MOLECULAR CLOUDS IN SPIRAL GALAXIES

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ABSTRACT

A large observational program investigating the 2.6 mm CO line in spiral galaxies is being conducted by myself and Nick Scoville using the 14 m telescope of the Five College Radio Astronomy Observatory (HPBW = 50"). Thus far we have observed 46 galaxies of types Sa, Sb, Sc and Irr, detected 31, and mapped 16. Our major findings are:

(1) In several late type spiral galaxies (IC 342, NGC 6946 and M51) the radial distribution of molecular gas out to 10 kpc follows the exponential blue luminosity profile of the disk within each galaxy (Young and Scoville 1982a, Scoville and Young 1983).

(2) From a comparison of the CO and B luminosities of the central 5 kpc in a sample of Sc galaxies, we find that the blue luminosity is proportional to the first power of the CO content (Young and Scoville 1982b). We interpret this to mean that the star formation rate per H_2 in Sc galaxies (indicated by the B luminosity) is constant.

(3) No molecular rings like the one in the Milky Way at radii 4 to 8 kpc were seen in the Sc galaxies.

(4) We have found molecular rings in two Sb galaxies, NGC 7331 and NGC 2841, with peaks at radii of 4-5 kpc (Young and Scoville 1982c). The central holes in the CO distributions are possibly related to the presence of large nuclear bulges in these galaxies.

1. INTRODUCTION

In order to investigate the relationship of the dense molecular clouds to star forming activity in other galaxies, we have been observing the 2.6 mm CO line using the 14 m telescope of the Five College Radio Astronomy Observatory (HPBW = 50"). The aims of these observations are to determine (1) the radial distributions of molecular gas in spiral galaxies, (2) the dependence of the CO distributions on morphological type and galaxy luminosity, (3) the relative amounts of star-forming material in the nuclei of normal and active galaxies, and (4) the relative confinement of molecular clouds to spiral arms.

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2. SC RADIAL DISTRIBUTIONS

In IC 342, NGC 6946 and M51 (types Sc and Scd) we have mapped the CO radial distributions out to 10 kpc at 1-2 kpc resolution (Young and Scoville 1982a, Paper I; Scoville and Young 1982, Paper II). In each of these galaxies we have compared the CO distributions with the optical light profiles and find that the radial distribution of molecular gas out to 10 kpc follows the exponential blue luminosity profile of the disk within each galaxy, as shown in Figure 1 for NGC 6946. Although the B luminosity may not itself be primarily from the youngest stars, it is an indicator of the recent star formation rate for several reasons. First, the B-V colors are relatively constant within these Sc galaxies. Second, as we have shown for M51 (Paper II), in galaxies for which Hα light distribution has been measured the Hα and B luminosity profiles have similiar exponential scale lengths. Assuming the abundance of molecular gas is proportional to the CO emission, the close correspondence between the CO emission and blue light indicates that the star formation rate per H_2 is constant within a particular galaxy.

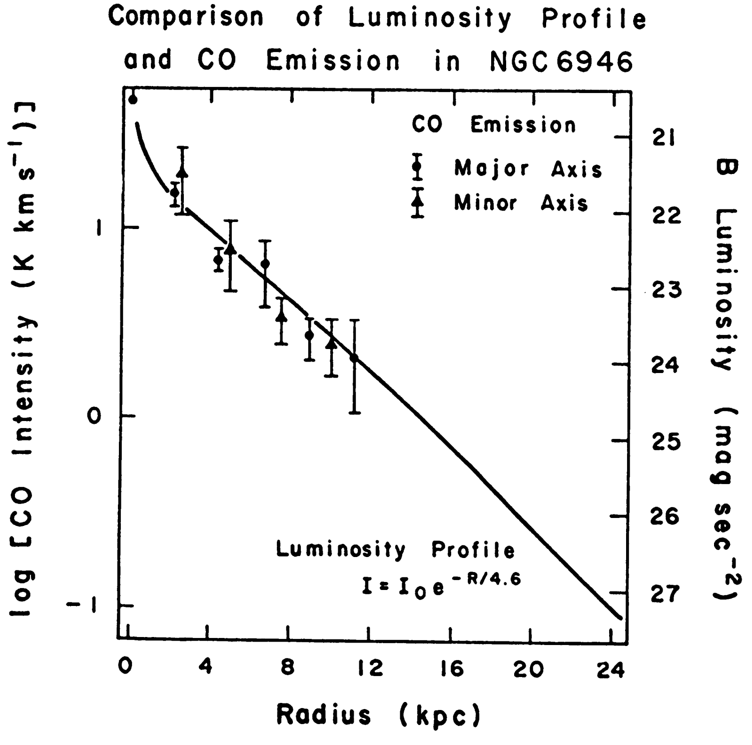

Figure 1. Comparison of CO emission with the exponential B luminosity profile of Ables (1971) for NGC 6946. Points plotted are the mean CO intensities at each radius, with bars indicating the spread in observed intensities.

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We have derived an empirical relationship for determining H_2 column densities (N_{H_2}) from CO intensities (I_{CO}) based on visual extinction and CO observations in our own galaxy. In the Appendix of Paper I we showed that both dark cloud and giant cloud samples are consistent with $N_{H_2}/I_{CO} = 4 \pm 2 \times 10^{20}\ H_2\ cm^{-2}/(K\ km\ s^{-1})$. Using this conversion in the external galaxies we find that H_2 dominates HI by as much as a factor of 100 in the interiors of the high luminosity Sc galaxies. The H_2 and HI distributions diverge at the centers of these galaxies; the H_2 exhibits an exponential increase while the HI profiles are flat with central holes. In the Sc galaxies the H_2 masses within ~ 10 kpc are comparable to those of HI interior to 25 kpc. Global spiral structure is not evident in the molecular data at the present resolution.

3. COMPARISON OF SC GALAXIES

The correlation of CO intensity with blue luminosity within a particular Sc galaxy led us to investigate a larger sample of Sc'c covering a wide range of size, mass, and total luminosity. We have compared the CO and blue luminosities of the central 5 kpc for each of nine galaxies and an approximately linear correlation is revealed as shown in Figure 2. Assuming the CO emission is proportional to the abundance of molecular gas, this correlation implies that low luminosity regions have little H_2 while high luminosity regions have large amounts. If the B luminosity is an indicator of the recent star formation rate, these results suggest that the star formation rate per H_2 in Sc galaxies is constant.

Within this sample the molecular masses out to a fixed radius, $R < 2.5$ kpc, range from $< 6 \times 10^7\ M_\odot$ for M33 to $\sim 2 \times 10^9\ M_\odot$ for NGC 6946. However, the H_2 mass to blue luminosity ratio is relatively constant, with $M_{H_2}/L_B = 0.17 \pm 0.08\ M_\odot/L_\odot$ over two orders of magnitude in L_B. In contrast, these galaxies all have similar amounts of HI in the central $R < 2.5$ kpc, so that H_2/HI ratio varies from < 0.4 in M33 to ~ 32 in M51. However, the total ISM mass (H_2 + HI) to B luminosity ratio is also relatively constant in these galaxies.

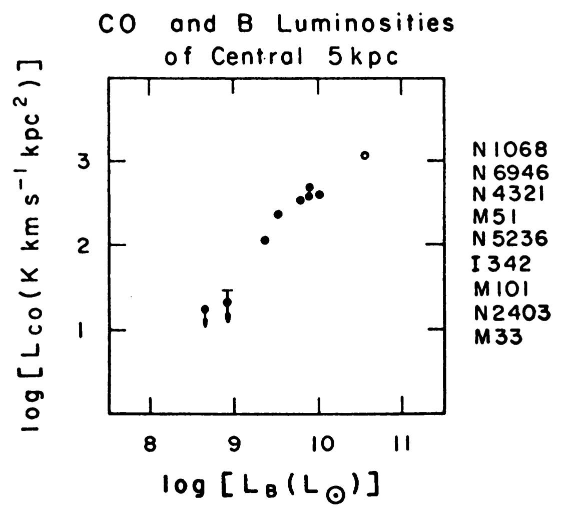

Figure 2. Comparison of CO and blue luminosities in regions 5 kpc in diameter in 8 Sc galaxies and NGC 1068. Over 2 orders of magnitude in luminosity a linear correlation is evident: $L_B = 4 \times 10^7\ L_{CO}^{1.0}$.

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4. MOLECULAR RINGS

No molecular rings like the one in the Milky Way at radii 4 to 8 kpc were seen in the Sc galaxies as shown in Figure 3a. In Paper I we suggested that the difference in the radial distributions is the absence of gas at R ~ 1 to 4 kpc in the Milky Way. Recently, however, we discovered molecular rings in two Sb galaxies, NGC 7331 and NGC 2841, with peaks at radii of ~ 4 kpc (Young and Scoville 1982c) as shown in Figure 3b. In these galaxies, the central CO holes are coincident with the size of the bulge components measured by Boroson (1981). The CO distributions in NGC 7331, NGC 2841 and possibly the Milky Way appear to be related to the nuclear bulges. Rather than being in molecular clouds the gas which was present during the formation of the galaxy may have been depleted in forming stars in the nuclear bulge.

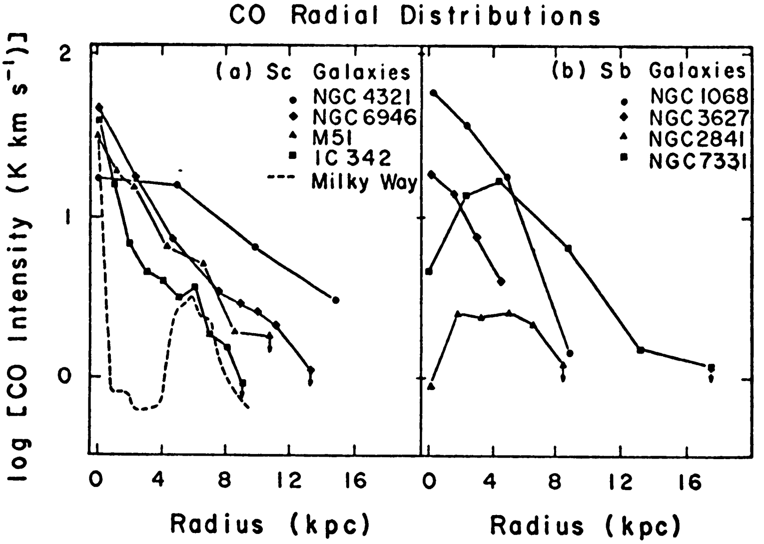

Figure 3. (a) Observed CO radial distributions in 4 relatively face-on Sc galaxies do not show a molecular "hole" like that in the Milky Way at R ~ 1 to 4 kpc. (b) Central CO holes are observed in several Sb galaxies with large nuclear bulges.

REFERENCES

Ables, H.D.: 1971, Publ. U.S. Naval Obs. Sec. Ser., Vol XX, Part IV, Washington, D.C.
Boroson, T.: 1981, Astrophys. J. Supp., 46, 177.
Scoville, N.Z. and Young, J.S.: 1983, Astrophys.J., in press.
Young, J.S. and Scoville, N.Z.: 1982a, Astrophys. J., 258, 467.
________ 1982b, Astrophys.J.(Letters), Sept. 1.
________ 1982c, Astrophys.J.(Letters), Sept. 15.

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