HNCO survey of high mass star forming cores

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Introduction

In recent years we performed extensive surveys of dense cores in regions of high mass star formation, mainly in CS (Zinchenko et al., 1995, 1998). We used water masers as signposts of high mass star formation. Both outer and inner Galaxy was covered by these surveys. The innermost part of the Galaxy was observed in a similar way by Juvela (1996). In addition, we surveyed sources associated with water masers in thermal SiO (Harju et al., 1998) which is supposed to be a good indicator of shocks in molecular clouds. From these observations we derived basic physical parameters of the cores and constructed their statistical distributions (Zinchenko, 1995; Zinchenko et al., 1998). In order to investigate a range of core densities, observations of lines with different excitation conditions are needed.

Isocyanic acid (HNCO) is a promising tracer of immediate surroundings of high-mass protostars. It has a rich spectrum of rotational transitions at radio frequencies, with a wide range of upper state energies. This makes HNCO suitable for density and temperature determinations in the densest parts of molecular clouds. Furthermore, some of its high-lying rotational levels with very high spontaneous emission rates can be only excited by far-infrared radiation. Therefore, HNCO can probe far-infrared radiation field from warm dust in the vicinity of a newly-born massive star.

Most studies conducted so far have concentrated on the galactic center region where HNCO emission was found to be especially strong and on a few well-known giant molecular cloud (GMC) cores (Jackson et al., 1984; Churchwell et al., 1986; Wyrowski et al., 1999). In this paper we present preliminary results of a survey towards a sample of some 80 GMC cores in HNCO using several rotational transitions ranging in frequency from 22 to 461 GHz. Our purpose was to find out how widely spread this molecule is in high-mass star forming cores, and what are the physical conditions of the gas where it thrives. A comparison with other molecules, especially tracers of shocks like SiO and the total gas column density like $C^{18}O$, was hoped to provide information of the abundance and production pathways of HNCO. It should be noted the chemistry of HNCO is not well understood yet. Moreover, we wished to study the relation between the intensities of highly excited HNCO lines and radiation from associated far-infrared sources.

Observations

For this study we selected those dense cores detected by Zinchenko et al. (1995, 1998) and Juvela (1996) that are characterized by strong CS emission ($T_{\rm mb} > 3$ K). Several strong SiO ($v = 0$) sources detected by Harju et al. (1998) are also included in our sample. The original survey was performed in the south with the 15-m SEST (at 1.4 mm) and in the north with the 20-m OSO (at 3 mm) radio telescopes. Several sources were observed at 2 and 3 mm with SEST and at 3.5 mm with OSO. Later the survey was complemented by 1.3 cm observations of a few cores with the 100-m radio telescope in Effelsberg and by submillimeter observations with the 10-m HHT telescope in Arizona. The receiver bands at SEST, OSO and HHT covered also higher K_{-1} HNCO transitions as well as nearby $C^{18}O$ and some other lines. These data are used for data analysis too. The basic observing parameters are summarized in Table 1.

Table 1: Observing parameters.

Molecule	*Transition*	*Frequency* (MHz)	*Telescope*	*HPBW* ($''$)	η_{mb}	T_{sys} (K)	$\Delta\nu$ (kHz)
HNCO	$1_{01}-0_{00}$	21981.460	Eff.	40	0.3	50–100	12.5
	$4_{04}-3_{03}$	87925.252	OSO	40	0.60	210–290	250
	$5_{05}-4_{04}$	109905.76	OSO	35	0.52	300–450	250
	$5_{05}-4_{04}$	109905.76	SEST	47	0.71	200–270	86
	$7_{07}-6_{06}$	153865.08	SEST	33	0.64	150–180	86
	$10_{0,10}-9_{0,9}$	219798.32	SEST	24	0.52	190–360	86
	$21_{0,21}-20_{0,20}$	461450.67	HHT	18	0.38	900–2000	480
$C^{18}O$	$1-0$	109782.16	OSO	35	0.52	300–450	1000
	$2-1$	219560.32	SEST	24	0.52	190–360	1400

Results

HNCO was detected in 36 SEST sources (from 56 observed) and in 21 OSO sources (from 27). Most of our HNCO sources are new detections. In many cases $K_{-1} > 0$ transitions were detected too. Examples of the measured spectra are given in Figs. 1,2. The first one shows HNCO spectra in comparison with CS and SiO. The second one presents spectra of a few sources covering $K_{-1} = 0$, 2 and 3 transitions at 1.4 mm.

In order to get an idea of the source sizes and their relation to YSO and IR sources we mapped 2 southern sources in the $10_{0,10}-9_{0,9}$ HNCO line and Orion A, W49N and W51M in the $21_{0,21}-20_{0,20}$ line. W51M was mapped also in the $5_{05}-4_{04}$ line. The sources remain spatially unresolved. E.g. for G 301.12–0.20 we obtain a FWHM $\approx 29''$ in right ascension (from the strip scan across the map) which is very close to the beam size at this frequency ($24''$). The comparison with the observations at other instruments (Jackson et al., 1984) also imply implicitly a very small angular extent of the sources.

It is worth noting that we detected for the first time the $K_{-1} = 5$ HNCO transitions with the excitation energy ~ 1300 K above the ground level and probably $HN^{13}CO$. If the identification with $HN^{13}CO$ is correct this implies rather high optical depth in the $10_{0,10}-9_{0,9}$ lines of the main isotopomer, τ(HNCO) ~ 10.

As a first step in the excitation analysis we construct traditional rotational diagrams for our sources. The highest observed transition for Orion lies as high as ~ 1300 K above the ground level. For other sources we managed to observe transitions up to ~ 450 K above the ground state. Examples of the rotational diagrams are presented in Fig. 3.

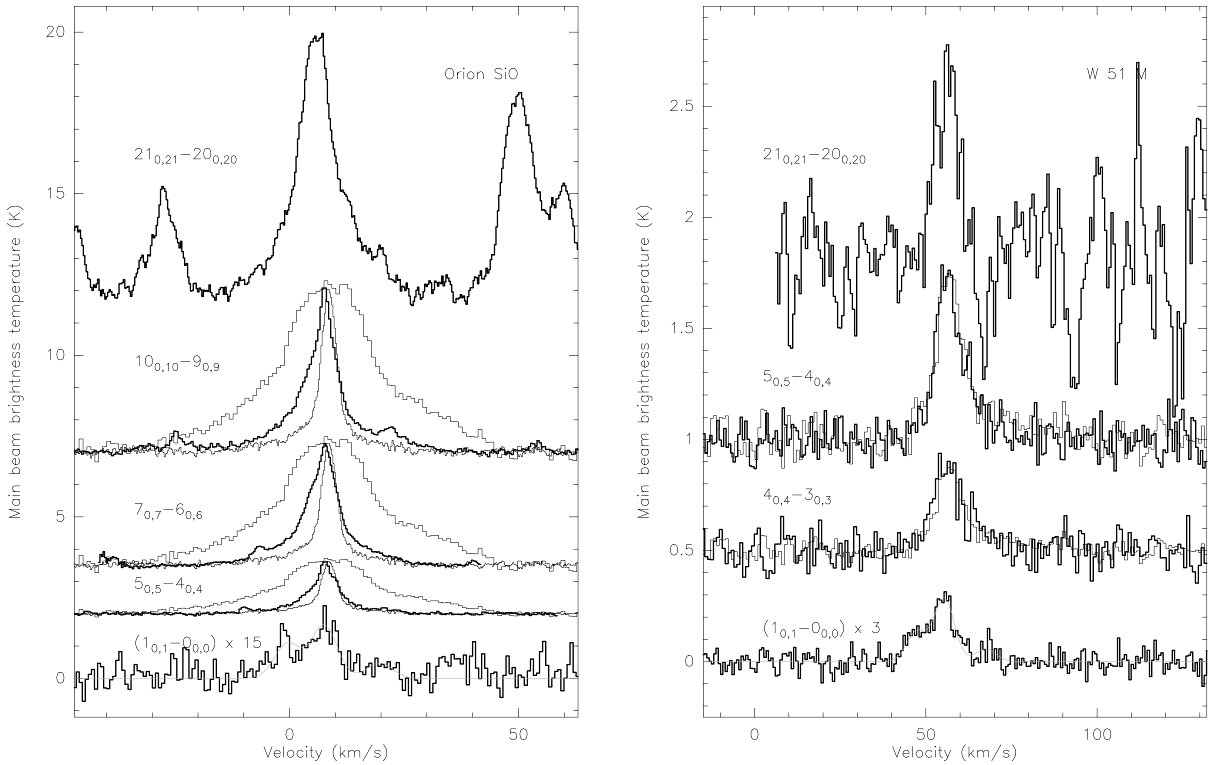

Figure 1: HNCO lines in several sources (thick lines) in comparison with the CS(2–1) and SiO(2–1) lines. The latter are scaled to the same peak values as HNCO and overlaid on the HNCO spectra. For the $1_{01}-0_{00}$ transition the 3-component gaussian fit is shown

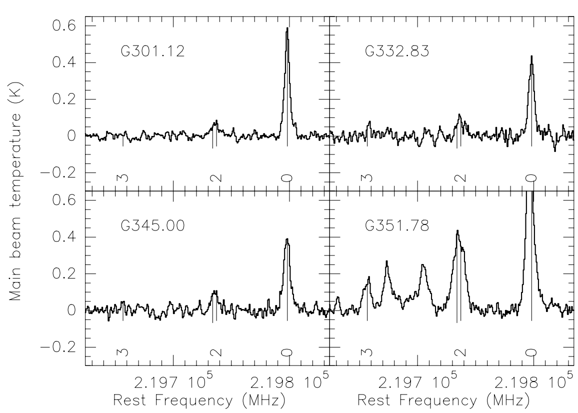

Figure 2: Examples of 1.4 mm HNCO spectra obtained at SEST covering $K_{-1}=0$, 2 and 3 transitions

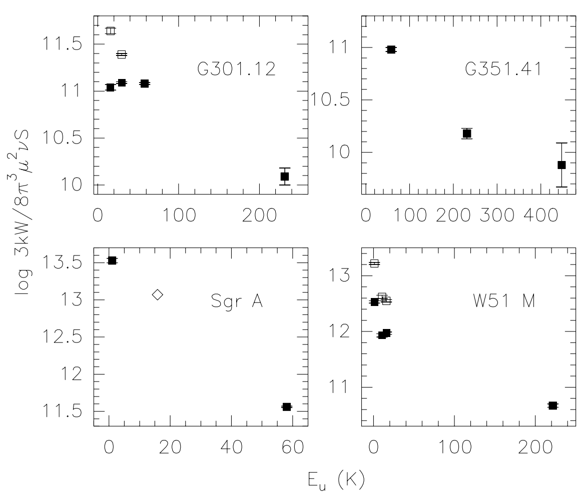

Figure 3: Examples of the rotational diagrams for the sample sources ($W=\int T_{\rm mb}dv$, S is the line strength). Filled squares correspond to the measured values and the open squares to the values corrected taking into account the beam sizes. The diamond on the Sgr A plot corresponds to the data from Lindqvist et al. (1995)

Conclusions

1. HNCO is widespread in dense cores forming high mass stars. There is no significant galactic gradient in its abundance.

2. The sources of HNCO emission are very compact. Though they are close to strong FIR sources there is no strict spatial coincidence and the correlation with the FIR flux is rather weak.

3. We detected HNCO transitions with the excitation energy up to $E/k \sim 1300$ K. The rotational temperatures lie in the range $\sim 10 - 300$ K. Typical HNCO column densities constitute $\sim 10^{13} - 10^{14}$ cm^{-2} and relative abundances are $\sim 10^{-9}$.

4. The relative abundance of HNCO molecules increases with increasing velocity dispersion. It is enhanced in high velocity gas though to a lower degree than SiO.

5. $HN^{13}CO$ was probably detected for the first time in the interstellar medium. This detection implies rather high HNCO $10_{0,10} - 9_{0,9}$ optical depth, τ(HNCO) ~ 10.

6. HNCO does not correlate with CS which is a typical high density probe but correlates well with SiO. This comparison shows, in particular, that HNCO is closely related to SiO which is thought to be produced primarily in shocks and other energetic processes.

7. The hyperfine intensity ratios in the HNCO $1_{01} - 0_{00}$ transition are consistent with the LTE values.

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