CO Isotope Chemistry in GMC Simulations: Impact of the $^{12}CO/^{13}CO$ Ratio on Column Density Estimates

László Szűcs and Simon C. O. Glover

Universität Heidelberg, Zentrum für Astronomie, Institut für Theoretische Astrophysik

Introduction

Carbon monoxide and its isotopes are used as a tracer of column density in studies of the interstellar medium. The most abundant CO isotope, ^{12}CO, is usually optically thick in intermediate density regions and so provides a lower limit for the column density and total mass. In these regions, less abundant isotopes are used, such as ^{13}CO. To relate observations of ^{13}CO to the ^{12}CO column density, a constant $^{12}CO/^{13}CO$ ratio is often adopted. In numerical studies the constant ratio is also used to infer ^{13}CO abundances when only ^{12}CO chemistry is included due to the high computational expense of additional species. In this work, we examine the impact of two effects – **selective photodissociation** of ^{13}CO and **chemical fractionation** – on the isotopic ratio, with the aid of numerical simulations.

Questions to Answer:

1) Can we infer ^{13}CO column densities and emission from simulations which only include ^{12}CO chemistry?
2) How much CO mass do we miss if we use a constant isotopic ratio when interpreting observations?

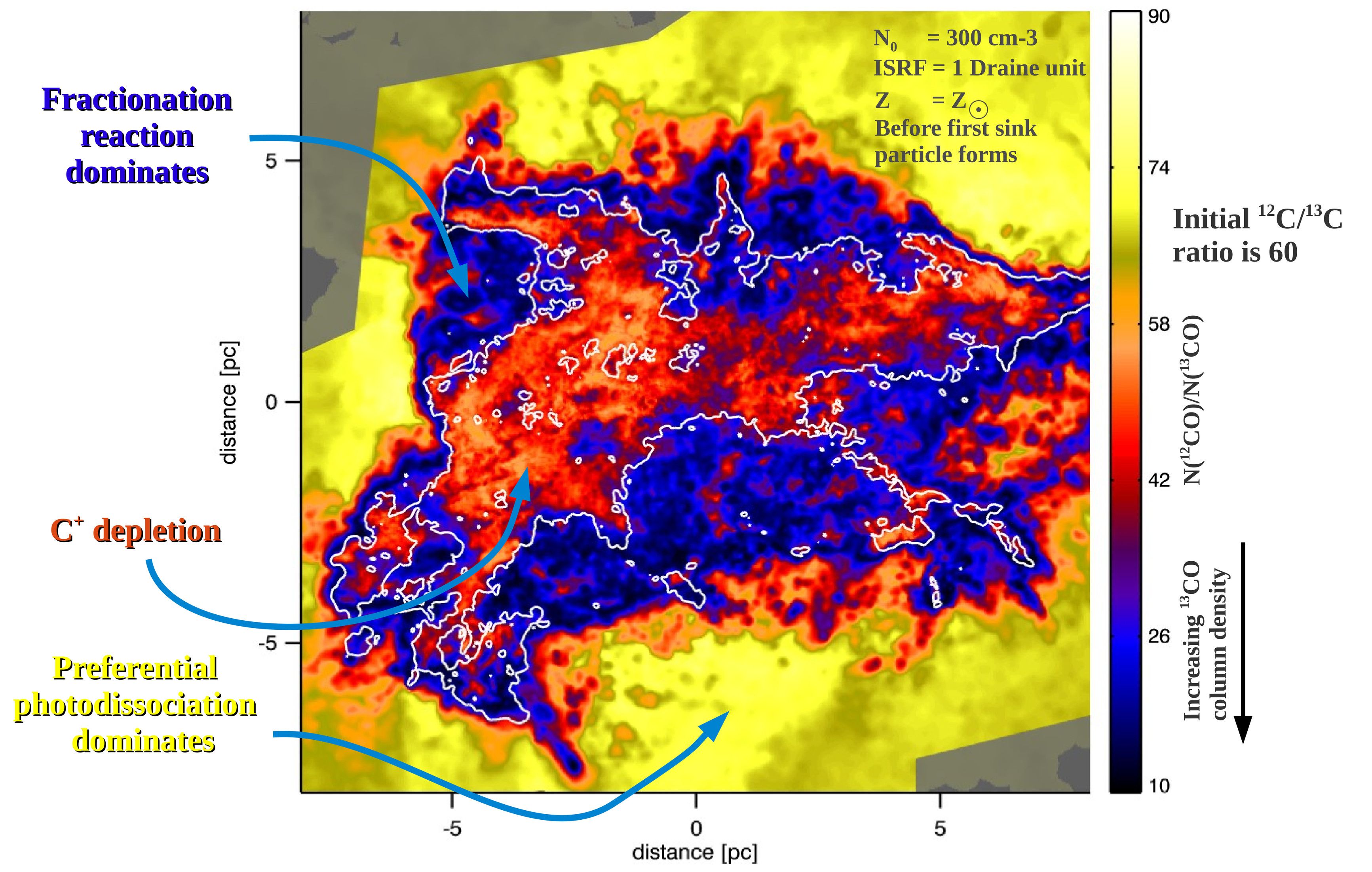
Methods:

- ✗ GADGET-2 (Springel 2005) SPH (Lagrangian) hydrodynamics code with self-gravity
- ✗ TreeCol (Clark et al. 2012) to calculate the attenuation of the interstellar radiation field due to dust grains, H_2, ^{12}CO and ^{13}CO.
- ✗ Nelson & Langer (1999) chemical network with multiple CO formation pathways. Coppied ^{12}CO creation and destruction pathways for ^{13}CO
- ✗ Fractionation reaction added: $^{13}C^+ + {}^{12}CO \Leftrightarrow {}^{12}C^+ + {}^{13}CO + \Delta E$
- ✗ Line radiative transfer post processing with RADMC3D (Dullemond) in ^{12}CO and ^{13}CO J = 1→0 transition

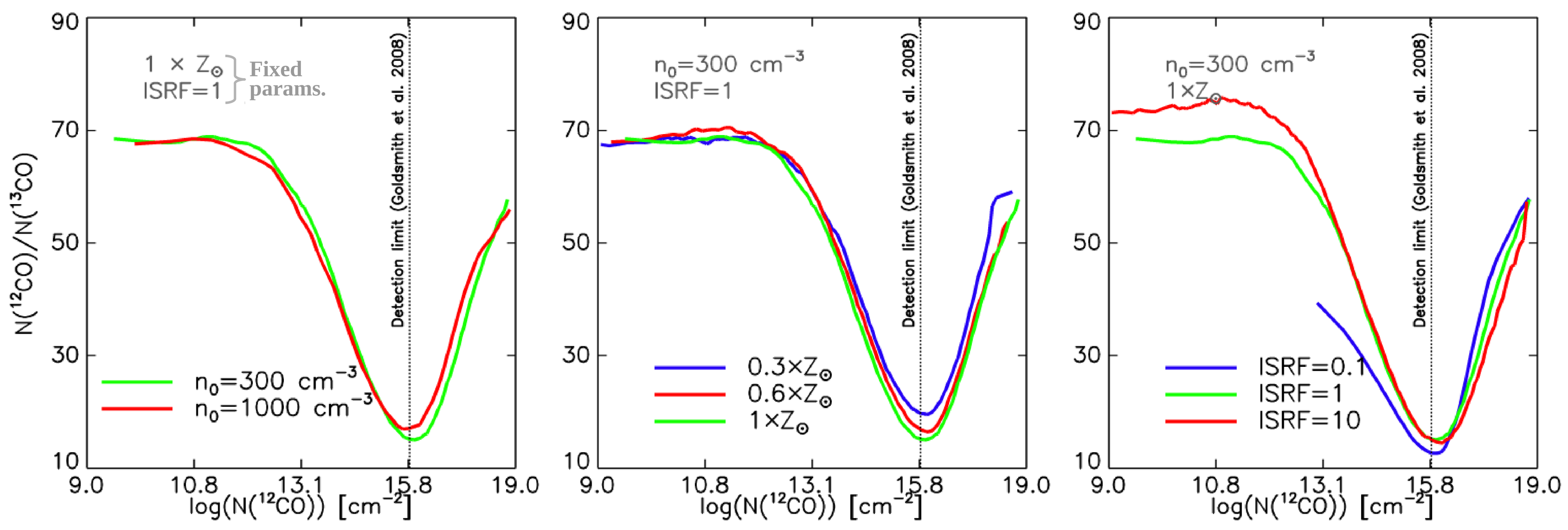
Initial Conditions:

- ✗ $10^4\ M_\odot$ fully molecular cloud, 0.5 $M_\odot$ mass resolution
- ✗ Initial density 300 or 1000 particle per cm^3
- ✗ 0.3, 0.6 and 1 × $Z_\odot$
- ✗ 0.1, 1, 10 × Draine unit for the ambient radiation field
- ✗ Decaying turbulence with a power spectrum of $P(k) \propto k^{-4}$
- ✗ $^{12}C/^{13}C$ ratio of 60

The $N(^{12}CO)/N(^{13}CO)$ Ratio

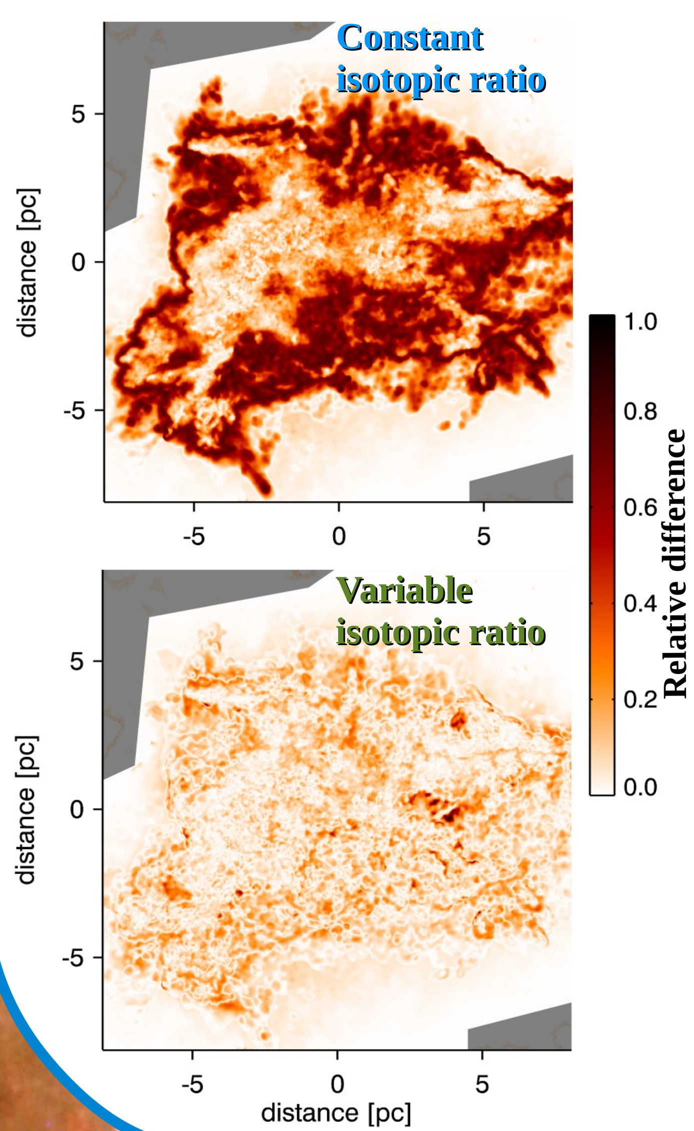


At the outer parts of the domain, where total column densities are low, thus the shielding is ineffective – but CO is not fully destroyed – the preferential photodissociation dominates, increasing the ratio (**yellow**). Further in, where the column densities are high enough for both isotopic species, the fractionation reaction takes over and decreases the ratio (**blue**). At the core of the cloud the ISRF is attenuated to high extent and thus it can not ionize carbon atoms, the fractionation reaction stops. The ratio increases again to the initially set ratio of ^{12}C and ^{13}C (**orange**).



The isotopic ratio does not show a clear correlation with the volume density. The ^{12}CO column density, however, correlates well with the column density ratio of the isotopic species (see **figure above**). The correlation does not change significantly over wide parameter ranges, but shows mild trends: high n_0 and low $Z_\odot$ result in shallower dips, while ISRF tilts the curve. Note that the total column density, into which a given ^{12}CO column density translates, changes in wide range depending on $Z_\odot$ and the ISRF.

Emission Maps:



We calculated the ^{13}CO emission, assuming different number densities: self-consistently calculated, constant scaled (1/60) and variable scaled ^{12}CO number density. For the later in each line of sights the ratio is calculated using the correlation of the isotopic ratio and ^{12}CO column density.

The **figures to the left** show the relative difference of emission when the later two are compared to the self consistent case. When using constant scaling the average relative difference is 21.4%, while in case of the variable scaling it is 5.3%. The estimated total ^{13}CO mass with the standard method (Wilson et al. 2009) is 0.127 $M_\odot$ for the self consistent emission map, 0.098 $M_\odot$ (77%) for constant scaling, and 0.125 $M_\odot$ (98.4%) for variable scaling.

Conclusions:

- ✗ The $^{12}CO/^{13}CO$ ratio changes within a factor of ~4 on the spatial scale
- ✗ The ratio correlates with $N(^{12}CO)$. The correlation depends weakly on cloud parameters
- ✗ With the correlation ^{13}CO emission could be better infered from simulations including only ^{12}CO chemistry

Work in Progress:

- ✗ Dependence on the fractionation reaction and photodissociation rates?
- ✗ Are there morphological differences of emission maps when using constant and self-consistent scaling?
- ✗ Implementation of iterative method to improve observational mass estimates

The Author

If you have any questions or comments, then please feel free to ask me here or send an e-mail to:

szucsl@uni-heidelberg.de

Background: Large Magellanic Cloud, Herschel HERITAGE key program and Spitzer SAGE