CN OBSERVATIONS IN TAURUS DARK CLOUDLETS

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ABSTRACT

CN(N = 1→0, J = 3/2→1/2) has been searched for toward 8 locations in the Taurus dark cloud complex where NH_3 and HC_3N and/or HC_5N have been observed. CN was detected in TMC1(NH_3) and TMC2(cont.) and was probably detected in L1533(NH_3) and L1544(NH_3). CN appears to be correlated with NH_3 and anti-correlated with HC_5N and HC_3N. It is postulated that NH_3 is likely a dominant precursor of CN and HCN but that CN and HCN are probably not important precursors of HC_3N and heavier cyanopolyacetylenes.

Several small, low mass (M ∿ a few $M_\odot$), cool (T_K ∿ 10K) cloudlets in the Taurus dark cloud complex have been studied in some detail in the lines of NH_3, HC_3N and HC_5N. The primary results of these studies seem to be that: 1) the NH_3 and HC_3N-HC_5N distributions are different; 2) HC_3N and HC_5N are apparently more abundant than HCN and CN (in TMC1); 3) the cyanopolyacetylene molecules (HC_nN, n=3,5,7,9) are more abundant in Taurus than in other dark cloud complexes with similar densities and temperatures; and 4) the line widths of NH_3, HC_3N and HC_5N are typically ∿0.15-0.2 km s^{-1}, i.e., thermal, so that very quiescent conditions are implied.

The observed CN data are presented in tabular form and spectra are shown. CN was detected in TMC1(NH_3) and TMC(cont.). It may have also been detected at about the 2σ level in L1533(NH_3) and L1544(NH_3), but these detections require independent confirmation.

Allen and Knapp (1978 - hereafter AK) detected CN in L1529 but did not detect it in TMC1(HC_5N); among the four dark clouds detected by AK two are known NH_3 sources (L1529 and B335 - Ho et al. 1978), one (Ori I-2) has a measured upper limit (Ho et al. 1978), and no published NH_3 data could be found for one (IC 1848-1). CN was not detected in any of the positions where HC_5N or HC_3N are strong but was detected where NH_3 is strong and where there is a known compact radio continuum source. From analyses of other molecules it appears that most of the cloudlets where CN was not observed differ little in density and temperature from those where CN was detected.

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TABLE 1

MEASURED PARAMETERS OF CN TOWARD DARK CLOUDLETS IN TAURUS

SOURCE	OBSERVED POSITION α(1950)	δ(1950)	<ATM>	$F_u \rightarrow F_\ell$	T_L^* K	ΔV km s^{-1}	V_{LSR} km s^{-1}	$\int T_L dV$ K km s^{-1}	Notes
TMC-2(cont)	04 29 33.4	24 14 03	1.26	5/2 - 3/2	$\gtrsim$ 0.60 ± .17	0.6±.3	6.0±.1	0.37	1
L1529	04 29 43.0	24 16 45	1.12	5/2 - 3/2	$\lesssim$ 0.70				
L1535	04 32 30.0	23 48 00	1.07	5/2 - 3/2	< 0.50				
L1533(NH_3)	04 32 38.0	24 02 00	1.48	5/2 - 3/2	~ 0.26 ± .14	$\lesssim$ 0.26	5.8±.1	∿ 0.18	1,2,2a
TMC-1(NH_3)	04 38 20.3	25 42 00	1.10	3/2 - 1/2 5/2 - 3/2 1/2 - 1/2	0.35 ± .10 0.80 ± .10 0.40 ± .10	0.35±.2	5.83±.10	∿ 0.55	3
TMC-1(HC_5N)	04 38 38.0	25 36 00	1.88	5/2 - 3/2	< 0.39				
L1544(HC_5N)	05 01 08.0	25 07 40	1.73	5/2 - 3/2	< 0.75				
L1544(NH_3)	05 01 14	25 07 00	1.61	5/2 - 3/2	~ 0.4 ± .2	≤ 0.26	7.0±.1	∿ 0.28	2,2b

Notes

1 The line is probably not fully resolved with 100 kHz (0.26 km s^{-1}) resolution. Unfortunately the 30 kHz filterbank had a large gain step between the 4th and 5th cards of 16 filters which occured very close to where the line was. It was therefore not possible to derive reliable line parameters from the 30 kHz filters.

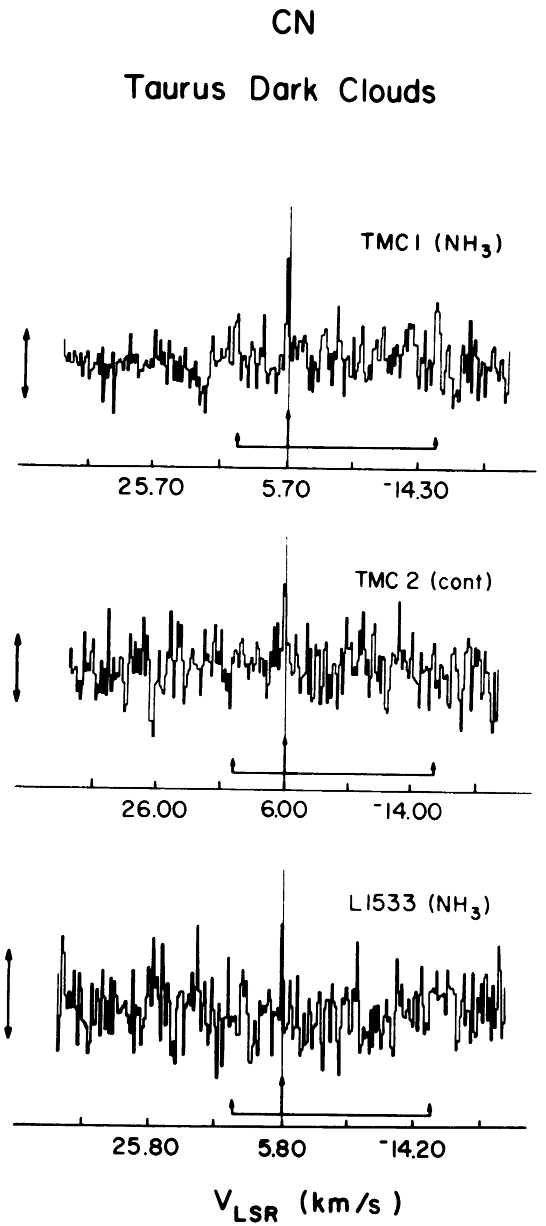
2 The feature is only 2σ above the noise and is therefore very uncertain. It occurs at the same velocity as NH_3 and appears in both the 100 kHz and 250 kHz spectra, which were taken on different days.

2a The feature is only 0.17 ± .10 K in the 250 kHz filters, which, if real, would imply that it is unresolved at this resolution.

2b The feature is only ∿ 0.28 ± .13 K in the 250 kHz filters, which, if real, would imply that it is not revolved at this resolution.

3 The lines are probably unresolved and therefore may be more intense. If the relative intensities are roughly correct, then the hf line ratios indicate a mean opacity in the F = 5/2 → 3/2 component of $\langle\tau\rangle_{27} \simeq 1.2^{+.7}_{-.6}$.

The frequency resolution was 100 kHz (0.26 km s^{-1}) and 250 kHz (0.66 km s^{-1}) at each position. At a few positions the 30 kHz filters were used, but there was such a bad instrumental ripple that these were considered unreliable.


CN
Taurus Dark Clouds
TMC I (NH3)
25.70
5.70
-14.30
TMC 2 (cont)
26.00
6.00
-14.00
L1533 (NH3)
25.80
5.80
-14.20
VLSR (km/s)

The anti-correlation of CN with HC_3N and HC_5N and its apparent positive correlation with NH_3 suggest that chemistry rather than cloud density or temperature probably plays a dominant role in the observed CN abundance variations. In clouds with $n \gtrsim 10^4$ cm^{-3}, all gas-phase models predict that CN formation is primarily via the reaction $H_2CN^+ + e \rightarrow CN + 2H$, and destruction is via reaction with the ions He^+, H_3^+, and perhaps H^+. Iglesias (1977) suggested that $CN + O_2 \rightarrow NCO^+ + O$ is the primary destruction path in dense clouds ($n \gtrsim 10^4$ cm^{-3}), so that the CN abundance will decrease with cloud age (i.e., increasing density) roughly as $[CN]/[n] \propto n^{-1}$ even if condensation onto grains is not included. NH_3 is typically 10-100 times more abundant than CN or HCN and therefore would not be greatly depleted even if all CN and HCN were formed from NH_3. The apparent correlation of CN with NH_3 would seem to support the idea initially proposed by Herbst & Klemperer (1973) that NH_3 is a primary precursor of CN,probably via the reaction chain $NH_3 + C^+ \rightarrow H_2CN^+ + H$ and $H_2CN^+ + e \rightarrow CN + 2H$. The possible anti-correlation of CN and NH_3 with HC_3N and HC_5N in Taurus is not easy to interpret. Simplistically, one might assume that CN, HCN and HNC have mostly been converted to HC_3N and HC_5N, but in this case one would expect also a close correlation of HC_3N and NH_3, which is not observed. A possible ion-molecule formation scheme which does not involve CN, HCN or HNC is: $C_2H_2^+ + CH_4 \rightarrow C_3H_5^+ + H$; $C_3H_5^+ + N \rightarrow C_3H_3N^+ + H_2$; $C_3H_3N^+ + e \rightarrow HC_3N + H_2$.

It is unlikely that these reactions could dominate those involving CN, HCN, and HNC unless CH_4 is overwhelmingly abundant in Taurus.

The observational correlations are not well enough established to rule out or establish one chemical network over another. The correlation of CN with NH_3 and anti-correlation of CN with HC_3N are important clues to CN chemistry, but further observations are required to establish the validity of these. The Taurus complex is probably one of the best regions in which to pursue this problem further because of its small distance and its apparently anomalously high HC_3N abundance.

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