CO depletion in ATLASGAL-selected high-mass clumps

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Abstract

In the low-mass regime, it is found that the gas-phase abundances of C-bearing molecules in cold starless cores rapidly decrease with increasing density, as the molecules form mantles on the grains. We study CO depletion in 102 massive clumps selected from the ATLASGAL 870 μm survey, and investigate its correlation with evolutionary stage and with the depletion of CO in massive clumps behaves as in the low-mass regime, with less evolved clumps showing larger values for the depletion than their more evolved counterparts, and increasing for denser sources.

1 - Introduction

A significant decrease in molecular abundance (referred to as depletion) is commonly observed for molecules such as CO and C3 in the cores of starless cores (1). CO depletion is a temperature- and density-sensitive process at low temperatures and high densities where higher, because under those conditions it is easier for the molecules to freeze out onto the grains. When protostars are formed, the temperature rises and the molecules evaporate back into the gas phase, and the abundance returns to canonical levels. The degree of depletion can thus be used as an indicator of evolution. Very few studies address the variation with time CO depletion in massive clumps (2), and claims exist both of significant CO depletion (3) and of canonical abundances (4).

In this work we investigate the CO abundance in a large sample of massive clumps, selected from ATLASGAL.

2 - Observations and TOP100 Sample

Sources survey (7); (DB) the 23 brightest objects dark at 6 pc and the brightness sources dark at 24 microns. As shown in Fig. 1, all clumps selected in this way have the property of forming high-mass stars.

We observe CO(I)–(2) in all sources (APEX/FLASH, 12CO and 13CO) for the inner Galaxy, in agreement with previous works. The radius of the depleted region is of the order of a few tenths of a pc. The masses of massive sources. If the derived mass is indeed unstable. Depletion of CO may play a role in recent and more massive objects are better represented by a centrally heated cloud with only moderate depletion. On the other hand, IR-dark sources are consistent with cold, isothermal clumps, but need a larger f0 to reproduce the line fluxes. A more detailed study is carried out for some individual sources in the sample. (IRB (e.g. Fig. 4 left) and RMS and DB and D24 (e.g. Fig. 4 right) show different f0, between T = 3 and 3 – 15, respectively.

A different approach is to use a drop probability for the CO abundance. In this case we find that CO is depleted in the central regions, for densities above a critical threshold of 10 cm^-3 (cf. Fig. 5). The critical density is derived with the previous simple estimate. The radius of the depleted region is of the order of a few tenths of a pc. The masses are up to five times larger for this kind of model, than in the previous ones.

5 - Depletion Radius and Critical Density

Comparing the depletion lifetime of massive starless clumps with τdep, we derive the estimate the size Rdep of the central depletion region. We find Rdep is ∼ 0.1 pc for M/⊙ > 550 M/⊙ and an age of 10^7 yr. This radius increases for larger masses.

Assuming τdep = t, we derive an expression for the critical density n0(CO) above which all CO is depleted. We find n0(CO) depends only on the temperature T and on the mean grain cross section per H atom (τg):

n_CO = (8 x 10^-19) T^0.5 (n_H/10^21 cm^-2) (1/2) 1/cm^-2.

where ν_CO is the thermal velocity for CO and B is the sticking probability. The value for n0(CO) (= 0.5n_H) in a fully molecular envelope in good agreement with studies of low-mass starless cores (8).

6 - RATRAN Models

The previous analysis assumes that molecules are in LTE. We used RATRAN to build one-dimensional models of the clumps for typical parameters of the sample. The more evolved sources are much better represented by a centrally heated cloud with only moderate depletion. On the other hand, IR-dark sources are consistent with cold, isothermal clumps, but need a larger f0 to reproduce the line fluxes. A more detailed study is carried out for some individual sources in the sample. (IRB (e.g. Fig. 4 left) and RMS and DB and D24 (e.g. Fig. 4 right) show different f0, between T = 3 and 3 – 15, respectively.

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7 - Gravitational Stability

Unlike objects in IRB and RMS, the most massive sources in groups DB and D24 appear to be unstable. Depletion of CO may play a role in this. As CO depletion is confirmed and M is overestimated. This may be the cause of the difference between dark and bright sources. Magnetic fields of the order of a μG would be needed to halt the collapse for the most massive sources. If the derived mass is indeed overestimated by up to a factor of 5, a smaller magnetic field is needed to stabilise the clumps, and the magnetic and turbulent energy density are then approximately of the same order of magnitude even for the most unstable sources.

8 - Conclusions

In this work we investigated the CO depletion in massive clumps, and found it to decrease from starless objects to those where massive stars are already formed, and to increase in denser sources. We could estimate the radius of depletion. CO depletion is depleted to be a few tenths of a pc and the critical density above which all CO is depleted is depleted to be 10^-17 cm^-3. We find that CO depletion may lead one to significantly overestimate the masses. Finally, we derived the [12C] and [13C] for the inner Galaxy, in agreement with previous work.

References