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H_2 FORMATION : EFFECT OF DUST GRAIN TEMPERATURE FLUCTUATIONS

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PROBLEM

H_2 **formation** in the interstellar medium occurs through **surface reaction on dust grains**.

The standard mechanism involving physisorption of H atoms and random hopping across the surface (Langmuir-Hinshelwood mechanism) is **only efficient at low dust temperatures**. But **PDR observations** have found **efficient formation despite hot grains** [1].

Several explanations have been proposed: stronger binding energies (surface roughness) [2], **Eley-Rideal mechanism** on chemisorption sites [3],...

However, **small grains** in strongly illuminated environments (PDRs) **exhibit strong temperature fluctuations**. These **stochastic excursions in the high temperature regime** affect the formation rate in a way that is **not equivalent** to a calculation at the **mean temperature**.

The work presented here computes this effect on the Eley-Rideal formation rate.

METHOD

We aim to compute the **adsorbed H atom population fluctuations coupled to the grain temperature fluctuations**. This will then allow us to compute the formation rate.

We use a **master equation approach**, but instead of solving the main master equation in two variables (T_{grain} and n_{ads}), we take advantage of a simplification.

As the **temperature fluctuations** are governed by **only photon interactions**, they obey a **reduced master equation** for the PDF in only one variable, $f_T(T)$.

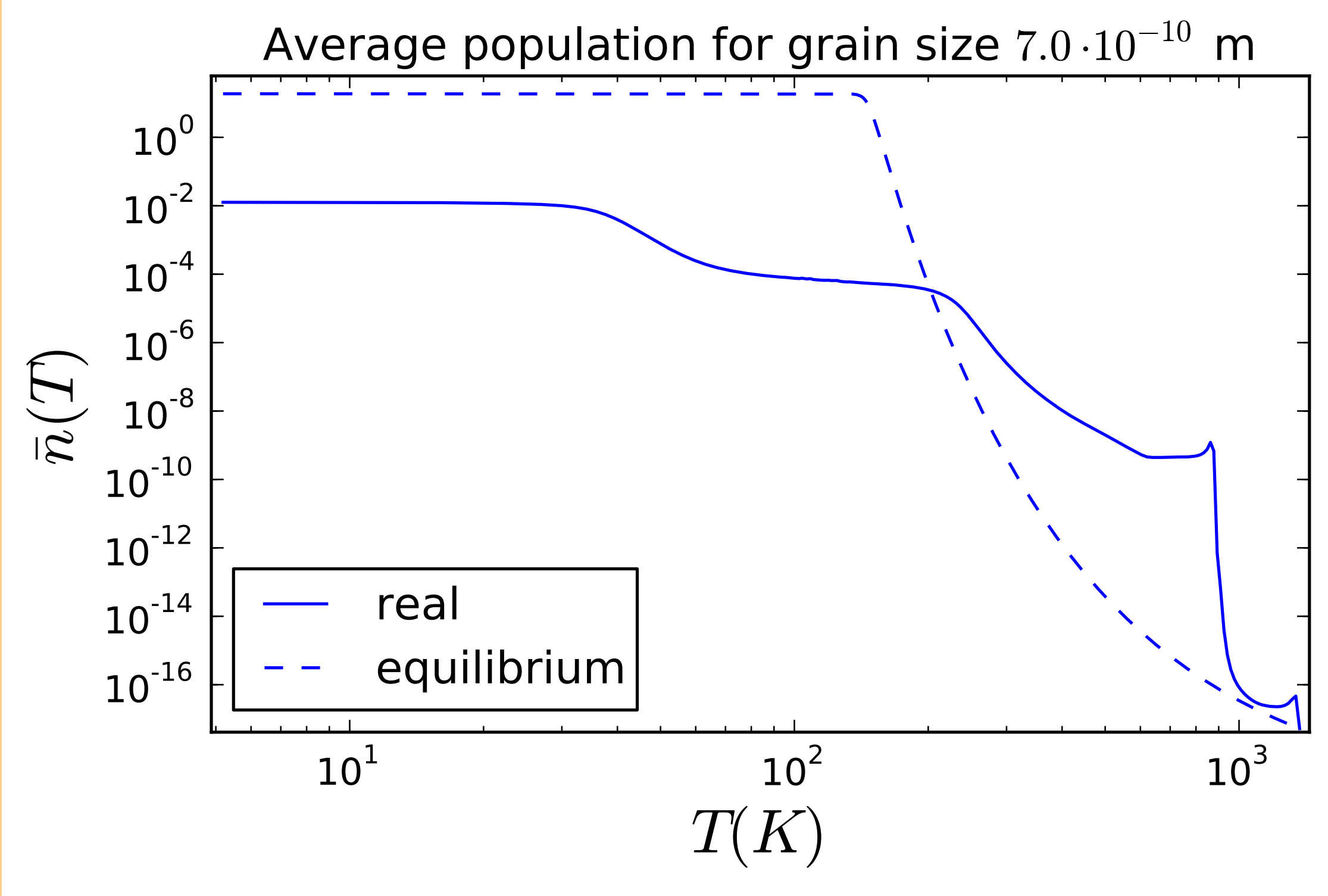
Then, averaging the main master equation over n_{ads} gives **a simpler equation in** $< n_{ads} > (T)$, which is enough for us to compute the formation rate.

Both equations are **eigenvector equations for integral operators** of the shape :

$$f(x) = \int_0^{+\infty} dy\, K(x,y)\, f(y)$$

We solve them numerically using iterative methods.

OUT OF EQUILIBRIUM



REFERENCES

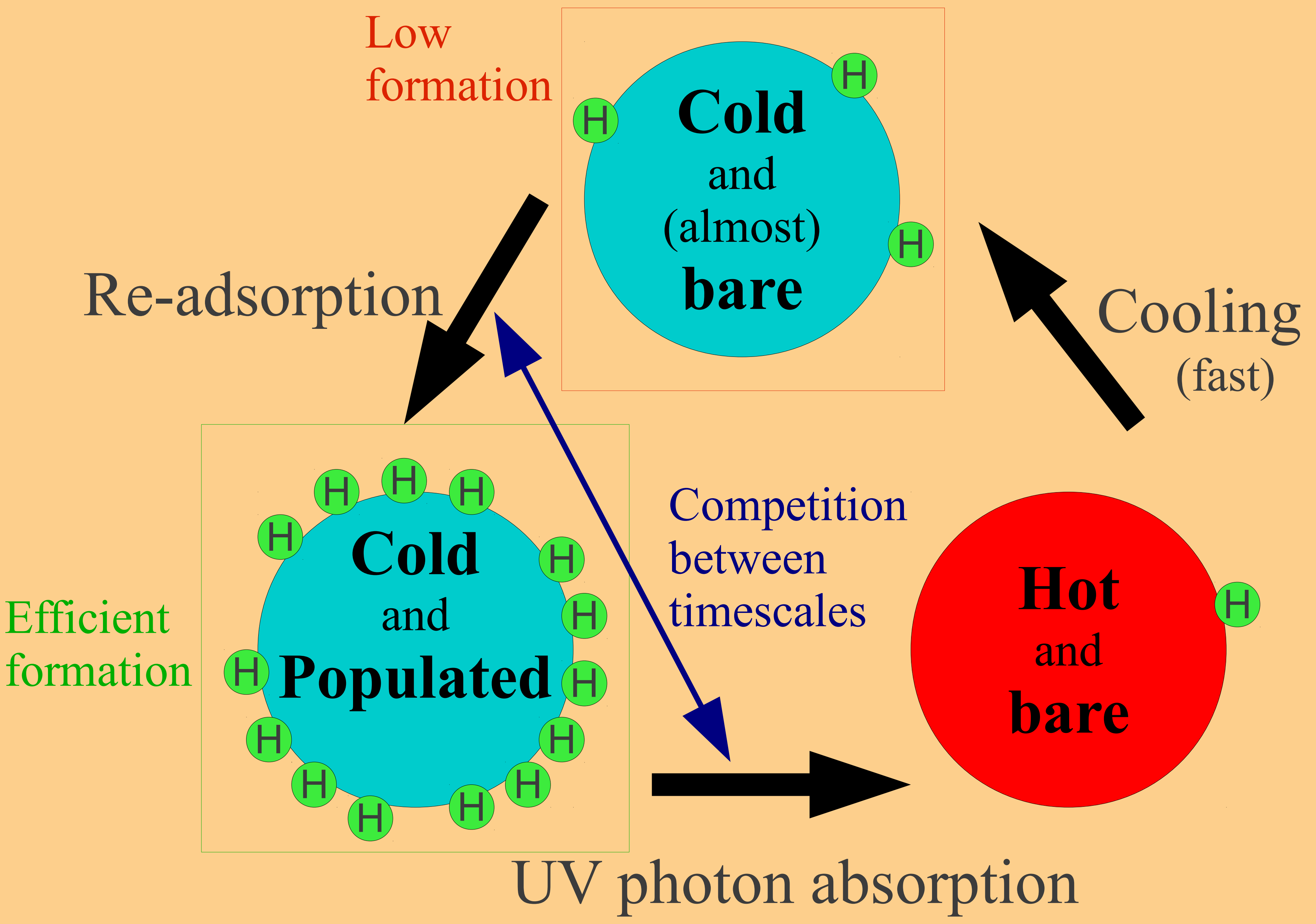
[1] E. Habart, F. Boulanger, L. Verstraete, C. M. Walmsley, G. Pineau des Forêts, A&A, 414, 531, 2004

[2] Q. Chang, H. M. Cuppen, E. Herbst, A&A, 434, 599, 2005

[3] J. Le Bourlot, F. Le Petit, C. Pinto, E. Roueff, F. Roy, A&A, 541, A76, 2012

[4] F. Le Petit, C. Nehmé, J. Le Bourlot, E. Roueff, ApJS, 164, 506, 2006

MECHANISM


Low formation

Cold and (almost) bare

Re-adsorption

Cooling (fast)

Efficient formation

Cold and Populated

Competition between timescales

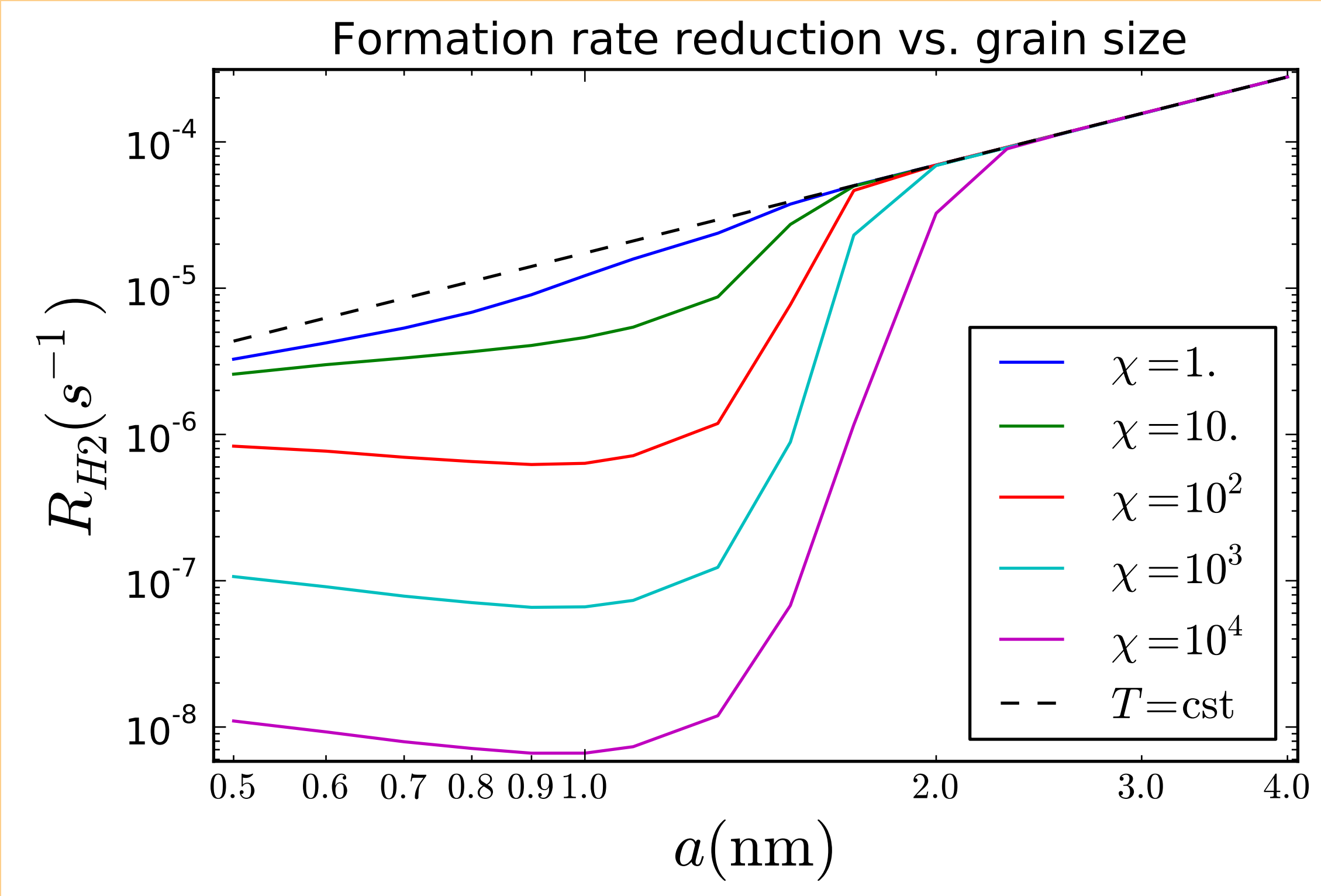
Hot and bare

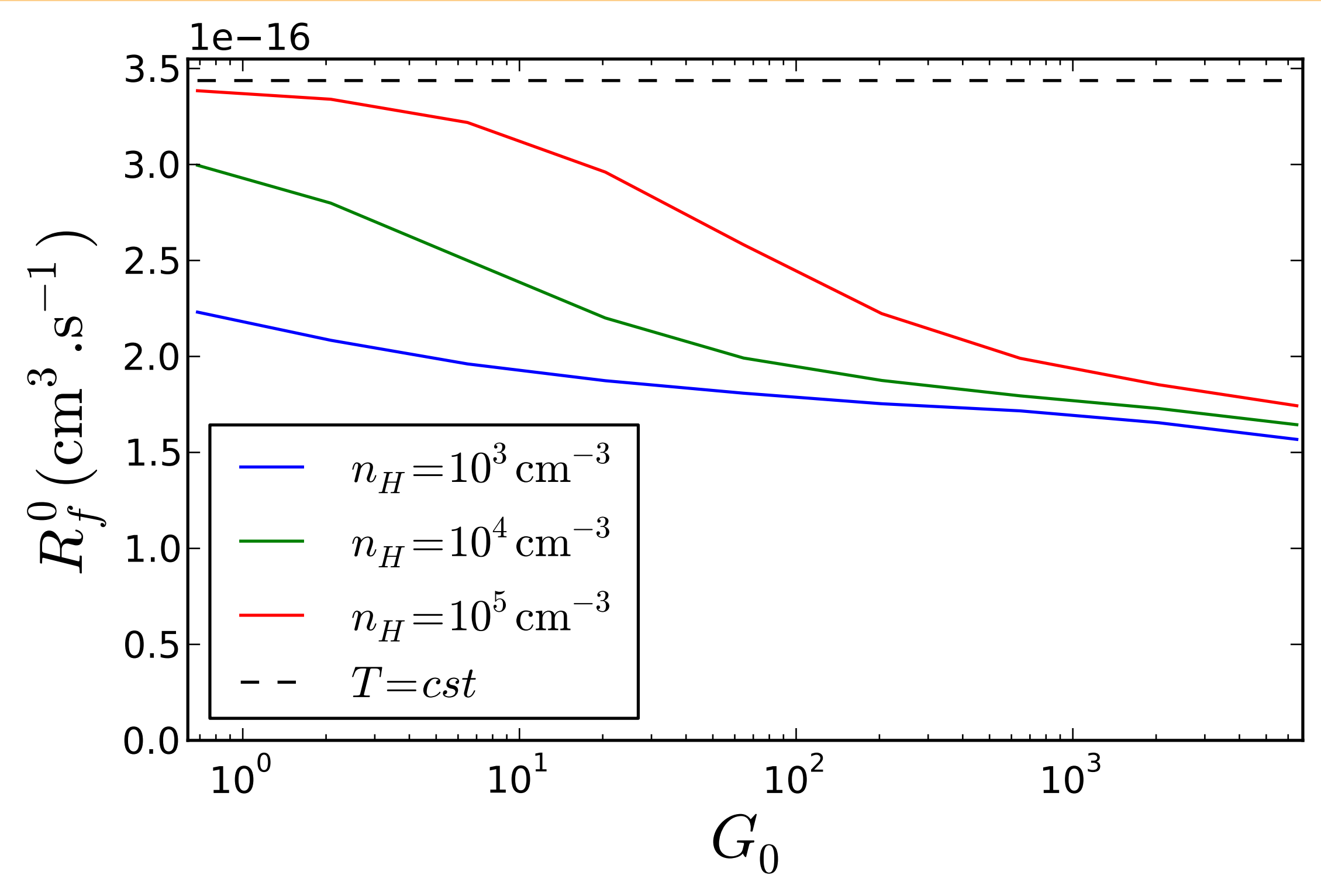
UV photon absorption

RESULTS

As expected, we obtain a **reduction of the formation rate**, which is **stronger for smaller grains** (up to 2 nm) and **for stronger radiation fields**.

This **reduction of the formation rate** with illumination intensity is **stronger for lower gas density**, as the adsorption timescale is longer, giving more importance to the temperature fluctuations.

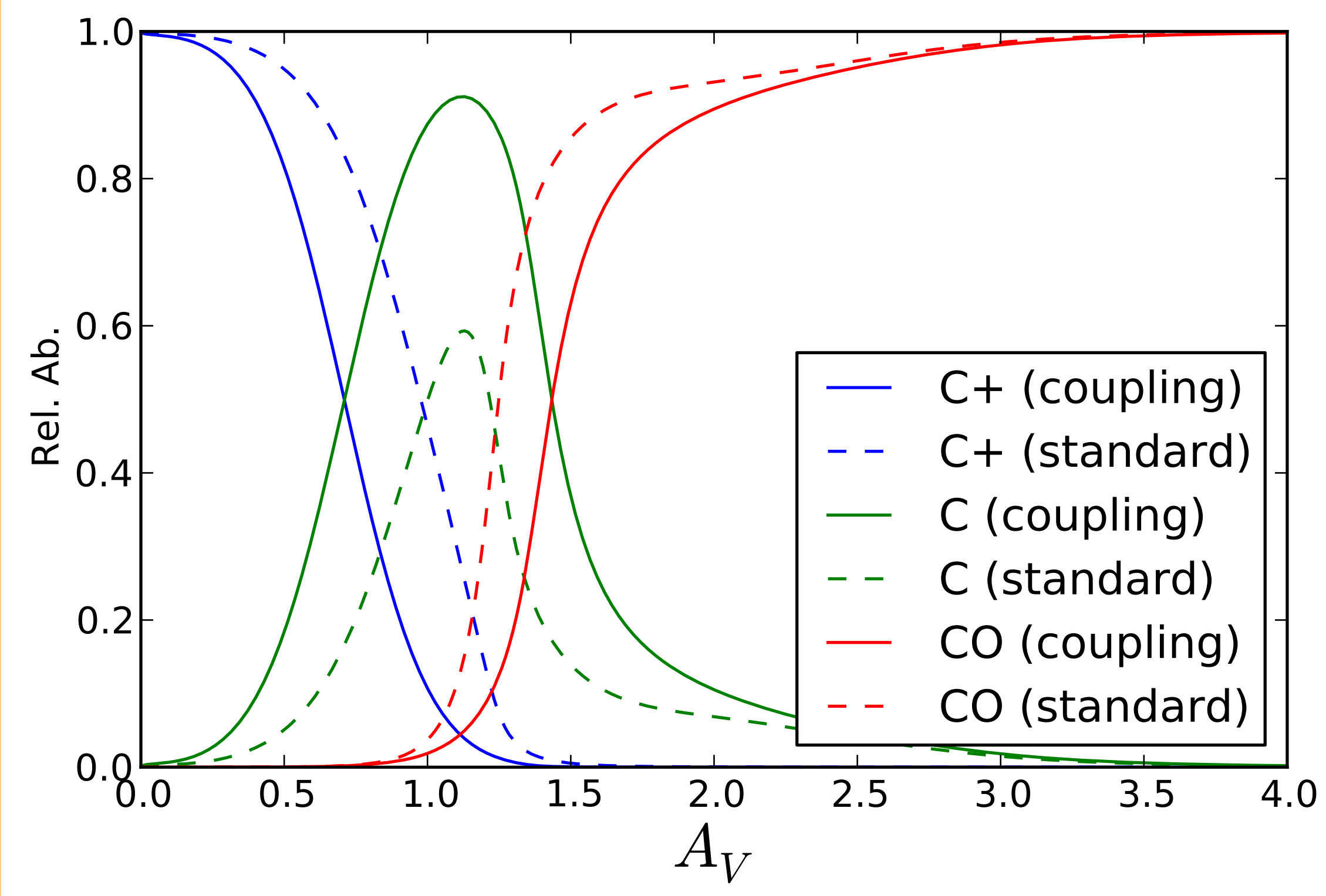


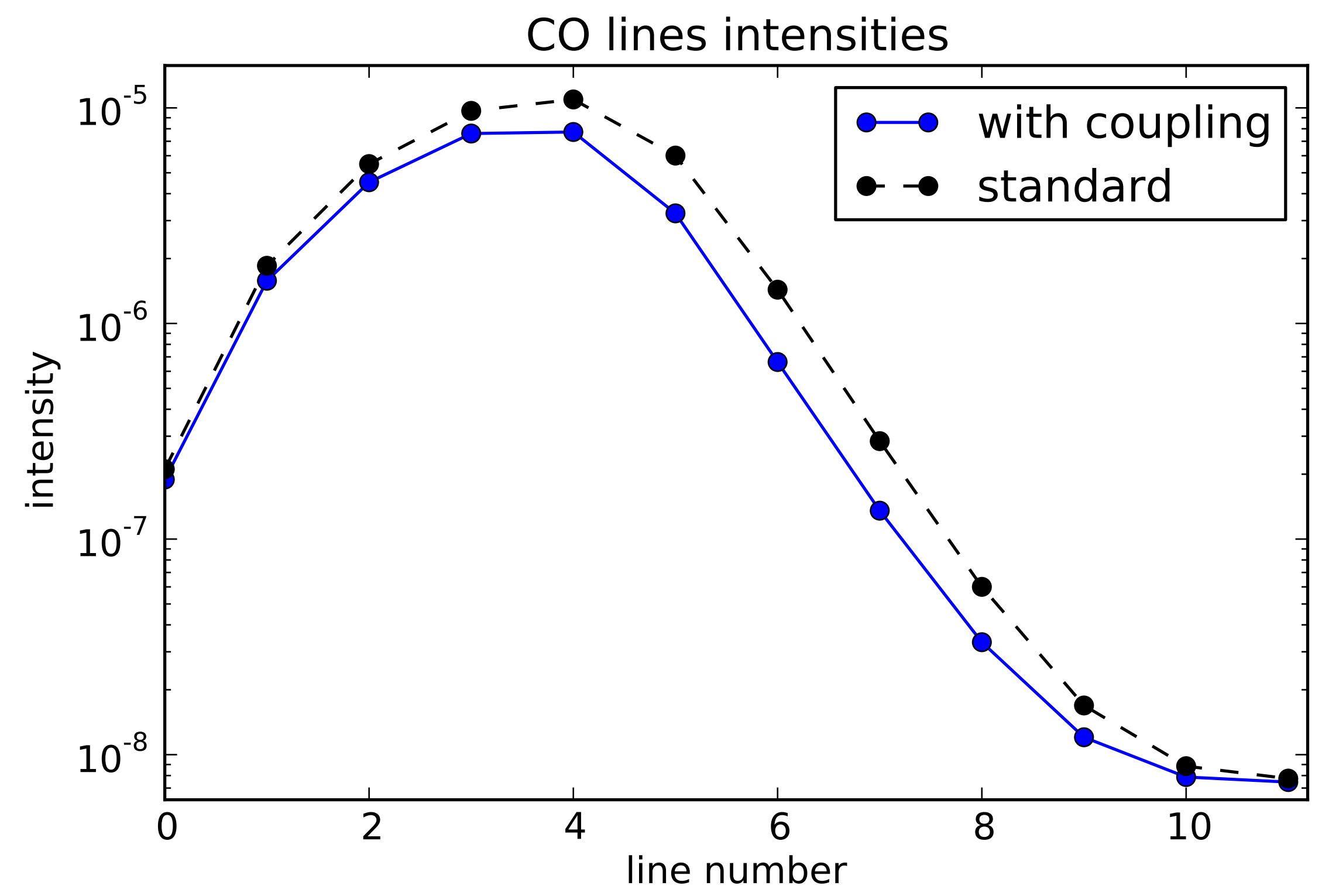


FULL CLOUD SIMULATION WITH THE MEUDON PDR CODE

We coupled this formation rate computation to the **Meudon PDR Code** [4], for a cloud with $\chi = 100$ and $P = 1 \cdot 10^6\,\mathrm{K.cm}^{-3}$.

The **H/H₂ transition is deeper in the cloud** resulting in **slightly reduced H₂ lines** (less than 25%). The C+/C/CO transition is also modified, with a **quicker C+/C transition** (resulting in **C lines increased by a factor of 2**), but a **later C/CO transition** (resulting in **CO lines reduced by a factor of 2** for J=5-8).





CONCLUSIONS

1. **Temperature fluctuations significantly reduce the Eley-Rideal formation rate for small grain sizes, strong radiation fields. The effect is further enhanced by low gas density.**
2. **The minimal size in the dust size distribution controls the strength of this effect.**
3. **It leads to modifications of observable quantities by up to a factor of 4.**