Astron. Astrophys. 211, 315–317 (1989)

ASTRONOMY AND ASTROPHYSICS

Research Note

High spectral-resolution CO observations of NGC 6814 and NGC 7793 ⋆

J. Brand [1], **J.G.A. Wouterloot** [1], **R. Becker** [2], **and G.M. Stirpe** [3]

[1] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-5300 Bonn 1, Federal Republic of Germany
[2] Landessternwarte, Königstuhl, D-6900 Heidelberg, Federal Republic of Germany
[3] Sterrewacht, Postbus 9513, NL-2300 RA Leiden, The Netherlands

Received May 20, accepted September 20, 1988

Summary. We have searched for ^{12}CO ($J=1-0$) emission in six galaxies with the 15-m SEST (ESO, La Silla), and detected two of these (NGC 6814 and NGC 7793) at high (0.11 km s^{-1}) resolution. NGC 6814 shows a symmetric, double-peaked spectrum, in which the signature of at least one large CO complex can be distinguished. The spectrum of NGC 7793 is asymmetric, with a stronger blue-shifted side; this is a consequence of the asymmetric distribution of H II regions in the central region of this galaxy. The non-detections are probably mostly due to the limited velocity coverage.

Key words: galaxies: ^{12}CO ($J=1-0$) emission

1. Introduction

CO observations of external galaxies are generally made with a resolution of 1 MHz or more. The Seyfert 1 galaxy NGC 6814 was detected in CO by Blitz et al. (1986), using the 12-m telescope of the National Radioastronomy Observatory (NRAO) and the 7-m Bell Labs. antenna. The published spectra were smoothed to a resolution of 10.4 km s^{-1}. The width of the CO emission is about 70 km s^{-1}. The SA(s)d galaxy NGC 7793 was marginally detected in CO by Elmegreen et al. (1980), with the 11-m Kitt Peak telescope, and a resolution of 2.6 km s^{-1}.

In order to confirm the detections and to look for structure in the CO emission we have re-observed these galaxies with a resolution of 0.11 km s^{-1} (44 kHz). In addition we have observed four other galaxies; three of them are Seyferts, that had not been observed in CO before.

2. ^{12}CO ($J=1-0$) observations and results

In Sept./Oct. 1987 we used the 15-m Swedish ESO Submillimeter Telescope (SEST) at La Silla in combination with a He-cooled Schottky diode receiver (system temperature including sky 700–1000 K). At 115 GHz the beamsize is 43″, and the main-beam efficiency is 70%. The observations were done in the dual-beam-switch mode with a throw of 11′40″ in azimuth and a frequency of about 5 Hz. The chopper throw is much larger than the optical radius of the galaxies observed, except for NGC 300, where the reference beam is within the outermost optical isophote ($\mu_B = 25.0$ mag arcsec^{-2}; Carignan, 1985), and for NGC 7793, where it could be just at the optical edge, depending on the parallactic angle; however, this will not affect our results if all the CO is contained well within the optical contours, as in our own Galaxy. The baselines were in general straight, and only a few scans with curved baselines were rejected. The pointing was checked a few times per night on SiO masers, and was found to be accurate to within 10″. The backend was a 2048 channel AOS with a resolution of 44 kHz (0.11 km s^{-1}), giving a total velocity coverage of 220 km s^{-1}. Calibration was done with an ambient temperature load and the resulting T_A^*'s have a relative accuracy of about 10%.

Observational parameters of the galaxies are listed in Table 1. Columns 1 to 3 give the source name and the position observed (always the galaxy center). Column 4 to 6 list the galaxy type, the distance and the linear beam size. Distances are averages of mostly kinematic distances obtained by different authors (quoted from Huchtmeier et al., 1983), and have been scaled to a Hubble constant $H_0 = 50$ km s^{-1} Mpc^{-1}, except for NGC 300 where the Cepheid-based distance is adopted (Deharveng et al., 1988), and for NGC 7793, where we use the non-kinematic distance of Carignan (1985). We smoothed our spectra over 5 adjacent channels to an effective resolution of 0.57 m s^{-1}. Columns 7–9 give the heliocentric velocity of the central channel, the total integration time and the rms noise in the spectra.

Spectra of the emission detected in NGC 6814 and NGC 7793, after removal of a first order baseline, are displayed in Figs. 1 and 2. No detection was made in the other four galaxies, within 110 km s^{-1} of the velocity quoted in Table 1.

In Table 2 we list parameters, derived from the profiles. In columns 2 and 3 we give the peak T_A^* and $\int T_A^* dV$ and their uncertainties. Columns 4–8 list the velocity of peak emission, the range of CO emission (V_L to V_H), the mean (unweighted) velocity, and the width of the emission between zero intensity points, respectively. In column 9 is the CO luminosity.

Send offprint requests to: J. Brand

⋆ Based on observations collected at the European Southern Observatory, La Silla, Chile

Table 1. Observational parameters of the observed galaxies

Name (1)	RA (1950) (2)	Dec (3)	Type (4)	D (Mpc) (5)	Beam (pc) (6)	V_{hel} (km s^{-1}) (7)	t_{int} (h) (8)	rms (K) (9)
NGC 300	$00^h52^m31^s.2$	−37°57′24″	SA(s)d	1.53	320	159	1.9	0.016
Fairall 9	01 21 51.2	−59 03 59	S Sey1	270	56300	13512	0.6	0.021
NGC 6814	19 39 55.7	−10 26 34	Sbc Sey1	34.1	7090	1556	3.3	0.017
NGC 7213	22 06 12.0	−47 25 00	Sa Sey1	35	7300	1802	1.9	0.020
NGC 7496	23 06 59.3	−43 41 57	Sab Sey2	33	6880	1504	1.9	0.022
NGC 7793	23 55 15.5	−32 52 03	SA(s)dm	3.38	705	225	7.5	0.009

Table 2. Derived parameters

Name (1)	T_A^* (K) (2)	$\int T_A^* dV$ (K km s^{-1}) (3)	V_P (4)	V_L (km s^{-1}) (5)	V_H (hel) (6)	V_{AV} (7)	$\Delta V(0\%)$ (km s^{-1}) (8)	L_{CO} (K km s^{-1} kpc^2) (9)
NGC 6814	0.095	5.80	1528	1499	1606	1553	107	223.2
	(0.005)	(0.50)						
NGC 7793	0.062	2.01	212	185	265	225	80	0.77
	(0.002)	(0.20)						

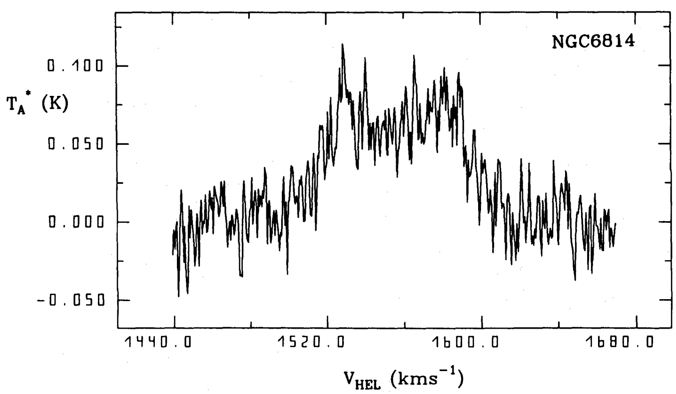

Fig. 1. CO ($J=1-0$) spectrum of NGC 6814, smoothed to a velocity resolution of 0.57 km s^{-1}. A first order baseline has been removed

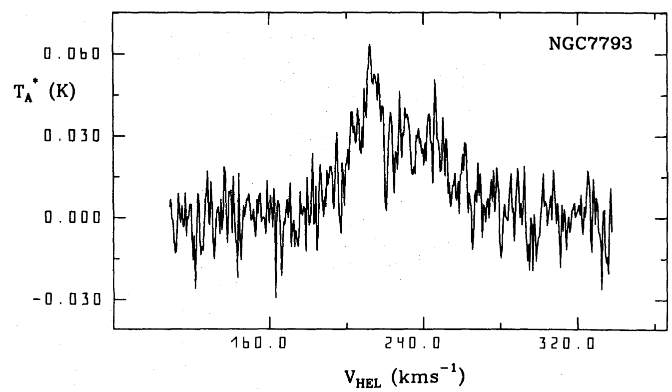

Fig. 2. As Fig. 1 but for NGC 7793

3. Discussion

3.1. NGC 6814

NGC 6814 is a Seyfert 1 galaxy of optical size 32 kpc, somewhat smaller than our own Galaxy (40 kpc). The spectrum of NGC 6814 is double-peaked and symmetric. The average heliocentric CO velocity of 1553 km s^{-1} is close to the observed center-of-weight velocity of the H I line (1565 km s^{-1}) obtained by Shostak (1978). Our CO line width is equal within the uncertainties to the H I line width (94 km s^{-1}, Shostak, 1978; 145 km s^{-1}, Heckman et al., 1978). The total half-power width of 69 km s^{-1} quoted by Blitz et al. (1986) differs less than one resolution element from that derived from our spectrum, if it is smoothed to their resolution of 10.4 km s^{-1} (77 km s^{-1}).

The double-peaked structure is also present in the line profiles observed with a 1.′1 beam and a 1.′7 beam by Blitz et al. (1986). The peak at $V_{hel} = 1529$ km s^{-1}, which is not resolved in the data by Blitz et al. (1986), could be the signature of a single large molecular complex; its half-power width is 8.0 ± 1.0 km s^{-1} (Fig. 1). Using the radius-line width relation for (galactic) molecular clouds $\Delta V = 1.20\, R^{0.50}$ (Dame et al., 1986), we derive a radius of about 44 ± 12 pc for this complex. This implies a virial mass $M_{vir} = 209.62\,(R/\text{pc})\,(\Delta V/\text{km s}^{-1})^2$ of $5.9 \pm 3.0\ 10^5\,M_\odot$ (for a uniform, spherical cloud). Such parameters are typical for a galactic GMC (Myers, 1987). There are hints of other narrow (a few km s^{-1}) features in our high-resolution spectrum of this galaxy (e.g. at $V_{hel} = 1540.1$, 1565.5, 1581.0, and 1589.1 km s^{-1}), but the signal-to-noise ratio is not large enough to decide whether they are significant. A way to test this single-complex interpretation would be to observe this galaxy at a higher spatial resolution, causing the complex to stand out more clearly with respect to the background. The CO luminosity L_{CO} of a region 3.5 kpc in radius (half the size of our beam at the distance of NGC 6814) around the center of our Galaxy, is 93 K km s^{-1} kpc^2 (derived from Sanders et al., 1984, scaling to $R_0 = 8.5$ kpc). Note that this number is somewhat low because the 3.5 kpc radius is just inside the galactic molecular ring. The CO luminosity of NGC 6814 (223 K km s^{-1} kpc^2) measured by us is close to the value determined by Blitz et al. (1986) (242 K km s^{-1} kpc^2, scaled to our distance of 34.1 Mpc). Because they observed with a larger beam (66″; 11 kpc), this indicates that their beam is partly empty, so that the CO in NGC 6814 is contained within 5.5 kpc from its center.

3.2. *NGC 7793*

The first hint of ^{12}CO emission from the nuclear region of NGC 7793 has been reported by Elmegreen et al. (1980) (beam size 65″ = 1065 pc). We have re-observed this galaxy with our beam centered at the nucleus and obtained a spectrum with a much higher signal-to-noise ratio. Our observation does not confirm the suggestion by Elmegreen et al. (1980) that the line profile exhibits a symmetric double structure and therefore contradicts their idea of a simple ring-shaped CO distribution. The shape of the line profile is asymmetric in the sense that the CO emission coming from the blue-shifted central 350 pc of the galaxy (east; Becker et al., 1988) is stronger than that from the red-shifted part (west). The observed position is only (5″ E, 7″ N) displaced from the isophotal position of the nucleus obtained by Carignan (1985); this difference is too small to explain this asymmetry. In addition, because the galaxy was observed on eight different nights, random pointing errors should average out. Consequently, an asymmetry of the CO distribution in the central region of NGC 7793 is implied. Projecting our beam onto Fig. 4 of Davoust and de Vaucouleurs (1980), which shows the distribution of H II regions in NGC 7793, we see that H II regions are found almost exclusively in the eastern part of our beam. Equating H II regions with H II region/molecular cloud complexes, this could explain the observed asymmetric CO line profile. We can interpret the asymmetry as being due to a single molecular complex (cf. the peak in NGC 6814). The half-power width is 7.5 ± 1.0 km s^{-1}, from which we derive a cloud radius R of 39 ± 11 pc, and $M_{vir} = 4.6 \pm 2.5\ 10^5\ M_\odot$, comparable to the GMC in NGC 6814.

It is interesting to note that in our spectrum there appears to be a sharp minimum ($\Delta V \simeq 2$ km s^{-1}) at a velocity $V_{hel} = 220.5$ km s^{-1}, close to that of the dip at $V_{lsr} =$ 210–217 km s^{-1} (i.e. $V_{hel} = 215$–222 km s^{-1}), reported by Elmegreen et al. (1980). Because their spectrum is very noisy this coincidence may be accidental. More observations are needed to check the reality of this minimum.

The average heliocentric CO velocity of this galaxy of 225 km s^{-1} corresponds well with the H I systemic velocity of 227 km s^{-1} found by Reif et al. (1982) and Whiteoak and Gardner (1977) and the velocity of 221 km s^{-1} derived by Davoust and de Vaucouleurs (1980) from Hα Fabry-Perot interferometric measurements. NGC 7793 has a low mass (about $1.0\ 10^{10}\ M_\odot$; Davoust and de Vaucouleurs (1980), scaled to $D = 3.38$ Mpc), comparable to that of giant irregular galaxies, which have all very weak CO emission. The H I mass of NGC 7793 (at 3.38 Mpc) is $6.7\ 10^8\ M_\odot$ (Becker et al., 1988), which means that the relative H I content is lower than for irregular galaxies. The metallicity in the central part of NGC 7793 is higher than for irregulars (Pagel and Edmunds, 1981) and only slightly lower than for the nuclear regions of other spiral galaxies, yet the CO luminosity of NGC 7793 is only $L_{CO} = 0.77$ K km s^{-1} kpc^2. Our own Galaxy has $L_{CO} = 20$ K km s^{-1} kpc^2 within 350 pc from the center (from Sanders et al., 1984, scaled to $R_0 = 8.5$ kpc), which is much larger than the value for NGC 7793 within the same area. The centers of other spiral galaxies also have significantly higher CO luminosities (Young and Scoville, 1982; Verter, 1985). The exceptions to this are M33 (Young and Scoville, 1982) and M31 (not detected; Stark, 1979). Therefore NGC 7793, like M31 and M33, does not have a central molecular peak.

Acknowledgements. We like to thank ESO for giving us the opportunity to use the SEST during its test period. We are grateful to the SEST staff at La Silla for providing a telescope in very good working condition, and for their help during the observations.

References

Becker, R., Mebold, U., Reif, K., van Woerden, H.: 1988, *Astron. Astrophys.* **203**, 21

Blitz, L., Mathieu, R.D., Bally, J.: 1986, *Astrophys. J.* **311**, 142

Carignan, C.: 1985, *Astrophys. J. Suppl.* **58**, 107

Dame, T.M., Elmegreen, B.G., Cohen, R.S., Thaddeus, P.: 1986, *Astrophys. J.* **305**, 892

Davoust, E., de Vaucouleurs, G.: 1980, *Astrophys. J.* **242**, 30

Deharveng, L., Caplan, J., Lequeux, J., Azzopardi, M., Breysacher, J., Tarenghi, M., Westerlund, B.: 1988, *Astron. Astrophys. Suppl.* **73**, 407

de Vaucouleurs, G., de Vaucouleurs, A., Corwin, H.G., Jr.: 1976, *Second Reference Catalogue of Bright Galaxies*, Univ. of Texas Press (2 RCBG)

Elmegreen, B.G., Elmegreen, D.M., Morris, M.: 1980, *Astrophys. J.* **240**, 455

Heckman, T.M., Balick, B., Sullivan III, W.T.: 1978, *Astrophys. J.* **224**, 745

Huchtmeier, W.K., Richter, O.-G., Bohnenstengel, H.-D., Hauschildt, M.: 1983, ESO preprint No. 250

Meyers, P.C.: 1987, in *Interstellar Processes*, eds. D.J. Hollenbach, H.A. Thronson, Jr., Reidel, Dordrecht, p. 71

Pagel, B.E.J., Edmunds, M.G.: 1981, *Ann. Rev. Astron. Astrophys.* **19**, 77

Reif, K., Mebold, U., Goss, W.M., van Woerden, H., Siegman, B.: 1982, *Astron. Astrophys. Suppl.* **50**, 451

Sanders, D.B., Solomon, P.M., Scoville, N.Z.: 1984, *Astrophys. J.* **276**, 182

Shostak, G.S.: 1978, *Astron. Astrophys.* **68**, 321

Stark, A.A.: 1979, Ph. D. Thesis, Princeton University

Verter, F.: 1985, *Astrophys. J. Suppl.* **57**, 261

Whiteoak, J.B., Gardner, F.F.: 1977, *Australian J. Phys.* **30**, 187

Young, J.S., Scoville, N.Z.: 1982, *Astrophys. J.* **260**, L11