MAPPING THE NUCLEUS OF NGC1068 IN CO(2-1)

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Molecular gas in active galactic nuclei (AGN) may play multiple roles: it can fuel a massive black hole, collimate jets, and/or obscure a broad-line region from most viewing angles. In order to understand the physical state and kinematics of molecular gas in AGN, we are using the Owens Valley Millimeter Array to map several nearby active galxies at high resolution in the CO(2–1) line. Our first target is NGC 1068, which hosts an obscured broad-line Seyfert nucleus as well as an extended starburst. We acquired data from 35 baselines out to 242 m, with $10.4\,\mathrm{km\,s^{-1}}$ resolution. After calibration with MMA (Scoville *et al.* 1992), we subtracted a 23 mJy nuclear continuum source from the visibility data and made CLEAN maps with AIPS. The resulting sensitivity in each line channel is 32 mJy per $1.8'' \times 1.5''$ robustly-weighted beam ($1'' = 70$ pc at 14.4 Mpc).

Our integrated intensity map only weakly detects the spiral arms which dominate CO(1–0) maps, due to severe primary beam attenuation. However, there is a strong detection of molecular gas in the nucleus (Figure 1a). This structure has a FWZI linewidth of $380\,\mathrm{km\,s^{-1}}$, a peak $T_\mathrm{b} = 9.4$ K, and a total $L_{\mathrm{CO}(2-1)} = 5.5 \times 10^7\,\mathrm{K\,km\,s^{-1}\,pc^2}$. Two strong lobes lie to the east and west of the continuum source but do not trace the kinematic major axis, which the line-wing channel maps reveal to have PA $\simeq 125°$. This angle is similar to both the PA = 135° HCN(1–0) kinematic major axis found by Tacconi *et al.* (1994) and the PA = 113° parsec-scale ionized gas disk found by Gallimore *et al.* (1997). Moving from the line wings to the line center, the red- and blue-shifted channel maps suggest symmetry about the "origin" (i.e. the continuum source). However, because none of the channel maps show *reflection* symmetry about the kinematic major axis, the molecular gas in the nucleus cannot be in a simple flat disk.

The kinematics may be consistent with inflow motions along a bar, as suggested by Tacconi *et al.* (1994), or with a discontinuous ring. However, they are also qualitatively consistent with a [nearly edge-on] warped disk. In this picture, the kink at systemic velocity in a position-velocity cut along

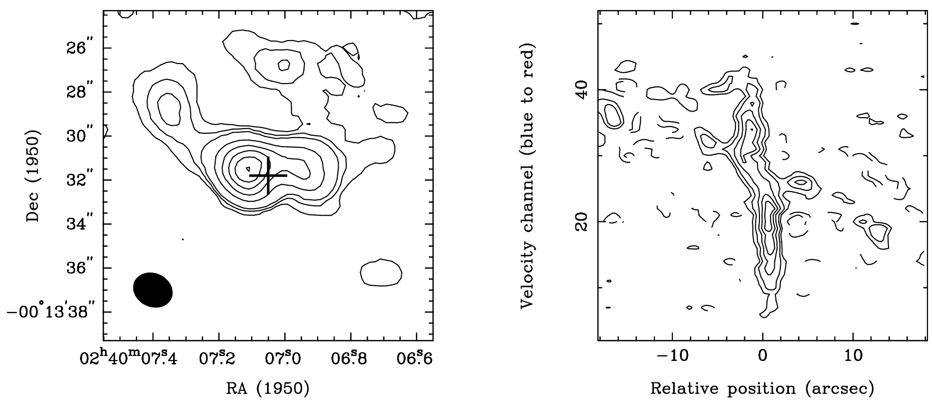

Figure 1. (a) Integrated intensity in CO(2–1). Contours are ±1, ±2, $\pm3n \times 5.5$ $\mathrm{Jy\,beam^{-1}\,km\,s^{-1}}$. Cross marks position of the continuum source. (b) Position-velocity cut through the nucleus along PA $= 125°$. Contours are ±1, $\pm2n \times 60\,\mathrm{mJy\,beam^{-1}}$.

the kinematic major axis (Figure 1b) is due to the predominance of line-wing gas in circular rotation at small radii. We can explain the difference in T_b between east and west by a slight tilt of the disk (in addition to a warp), which lets us see one disk surface that is more directly heated by the central engine than the other. The sense of this tilt would be consistent with the observed extinction of emission from the galaxy's narrow-line region (Macchetto *et al.* 1994).

We have also obtained observations of NGC 1068 in the CO(1–0) line. At the $3.6'' \times 3.5''$ resolution of our CO(1–0) map, we find a nuclear CO(2–1)/(1–0) ratio [in K] of $\sim$ 1.9, indicating that the gas we see has high excitation temperature and low optical depth. We also infer (for a Galactic conversion factor) at most a total nuclear $M_{\mathrm{H_2}} = 8.3 \times 10^7\,\mathrm{M_\odot}$. This is lower than the dynamical mass within 90 pc of the nucleus, $M_\mathrm{dyn} = 6.5 \times 10^8\,\mathrm{M_\odot}$, which we estimate from the CO(2–1) line wings assuming they come from an inner, relatively flat part of the nuclear structure.

References

Gallimore, J.F., Baum, S.A., and O'Dea, C.P. 1997, Nature, in press

Macchetto, F., Capetti, A., Sparks, W.B., Axon, D.J., and Boksenberg, A. 1994, ApJL, 435, L15

Scoville, N.Z., Carlstrom, J.E., Chandler, C.J., Phillips, J.A., Scott, S.L., Tilanus, R.P., and Wang, Z. 1992, PASP, 105, 1482

Tacconi, L.J., Genzel, R., Blietz, M., Cameron, M., Harris, A.I., and Madden, S. 1994, ApJL, 426, L27