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The FCRAO Extragalactic CO Survey: Global Properties of Galaxies

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I. Introduction and Observations

Since stars form in molecular clouds, a critical element in studies of galaxy evolution is knowledge of the molecular content of a large sample of galaxies. To this end, we have undertaken a survey of CO emission from galaxies using the FCRAO 14-m millimeter telescope at 115 GHz. We aim to better understand the differences found among and within galaxies with regard to the efficiency of star and cloud formation.

The galaxies observed as part of the FCRAO Extragalactic CO Survey have been selected on the basis of their optical or infrared properties. The galaxies observed thus far are (1) brighter than $B_T^{\circ} = 12.5$ in the blue, or (2) brighter than 20 Jy at 100 μm. From major axis CO observations at 45″ resolution and spacing in over 200 galaxies, we have determined the CO radial distributions, and derived global CO fluxes (cf. Kenney and Young 1988); H_2 masses were derived using the conversion factor $N(H_2)/I_{CO} = 2.8 \times 10^{20}$ $cm^{-2}/(K\ km\ s^{-1})$ (Bloemen et al. 1986).

Here, we concentrate on the global galaxy properties within the sample. HI masses for the sample galaxies were taken from Huchtmeier et al. (1983), blue luminosities and morphological types were taken from RC2. IR luminosities, colors, dust temperatures and dust masses were determined from coadded IRAS data (Young et al. 1989). We have chosen to first compare absolute luminosities and masses in order to determine the slope and scatter in each correlation; next we investigate luminosity independent ratios in order to intercompare large and small galaxies.

III. Results and Discussion

We find that the IR luminosities are related to the molecular gas and atomic gas masses and blue luminosities as follows:

$$L_{IR} \propto M(H_2)^{1.0\pm0.03} \quad \text{(corr. coeff. = 0.93)} \quad (1)$$

$$\propto M(HI)^{1.0\pm0.06} \quad \text{(corr. coeff. = 0.81)}$$

$$\propto L_B^{1.2\pm0.05} \quad \text{(corr. coeff. = 0.85).}$$

Thus, we find the infrared luminosity to correlate better with the molecular content of galaxies than with the atomic gas content. Furthermore, the scatter in the L_{IR}-$M(H_2)$ correlation is found to depend on the temperature of the dust, whereas the scatter in the L_{IR}-$M(HI)$ correlation does not (Young et al. 1989). We conclude that the IR emission is closely tied to the molecular content of galaxies. We find no difference in the L_{IR}-$M(H_2)$ correlation for early and late spiral types.

N(H2)/I sub CO = 2.8 times 10 to the 20th power cm(-2)/K km (-1)

We find the blue luminosities to be related to the molecular and atomic gas masses as follows:

$$L_B \propto M(H_2)^{0.7\pm0.03} \quad \text{(corr. coeff. = 0.91)} \quad (2)$$
$$\propto M(HI)^{0.7\pm0.04} \quad \text{(corr. coeff. = 0.79).}$$

We suggest that the shallower slope of the L_B-$M(H_2)$ correlation relative to the L_{IR}-$M(H_2)$ correlation is due to extinction lowering the blue luminosities in the most luminous galaxies, since these galaxies have higher H_2 surface densities and therefore larger dust column densities in their central regions (Young et al. 1989). Some of the scatter in the L_B-$M(HI)$ correlation arises from the morphological type dependence of the $M(HI)/L_B$ (cf. Roberts 1969); we find a much weaker type dependence in the L_B-$M(H_2)$ correlation. The combination of these two effects gives rise to a morphological type dependence to the $M(H_2)/M(HI)$ ratio (see Knezek and Young 1989, this conference).

The best correlation we find is that between the warm dust masses inferred from IRAS data with the molecular masses (see Figure 1), such that

$$M(H_2) \propto M_{dust}^{1.0\pm0.02} \quad \text{(corr. coeff. = 0.97)} \quad (3)$$
$$M(HI) \propto M_{dust}^{0.7\pm0.04} \quad \text{(corr. coeff. = 0.79).}$$

The tight $M(H_2)$-M_{dust} correlation and the unity slope suggest that the gas to dust ratio is constant from galaxy to galaxy and that the H_2 mass derivations are reasonably accurate even though the cloud properties may be different from galaxy to galaxy. This can be understood because the $CO \rightarrow H_2$ conversion depends on $T_{gas}\rho^{-1/2}$ (Dickman, Snell, and Schloerb 1986), and both the gas temperature and density are likely to be higher in actively star forming regions. The total gas to dust ratio is discussed elsewhere (Devereux and Young 1989, this conference).

Among 50 of the galaxies for which published $H\alpha$ fluxes are available in the literature (Kennicutt and Kent 1983; Bushouse 1986), we find $L_{IR} \propto L(H\alpha)^{1.0\pm0.1}$ (corr. coeff. = 0.78). Although $H\alpha$ suffers extinction, and there may be old as well as young stars contributing to the IR lumnosity, we suggest that both $H\alpha$ and IR luminosities are reasonable tracers of high mass star formation. We find the ratio $L_{IR}/M(H_2)$ varies with environment, such that merging/interacting galaxies have star formation efficiencies ~7 times higher that isolated galaxies (Young et al. 1986, 1989; Solomon and Sage 1988). We find *no* evidence for a type dependence to the star formation efficiency deduced from the global $L_{IR}/M(H_2)$, $L(H\alpha)/M(H_2)$, or Radio Continuum/$M(H_2)$ ratios (Allen and Young 1989, this conference; Devereux and Young 1989, this conference).

IV. Conclusions

We conclude that star formation is generally a local process, dependent on the amount of gas available to form stars and not the galaxy morphology. The relative amount of gas in molecular versus atomic form does appear to depend on morphology (Knezek and Young 1989, this conference). The single property which appears to influence both the H_2/HI ratio and $L_{IR}/M(H_2)$ ratio is environment; we find both higher star formation efficiencies and higher molecular gas fractions in interacting/merging galaxies.

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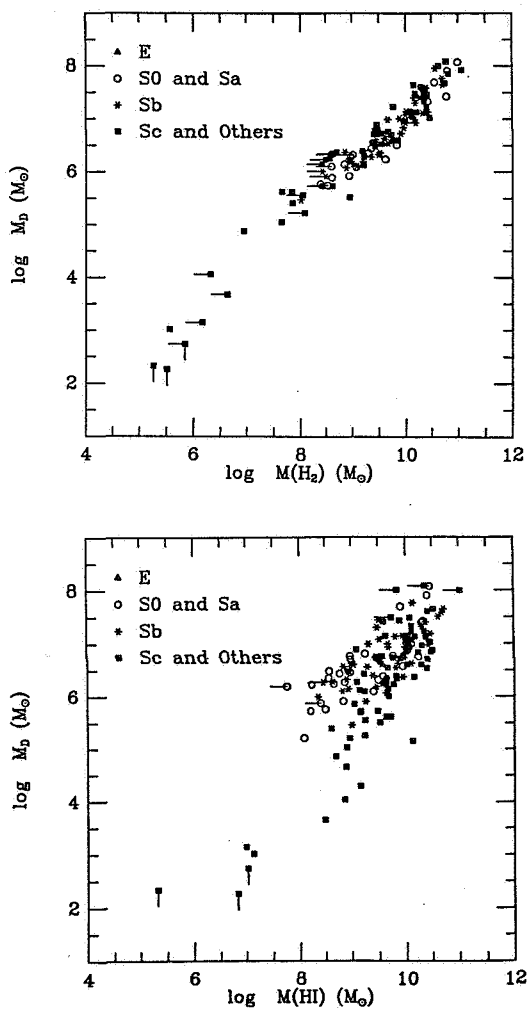

Figure 1. Comparison of dust masses derived from IRAS observations with H_2 and HI masses.