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CO EMISSION FROM MOLECULAR GAS AT −190 KILOMETERS PER SECOND NEAR SAGITTARIUS A

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ABSTRACT

Molecular gas at -190 km s^{-1} discovered by Güsten & Downes in 1981 is found to extend some 0°.2 (30 pc) near Sgr A* in a kinematically simple but somewhat fragmentary shell centered just to the west of the Galactic center. Most likely, the material is located on the near side of the extended, tilted, inner-galaxy molecular gas disk and associated with emission from the so-called "expanding molecular ring" at -135 km s^{-1}. Thus it is distant from and unrelated to phenomena occurring near Sgr A* itself. The mass of molecular material is estimated as $M_{H_2} = 10^5\ M_\odot$.

Subject headings: Galaxy: center — ISM: individual (Sagittarius A) — ISM: molecules

1. INTRODUCTION

The highest velocities observed in neutral gas toward Sgr A* arise in a relatively poorly studied feature at $v = -190$ km s^{-1} which was discovered in H I and H_2CO single-dish absorption spectra by Güsten & Downes (1981). Because the feature appeared in absorption, and because it appeared to straddle $l = 0°$, those authors suggested that it represented ejection from the Galactic nucleus. The parameters of this unusual flow pattern were given as follows: size greater than 10 pc (3′); column density $N_{H_2} \approx 10^{21}$–10^{22} cm^{-2}; mass $M_{H_2} \approx 10^3$–$10^4\ M_\odot$; age less than 10^6 yr. The size, age, and mass would be slightly smaller for the presently adopted value of $R_0 = 8.5$ kpc.

The -190 km s^{-1} gas has been observed sporadically and in a limited fashion up to the present time. Liszt et al. (1983) compared H I absorption (at 12″ resolution) with ^{12}CO emission (resolution 1′) over a small region around Sgr A*. Curiously, the compact source was not found to be occulted by the -190 km s^{-1} gas (also see Liszt et al. 1985b) which appeared confined to negative longitudes with respect to the center of the Galaxy in CO (see also Serabyn et al. 1986). When present in the high-resolution H I absorption spectra, the optical depth of the -190 km s^{-1} feature was some 50 times larger than found by Güsten & Downes (1981), suggesting that only a small fraction of the single-dish continuum flux from the Galactic center had been occulted in the earlier work. Because of the distributed nature of the continuum from the Galactic nucleus, failure to observe absorption against Sgr A* could be interpreted as suggesting that the -190 km s^{-1} gas is actually behind the center and infalling.

High-resolution VLA and ATNF synthesis absorption spectra of H I and OH toward Sgr A* were given by Zhao et al. (1992), who discussed a transient radio source nearby. They *detected* the -190 km s^{-1} gas toward the center in H I, in apparent contradiction to the earlier work by the present authors, and may also have seen it in OH. Most recently, fine-scale structure in HCO^+ absorption was studied by Marr et al. (1992), who noted that this species probably does not absorb Sgr A* even though present in that direction (because of beam smearing and the distributed nature of the background continuum flux). A related study of formaldehyde absorption by Pauls et al. (1993) shows similar behavior.

Here we present sensitive, finely grained (45″) maps of $j = 1$–0 CO emission from a 0°.45 × 0°.35 region ($l \times b$) about Sgr A*. These show the actual extent of the -190 km s^{-1} gas to be much greater and representative of much more mass than was suggested by any of the earlier work. At nearly constant velocity, the gas may be traced over a slightly elliptical, shell-like region some 0°.2 across. We attribute this behavior to gas on the nearside of the extended, tilted, inner galaxy gas disk which would normally be centered near -135 km s^{-1} in a broad-lined feature identified with the expanding molecular ring of Scoville (1972). Thus we believe that the main body of the -190 km s^{-1} emission is unrelated to phenomena occurring near the actual center of the Galaxy.

2. OBSERVATIONS

Our observations comprise $j = 1$–0 ^{12}CO spectra at 992 positions on a 36 × 28 position grid about Sgr A* with spacing 45″ (0°.0125) in Galactic longitude and latitude. The spectra were taken during several observing runs which occurred between 1987 July and 1992 May, using the NRAO 12 m and SEST 15 m telescopes. These telescopes have slightly dissimilar beam sizes (60″ and 45′, respectively) but produce remarkably compatible spectra. With various combinations and epochs of receivers, filters banks, and AOSs, we produced a composite data set having 256 2 MHz channels (5.20 km s^{-1}) spacings covering almost 1300 km s^{-1}) and representative rms noise of 0.07 K at each grid point. The intensity scale is that of the current 12 m telescope configuration, T_r^*. Our velocities are measured with respect to the LSR and our positions with respect to the compact source Sgr A* at $l \approx -0°.0558$, $b \approx -0°.0462$. At our adopted distance to the Galactic center of 8.5 kpc, 45″ corresponds to 1.85 pc.

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3. OBSERVATIONAL RESULTS

3.1. *Morphology*

The basic observational result of this work is shown in Figure 1 as a series of four integrated-intensity maps taken over contiguous 5 channel (26.0 km s^{-1}) intervals (centered as indicated in the upper left-hand corner of each frame between -213 and -135 km s^{-1}). The intensity coding in each panel is autoscaled to the range present there; the peak intensity increases greatly at lower $|v|$. Spectra taken at Sgr A* and at three positions of relatively high intensity in the upper right panel of Figure 1 are reproduced in Figure 2.

The main body of the -190 km s^{-1} gas appears in the two upper panels as an elongated ridge measuring $\sim 0.^\circ05$ by $0.^\circ2$. The projected length of the feature is some 30 pc. Over much of its extent it has not been resolved well in the narrow dimension but there is a notable extension in longitude well above the Galactic plane. The orientation of this upward extension of the gas is more nearly perpendicular to the long axis of the 2 pc circumnuclear disk than to the Galactic plane, but it is also suspiciously parallel to the tilt of the emission in the lower two panels which is associated with the near side of the kiloparsec scale molecular gas distribution (see Liszt & Burton 1978; Bally et al. 1988; or Burton & Liszt 1992). The gas at -135 km s^{-1} is frequently referred to as the expanding molecular ring from its low-latitude kinematic signature parallel to the Galactic plane (Scoville 1972). It clearly occurs below Sgr A*, and at higher latitudes to the West, effects which we ascribe to tilts in the gas distribution on kiloparsec scales around the Galactic center (Liszt & Burton 1978; Burton & Liszt 1992).

The spectra in the lower two panels of Figure 2, which occur at the southern and western peaks of the -187 km s^{-1} integrated-intensity map, show a feature at -180 km s^{-1} which is distinct from the expanding molecular ring. It is not the case that a bit of emission from the wing of the stronger higher velocity line has contaminated the upper right panel of Figure 1. In light of this morphology it would appear most efficient to gather all the gas in question into a single feature centered at $l \approx -0.^\circ1$ and associated with the near-side, "expanding" molecular material. Such an explanation has two clear virtues in light of the present observations. It accounts for the lack of velocity structure near Sgr A*, which would be hard to understand in terms of gas which actually passes close to the nucleus, and it removes the original center of mass velocity of the phenomenon to -135 km s^{-1}. The latter situation reduces the implied energy with respect to the nucleus by more than an order of magnitude [that is, by the square of the ratio (190–135)/190].

The -187 km s^{-1} ridge in Figure 1 is not obviously associated with corresponding structure in the radiocontinuum. This stands in sharp contrast to the detailed interrelationships present between gas at -60 km $s^{-1} < v < 60$ km s^{-1} and features in the cm-wave radiographs, as discussed by Liszt, Burton, & van der Hulst (1985a); Serabyn & Güsten (1987), and Bally et al. (1988). An examination of maps at 80 MHz (LaRosa & Kassim 1986) and 160–327 MHz (Yusef-Zadeh et

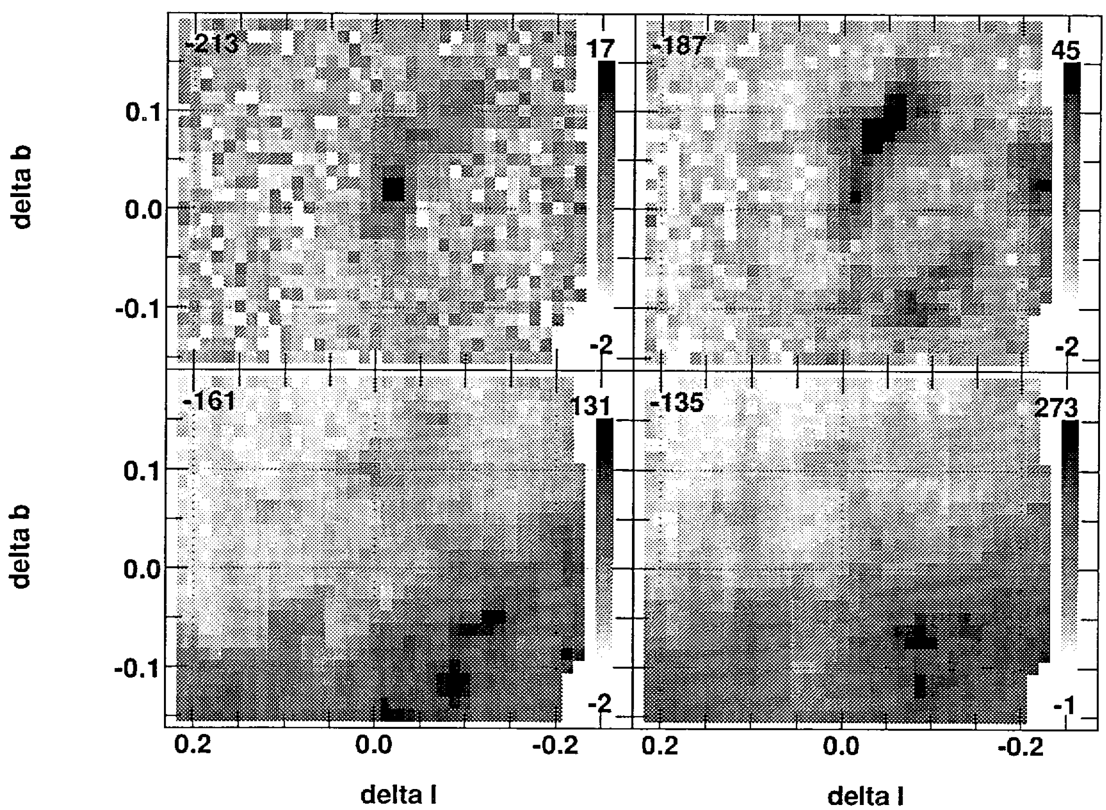

FIG. 1.—Maps of $j = 1$–0 CO intensity integrated over 26 km s^{-1} ranges centered at the velocities inset in each panel, displayed in Galactic coordinates measured with respect to the compact source Sgr A*. The gray scaling in each panel was done independently but the minimum and maximum values plotted (in units of K km s^{-1}) are shown.

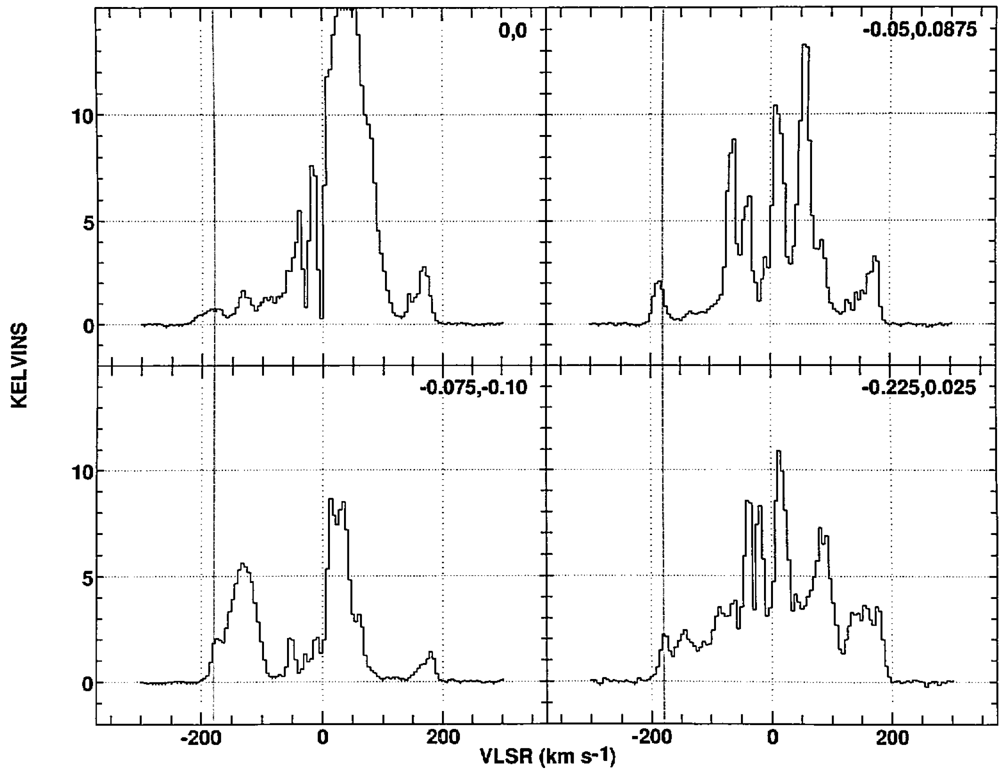

FIG. 2.—CO spectra observed at Sgr A* and at three positions having strong emission in the upper panel of Fig. 1 at -187 km s^{-1}. A vertical bar has been placed at -180 km s^{-1} in all frames. Note the presence of a feature distinct from the stronger expanding molecular ring gas at the lowest velocities in the lower two panels.

al. 1986) also reveals no associated feature. The molecular gas just above Sgr A* exhibits a rough antisymmetry with the 160 MHz jet of Yusef-Zadeh et al. (1986), which extends below the Galactic plane. Much or all of the structure in such low-frequency radio continuum maps is now believed to be an artifact of absorption by cold intervening gas (Pedlar et al. 1989).

3.2. *Physical Properties*

The peak intensity of the feature under discussion is above 2 K at the positions of highest integrated intensity; the full line width is typically 25 km s^{-1}. When a standard conversion from CO intensity to H_2 column density is applied [$N_{H_2} = 3 \times 10^{20}$ cm^{-2} (K kms^{-1})$^{-1}$ I_{CO}], one finds a peak value $N_{H_2} \approx 1.6 \times 10^{22}$ cm^{-2} and a mean value $\langle N_{H_2} \rangle \approx 6 \times 10^{21}$ cm^{-2} for material seen in the upper two panels of Figure 1. These values are consistent with earlier estimates by Güsten & Downes (1981), and do not seem unreasonable for molecular material, but they lead to fairly substantial masses and very high naive kinetic energy estimates. From the integrated intensity map, one has $M_{H_2} \approx 10^5\ M_\odot$ for all the gas which can be traced in the upper right panel, typical of a GMC in the disk of the Milky Way. Moving at $v = -190$ km s^{-1} relative to its surroundings, one finds $E = mv^2/2 = 3.6 \times 10^{52}$ ergs.

4. SUMMARY

The -190 km s^{-1} feature discovered by Güsten & Downes (1981) has been mapped in the $j = 1$–0 line of ^{12}CO and found to extend some 30 pc in a slightly elliptical partial shell having a nearly constant velocity ranging from -190 km s^{-1} to -180 km s^{-1}. Using CO-H_2 conversion factors applicable to clouds in the Galactic disk, we find $M_{H_2} \approx 10^5\ M_\odot$ for the portions of the gas which are readily visible in CO.

The emission is centered at nearly the same latitude as Sgr A* and at 0°.1 lower longitude. However, there is no evidence that the feature in question is physically associated with Sgr A* or in any way influenced by it. Because of this, and because of some striking parallels with the orientation of other negative-velocity emission from the extended inner-galaxy distribution, we place the -190 km s^{-1} feature on the near side of the nucleus in the midst of whatever structure gives rise to the -135 km s^{-1} emission commonly described as the expanding molecular ring (Scoville 1972). In this case the -190 km s^{-1} feature would be removed from the nucleus by at least 150 pc (the extent of the ring signature in the Galactic equator) and perhaps much more if one accepts our interpretation of the ring as a projection effect (Liszt & Burton 1978).

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