# HCN AND $HCO^+$ IN IR BRIGHT GALAXIES

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ABSTRACT. We report the preliminary results of a search for HCN and $HCO^+$ in the nucleus of 14 IR bright galaxies. The line intensity ratio HCN/$HCO^+$ is of the order of or larger than unity, except for M82 which has a line ratio of 0.5. The line ratios are discussed in terms of a model of chemistry of dense interstellar clouds. There is a correlation between the HCN and $HCO^+$ line intensities and that of CO.

## 1. INTRODUCTION

The nuclear region of starburst galaxies where massive star formation takes place can be investigated with tracers of dense gas, such as HCN, $HCO^+$ and CS. The HCN and $HCO^+$ lines are among the brightest thermal lines. The critical densities for collisional excitation of these lines are about 2 to 3 orders of magnitude higher than that of CO.

We have selected a sample of 14 nearby galaxies which have the brightest CO and far-IR emission for a survey of the HCN and $HCO^+$ ground state emission at 3 mm, using the IRAM 30 m telescope. The beam of the telescope at 3 mm is ~25".

## 2. RESULTS

In Table 1, we list the main beam brightness temperature integrated over the line profile, taken in the central 25" region surrounding the nucleus. Most of the sources in this list are starburst galaxies.

Emission of HCN and $HCO^+$ has been detected in almost all of the programme sources. For $HCO^+$, the observation is not yet complete. $H^{13}CO$ isotope as well as the HCN (J=3-2) and $HCO^+$(J=3-2) lines at 1 mm have also been observed in a few strongest sources to constrain the physical conditions. The lowest detected main beam brightness temperature is about 0.02 K.

The fact that the 3-2 lines in NGC253 and M82 are about the same or slightly stronger than the 1-0 lines suggests that HCN and $HCO^+$ emission arises in optically thick and warm regions of kinetic temperatures higher than 10-20 K. The HCN/$HCO^+$ line ratio listed in Table 1 indicates that the HCN emission tends to be stronger than the $HCO^+$ emission. There is however an exception for M 82 where $HCO^+$ is about 2 times stronger than HCN in both the ground state and the 3-2 excited transitions.



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According to a recent model of chemistry of dense interstellar clouds developed by Langer and Graedel (1989) , HCN and $HCO^+$ are formed through ion-molecule reactions. The $HCO^+$ abundance is however particularly sensitive to the gas temperature. $HCO^+$ is predicted to be usually less abundant than HCN at lower gas temperatures (about 20 K). At a higher temperature of about 40 K, $HCO^+$ becomes more abundant than HCN by a factor of 2-3. The dust temperature in M82 is high, about 50 K. The kinetic temperature is probably close to this value. Since HCN and $HCO^+$ have similar excitation requirements, a higher abundance due to a higher kinetic temperature may explain the low HCN/$HCO^+$ ratio observed in M82. The overabundance of $HCO^+$ may also be due to enhanced ionisation in the shocked gas (Elitzur, 1983). The observations of the 3-2 lines in a larger number of sources and a more quantitative interpretation taking into account the effects of clumping and photon trapping would be required to investigate the line ratios.

For IC342, NGC253 and M82, $H^{12}CO^+/H^{13}CO^+$ line ratios of 9, 15, and >29, respectively, are similar to the $^{12}CO/^{13}CO$ line ratio. The line ratio for $HCO^+$ seems to increase with the dust temperature. This trend has been found for CO by Young and Sanders (1986). The model of Langer and Graedel (1989) predicts that fractionation chemistry would favour the enhancement of $^{13}CO$ and $H^{13}CO^+$ and that the isotopic ratio of $HCO^+$ should be close to that of CO in dense shielded regions. Both isotopic ratios should also be close to the gas-phase ratio of 75. Furthermore, the $H^{12}CO^+$ and $^{12}CO$ lines are optically thicker than the $H^{13}CO^+$ and $^{13}CO$ lines. Therefore, the observed line ratios of 9 to >29 should be considered as lower limits to the isotope abundance ratio.

The HCN (1-0) and $HCO^+$ (1-0) mapping of M83 with a spacing of 15" around the nucleus indicates that HCN and $HCO^+$ are confined within a region of 30" diameter. The HCN (1-0) map of IC342 (Figure 1) is elongated approximately in the north-south direction, indicating that the HCN emission is associated with the bar detected in the interferometric map by Lo et al. (1984) and with the double ridge by Ishizuki et al. (1990). There is also an excess of HCN emission to the north similar to that observed by Ishizuki et al. These results suggest that HCN coexists with the warm nuclear gas associated with the CO bar.

The integrated intensity of HCN and $HCO^+$ (central 25" region) is plotted in Figure 2 against the integrated intensity of CO (central 50" region). There is a fairly good correlation, on the one hand, between the HCN and $HCO^+$ intensities, and between both HCN and $HCO^+$ intensities with that of CO, on the other.

It is interesting to compare the intensity of mm lines with that of the far infrared atomic fine structure lines. The CII line at 158 microns which is one of the strongest far infrared lines is an excellent tracer of star forming regions. The CII emission arises in the external layers of giant molecular clouds photodissociated by UV radiation. Stacey et al. (1988) have shown that the far infrared CII flux from starburst galaxies and galactic star forming regions is tightly correlated with the intensity of CO. Since HCN and $HCO^+$ is correlated with CO, they are also correlated with CII emision in starburst galaxies. CII is the product of photodissociation of HCN and CO and $HCO^+$ plays a key role in the formation of complex molecules. The observations of these mm lines combined with those of other far infrared lines which will be made with the ISO satellite will help investigate the photochemistry in the starburst environment.

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TABLE 1

| GALAXY | HCN 1-0 | $HCO^+$ 1-0 | HCN 3-2 | $HCO^+$ 3-2 | $H^{13}CO^+$ 1-0 | $HCN/HCO^+$ |
|---|---|---|---|---|---|---|
| | | | (K km $s^{-1}$) | | | |
| M83 | 21.2 | 15.6 | | | | 1.3 |
| IC342 | 16.9 | 11.9 | | | 1.25 | 1.4 |
| NGC891 | 3.5 | 2.1* | | | | 1.7* |
| NGC1068 | 24.2 | 22.1 | | | | 1.1 |
| Maffei 2 | 25.1 | 9.6 | | | | 2.6 |
| NGC2146 | 6.1* | | | | | |
| NGC2903 | 5.8 | | | | | |
| NGC3079 | 13.7 | ≤ 2.0 | | | | ≥ 6.8 |
| NGC3627 | 4.5* | | | | | |
| NGC3628 | 5.3 | | | | | |
| M51 | 7.5 | 5.4 | | | | 1.4 |
| NGC6946 | 8.2 | 9.2 | | | | 0.9 |
| NGC253 | 68 | 59 | ≤ 60 | 87 | 3.9 | 1.1 |
| M82 | 18.5[a] | 38.3[a] | 17.4[b] | 32.3[b] | ≤1.3 | 0.5 |

* Tentative
a Nguyen-Rieu et al.
b Wild et al.

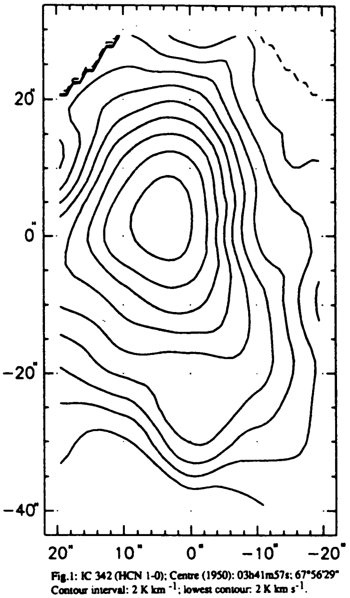


Fig.1: IC 342 (HCN 1-0); Centre (1950): 03h41m57s; 67°56'29"
Contour interval: 2 K km $^{-1}$; lowest contour: 2 K km $s^{-1}$.

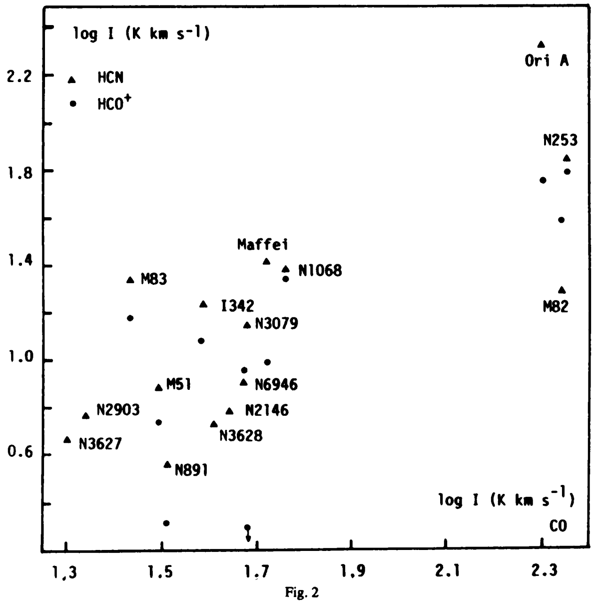


Fig. 2

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