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Molecular Clouds in the Centers of Galaxies: Constraints from HCN and ^{13}CO Line Emission

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Summary. We have searched for HCN J=1–0 line emission in the centers of 12 galaxies and have detected it in 10 of them. We have obtained complementary data on J=1–0 and 2–1 transitions of ^{12}CO and ^{13}CO in these systems. The ratio of integrated intensities, $I(\mathrm{CO}\ 1-0)/I(\mathrm{HCN}\ 1-0) = 25 \pm 11$ for this sample. We find that HCN emission of this strength can be produced under conditions of subthermal excitation. In combination with the line ratios in CO and ^{13}CO, HCN puts constraints on the mean conditions of molecular clouds and on the mix of cloud types within the projected beam.

Observations and Results. We have observed HCN J=1–0 at 88.6 GHz in a sample of galaxies for which we have been obtaining data on several transitions of ^{12}CO and ^{13}CO with the 15m Swedish–ESO Submillimetre Telescope (SEST), the 20m Onsala telescope, and the 12m NRAO telescope. The sample includes isolated "normal" spiral galaxies, interacting systems, and luminous mergers. As found previously by Solomon, Downes, and Radford (1992) for a different sample, the HCN profiles typically resemble those of CO 1–0, which suggests that the clouds responsible for these emissions have similar kinematical distributions. The intensity in HCN 1–0 is detected at a level of 2 to 10 % of that in CO 1–0. Our previous result (Aalto *et al.* 1991) on the ^{12}CO/^{13}CO intensity ratio in J=1–0 has been extended to more systems: while there is a well defined mean value near 10 for nuclei of most galaxies, much higher ratios are observed in the most disturbed, luminous mergers. New results on the ^{12}CO/^{13}CO intensity ratio in J=2–1 show a range of values and help to clarify the interpretation in terms of optical depth in the dominant CO–emitting clouds.

Discussion. Line emission from polar molecules like HCN is conventionally taken to arise in a denser component ($n(\mathrm{H_2}) > 10^4$ cm^{-3}) of molecular gas than CO emission, which is more readily excited at low density ($n(\mathrm{H_2}) \approx 10^2 - 10^3$ cm^{-3}). We are developing techniques to model unresolved ensembles of molecular clouds with more than one population defined by density/temperature/size or with internal gradients of density and temperature. We also compare the line emission with the degree of central concentration of total mass, with the distribution of CO intensity, and with indicators of star–forming activity.

Preliminary conclusions include:

(1) Any population of dense ($n(H_2) \geq 10^4$ cm^{-3}) clouds, invoked to explain the HCN emission, must be consistent with the observed intensities and intensity ratios of ^{12}CO, ^{13}CO, and C^{18}O lines, which often require large quantities of more dilute molecular gas.

(2) The observed HCN 1–0 emission can sometimes be produced under conditions of subthermal excitation at relatively low densities, $n(H_2) < 10^4$ cm^{-3}.

(3) In some galaxies, with centrally concentrated 10 μm sources and molecular distributions, the excitation of HCN 1–0 may be enhanced by infrared pumping through a vibrational transition at 14 μm wavelength.

(4) We have not yet found a correlation between the intensity ratio, $I(\mathrm{CO})/I(\mathrm{HCN})$, and disturbed morphology, far–infrared emission, or measures of star–forming activity in our sample of galaxies.

Future efforts will involve further observations of higher transitions of HCN and further refinements in the modeling of unresolved cloud distributions.

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References.

Aalto, S., Black, J.H., Johansson, L.E.B., & Booth, R.S. 1991, *A&A*, **249**, 323.

Solomon, P.M., Downes, D., & Radford, S.J.E. 1992, *ApJ*, **387**, L55.