TWO REMARKABLY THIN CO FILAMENTS TOWARD THE SUPERNOVA REMNANT G109.1-1.0

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Abstract: We observed the semicircular supernova remnant G109.1-1.0 in the J = 1-0 transition of CO with the Nobeyama 45-m radio telescope. It is found that two remarkably thin molecular filaments delineate the inner boundary of the X-ray jet feature in this remnant. These filaments seem to have experienced evaporation due to the hot gas in the remnant.

Introduction: The semicircular supernova remnant G109.1-1.0 was discovered at X-ray wavelengths (Gregory and Fahlman, 1980). There exists an X-ray pulsar at the center of the remnant (Fahlman and Gregory, 1981, 1983; Koyama et. al., 1987). At radio wavelengths this remnant contains radio arcs inside of the semicircular shell, but there is no feature corresponding to the X-ray pulsar or the X-ray jet (Downes, 1983; Sofue et al., 1983; Gregory et al., 1983; Hughes et al., 1984). Gregory and Fahlman (1981, 1983) proposed a precessing jet model analogous to SS433 based on the presence of the X-ray pulsar , the X-ray jet, and the radio arcs. Millimeter-wavelength studies using CO and/or less abundant ^{13}CO have revealed that there is a molecular cloud on the west of the remnant (Israel, 1980; Heydari-Malayeri et al., 1981; Tatematsu et al., 1985, 1987). Our previous study (Tatematsu et al., 1987) has shown that the main molecular cloud has prevented the isotropic expansion of G109.1-1.0 causing its semicircular shape. They have also revealed that the armlike molecular ridge ("CO arm" hereafter) extending from the main molecular cloud shows an apparent anticorrelation with the X-ray jet feature. We have investigated the structure and dynamics of the CO arm, and the interface between the main cloud and G109.1-1.0 using the Nobeyama 45-m radio telescope.

Observations: Observations were carried out in the J = 1-0 transition of CO at 115.271204 GHz in December 1986 and April 1987. The Nobeyama 45-m radio telescope had a half-power beamwidth of 17" and a beam efficiency of 0.45 at this frequency. The cooled Schottky diode receiver was employed and provided a system temperature of 600-700 K (SSB). The observations were made with 60" spacing in general, whereas the observations of the CO arm were carried out with 30" spacing. All spectra were obtained in the position switching

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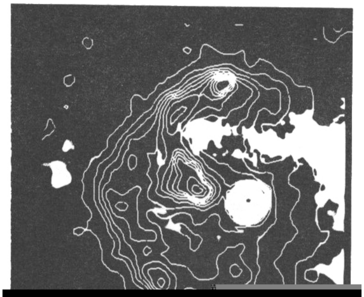

Fig. 1: The gray-scale map of CO (J = 1-0) intensity integrated over the radial velocity range V(LSR) = (-57, -43) km/s. The X-ray map of G109.1-1.0 (Gregory et al., 1983) is reproduced as white lines with a resolution of ~ 3'. Contours of the X-ray emission are drawn every 20 from 20 to 200, every 50 from 200 to 500, and every 100 from 500 to 1700, in an arbitrary intensity unit.

Fig. 2: The gray-scale map of CO (J = 1-0) intensity integrated over the range V(LSR) = (-51, -49) km/s. The X-ray map of G109.1-1.0 (Gregory et al., 1983) is also reproduced as white lines.

Fig. 3: The same as Fig. 2 but for the range V(LSR) = (-49, -47) km/s.

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mode and linear baselines were subtracted from them.

Results and discussion: The **gray-scale** map of CO intensity integrated from -57 to -43 km/s in V(LSR) is shown in Fig. 1. The X-ray map of G109.1-1.0 (Gregory et al., 1983) is reproduced as white lines with a resolution of $\sim$ 3'. To investigate the dynamics of the molecular cloud, we also show a **gray-scale** CO map for the range V(LSR) = (-51, -49) km/s in Fig. 2, and that for the range V(LSR) = (-49, -47) km/s in Fig. 3. The present observations give much more detail of spatial structure of the molecular cloud than previous lower-resolution studies. Figs. 2 and 3 clearly show that the CO arm consists of two filaments. One of them seen in Fig. 2 is a curled filament, and the other seen in Fig. 3 is a fairly straight filament. The west part of the straight filament is also seen in the range V(LSR) = (-47, -45) km/s. These two filaments emanate from a common root at the main molecular cloud and reach a common top of the CO peak. They have a width of $\sim$ 2 pc and a length of $\sim$ 18 pc, at a distance of 4.1 kpc (Sofue et al., 1983). It is remarkable that these filaments seem to delineate the inner boundary of the X-ray jet. In Fig. 1, there are small molecular clouds just outside of the X-ray jet feature.

To evaluate the mass of the two filaments, we reuse our CO and ^{13}CO data obtained with the Nagoya 4-m radio telescope (Tatematsu et al., 1987). We use the LTE method, and adopt Dickman's (1978) conversion factor from ^{13}CO column density to H_2 column density. The mean molecular weight per H_2 molecule is taken to be 2.76 m_H. The 4-m radio telescope could not resolve the two filaments. Therefore, we simply attribute the mass in the ranges V(LSR) = (-51, -49) km/s and V(LSR) = (-49, -45) km/s to the curled and straight filaments, and obtain masses, 4×10^2 $M_\odot$ and 1.6×10^3 $M_\odot$, respectively.

The interface between the main molecular cloud and G109.1-1.0 is clearly seen in Figs. 1 and 2, but the main molecular cloud is not conspicuous in Fig. 3. In the range V(LSR) = (-53, -51) km/s, the main molecular cloud extends toward the boundary of G109.1-1.0, but there is little CO emission of the CO arm. The main molecular cloud seems to be very clumpy or spongy: it may consist of many filamentary clouds. There is no significant enhancement in the CO intensity along the interface between the main molecular cloud and G109.1-1.0, however. The semicircular shape of G109.1-1.0 is not due to absorption by the molecular cloud, but a result of the anisotropic expansion taking place near the molecular cloud (Tatematsu et al., 1987). Expansions of supernova remnants near molecular clouds were studied also on the basis of hydrodynamical calculations by Tenorio-Tagle et al. (1985). Their result for a supernova remnant which has exploded slightly outside of the molecular cloud wall is similar to the case of G109.1-1.0, although parameters adopted by them are not exactly equal to these of G109.1-1.0.

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In Fig. 2, there is an intense molecular ridge in the northern part of the main molecular cloud, and it is connected with the straight filament. The CO intensity decreases steeply just at the boundary of the remnant. This suggests that the straight filament has been partially evaporated due to the hot plasma of the remnant. The remarkable thin shape of the straight filament may be explained as a result of evaporation. The curled filament may have experienced evaporation, because the common top and root of these two filaments suggest the closeness between them. They seem to form a molecular loop surviving evaporation within the remnant. The appearance of the X-ray jet feature has been explained in terms of the presence of the CO arm as discussed in Sect. 4.2 of Tatematsu et al. (1987).

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