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A Gas Streamer Feeding the Circumnuclear Disk

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Abstract.
We present VLA maps of $NH_3(1,1)$ and $NH_3(2,2)$ emission in the inner 10 pc of the Galaxy, covering Sgr A*, the circumnuclear disk (CND), and the 20 km sec^{-1} cloud. In the central 3 pc surrounding Sgr A* we map a portion of the CND which is connected to a long, narrow 2 pc by 10 pc streamer of clumpy molecular gas located towards the south. This southern streamer appears to be carrying gas from the nearby 20 km sec^{-1} cloud to the CND. We find a velocity gradient along the streamer, with progressively higher velocities as the gas approaches Sgr A*. The gas is the northern tip of the streamer is heated and the line width increases dramatically, which may be a kinematic signature of accretion onto the CND.

1. Introduction

Immediately surrounding Sgr A West is the circumnuclear disk (CND), located 1.5 pc to 7 pc from Sgr A*. The CND is dense (10^5 cm^-3), clumpy, and turbulent with large line widths ($\geq$40 km sec^{-1}). The gas is predominately rotating around the nucleus at 110 km sec^{-1}, but non-circular motions are also present. The CND appears to be only semi-complete and possibly not in equilibrium. It may be part of an accretion process which funnels gas towards the nuclear region. The question remains as to how the disk itself is fed.

To the south of the CND lies a giant molecular cloud (GMC) named the 20 km sec^{-1} cloud (M-0.13-0.08 in Galactic coordinates). Ho et al. (1991) map in $NH_3(3,3)$ a long gas streamer which connects the 20 km sec^{-1} cloud to the location of the CND. They propose that this gas streamer feeds the circumnuclear region with gas from the 20 km sec^{-1} cloud. No velocity gradient along the streamer is detected within their spectral resolution of 10 km sec^{-1}, and no increase in line width is seen, prompting an interpretation that the gas is moving towards Sgr A* across the line of sight. Hints of this streamer are also seen in HCN (Marr et al. 1993) and submillimeter continuum emission (Dent et al. 1993). However, these studies also find no clear velocity gradient in the streamer along the line of sight.

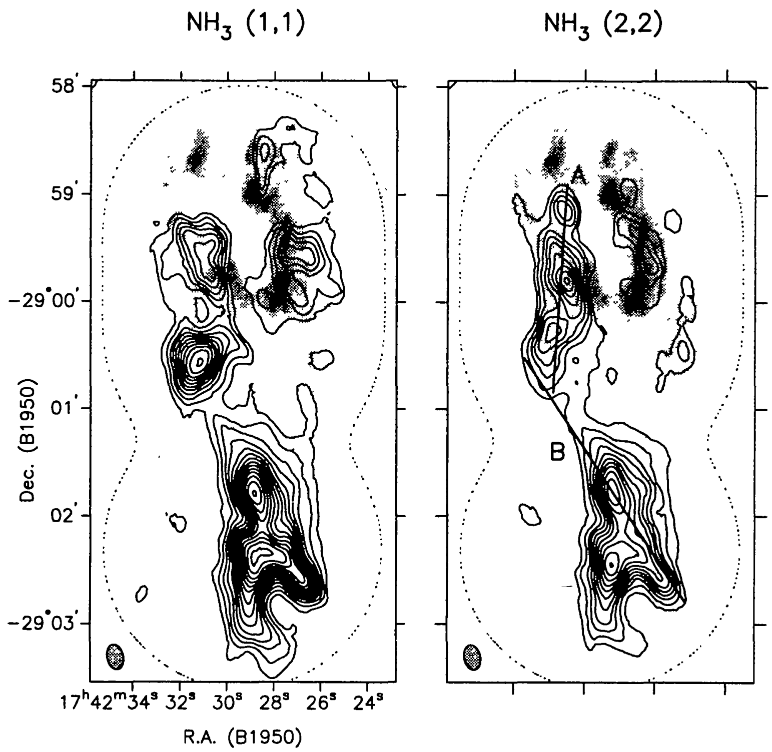

Figure 1. Velocity-integrated maps of NH_3(1,1) and (2,2) emission in the central 10 by 15 pc of the Galaxy are shown in contours over a false color image of the circumnuclear disk (CND) in HCN(1-0) emission (Marr et al. 1993). A 2 pc by 10 pc streamer connects the 20 km sec^{-1} GMC to the south with the CND to the north. NH_3 emission also traces portions of the eastern and western sides of the inner edge of the CND. The contours are at integer levels of 0.4 Jy $beam^{-1}$ km sec^{-1}, and the 9" by 14" synthesized beam is shown in the lower left corner. The straight lines labeled A and B correspond to position-velocity cuts shown in Figure 2.

In order to further probe the morphology and kinematics of this streamer, we observed NH_3(1,1) and (2,2) emission surrounding Sgr A* and the region directly south with the VLA in C/D configuration. With a 12 MHz bandwidth and a spectral resolution of 4.9 km sec^{-1}, we made three-pointing mosaics in MIRIAD with a $2'$ primary beam per pointing.

2. Results

2.1. Morphology

Figure 1 presents the velocity-integrated NH_3(1,1) and (2,2) emission in contours overlaid on a false color HCN map of the inner region of the CND. A long, narrow, 2 pc by 10 pc north-south streamer can be seen in both maps. The southern half of this streamer extends into the 20 km sec^{-1} cloud, and the streamer ends to the north at the location of the CND where little HCN emission

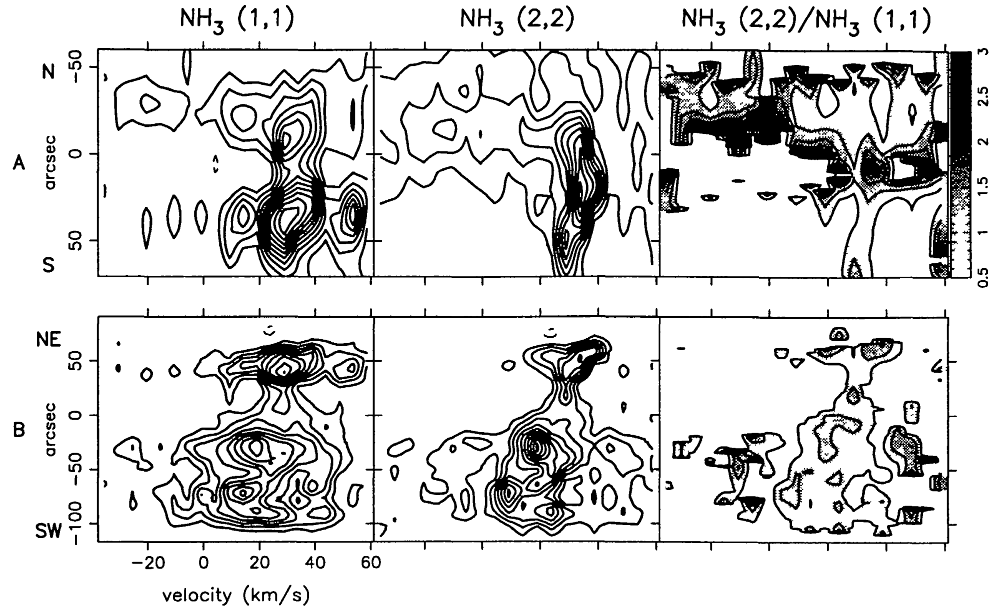

Figure 2. Position-velocity diagrams taken along A and B as shown in Figure 1 along the northern and southern lengths of the streamer. $NH_3(1,1)$ and (2,2) emission are shown, as well as the divided $NH_3(2,2)/(1,1)$ ratio which indicates heating, where the darker regions trace hotter gas. A clear redshift is seen along the southern part of the streamer, where no significant heating is apparent. A dramatic increase in line width is seen at the northern top of the streamer, where the gas is heated. This may be a result of accretion of the streamer onto the CND.

is seen. A semi-complete ring is mapped in NH_3 around the CND. The greatest morphological differences between the $NH_3(1,1)$ and (2,2) emission are around the nuclear region, where the $NH_3(1,1)$ emission traces the CND at slightly larger radii. The northern tip of the streamer extends further into the interior of the disk in the $NH_3(2,2)$ map. The northeastern quadrant of the CND is missing in the NH_3 maps due to the limited spectral window of this experiment, which does not cover the range of HCN velocities observed in the disk.

2.2. Kinematics

Position-velocity diagrams of the streamer are shown in Figure 2 for both the $NH_3(1,1)$ and (2,2) transitions, as well as the divided line ratio of the two, which gives an indication of temperature. The black regions, where the $NH_3(2,2)/(1,1)$ ratio is the highest, trace the hotter gas. The lower row of diagrams from the southern half of the streamer (cut B) show an overall redshifting of the gas of about 5 to 8 km sec^{-1} $arcmin^{-1}$, with the velocities increasing towards the nuclear region. The $NH_3(2,2)/(1,1)$ diagram indicates that there are no significant temperature effects in this region of the streamer.

In the top row of diagrams from cut A along the northern section of the streamer, the most obvious feature is the dramatic increase in line width of the gas where the streamer meets the CND as seen in the $NH_3(2,2)$ diagram.

The (2,2) line traces the intrinsic line width of the gas better than the (1,1) line, which has unresolved hyperfine structures that artificially broaden the line widths. The (2,2) diagram shows that the gas just south of the CND has narrow line widths, 10 km/s, while at the northern tip of the streamer, located inside the CND in projection, the line widths increase significantly and emission is seen across our entire sampled velocity range, from 60 km sec^{-1} to -25 km sec^{-1}. The NH_3(2,2)/(1,1) diagram of the northern part of the streamer shows that the gas at the northern tip is heated, where the blue-shifted wing of emission is seen in black.

3. Discussion

Whether this gas streamer is seen only in projection against the Galactic Center or whether it is actually approaching the central mass concentration can only be determined if we see the direct effects of the deepening gravitational potential well on the purported infalling feature. Our new data support this accretion theory with morphological, thermal, and kinematic evidences.

In Figure 1 it is of special significance that the streamer stops at the CND. This can also be seen in Figure 2 where in the top row the gas moving into the region at 30-35 km sec^{-1} with narrow line widths clearly stops in the center of the diagram, where the gas just above to the north has much larger line widths. The comparison of the different NH_3 transitions suggests that the termination of the streamer is not a temperature effect.

We find that the northern tip of the streamer, located nearest to Sgr A* in projection, is stronger in NH_3(2,2) emission than in (1,1) emission, indicating that the gas is heated (Figure 2, top row, diagram on the right). This would seem to indicate that the gas is located at the distance of the Galactic Center and is being heated by the nuclear processes.

Velocity gradients are detected along the streamer. The expected gradient at a radius of 5 pc for a central mass of 10^7 $M_\odot$ is 9 km sec^{-1} pc^{-1}, roughly 3 or 4 times more than we observe. Thus, our detected gradient suggests that if this motion is infall, the bulk of the motion is across the line of sight, with the geometry such that the streamer is more to the side of Sgr A* rather than along the line of sight.

Finally, the velocity dispersion of the observed motions indicate that the line width of the gas increases substantially at the northern tip of the streamer, where the CND is located. Other studies of the southern streamer have coarser spectral resolutions than our 5 km sec^{-1}, and this increase in line width has not been detected before. It is expected that if the gas is moving from the 20 km sec^{-1} cloud to the nuclear region, it would interact with the CND and become disrupted, resulting in an increase in the line widths of the gas, regardless of whether the motion is predominantly along or across the line of sight. The disk is known to have inherently large line widths, and our detection and measurements of a component with increased line widths concretely place the northern tip of the streamer at the location of the CND and are consistent with the gas in the southern streamer accreting onto the CND. This kinematic evidence does not reflect chemistry or abundance effects and is the strongest argument for the streamer transporting gas to the nuclear region along the southern streamer.

4. Summary

We map a streamer which appears to be feeding the nuclear region with molecular gas from the nearby 20 km sec^{-1} GMC. The streamer originates from the northeastern edge of the 20 km sec^{-1} cloud, south of Sgr A West, and ends to the north at the location of the CND, just southeast of Sgr A*. We detect a clear velocity gradient along its length of 5 to 8 km sec^{-1} $arcmin^{-1}$. The line widths of the gas increase substantially in the northern portion of the streamer, with FWHMs of $\geq$50 km sec^{-1}, possibly indicating accretion onto the CND. The gas at the location of the CND also appears to be heated, as indicated by the ratio of the NH^3(2,2)/(1,1) emission. Our morphological, kinematical, and thermal data strongly support the thesis that gas is falling in towards the circumnuclear region from the 20 km sec^{-1} cloud along the southern streamer and accreting onto the CND.

A more detailed report of the data will be published in Coil & Ho (1999). We would like to thank Mel Wright for providing the HCN maps of the CND.

References

Coil, A. L. & Ho, P. T. P. 1999, to appear in ApJ, 513.

Dent, W. R. F., Matthews, H. E., Wade, R., & Duncan, W. D. 1993, ApJ, 410, 650

Ho, P. T. P., Ho, L. C., Szczepanski, J. C., Jackson, J. M., Armstrong, J. T., & Barrett, A. H. 1991, Nature, 350, 309

Marr, J. M., Wright, M. C. H., & Backer, D. C. 1993, ApJ, 411, 667