# INTERPRETATION OF LOW J $^{12}$CO AND $^{13}$CO OBSERVATIONS OF ORION A BY MEANS OF AN ONION SHELL RADIATIVE TRANSFER MODEL

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$^{12}$CO and $^{13}$CO $J = 1 \rightarrow 0$ and $J = 2 \rightarrow 1$ observations of a $1\,\mathrm{deg} \times 2\,\mathrm{deg}$ region centered on the BN/KL nebula in Orion A showed almost everywhere surprising intensity ratios. According to the standard interpretation of CO lines the $^{13}$CO $T_A(2 \rightarrow 1)/T_A(1 \rightarrow 0)$ ratio meant optically thick and thermalized $^{13}$CO emission whereas at the same positions the $^{12}$CO/$^{13}$CO intensity ratios indicated optically thin $^{13}$CO (Castets et al. 1989). Castets et al. (1990) suggested that temperature gradients in the observed clumps caused by external UV heating could be responsible for these results.

Using an Onion shell radiative transfer model (Gierens 1990) we show that the apparently contradictory intensity ratios can be reproduced over a large range in average density and column density. A temperature gradient is not sufficient to explain the intensity ratios, we must take into account also the density profile and the abundance gradients in the clumps. The radial dependences of kinetic temperature and abundance are taken from the models of photodissociation regions by Tielens and Hollenbach (1985). A $n \propto r^{-3/2}$ density law is applied according to the results of starcounts (Cernicharo, Bachiller, Duvert 1985) and hot edged polytropic models (Dickman and Clemens 1983).

We find the following structure of the Orion A clumps : A cold core ($T_{kin} \leq 15$ K, $R \approx 0.3$ pc) is surrounded by a photodissociation region (PDR). The $^{12}$CO $J = 1 \rightarrow 0$ line emerges mainly from a layer at the inner edge of the PDR where the kinetic temperature begins to raise. A typical temperature in this layer is 30 K. The density is high enough to keep the transition thermalized. The $J = 2 \rightarrow 1$ line emerges farther out in the clump (because of the higher opacity). This transition is not thermalized there but its excitation temperature is also around 30 K in the PDR and does not change very much with radius. So the $^{12}$CO $T_A(2 \rightarrow 1)/T_A(1 \rightarrow 0)$ ratio is approximately one.

The main contribution to the $^{13}$CO lines comes from the cold isothermal clump cores, where both transitions are thermalized. This explains the two other intensity ratios, namely $^{13}$CO $T_A(2 \rightarrow 1)/T_A(1 \rightarrow 0) \approx 1$ and $^{12}$CO/$^{13}$CO$\approx 3$.



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We derive as typical clump properties (including the PDR) :

(1) average density 500 - 3000 $cm^{-3}$ (this is twice the density at the edge of a clump),
(2) $H_2$ column density $5 \cdot 10^{20}$ - $10^{22}$ $cm^{-2}$,
(3) core kinetic temperatures less than 15 K,
(4) radii 0.25 - 1.5 pc,
(5) masses 10 - 1000 solar masses.

These values agree well with those given by Bally et al. (1987) for some typical clumps in Orion A.

## References

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