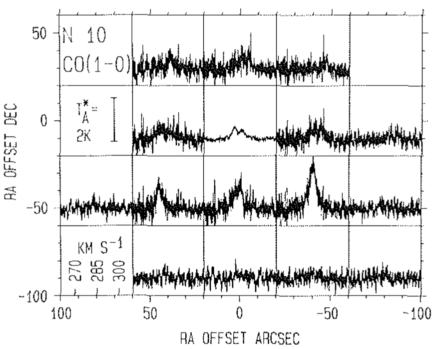

Figure 5: *J = 1-0 CO spectra of the molecular cloud complex associated with N10 measured with the SEST. The reference position is* $\alpha = 04^h\,56^m\,46^s$, $\delta = -66°\,28'\,20''$ *(1950.0).*

frared source in N160A. The reason for the difference to the infrared N_{H_2} value is that in the CO measurements we indirectly observe the much larger amount of cold H_2 gas along the line of sight, while the near infrared H_2 lines yield information only about the very small amount of hot H_2 gas. We also have to consider that the radio beam is much larger than the infrared beam and that the H_2 line emission source is probably unresolved. A comparison of the intensity ratios of the observed lines with those resulting from model calculations for shock excitation (Shull and Hollenbach, 1978) and for radiative excitation (Black and van Dishoeck, 1987) shows that the energy levels may be partly populated from ultraviolet pumping. The strong Q(2) line could result either from a lower ratio of the ortho to para-hydrogen than 3 or from non-thermal equilibrium. In the latter case the gas density would be less than 10^5 cm^{-3}.

Acknowledgements

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Search for HCOCN in Interstellar Space

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1. Interstellar Molecules

More than 80 different molecular species have been observed in the interstellar medium (ISM) in one or more molecular sources (cf. the review of Irvine et al., 1987). Most of them were discovered and identified via their centimetre and millimetre lines. However, to get a better understanding of the complex chemical processes at work in interstellar clouds, we need to observe many more species. On the one hand, only a few among all species involved in the reaction networks are observed: most of the reactions are exothermic and involve radicals and/or molecular ions. These species have low abundances and complex spectra, and are therefore very difficult to detect, but their observation would provide important constraints on the chemical models. On the other hand, there are often competitive ways to synthesize complex molecules, with poorly known reaction rates. Observations of these elaborated species could provide constraints on the reaction rates, synthesis modes, and give an insight into the degree of complexity that this kind of chemical system can reach (how many heavy atoms, and what structure can we observe/are present in complex molecules?). This research topic was initiated by the search of Glycine and Urea after several organic molecules were found in the ISM in the mid 1970's (Hollis et al., 1980; Guelin 1989).

When searching for new interstellar species, several approaches are possible: systematic frequency surveys of a given molecular source provide a good picture of this source, and some non-identified lines! These lines are due both to new molecular species and to high excitation lines of already known species. The molecular source near Orion IRc2 is very hot, and vibrationally excited molecules like CH_3OH radiate a lot of lines in the millimetre and sub-millimetre domain. (Methyl formate $HCOOCH_3$ has about 1 line per GHz from 80 to 300 GHz!). The main problem of this kind of work is to achieve a good and uniform sensitivity in a complete frequency range (>20 GHz).

Another method is to concentrate on a few interesting species and obtain long integration times for a few lines on well-known molecular sources. For both methods, the knowledge of the line frequencies with an accuracy better than 100 kHz ($\Delta v/v < 10^{-6}$) is crucial to get a secure identification; there are so many lines at a noise level of 10 mK that the probability of a random coincidence is quite large. Spectroscopic work in the laboratory is therefore required before each new identification can be made, even though the lines were first detected in the ISM. This is particularly difficult for radicals and molecular ions which are very unstable and difficult to produce in sufficient quantities to complete spectroscopic measurements.

For this observing run, we had scheduled the observations of several lines of two new species: HCOCN and CH_2D^+. The first one was studied by J.L. Destombes and his colleagues at the "Laboratoire de Spectroscopie Hertzienne" of the Lille University. We have a long-term collaboration with them, which has already succeeded in observing new species in the ISM, such as CCD (Combes et al., 1985), C_3HD (Gerin et al., 1987), Acetone (Combes et al., 1987), etc. The other one, CH_2D^+ (is a tracer of the important ion CH_3^+, which is one of the main reactants of the

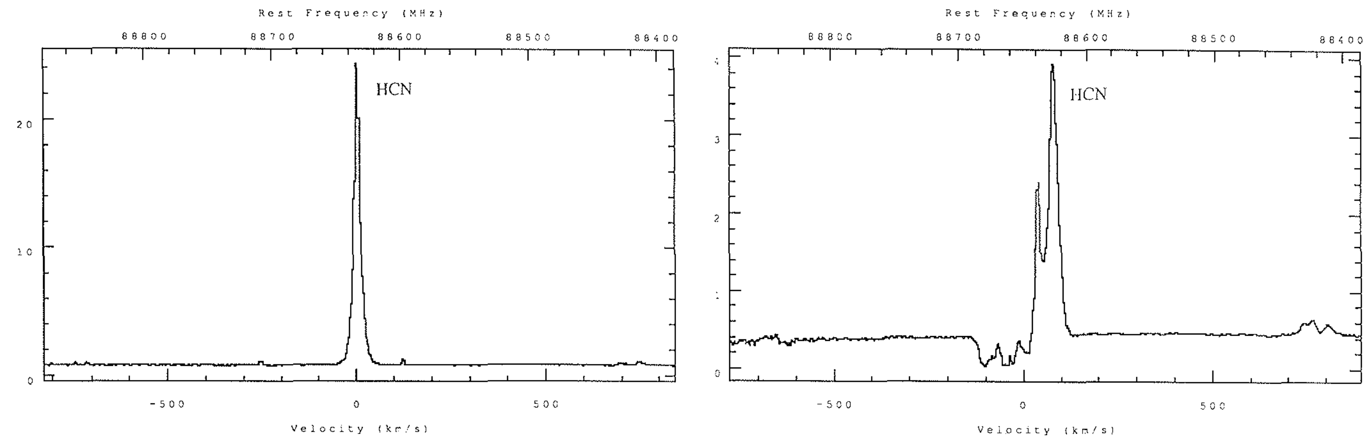

Figure 1: *Raw spectra taken towards IRc2 in Orion (a) and SgrB2(s) (b) with the SEST; central frequency 88631.8 GHz, the HCN (J = –0) line σ = 10 and 9 mK.*

chemical reactions forming complex hydrocarbons. Quantum mechanical calculations have been done by F. Pauzat (private communication), which gave the dipole moment (0.3 D) and the molecular constants with an accuracy of a few per cent. Spectroscopic work was then done at Lille, but did not succeed in detecting a line (the line is very faint and somewhat below the detection limit since the production of CH_2D^+ is very difficult, and the frequency range of the expected line quite large). To pursue their work, J. L. Destombes and his colleagues need better estimates of the molecular constants, which may be provided by infrared spectroscopy of the vibrational lines.

We decided to observe HCOCN and another molecule whose rotational constants were just measured by G. Wlodarczak at the "Laboratoire de Spectroscopie Hertzienne" of the Lille University (private communication), cyclopropenone c-C_3H_2O, the cyclic isomer of propynal which was recently detected by Irvine et al. (1988) in TMC1. These two molecules are asymmetric tops, with a dipole moment on the two principal axes A and B for HCOCN, and A only for c-C_3H_2O. We searched for several lines in the two molecular sources Orion-IRc2 and SgrB2(S).

2. The Observations

The observations were done from March 6 to 10, 1989, under clear sky conditions with the Swedish-ESO Submillimetre Telescope (SEST) at La Silla. It has been described by Booth et al. (1987). The antenna parameters at 2.6 mm are: HBPW = 43″, beam efficiency 0.78, aperture efficiency: 0.67, moon efficiency > 0.85. At the front-end, a dual polarization 80–115 GHz receiver with two cooled Schottky diode mixers was available, providing SSB noise temperature ranging from 280 K to 400 K. The side band rejection was always better than 10 dB, more often around 20 dB. At the back-end, we used a wide-band Acousto-Optic Spectrometer (AOS) with 2000 channels spaced by 690 kHz. The receiver temperature was measured by observing two loads at about 273 and 320 K. The results reported here are in units of T_A^*, the antenna temperature outside the atmosphere. Since the correction factor to get T_R^* (η_{fss}) is close to 1 and changes with frequency, we prefer to quote the result in the unit given by the chopper wheel method, T_A^*. The observed line intensities have been compared with existing frequency surveys of the same sources (Turner (1989), Cummins et al. (1986)) with similar angular resolution and are in reasonable agreement.

The spectra were saved on tape with FITS format, then read and converted to CLASS format read on the Vax computer at La Silla, and in Meudon. We used CLASS to correct the baselines, identify the line frequencies, fit gaussian profiles and do Hanning smoothing. Due to the line blending problem, the rms noise was difficult to estimate in the spectra (we have to find a frequency range without lines), but ranges from 8 to 40 mK depending on the time spent and the observing mode.

We observed two well-known molecular sources: the infrared source in the Orion Molecular Cloud IRc2 at α (1950) = 5h32m47.0s, δ (1950) = –5°24′22.0″, V_{LSR} = 9 km s^{-1}, and the southern H II region in the SgrB2 molecular cloud at α (1950) = 17h44m11.0s, δ (1950) = –28°22′30″, V_{LSR} = 60 km s^{-1}. For the first source, the reference was done switching the beam to a position 12′ from the source every 1 or 2 minutes. For the second, the emission is more extended than 12′, so we had to move the antenna to a reference position located 30′ north and 30′ west. This observing mode has two main disadvantages: (1) the antenna moves slowly, and the efficiency of the observations is lower than in the beam switch mode; (2) we had sometimes a very bad baseline with strong ripples extending through part or all of the frequency range. These ripples diminished or disappeared when the switch in position was done in azimuth instead of elevation and if the reference position was close to the observing position. However, at some frequencies the ripples were in every scan, so we chose to also observe this source in beam switch mode, since any emission in the reference position should anyhow be much weaker than in the "on" position. The absorption features on the strong HCN line at 88 GHz show the maximum level of contamination, since some are due to absorbing gas on the same line of sight, as shown by the comparison of this spectrum and that taken by Turner (1989) with the 12 m NRAO antenna with another reference position.

3. The Results

Figure 1 presents two of the spectra obtained with the SEST, and Figure 2 shows enlargements of some of them, after baseline subtraction and sometimes Hanning smoothing. For the spectra obtained towards IRc2 in Orion, the offset level is very stable from one scan to the other, and measures the continuum emission of the H II region in front of the molecular cloud. It should be accurate to about 0.1 K (about 10 %).

The line confusion limit is reached in most of the spectra as shown by the numerous faint features at the 10 mK level. The frequency of the expected lines is indicated by arrows; we sometimes observe a line at the right position, but not always! Therefore, we conclude

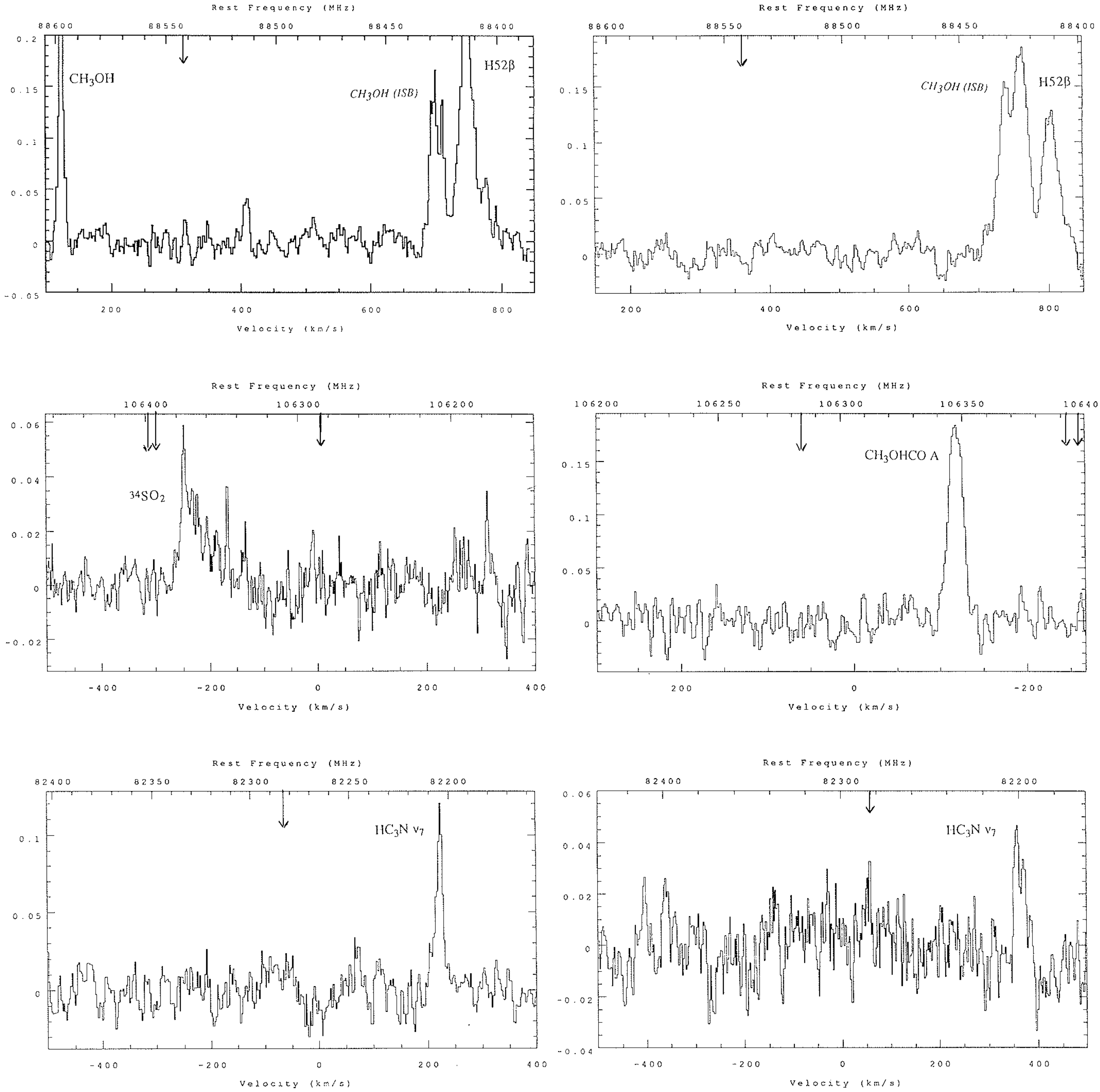

Figure 2: *Enlargements of some of the spectra. Expected line frequencies are shown by arrows.*

that neither HCOCN nor c-C_3H_2O were detected during this run. Taking the observed line intensities or a 3σ limit, we can construct for HCOCN a rotational diagram in the two sources. Typical rotational temperatures range from 50 to 200 K in Orion, and 10–30 K in SgrB2. This seems to be the case for both molecules. Assuming T_{ROT} = 100 K, $N(H_2) = 3\ 10^{23}\ cm^{-2}$ in Orion and T_{ROT} = 20 K, $N(H_2) = 10^{24}\ cm^{-2}$ in SgrB2(S) (Irvine et al., 1987), we obtain upper limits for the column density of HCOCN and its abundance relative to H_2: towards IRc2 in Orion N(HCOCN) $< 2\ 10^{13}\ cm^{-2}$ and [HCOCN] $< 7\ 10^{-11}$; towards SgrB2(S) N(HCOCN) $< 5\ 10^{13}\ cm^{-2}$, and [HCOCN] $< 5\ 10^{-11}$. These values are similar to or lower than the abundances of other complex molecules with four heavy atoms in SgrB2: HC_3N ($2\ 10^{-9}$), $HCOOCH_3$ ($2\ 10^{-9}$) (Irvine et al., 1987), acetone ($5\ 10^{-11}$, Combes et al., 1987), H_2C_3O ($4\ 10^{-11}$, Irvine et al., 1988).

A line might be present at the expected frequency of the $6_{(0,6)}$–$5_{(0,5)}$ transition of cyclopropenone near 82.3 GHz, but we detected nothing at the frequency of the $8_{(0,8)}$–$7_{(0,7)}$ transition near 107 GHz. If the line at 82.3 GHz is due to cyclopropenone, we can explain the non-detection at 107 GHz by excitation effects: due to the high dipole moment of 4.4 D, the rotational temperature of this species could be around 10 K, although the kinetic temperature is much larger in both sources. In this case, the upper energy level of the second line is too high to be populated at this temperature, explaining the non-detection. The other possibility is of course a chance coincidence with a transition of another species. More observations of other lines of cyclopropenone of low excitation (less than 15 K), and in other sources should be done before this question can be definitively settled.

These observations with the SEST have not added new species to the already long list of interstellar molecules, but have demonstrated that more work can be done with this instrument: the 3 mm mixers are very easy to tune at nearly any frequency between 80 and 115 GHz and are stable, permitting long integration times on the same position. In the beam switching mode, the baselines are very flat over the whole frequency range; this observing mode is the best to use in the line search. Finally the southern position of the La Silla observatory allows one to track these molecular sources 10 hours per day above 30° elevation. The elevation of SgrB2 rises to more than 80°, where we had to stop the tracking (this is the telescope limit), while from the northern hemisphere we can observe it only 4 hours per day at elevations between 20° and 28°!

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The Arc in Cl 0500-24

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In 1986, luminous arcs in two clusters of galaxies were detected; their highly elongated unusual morphology posed a problem to the nature of their origin. Whereas several interpretations have been suggested, it soon became clear that they may be the result of gravitational lensing of a background galaxy by the cluster. The gravitational lens hypothesis was confirmed for the arc in A 370 when its spectrum was measured; the redshift is about 0.724, i.e. roughly twice that of the cluster, which also is close to the ideal redshift for efficient lensing. The nature of the arc in Cl 2244 is less clear, but from the similarity of the morphology and colour of

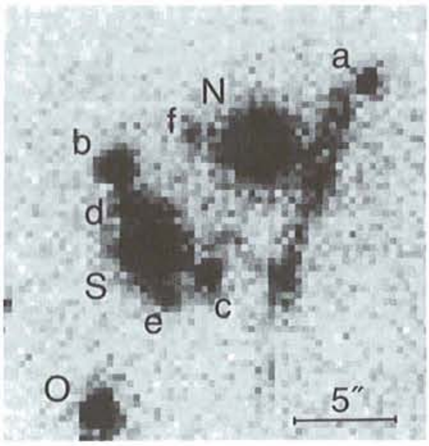

Figure 1: *A section of a CCD frame in the B-band showing the arc-like feature in Cl 0500-24 (exposure time: 56 min). North is up and east is to the left. On this image, taken with a seeing of 0.9 arcsec, the arc-like feature and galaxy N are well separated. Contrary to other arcs it appears nearly straight. However, its shape and the varying width can be well explained by a lens model. On the other hand, galaxies N and S have the same redshift. Thus we cannot exclude the hypothesis of tidal interaction.*

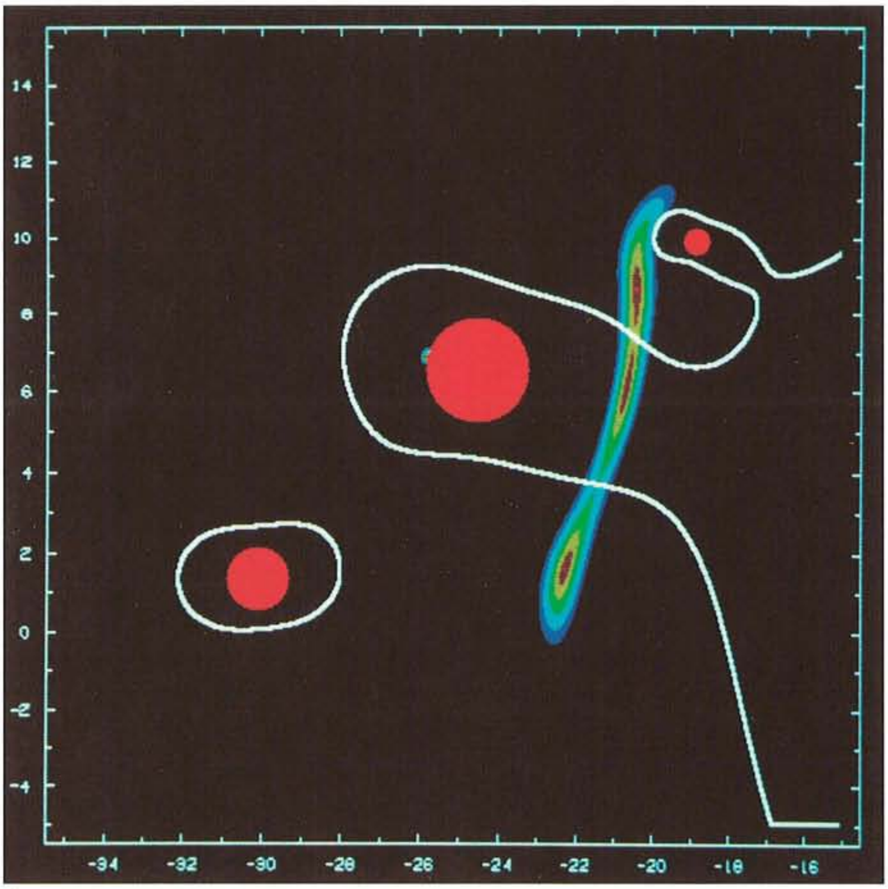

Figure 2: *A gravitational lens model of the observed arc in Figure 1. In this model we used an isothermal sphere for the cluster potential and three point masses for the three galaxies N, S, and a. We used a circular source of radius 0.6 arcsec. The different colours of the arc correspond to images of concentric rings of the extended circular source. The white lines are "critical lines" of the lens. The scale is in arcsec.*