A CO SURVEY OF THE HALO OF NGC891

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ABSTRACT. We report ^{12}CO J=2–1 line observations of the edge-on galaxy NGC 891, made with the IRAM 30 m telescope. These observations show that the molecular gas probably extends to large distances from the galactic plane.

The distribution of the molecular gas perpendicularly to the plane of spiral galaxies is poorly known. Distance uncertainties plague most Milky Way studies (see however Grabelsky et al. 1987), whereas small angular sizes and low intensities limit those of extragalactic systems.

We have used the IRAM 30 m telescope to study the z-distribution of CO in the edge-on galaxy NGC 891. At 230 GHz, the IRAM 30 m telescope allies a high angular resolution with a high sensitivity to extended sources. We selected NGC 891, because it looks similar to the Milky Way, it is seen perfectly edge-on (incl$\geq$ 89°) and it is not too distant from us (between 8 and 14 Mpc, e.g. Sancisi and Allen 1979, Rand et al. 1990). This galaxy is known to give rise to strong CO emission (Solomon 1983, Sofue et al. 1987) and to possess an ionized halo, visible in radio continuum (Allen et al. 1978) and Hα emission (Rand et al. 1990, Dettmar et al. 1990). The halo of NGC 891 has not been detected in HI (Sancisi and Allen, 1979) and, so far, there was no indication of any out-of-the-plane extension of the neutral gas. Optically, NGC 891 appears as a bright, elongated ellipse, 10' long, 1' wide, divided along its major axis by a narrow dust lane, and oriented almost north-south (P.A.= 23°).

Twenty cuts, perpendicular to the galactic plane (i.e. in the $\mathbf{z}$ direction), were observed. They consisted of strip maps of typically 8–10 points spaced by 6" in $\mathbf{z}$. Six of these cuts were made at intervals of 6" along the major axis ($\mathbf{x}$ direction), providing a fully sampled map of the central bulge. The other cuts, made every 60" or 30" in $\mathbf{x}$, were aimed at observing further out the z-extent of the gas. The cuts at x=±108" and ±102" from the centre, were slightly shifted from the regular grid, in order to cover a conspicuous dust spur, or "chimney", raising at right angle from the major axis.

Each cut was observed 3–6 times. The individual strip maps were followed by a pointing/focussing session on the nearby radio-galaxy 3C 84, one of the brightest continuum sources of the sky at 230 GHz, then repeated. In this way, integration times of 8–15 min

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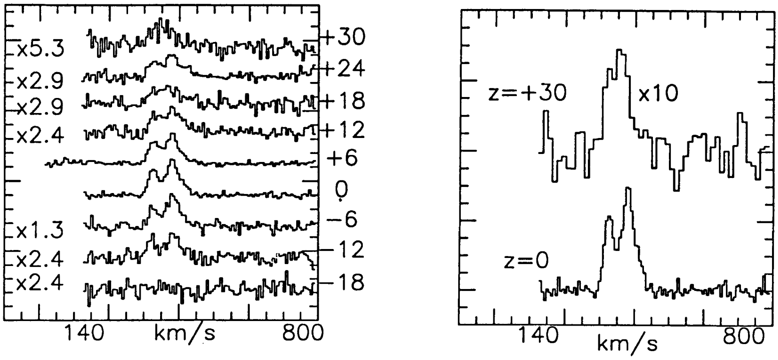

Figure 1.a: Cut perpendicular to the plane of NGC 891, made at +108" to the north of the centre. The **z** offsets, in arc sec., are relative to the mid-molecular disk. The intensities of the spectra have been multiplied by the factors indicated on the left and are not at the same scale. The velocity resolution is 6.5 kms^{-1}.**b:** The upper (z=+30") spectrum of Fig. 1a, smoothed to a resolution of 13 kms^{-1}, compared to the spectrum at z=0.

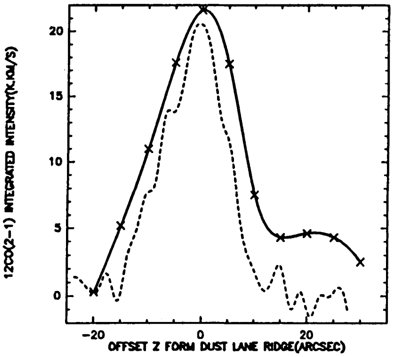

Figure 2. / *full line:* The velocity-integrated intensity distribution perpendicular to the plane of NGC 891 (offsets in **z**, in arc second, are relative to the mid molecular disk ; they are positive to the southeast, negative to the northwest) / *dashed line:* The intensity distribution across 3C 84 in the same direction (see text).

on-source per point could be achieved, while keeping a good pointing; moreover the shape of the telescope beam could be monitored almost in real time. This proved to be important as the observations were carried out during day time: although the weather was clear and dry and the source elevation high (40° most of the time) the beam pattern was found dirtier than observed routinely during the night.

The cuts at x= +108" and −108" were observed respectively when the source, still high in the sky, was setting down and rising up. Fig. 2 show the CO integrated intensities, observed along the direction perpendicular to the galactic disk, compared to the average of 18 cuts across 3C 84, made in the same direction (elevation) after the individual strips. The beam in this direction shows an asymmetric coma-like extension, or "tail", possibly due to a distortion of the dish caused by sunshine; it is somewhat broadened (FWHP=14") by atmospheric turbulence (Altenhoff et al. 1987) and/or by changes in focal length caused by thermal gradients. In the orthogonal direction (azimuth), the beam is symmetrical and cleaner (FWHP= 13"). The broadening of the telescope beam, observed on 3C 84, has been taken into account in the data analysis. In the case of the cuts of Fig. 2, the elevation "tail", located below the main beam, tends to enhance the signals to the east of the galactic disk. It could explain the broadening of the CO disk observed at negative **z**s, but not the extended emission observed to the west at positive **z**s.

The relatively high integrated intensity observed at z= 30" argue against an error-beam contamination. The 30 m telescope error-beam response to an uniformly bright, 6" thick, CO ridge (such as that suggested by our in-plane observations and the recent interferometric measurements of Handa et al. 1990), should be much wider in frequency and a factor of 5 weaker than observed on Fig. 2. Hence, although additional (e.g. nightime) observations would be needed to determine the exact distribution of CO in the **z** direction, we can probably conclude that CO extends far outside the bright CO ridge.

The results of the other cuts supports the picture emerging from the discussion above. A bright and narrow ridge of CO emission (6–7" wide, after beam deconvolution), follows closely the dust lane which marks the near edge of NGC 891's disk. It is relayed to the west by a weak CO extension, or "plateau".

The coincidence of the CO ridge with the dust lane is remarkable and supports the image of a thin gaseous disk, seen almost perfectly edge-on. Both CO and the dust exhibit a slight warp, "raising" westwards, 3' to the south of the centre, and "falling back" further out (i.e. at x$\simeq -4'$). At places, the ridge emission shows a complex velocity structure (double or triple-peaked spectra), partly arising from molecular arms or rings.

Table 1. Out of the plane gas detections

Strip positions along major axis(arcsec)	Out of the plane detections (arcsec)	Indicative distance from the plane(kpc)
+102"	+24"	0.8 kpc
-102"	+27"	1 kpc
+108"	+30"	1.2 kpc
-108"	≥24"	≥0.8 kpc
+150"	+27"	1 kpc
-150"	+24"	0.8 kpc
+210"	+18"	0.5 kpc
-210"	+12"	-
centre	+27"	1 kpc

Table 1. limits in **z** of the "plateau" component (detections at $> 5\sigma$ in the CO J=2–1 line)

The data relative to the extended CO "plateau" is summarized in Table 1, which gives the limits in the z-direction of the detections at $> 5\sigma$. CO is detected at z$\geq +24''$ (to the west of the galactic plane) on all inner ($|x| \leq 150''$) high sensitivity cuts. On several cuts, CO is observed $30''$ "above" the mid-ridge. In the case of Fig. 2, this corresponds, after beam deconvolution, to a projected distance in the plane of the sky of $\geq$ 1 kpc. Taking into account the shape of the telescope beam, CO is marginally or not at all detected at negative zs.

The question raises whether the CO "plateau" component comes from a halo, or from the edges of the molecular disk, which could be warped, flaring, or simply less inclined than indicated by the optical image. As can be seen on Fig. 1b, the profile at (108,30) has a mean velocity (first moment) slightly lower than that of the (108,0) disk profile (350 vs 370 $\mathrm{kms^{-1}}$). It should have had a larger velocity (i.e. much closer to the systemic velocity of 510 $\mathrm{kms^{-1}}$) if it were arising near the edges of the molecular disk. In fact, assuming axial symmetry and using the rotation curve and the CO distribution observed along the major axis, we calculate that the gas at the edges of the disk has a velocity of 470 $\mathrm{kms^{-1}}$. The plateau component appears thus to follow the motion of the gas on the major axis and should lie some 1 kpc above the molecular disk.

The average integrated intensity in the (2–1) line, at z= +30", is 3 $\mathrm{K.kms^{-1}}$, a factor 7–8 times lower than the intensity at z= 0. The corresponding ratio of the H_2 column densities could be somewhat larger, judging from the low value of the CO to H_2 conversion factors derived for the galactic high latitude clouds.

Besides the z-distribution of CO, our observations allow to study the kinematics and in-plane distribution of the molecular gas, as well as, from (2–1)/(1–0) and $^{12}CO/^{13}CO$ line intensity ratios, the gas excitation at selected positions (Garcia-Burillo et al. in preparation). The $^{12}CO/^{13}CO$ ratio is found to vary within the line profile, a behaviour which can be explained by a higher value of this ratio in the interarm regions. A similar effect is observed in M51 (Garcia-Burillo,S. and Guélin,M. 1990).

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REFERENCES:

Allen, R.J., Baldwin, J.E. and Sancisi, R. (1978) *AaA* **62**, 397

Altenhoff,Baars,Downes,Wink (1987) *AaA* **184**, 381

Dettmar R.-J. (1990) *AaA* **232** ,L15-L18

Garcia-Burillo,S.,Dahlem,M.,Guélin,M. and Cernicharo,J. (1990) *in prep*

Garcia-Burillo,S. and Guélin,M. (1990) *proceedings IAU symposium No. 146*

Grabelsky, D.A., Cohen, R.S., Bronfman, L., Thaddeus, P. and May, J. (1987) *Ap.J.* **315** ,122.

Handa,T.,Kawabe,R.,Ishizuki,S.,Ikeuchi,S. and Sofue,Y. (1990) *poster proceedings IAU symposium N 144*

Rand,R.J. and Kulkarni S.R. (1990) *Ap.J.* **352** ,L1-L4

Sancisi,R. and Allen,R.J. (1979) *AaA* **74** ,73-84

Sofue,Y.,Nakai,N., and Handa,T. (1987) *Pub. Astr. Soc. Japan* **39**, 47

Solomon,P.M. (1983) *proceedings IAU Symp No. 100* , p.35