

DENSE MOLECULAR GAS IN NEARBY GALAXIES

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1. Introduction

HCN, one of the most abundant high dipole-moment molecules (traces molecular gas at densities $n_{\text{H}_2} \gtrsim 3 \times 10^4 \text{ cm}^{-3}$ whereas CO traces at $\sim 500 \text{ cm}^{-3}$), has only been detected in ~ 25 galaxies, primarily towards the galactic nuclei (Solomon et al. 1992; Nguyen-Q-Rieu et al. 1992; Helfer & Blitz 1993; Aalto et al. 1995). Dense molecular gas properties in “normal” galactic disks, as compared to the centers of “normal” spirals, starbursts, and luminous IR galaxies are not clear. As part of a large HCN survey in 60 galaxies (Gao 1996; Gao & Solomon 1997), we present here HCN observations in central regions of a few nearby galaxies. HCN was mapped at least along the major axes in the inner disks to determine the total HCN luminosity, the distribution with radius of HCN emission, and of the surface brightness ratio of $\text{SBR} \equiv I_{\text{HCN}}/I_{\text{CO}}$.

2. Extent and Distribution of Dense Molecular Gas

There are almost no HCN observations beyond the nuclear $\sim 1 \text{ kpc}$ regions in galaxies. We have mapped HCN along the major axis in ~ 10 nearby galaxies. An example is shown in Fig. 1 for M82. Apparently, the *dense* molecular gas is not confined to the inner $\sim 1 \text{ kpc}$ nuclear region, although the highest concentrations of *dense* molecular gas are in the center. A significant fraction of *dense* molecular gas is distributed in the inner disks of galaxies outside the nuclear or inner ring starburst regions, and

can be detected to radii as large as a few kpc (e.g., in NGC 891), perhaps to diameters of $\sim D_{25}/4$.

The radial distribution of HCN emission and the SBR in NGC 253 obtained from both the IRAM 30m and NRAO 12m are presented in Fig. 2. The HCN distribution in the innermost part of disks of galaxies seems to follow approximately an exponentially decreasing law. However, it seems to be more difficult to describe the SBR as a function of radius.

3. Starburst Indicator $SBR \equiv I_{\text{HCN}}/I_{\text{CO}}$

The SBR in NGC 253 reveals a nuclear starburst core of highest SBR ~ 0.1 with a linear scale $\lesssim 0.5$ kpc. At larger radius, $R \gtrsim 0.3$ kpc, the fraction of dense molecular gas becomes smaller and the SBR drops to the global value for normal spirals like NGC 891 (~ 0.025), which shows slowly declining but almost constant SBR across the inner disk (on a linear scale of ~ 5 kpc). In galaxies like M82 and NGC 6946, a rather constant SBR $\sim 0.04 - 0.05$ (moderate starburst) across the innermost a few kpc region is observed, whereas normal galaxies and even the outer part of the inner disks of the starburst galaxies (e.g., NGC 253) have SBR about $0.02 - 0.03$ (non-starburst, normal).

Ultraluminous IR galaxies have the highest HCN-to-CO luminosity ratio, $L_{\text{HCN}}/L_{\text{CO}} \sim 0.1 - 0.3$ (Solomon et al. 1992; Gao & Solomon 1997), similar to the SBR in the starburst cores, whereas “normal” spirals have a ratio $L_{\text{HCN}}/L_{\text{CO}} \sim 0.01 - 0.05$, same as the SBR in non-starburst galaxies or the disks outside the starburst regions.

Therefore, the SBR seems to be an indicator of the starburst and the radial distribution of SBR as a function of galactic radius may suggest the starburst size scales in galaxies.

4. References

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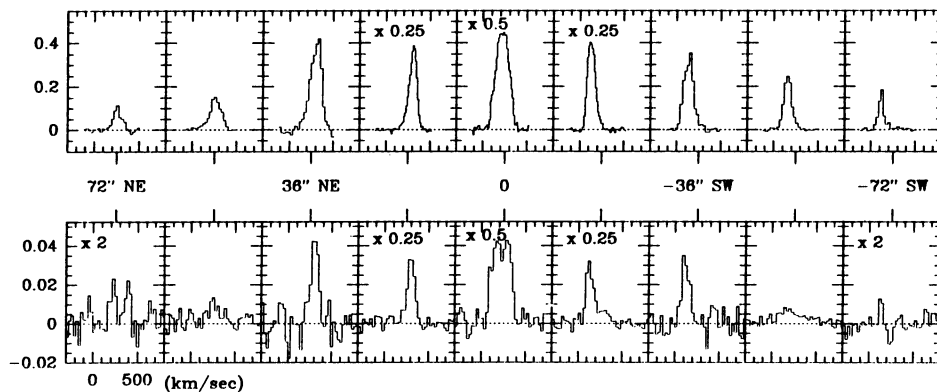


Figure 1. HCN spectra (bottom) mapped along the major axis in M82 as compared with the CO(2-1) spectra (top) obtained simultaneously from the IRAM 30m telescope. The vertical scale is the antenna brightness temperature T_A^* (K).

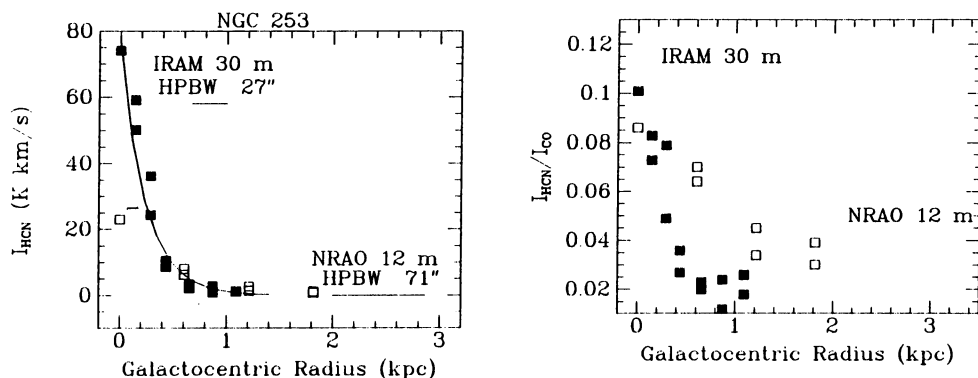


Figure 2. HCN emission (the integrated line intensity) and the surface brightness ratio $SBR \equiv I_{\text{HCN}}/I_{\text{CO}}$ as a function of the galactic radius in NGC 253 (filled squares are the IRAM 30m data and the open squares are the NRAO 12m observations). The line is an exponential fit.