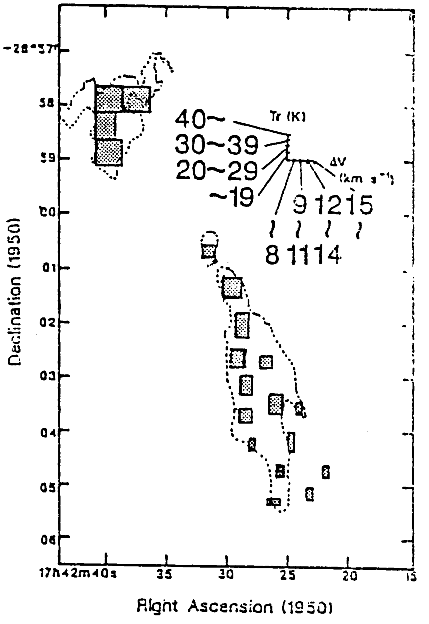


Fig. 3 NH_3 line profiles toward M-0.02-0.07. The positions where the line profiles were made are indicated as 30"x30" areas in a left panel. We integrated NH_3 emission within each area in all the line maps with 2.0 km/s width. Error bars indicate the 2r.m.s. noise levels. We derived peak velocities and linewidths using a non-linear least-square fitting taking hyperfine splitting into consideration. The spacing of the hyper-fine transitions is marked at the bottom of each panel.

Fig. 4. The structure of NH_3 rotation temperature and linewidth. Each line profile is obtained by integrating NH_3 emission in the 30"x30" area whose bottom-left corner coincides with that of the box shown here. The box width is proportional to the averaged linewidth of two transitions. The box height gives NH_3 rotation temperature. Both scales are shown in the upper-right corner.



with the case of M-0.13-0.08, a large amount of energy appears to be put into the molecular cloud. This would explain the molecular gas being hotter and more turbulent than that in M-0.13-0.08.

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