Carbon isotope chemistry in intermediate and high-mass star-forming cores

The impact of cosmic rays

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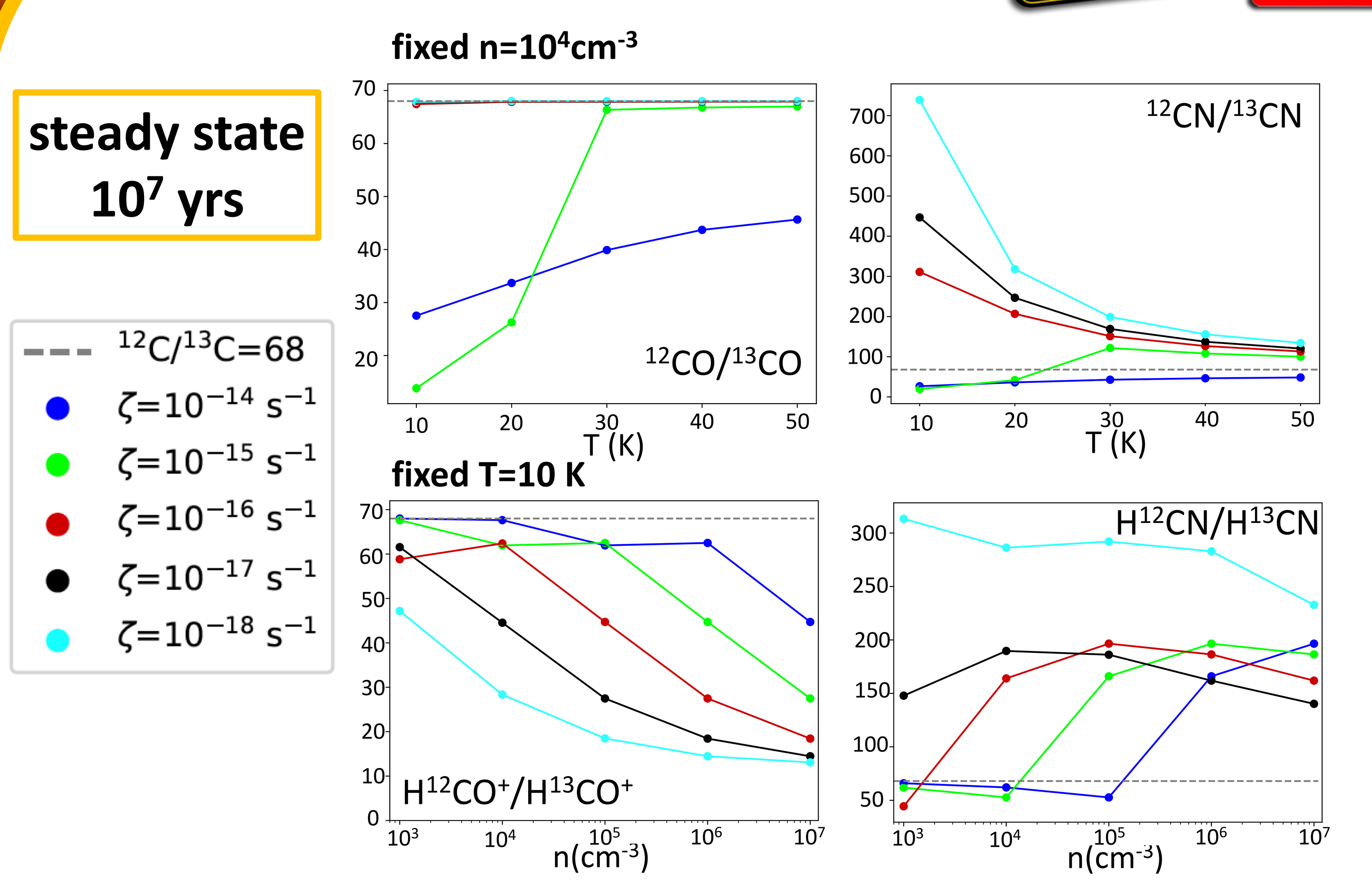
Context: The **isotopic abundance ratio** is considered a good **indicator of stellar nucleosynthesis**, since different isotopes of the same element are not originated in the same way. For example, the $^{12}C/^{13}C$ isotope ratio reflects the relative degree of primary to secondary processing in stars. Several studies have been conducted toward molecular clouds throughout the Galaxy (e.g. Langer & Penzias, 1990, Milam et al., 2005), comparing line intensities of the ^{12}C and ^{13}C isotopomers of molecules such as CO, CN and HCO^+. However, possible **effects of chemical fractionation** may also affect these ratios. Moreover, the **$^{12}C/^{13}C$ ratio** is also very important for **constraining the $^{14}N/^{15}N$ isotopic ratio**, which is usually derived from observations of the ^{13}C-isotopologues.

The model: In this work we use the chemical model program **«pyRate»** (Sipilä et al., 2015a, b), which calculates the rates of **chemical reactions** in the **gas-phase and on grain-surfaces**, linked by adsorption and thermal and non-thermal desorption. For the present work we have developed a new model for carbon isotope chemistry in the ISM, and **this poster** presents the **effect of cosmic rays on the $^{12}C/^{13}C$ abundance ratio in different star-forming regions in a gas-phase model** (Colzi et al., in prep).

WORK IN PROGRESS

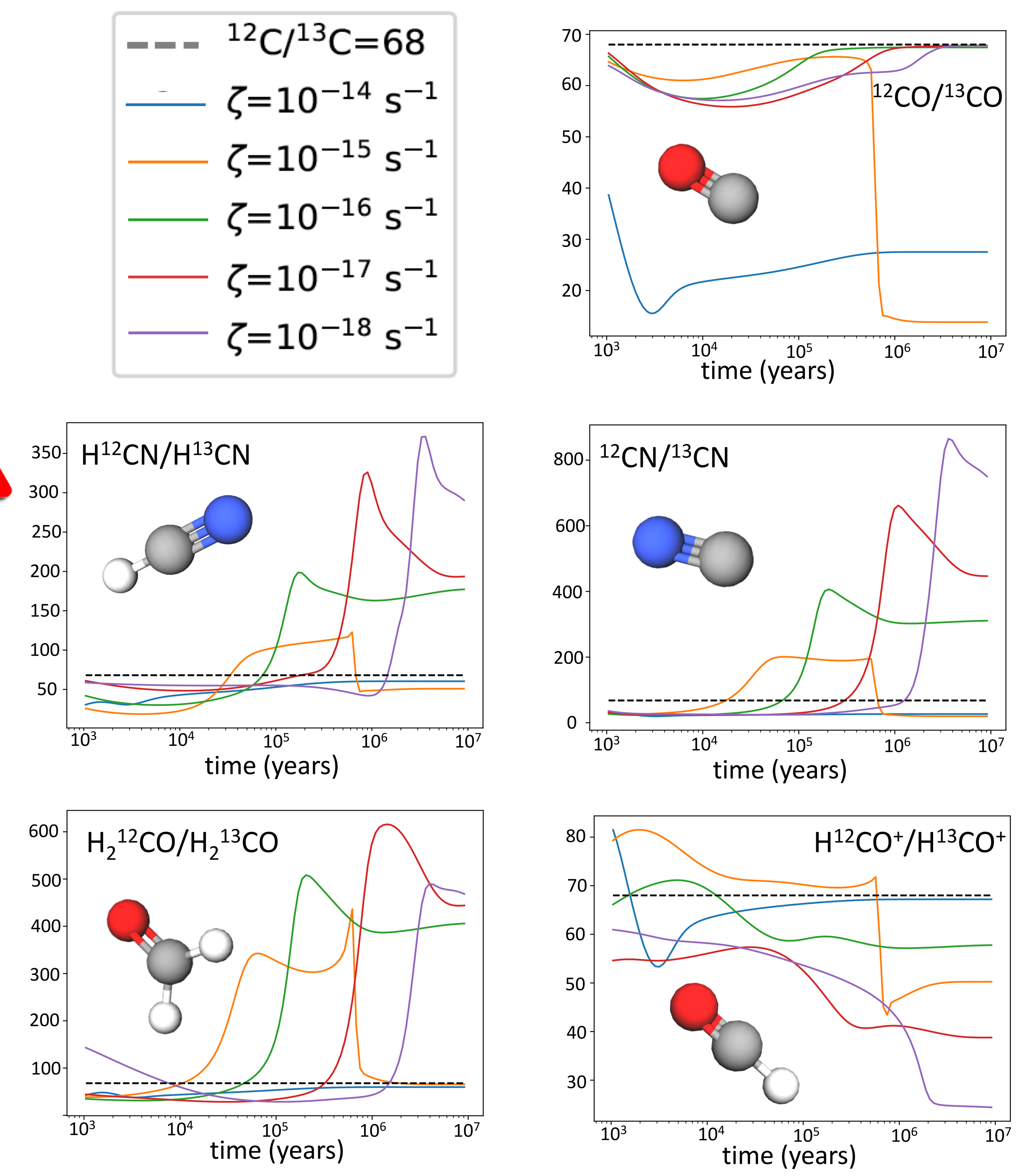
$^{12}C/^{13}C$ vs T and n



Upper panels: $^{12}C/^{13}C$ abundance ratio, for CO and CN, as a function of temperature for steady state, fixing the density to 2×10^4 cm^{-3}. *Lower panels*: $^{12}C/^{13}C$ abundance ratio, for HCO^+ and HCN, as a function of density for steady state, fixing the temperature to 10 K.

$^{12}C/^{13}C$ vs time

T=10 K
n=$2 \times 10^4 cm^{-3}$



$^{12}C/^{13}C$ abundance ratios, for different molecules, are shown as a function of time, varying the cosmic-ray ionisation rate (**ζ**). In these models we have fixed the temperature (T) to 10 K and the volume hydrogen density (n) to 2×10^4 cm^{-3}.

! **Note** that our models do not take into account the heating and cooling terms: **the heating due to cosmic rays is ignored** for high **ζ** ($\geq 10^{-16} s^{-1}$). Moreover, the effect that we found at high **ζ** would be less highlighted with the introduction of adsorption and neutralization of molecules on grains.

Conclusions

(1) if the physical conditions of the observed region are known, observations of the $^{12}C/^{13}C$ isotopic ratio in various species could be used to infer the cosmic-ray ionisation rate;

(2) large variations in the $^{12}C/^{13}C$ ratios are apparent even for standard ζ values, in agreement with Roueff et al. (2015), so that this study will be crucial to refine other fractionation ratios, in particular the $^{14}N/^{15}N$ ratio.

References: Langer & Penzias 1990, ApJ, 357, 477; Milam et al., 2005, ApJ, 634, 1126; Roueff et al., 2015, A&A, 576, 99; Sipilä et al., 2015a, A&A, 578, A55; Sipilä et al., 2015b, A&A, 581, A122

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