# L134N REVISITED

**L. Pagani[1], J.R. Pardo-Carrion[2], and B. Stepnik[3]**

[1]DEMIRM & CNRS UMR 8540, Observatoire de Paris 61, Av. de l'Observatoire, 75014 PARIS, France
[2]CSIC-IEM, c/Serrano 113bis, 28006 Madrid, Spain
[3]IAS, Bât 120, Campus Universitaire, 91405 ORSAY Cedex, France

## Abstract

L134N (also known as L183) is a very cold, starless and nearby dark cloud which has attracted much attention from the astrochemists in the past. They have been using it as an oxygen-rich reference to test their models in parallel with TMC-1, the other, but carbon-rich, reference. However, our knowledge of the cloud temperature, structure, and various species abundances has relied for a long time largely on the work by Swade (1987a, 1987b) which suffers from low signal-to-noise $C^{18}O$ and CS maps and limited excitation analysis. This work has been recently repeated and improved by Dickens et al. (2000) but they still lack adequate surface coverage, higher rotational lines of important species and comparison with the dust. While FIRST will probably find many new species in this cloud, it is time to revisit completely this source in order to interpret correctly the FIRST results to come. We have thus made a complete survey of several transitions of CO, $^{13}CO$, $C^{18}O$, $C^{17}O$, CS, $C^{34}S$, SO and $^{34}SO$ species with the NRAO 12-m and CSO 10-m together with maps of the dust from ISO and SCUBA to assess the fundamental properties of this cloud. Preliminary results are reported here.

Key words: ISM: individual objects: L134N – ISM: abundances – ISM: molecules – dust, extinction –

## 1. Introduction

Modeling the chemistry of dense clouds has proven to be very difficult. The dense medium is intricate with many unknowns. First, we need to know the physical conditions of the cloud (shape and intensity of the ISRF around the object, local cosmic ray rate, presence of external near-by or internal heat sources, flows, shock waves etc.). We also need to know its proper density and temperature structures both for the gas and the dust as they seem to differ (as shown by Thoraval et al. 1997, 1999). We also know little about adsorption onto and desorption from grains, what is their exact role in the chemistry, and many reaction rates are unknown or ill-determined, and so on. The output of the chemical models needs to be compared to observations. Here the problem comes from the identification of species (many lines remain unidentified) and from their abundance measurement. Again the ignorance of the density and temperature structures is a major obstacle to this measurement if only we do have secure collisional cross-sections to evaluate the exact excitation temperature for each species, which is rarely true.

To partly simplify the problem, attention has been concentrated on a few starless clouds, especially L134N and TMC-1. L134N is considered as a rather oxygen-rich cloud (presence of SO, $SO_2$, $CH_3OH$,...) while TMC-1 is definitely carbon-rich ($CH_3CCH$, $HC_{2n+1}N$,...). Without embedded heating sources, the cloud temperature is in a rather narrow range, generally estimated to be 8 to 12 K, which has the advantage of limiting the role of the dust (no sublimation of species like $H_2O$), the number of possible gas-phase reactions and the range of excitation temperatures for molecules.

However, because the temperature is low, the first rotational levels of most if not all species are overpopulated making even rare species with a weak dipole moment like $C^{18}O$ optically thick. Another difficulty comes from the fact that a 2 K incertitude on the temperature makes a drastic change on density estimates (almost a factor of 2 in $H_2$ density when going from 10 to 8 K). The unknown 3-dimensional structure of the cloud and the high opacity of most species make the abundance determination a difficult task which should be handled with a lot of precautions.

In this study, we have limited ourselves to 3 main species, CO, CS and SO (including some rarer isotopes) but we have tried for each isotope to observe at least 2 transitions. We have also observed the first rotational transition of $N_2H^+$. The later is supposed to trace dense gas and be less sensitive to depletion onto grains than the first three. We have observed CO to map the whole cloud, identify weaker velocity components, estimate total column density of gas and search for possible depletion onto grains in the core. CS can be used to trace dense gas (if not too depleted) in the range $10^4$–$10^6$ $cm^{-3}$ (SO is also a very sensitive tracer in this range of densities but SO cross-collision coefficients are only crudely estimated at the moment) and time dependent chemical models predict that the CS/SO abundance ratio is a chemical clock (see e.g. Nilsson et al. 2000, Dickens et al. 2000). Finally, all isotope abundances can be estimated separately and isotopic ratios can be derived.

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Another important component of molecular clouds is dust. We need dust maps to independently estimate the total mass and thus derive C and O depletion. We also want to search for possible local molecular depletions, correlations with gas, dust properties variations and so on. To reach these goals, we have preliminary ISOPHOT 100 (uncalibrated) and 200 (calibrated) $\mu$m maps and we should be able to obtain a SCUBA 450/850 $\mu$m map soon, weather permitting.

## 2. PRELIMINARY RESULTS

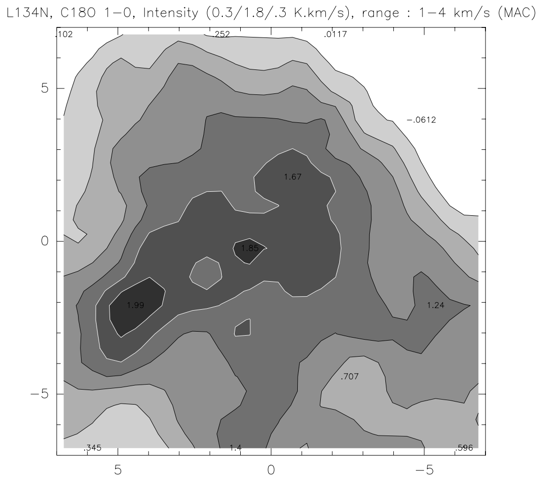

*Figure 1.* *$C^{18}O$ intensity map. Reference position is (J2000) $\alpha$ : 15h54m09s, $\delta$ : -2° 51'39". The strongest spot (4.5',-2.5') is also rather weak in the 2-1 line, leading to a very high column density in a single layer, LVG model.*

We present a series of pictures which illustrate a couple of interesting points under investigation. Fig. 1 shows the $C^{18}O$ 1-0 intensity map. The strongest spot of $C^{18}O$ is not towards the centre but 5' off eastward. It coincides with the strongest 200 $\mu$m dust spot (Fig. 2). However this spot seems to be due to a temperature increase rather than to a mass increase. Indeed, correlation between 100 and 200 $\mu$m maps (Fig. 3) shows the presence of two temperature components (one cold at 16 K [?] and one very cold, below 12 K, possibly 8 K [?] 100 $\mu$m data are not yet calibrated and mm data are uncertain) and subtraction of the cold (16 K) component makes this spot disappear (Fig. 4). On the other hand, $C^{18}O$ 2-1 emission is rather weak there (2-1/1-0 $\leq$ 0.5) and a simple LVG analysis would yield a very low density (600 $cm^{-3}$) and high column density (9 $10^{15}$ $cm^{-2}$) (Fig. 5). The status of this spot is not yet clear but one wonders whether this could be the sign of the very first step of a pre-protostellar core formation. If we ignore the few points with such a low 2-1/1-0 ratio, we see that $C^{18}O$ column density correlates very well with the extra-cold (between 8K and 12 K ?) dust component total column density (Fig. 5). We do not see $C^{18}O$ depletion. However, depletion occurs only in the densest spots of gas ($n(H_2) \geq 10^6$ $cm^{-3}$ ?) in which case, the effect might be masked by front, optically thick gas or its differential effect might be simply too weak compared to the large amount of gas along the line of sight. In this cloud, $C^{18}O$ 2-1/1-0 ratio indicates that almost everywhere the $C^{18}O$ 1-0 transition has an opacity between 0.75 and 2, while the 2-1 transition opacity is greater than 1 in most of the cloud. The depletion phenomenum might be best seen with an even rarer isotope, $C^{17}O$. Indeed, $C^{17}O$ intensity map seems to show a shallow weakening towards the two 200 $\mu$m peaks (Fig. 6).

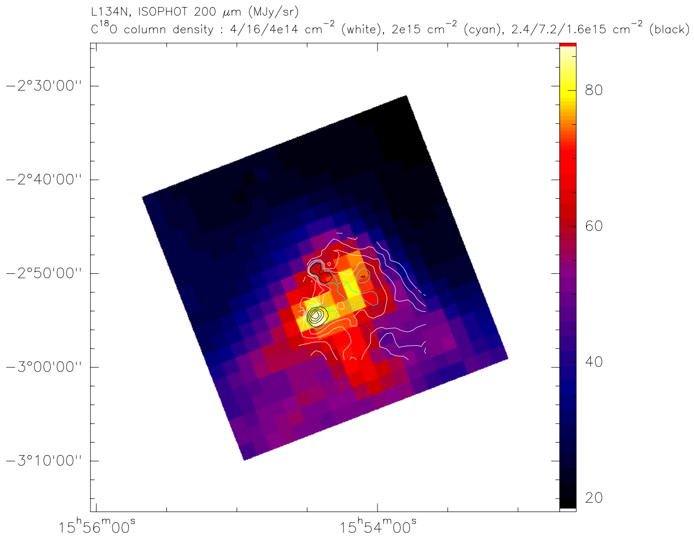

*Figure 2.* *$C^{18}O$ column density superimposed on ISOPHOT 200 $\mu$m image. Strong $C^{18}O$ column density spots at 15h54m30s (both), -2° 48' (twin spots) and -2° 54' (dust spot) are due to very low 2-1/1-0 ratio. They might be overestimated. The strongest spot could represent the very early pre-protostellar phase ?*

Another unexpected result is the $C^{18}O/C^{17}O$ ratio (Figs. 7 and 8). Neither the intensity ratio (which is not a good indicator of the abundance ratio when the isotopes are not thermalized and/or optically thick) nor the column density ratio (which suffers from interpretation. LVG is admittedly crude) can be reconciled with the standard, seemingly universal ratio of 3.65 in our galaxy (Wilson et al. 1981, Penzias 1981) for more than half of the points observed (135 points in total). The ratio seems to run from 2 to 10 (even 20 if we use the simple LVG model with our low 2-1/1-0 values).

Finally, Fig. 9 reveals the presence of a dip in what should be an optically thin line ($C^{34}S$ 2-1). This dip is seen in several weak lines with high spectral resolution and signal to noise ratio, (SO, $^{34}SO$,...). Is it due to self absorption of very cold gas in front of the core or to the presence of two components in the core ?

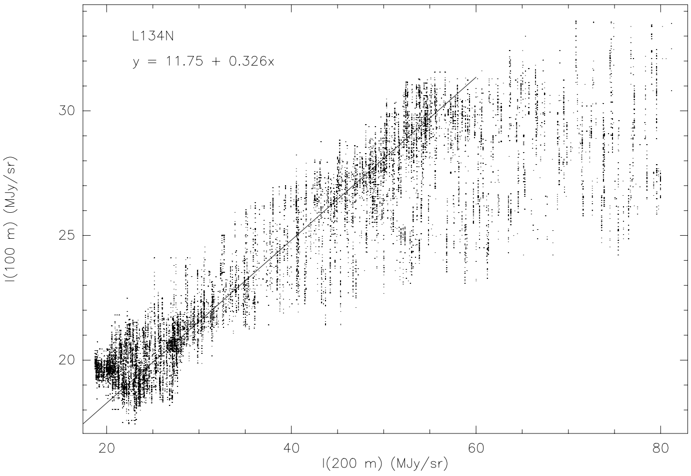

*Figure 3. ISOPHOT 100 μm – ISOPHOT 200 μm correlation. The 100 μm data are not calibrated. The large number of points is due to oversampling only. The plot is suggestive of 2 components, one cold (the slope would be emission at 16 K [β = 1.5] under provisional calibration) and one very cold (200 μm excess on the right, somewhere between 8 and 12 K ?). We use this slope to subtract the cold component from the 200 μm map.*

Preliminary analysis of both CS and SO $^{32}S/^{34}S$ ratio points towards a very high ratio value. First estimates yield $^{32}S/^{34}S \approx 10$ instead of the terrestrial value of 22.

## 3. CONCLUSION

Exciting preliminary results emerge from this study which will hopefully demonstrate the need for multi-line multi-transition studies of dark clouds to retrieve more secured species abundances. The benefit of such a study to interpret ODIN and FIRST data should be large.

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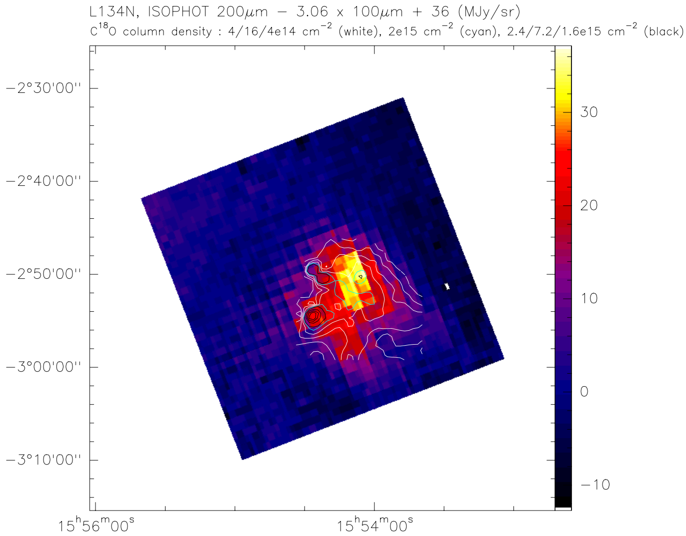

*Figure 4. $C^{18}O$ column density superimposed on very cold dust map (ISOPHOT 200 μm - ISOPHOT 100 μm scaled) image. The $C^{18}O$ column density strong spot at 15h54m30s -2° 54' does not coincide with large amounts of very cold dust.*

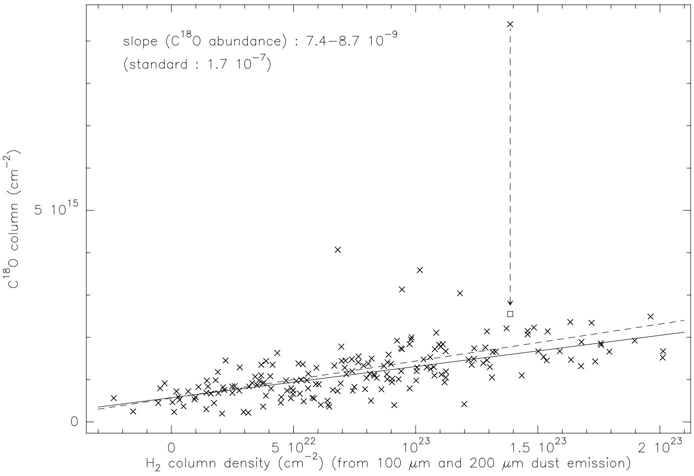

*Figure 5. $C^{18}O$ column density versus total gas column density derived from the very cold dust map (ISOPHOT 200 μm - ISOPHOT 100 μm scaled). The total gas column density is derived with a dust temperature of 8 K. Though this value is coherent with measurements at 1300 and 850 μm (Ward-Thompson et al. 1994, 1999), it might be too low and thus would lead to an overestimate of the total amount of material. However, we do not see $C^{18}O$ depletion on the grains. The five points above the main slope are those with a low 2-1/1-0 $C^{18}O$ ratio. If we ignore the 2-1 emission, even the highest point drops close to the others (arrow)*

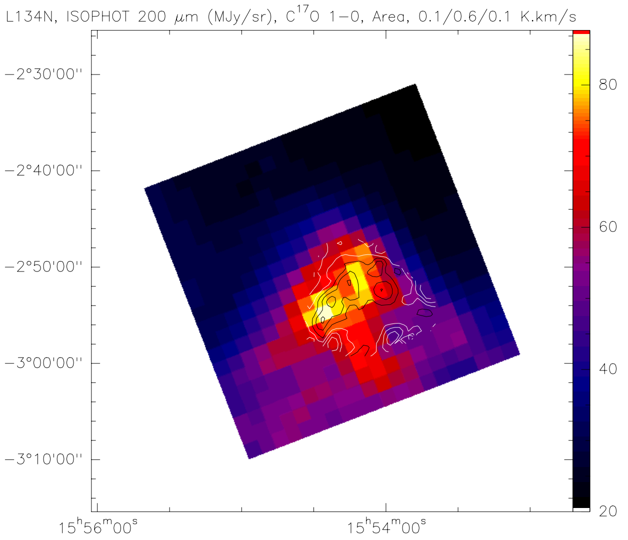

*Figure 6.* $C^{17}O$ *intensity superimposed on ISOPHOT 200 μm image. Locally weaker signal towards the two dust hot spots may be a trace of possible depletion*

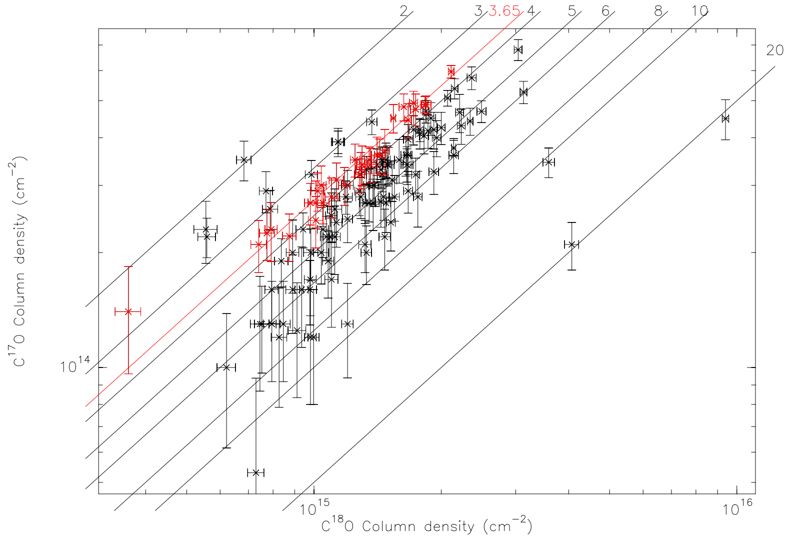

*Figure 8.* $C^{17}O$ *column density versus* $C^{18}O$ *column density. Error bars are 1 σ intensity error bars directly applied to column density estimates (just to give an idea). In red, all values compatible with a ratio of 3.65 within 1 σ. Compared to fig 6, the bulk of the values are shifted towards higher ratios because* $C^{18}O$ *being more optically thick than* $C^{17}O$*, its correction is larger.*

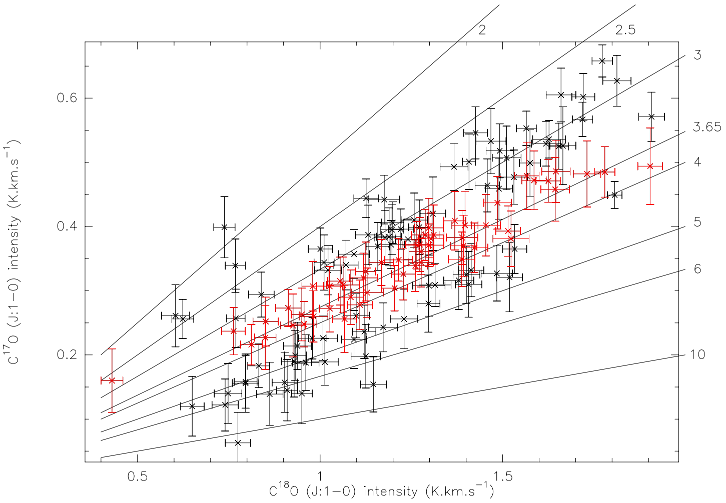

*Figure 7.* $C^{17}O$ *intensity versus* $C^{18}O$ *intensity. Error bars are 1 σ amplitude. Points in red are those compatible with the 3.65 ratio within 1 σ. In principle, points below the 3.65 ratio (in value) could represent optically thick* $C^{18}O$ *emission but it is in contradiction with LVG opacity estimates in most cases. On the other hand, half of the points above 3.65 are not compatible with this value and can be explained only with a higher* $C^{18}O/C^{17}O$ *ratio*

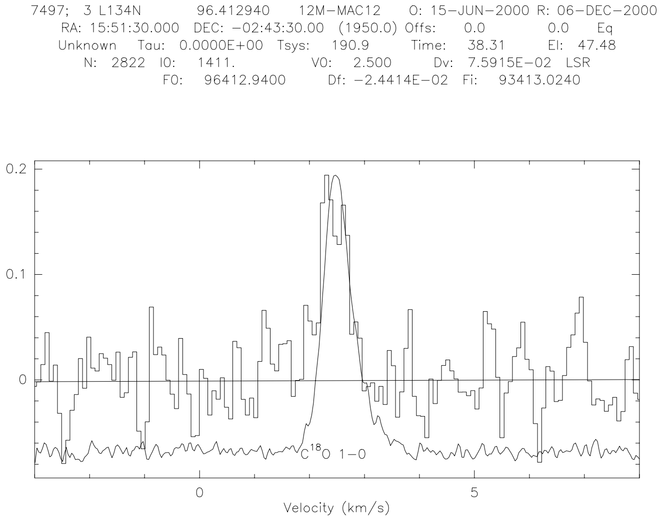

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*Figure 9.* $C^{34}S$ *2-1 line (reference position) and* $C^{18}O$ *1-0 line.* $C^{34}S$ *shows a dip at the peak* $C^{18}O$ *velocity. It is not yet clear whether this is linked to self-absorption close to the core of the cloud or the appearance of 2 components.*