

AMANDEEP SINGH

A SUB-GRID MODEL FOR MOLECULAR
GAS IN A COSMOLOGICAL GALAXY
FORMATION SIMULATION

THE “WHAT” OF MY PROJECT

“WHAT”

- ▶ **Studying the CO line luminosity (L_{CO}) and the shape of the CO spectral line energy distribution (SLED) in galaxies in the Epoch of Reionization (EoR)**

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- ▶ **RESULTS: post-process and resolve a cosmological simulation of a sample galaxy**

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- ▶ MODEL (+) :a simplified model for radiative transfer
- ▶ RESULTS: post-process and resolve a cosmological simulation of a sample galaxy
- ▶ **FINALLY: compared to observations taken of similar galaxies**

THE “WHY” OF MY PROJECT

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- ▶ WHY SUCH A MODEL? :
 - small physical scales ($\approx 0.1 - 1$ pc) of clumps in GMCs + complex network of chemical and physical reactions in the fully molecular parts of GMCs
 - **the high-resolution hydrodynamical simulations (down to scales of ≈ 30 pc) of the interstellar medium (ISM) density, turbulence level, metal enrichment & radiation field into which GMCs are embedded**

THE “HOW” OF MY PROJECT

“HOW” - MODEL OUTLINE

MACH_NO ; METALLICITY ; G_O ; n_H_MEAN ; TEMPERATURE

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MACH_NO ; METALLICITY ; G_O ; n_H_MEAN ; TEMPERATURE

▶ `pdf = pdf(mach_no, n_H_mean)`

“HOW” - MODEL OUTLINE

MACH_NO ; METALLICITY ; G_O ; n_H_MEAN ; TEMPERATURE

- ▶ `pdf = pdf(mach_no, n_H_mean)`
- ▶ **c_s = c_s(T)**

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MACH_NO ; METALLICITY ; G_O ; n_H_MEAN ; TEMPERATURE

- ▶ `pdf = pdf(mach_no, n_H_mean)`
- ▶ `c_s = c_s(T)`
- ▶ **`jeans_length = jeans_length(c_s)`**

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MACH_NO ; METALLICITY ; G_O ; n_H_MEAN ; TEMPERATURE

- ▶ `pdf = pdf(mach_no, n_H_mean)`
- ▶ `c_s = c_s(T)`
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✓ Density PDF

✓ Length Scale

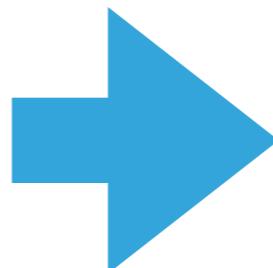
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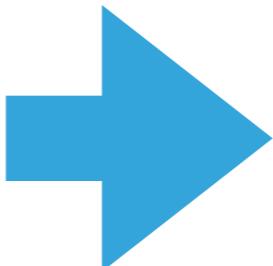


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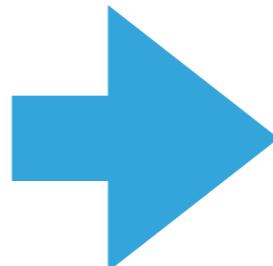
A gas cloud and it's size

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A gas cloud and it's size

- ▶ Solve the rate equation to get optical_depth, Lyman-Werner photons, molecular fractions of H2 and CO

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- ▶ `jeans_length = jeans_length(c_s)`
- ▶ **`tau = tau(jeans_length)`**

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- ▶ pdf = pdf(mach_no, n_H_mean)
- ▶ c_s = c_s(T)
- ▶ jeans_length = jeans_length(c_s)
- ▶ tau = tau(jeans_length)
- ▶ **n_LW = G_O * exp(-tau)**

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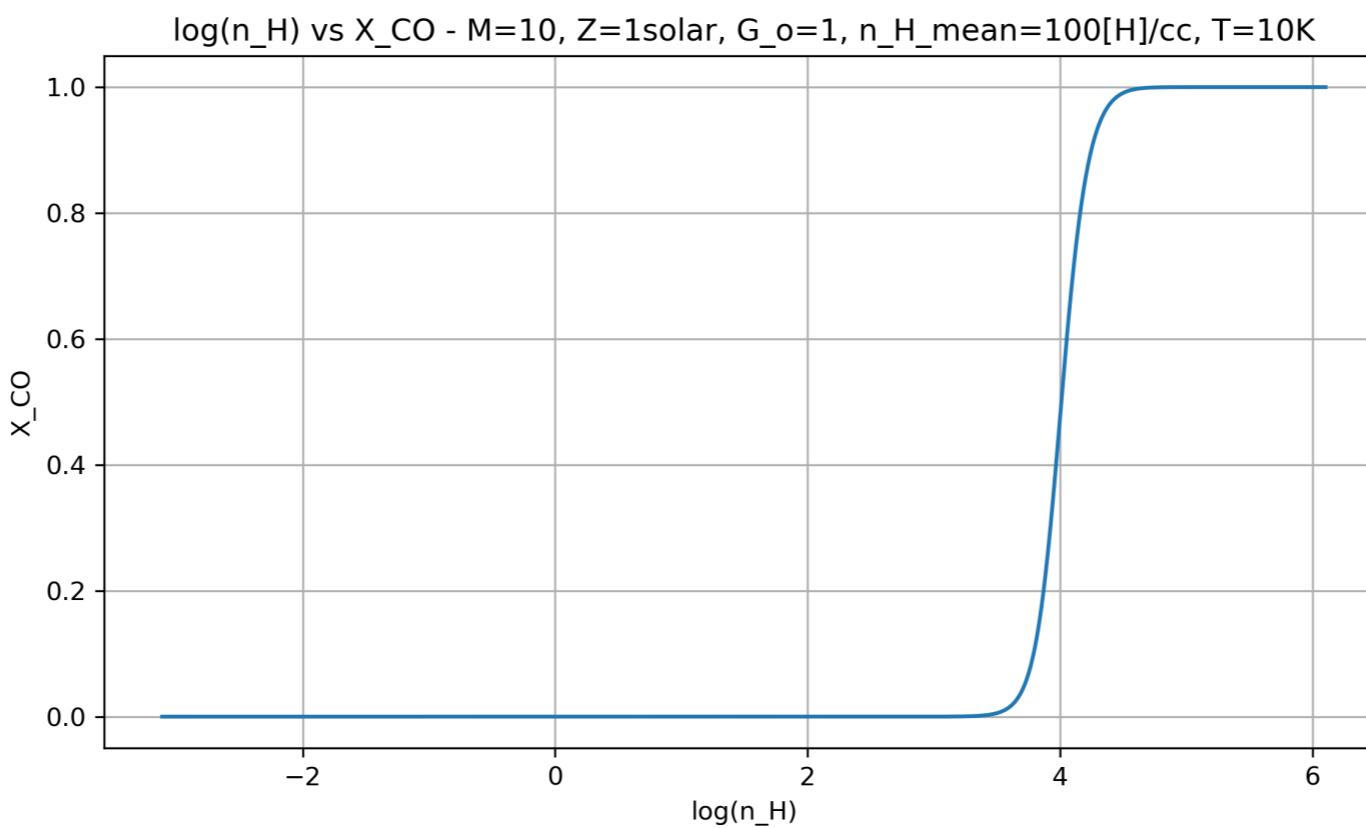
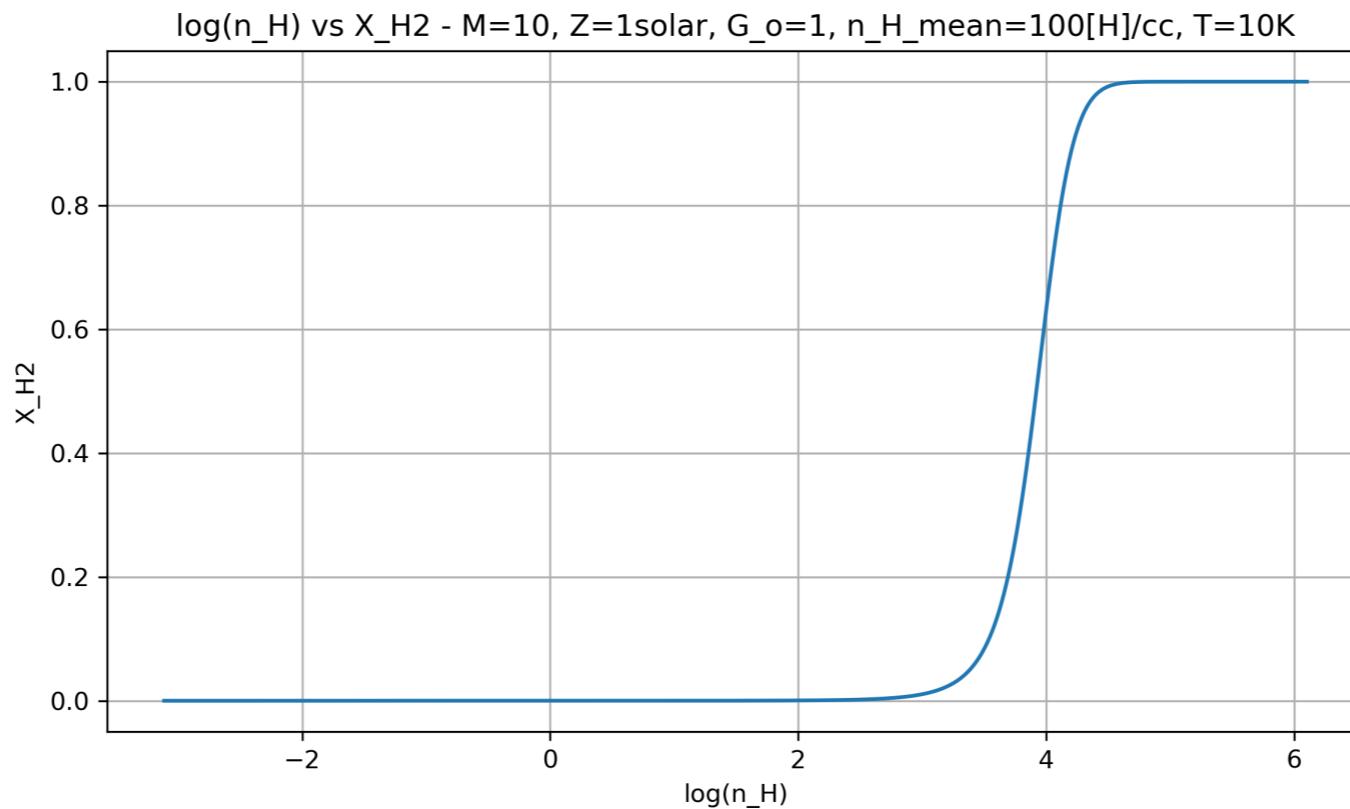
▶ n_LW = G_O * exp(-tau)

▶ **x_H2 = x_H2(z, n_LW)**

▶ **n_H2 = n_H * x_H2**

▶ **x_CO = x_CO(n_H2, n_LW)**

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- ▶ **n_H2 = n_H * x_H2**
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SELF-SHIELDING OF H2 !

(Draine & Bertoldi 1996)

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- ▶ **n_LW = G_O * exp(-tau)** ▶ **n_LW_ss = G_O * exp(-tau) * S_H2(n_H2, j_len)**
- ▶ **x_H2 = x_H2(z, n_LW)** ▶ **x_H2_ss = x_H2(z, n_LW_ss)**
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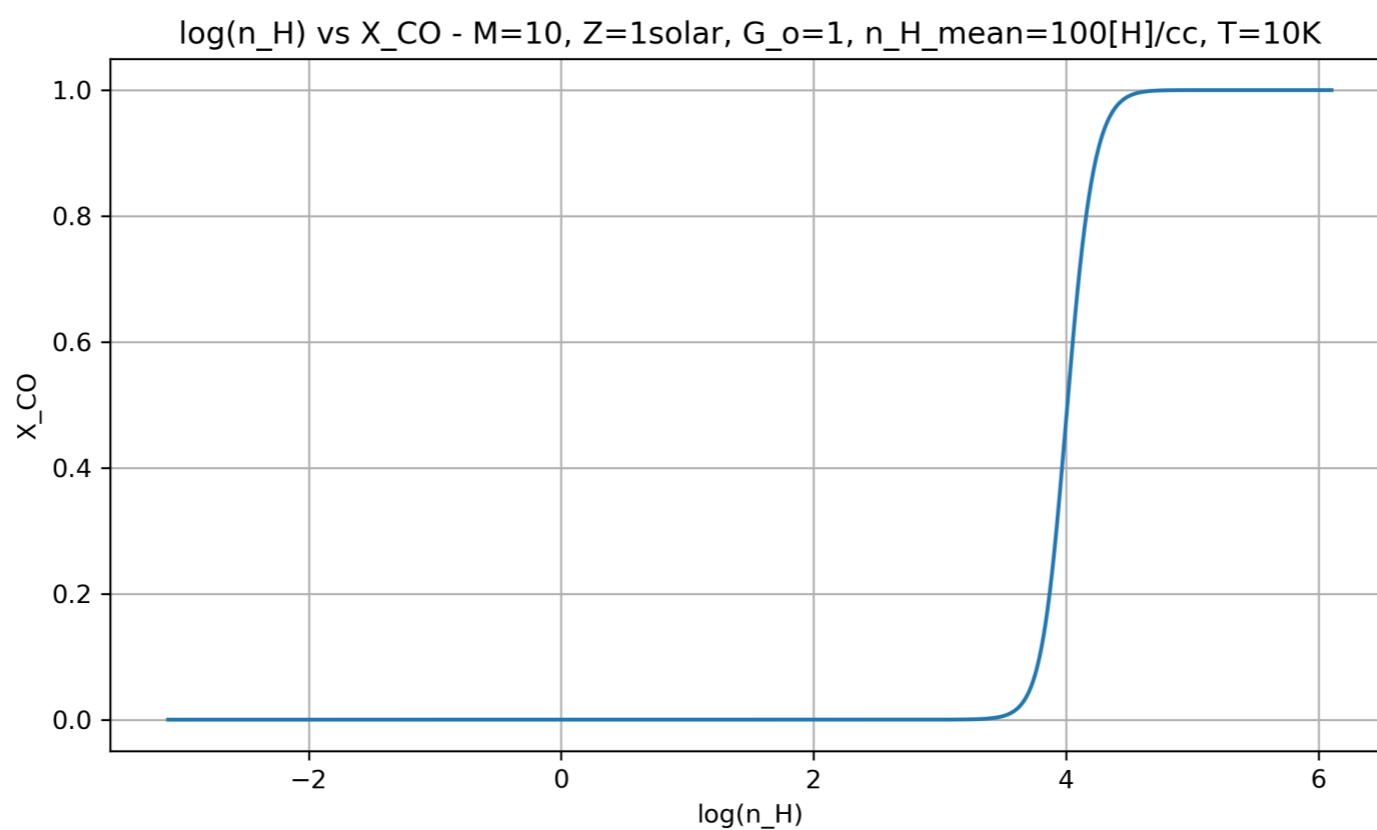
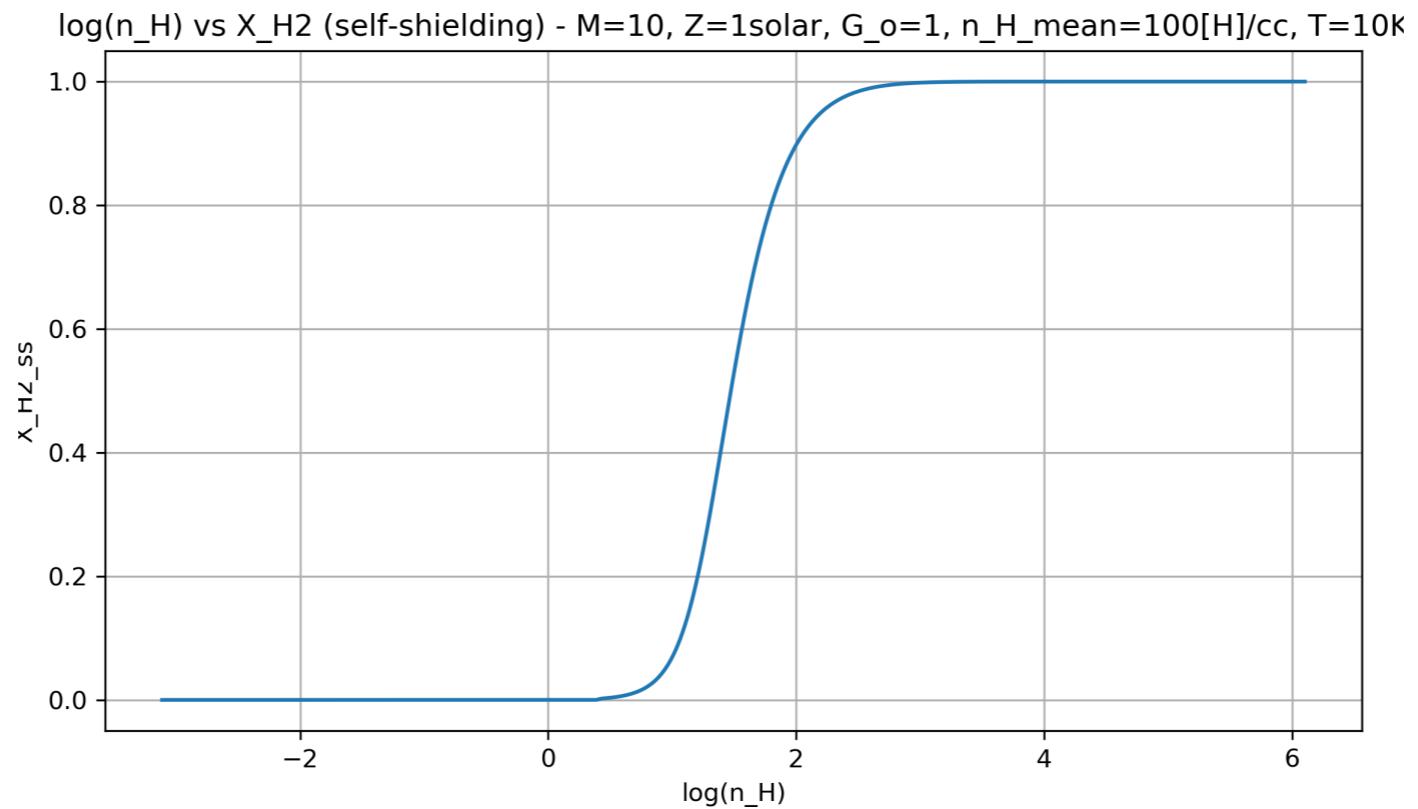
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- ▶ `x_CO = x_CO(n_H2, n_LW)`

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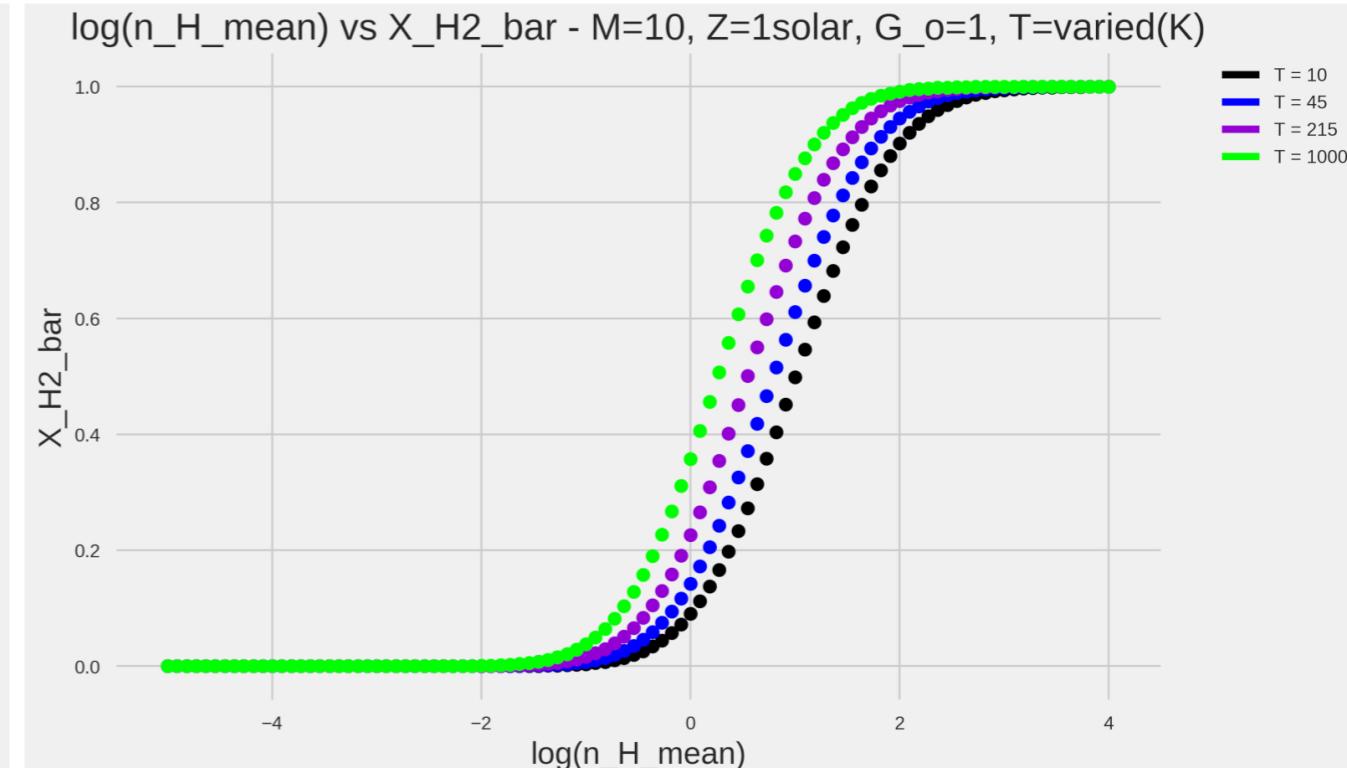
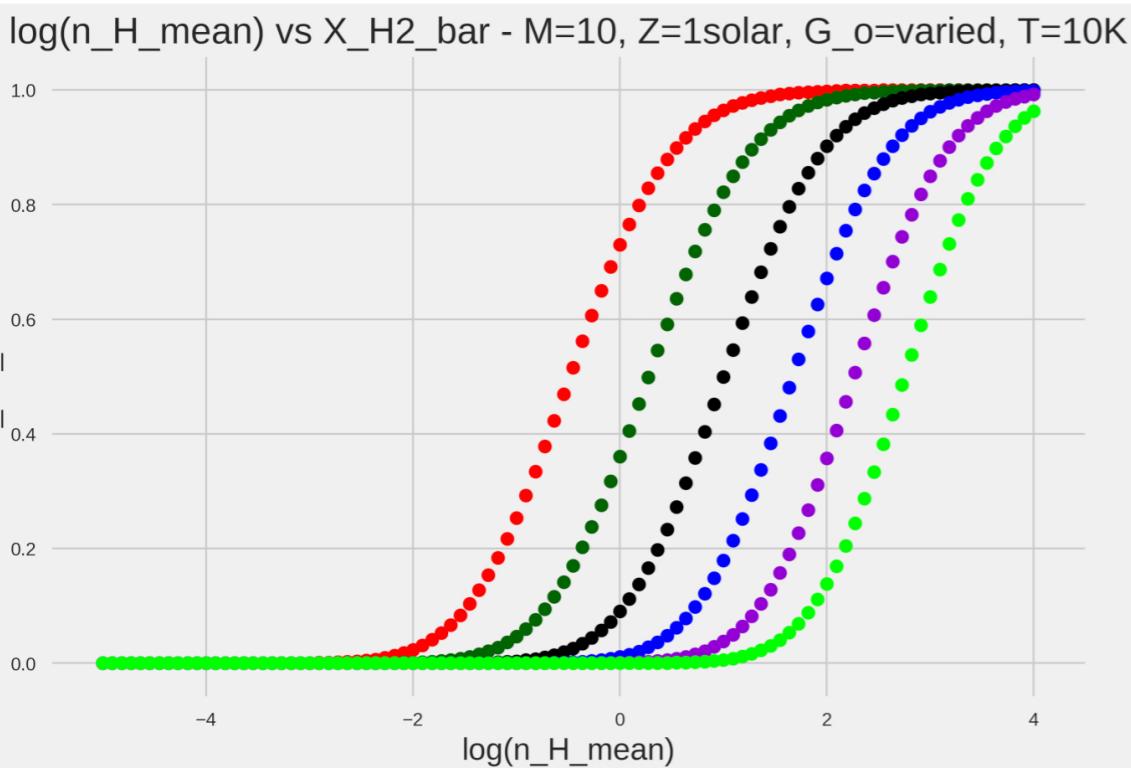
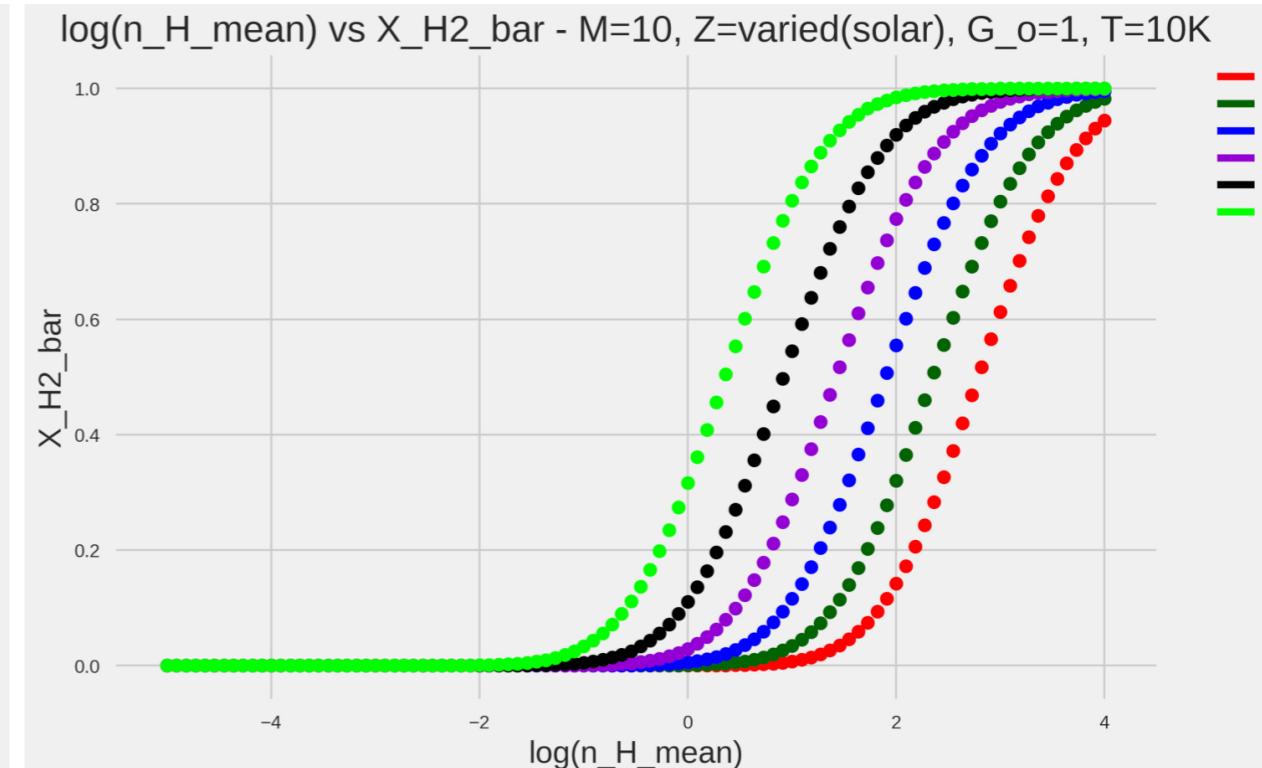
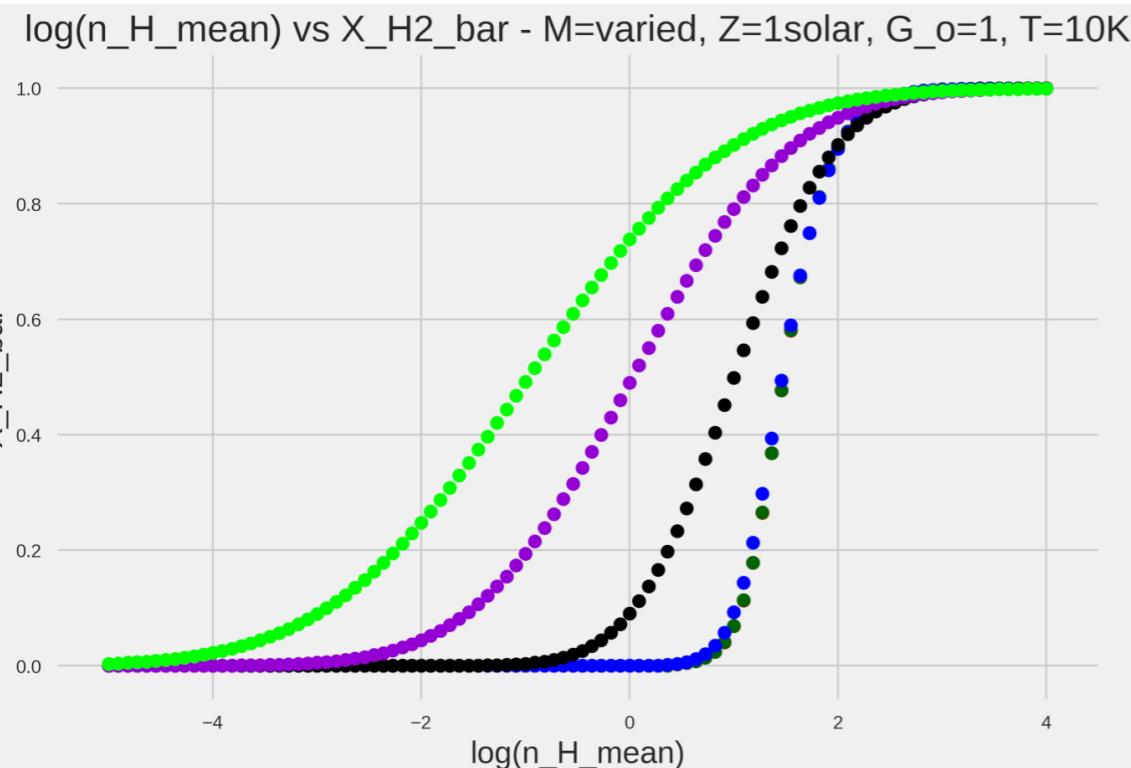
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- ▶ `n_H2 = n_H * X_H2` ▶ `n_H2_ss = n_H * X_H2_ss`

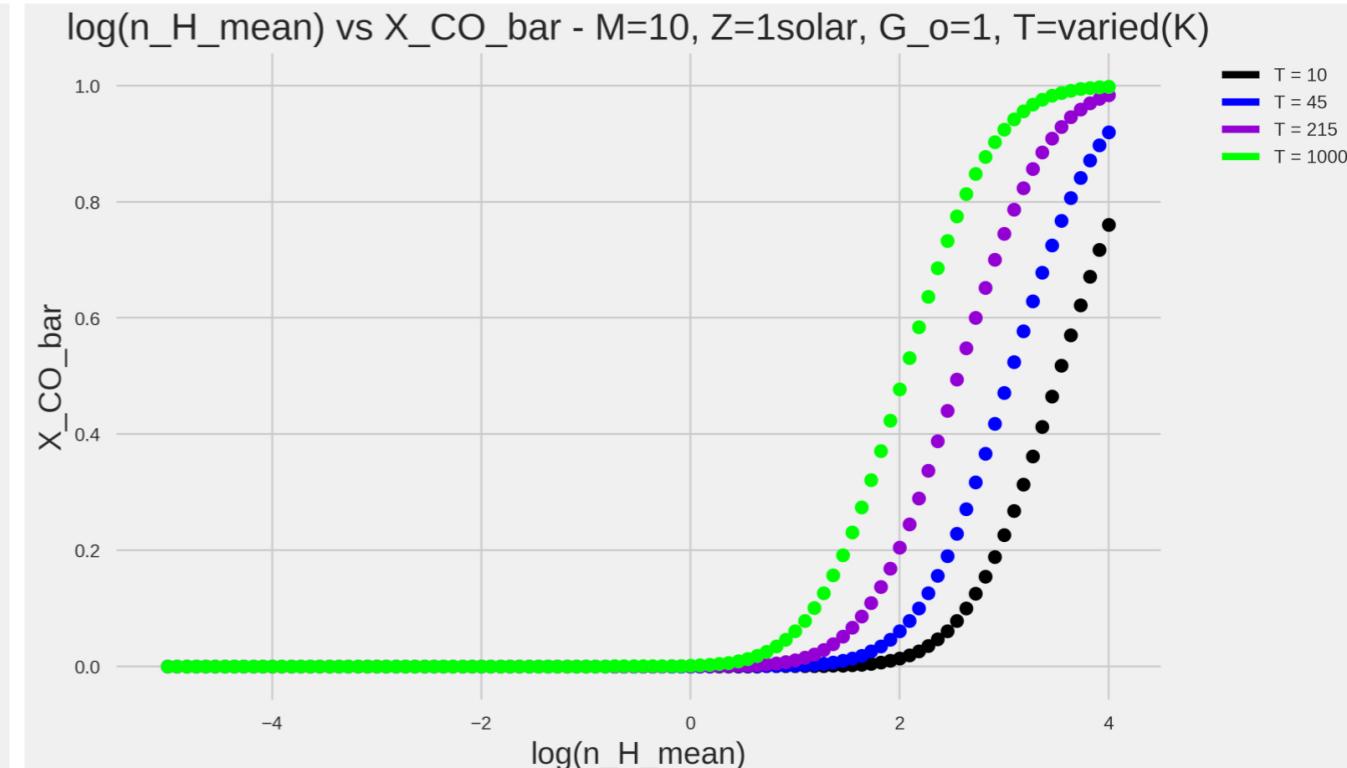
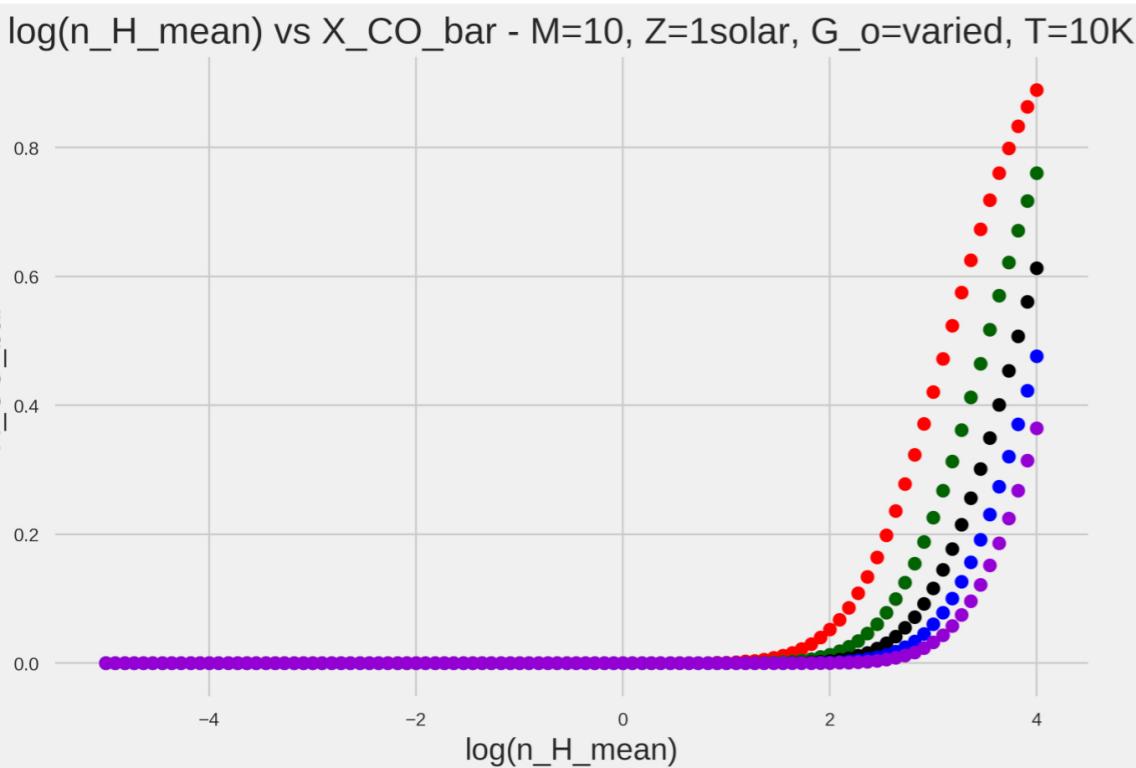
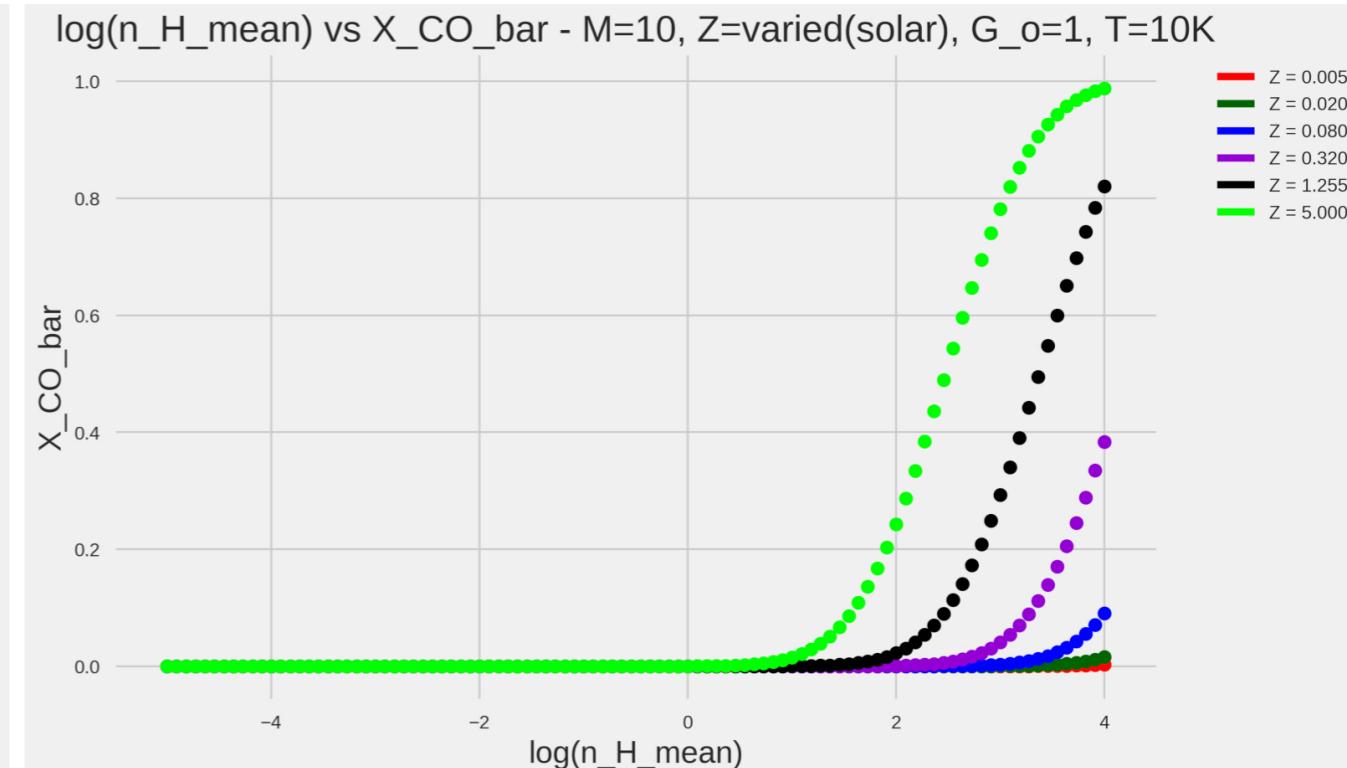
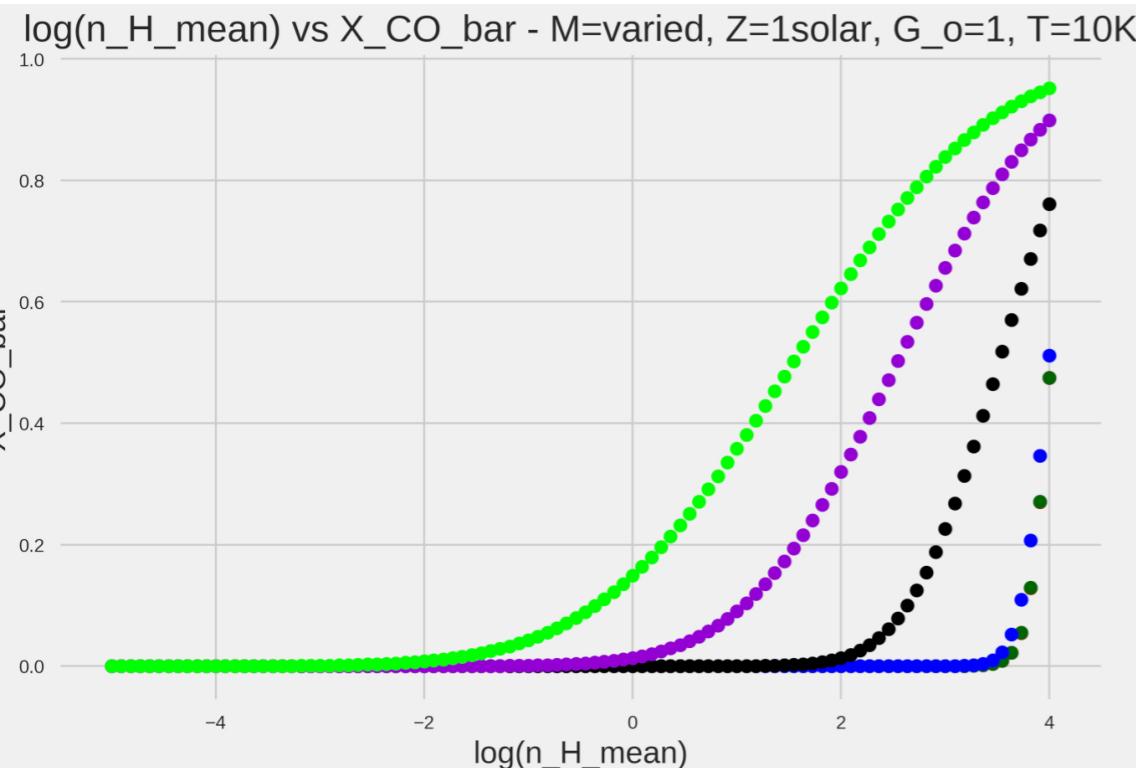
- ▶ `X_CO = X_CO(n_H2, n_LW)`
- ▶ `x_H2_bar = integ (exp(s)* pdf * x_H2_ss * ds)`
- ▶ `x_CO_bar = integ (exp(s)* pdf * x_CO * ds)`

RESULTS

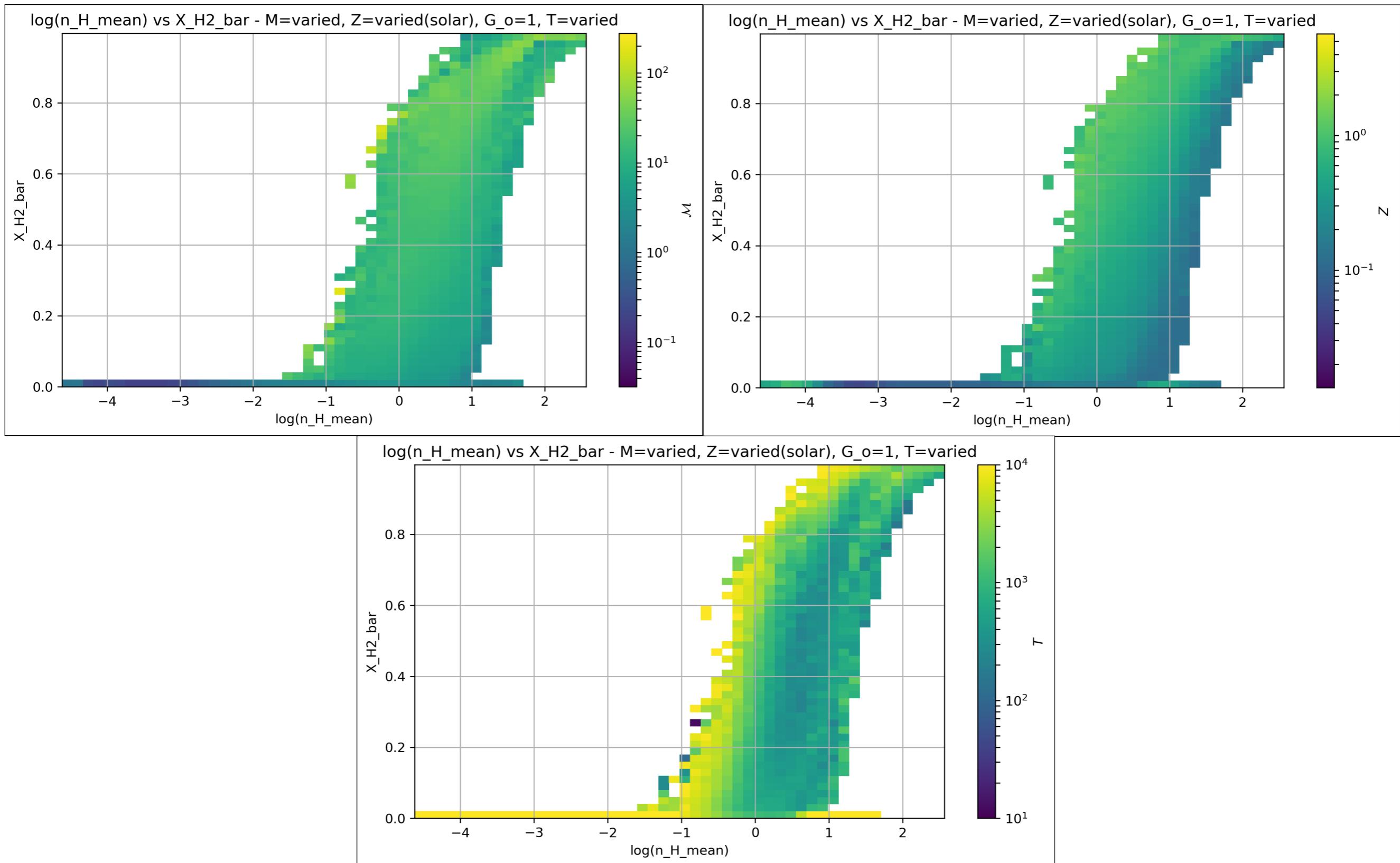
X_H2_BAR: (REFERENCE PLOTS)



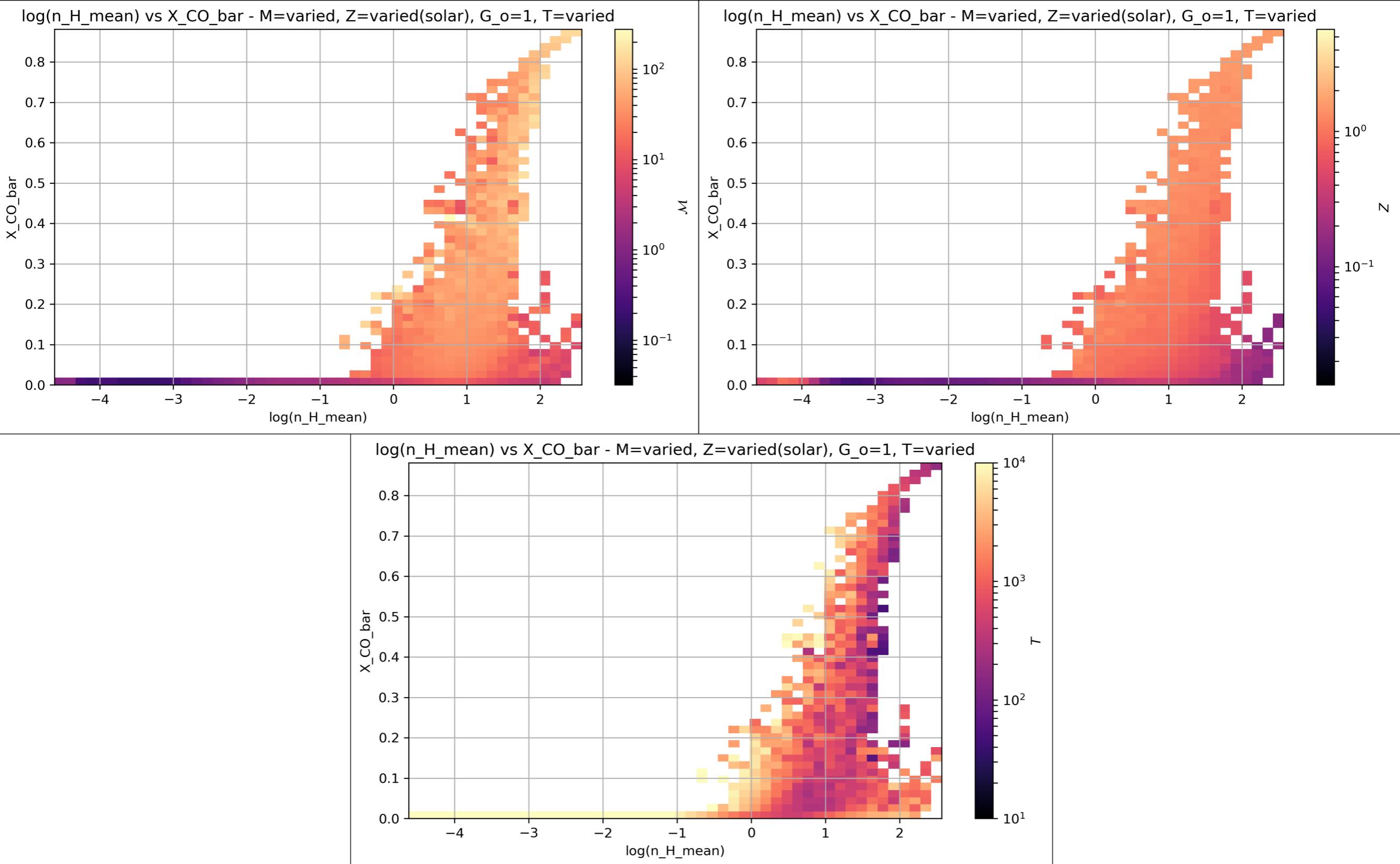
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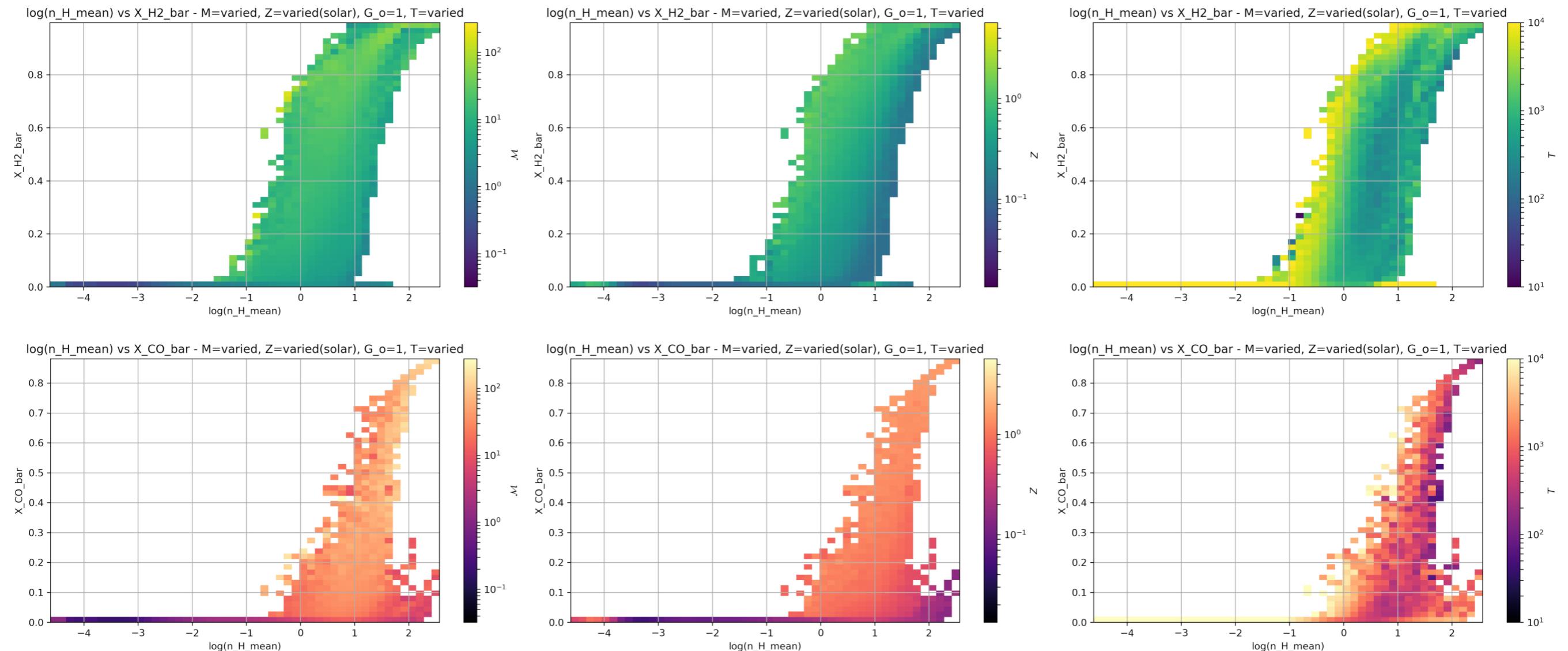
X_H2_BAR: (GALAXY SIMULATION)



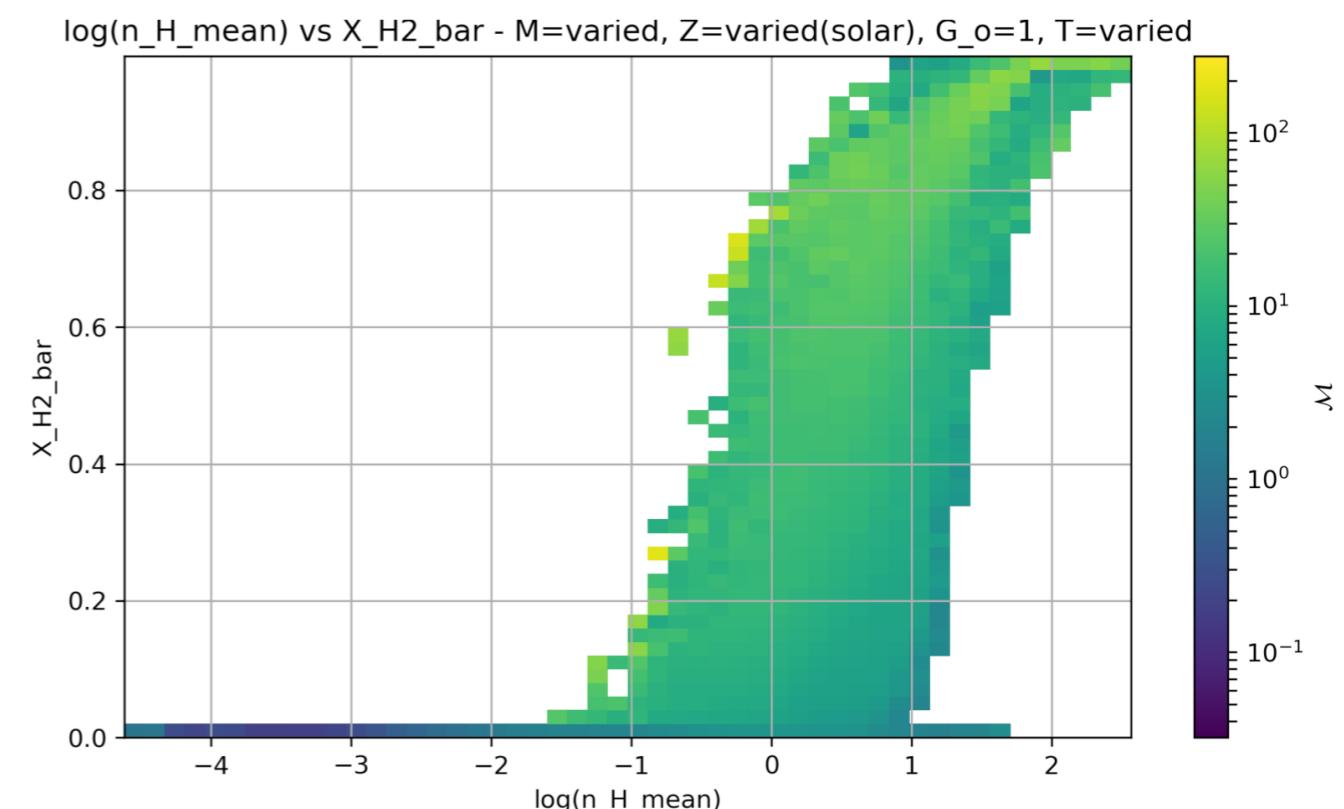
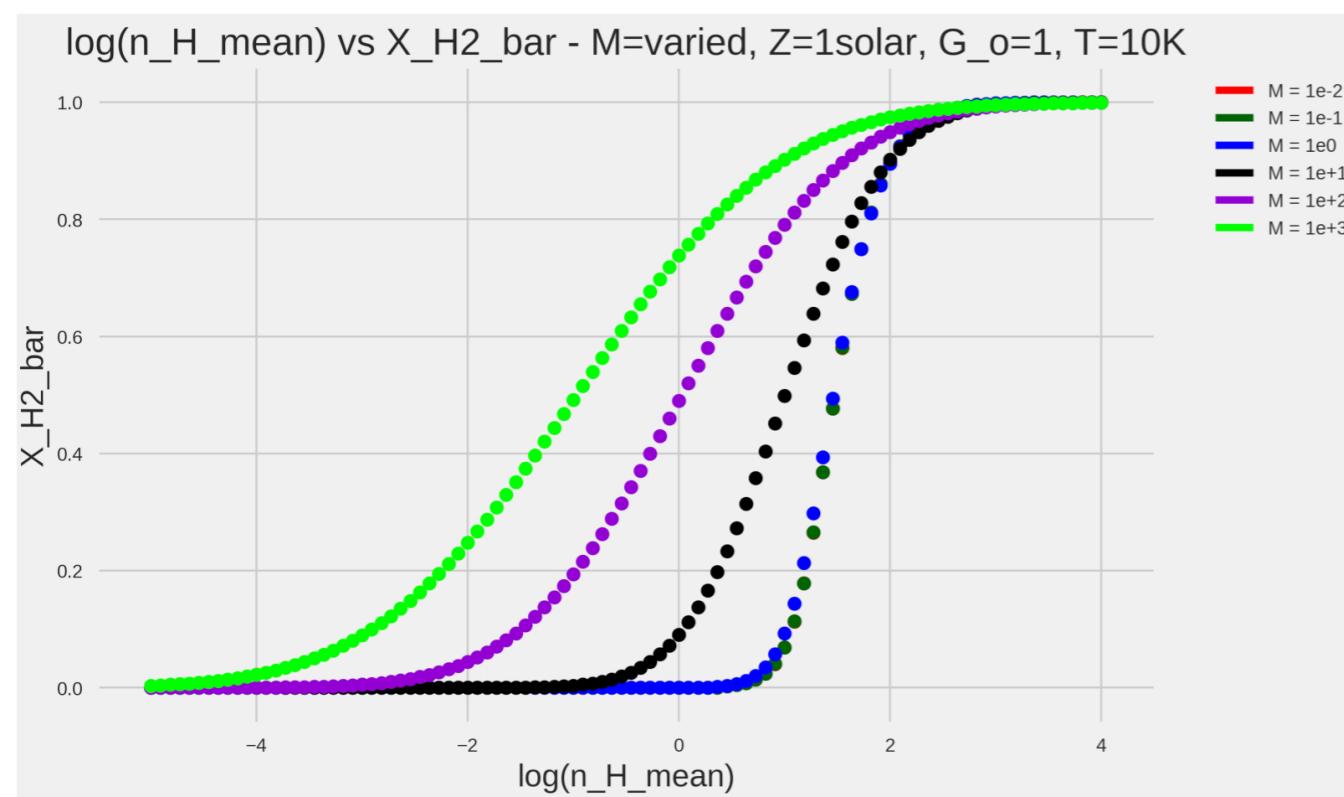
X_CO_BAR: (GALAXY SIMULATION)



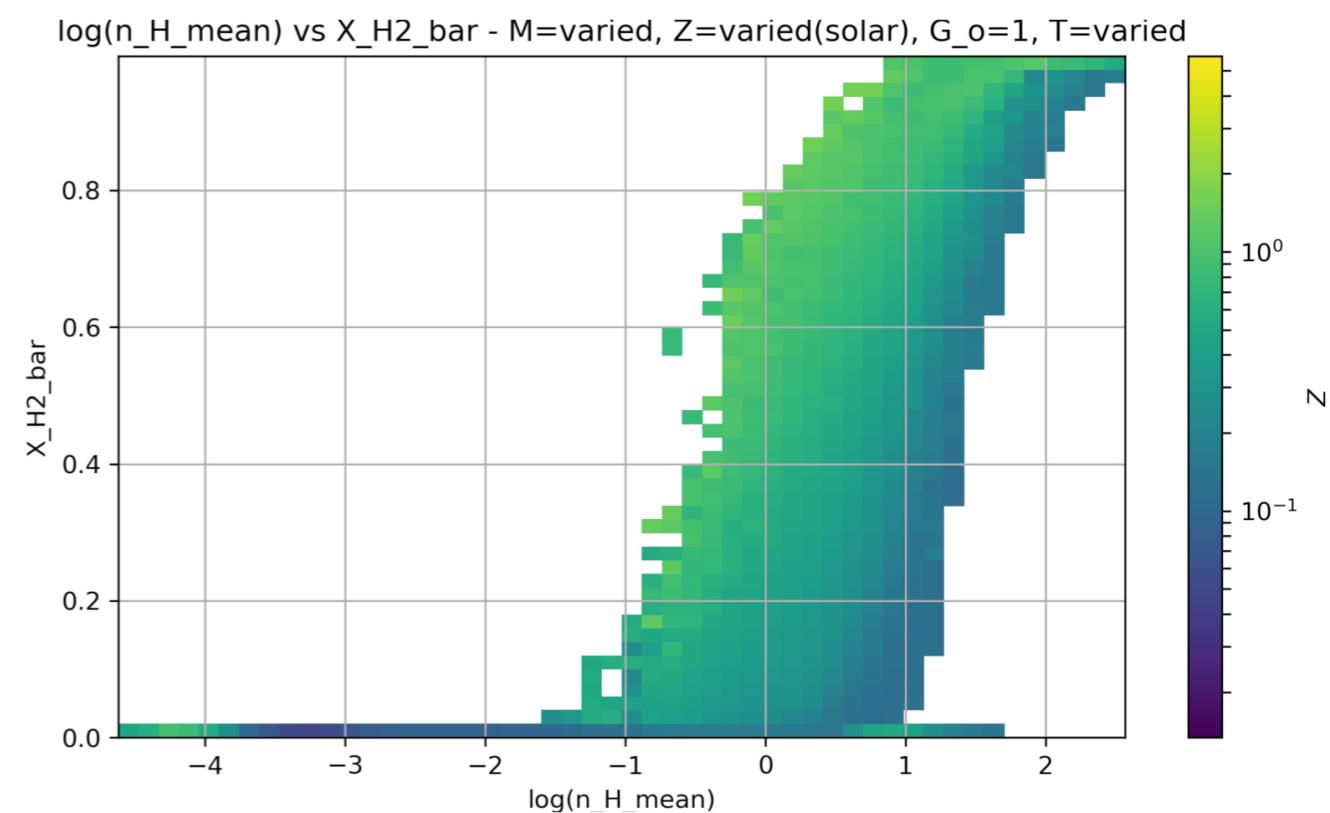
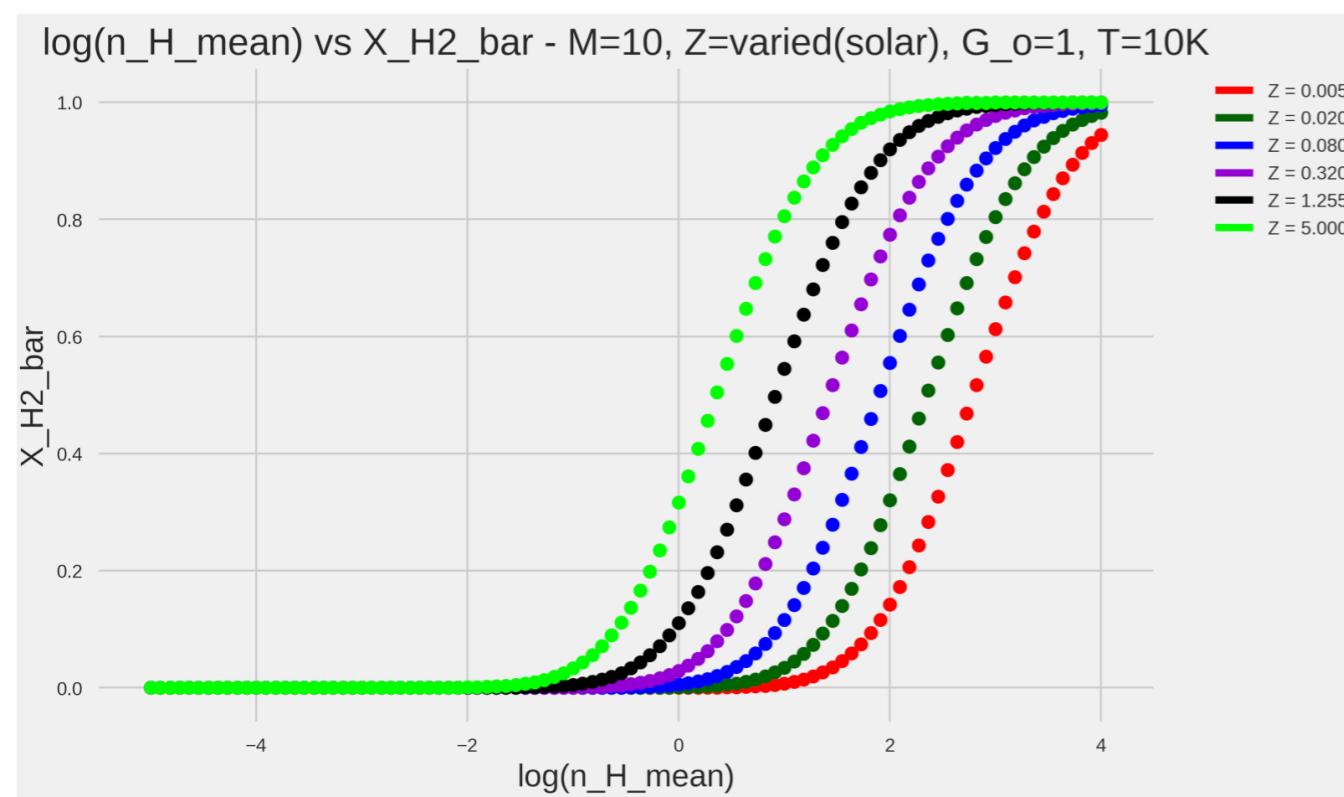
COMPARISON:



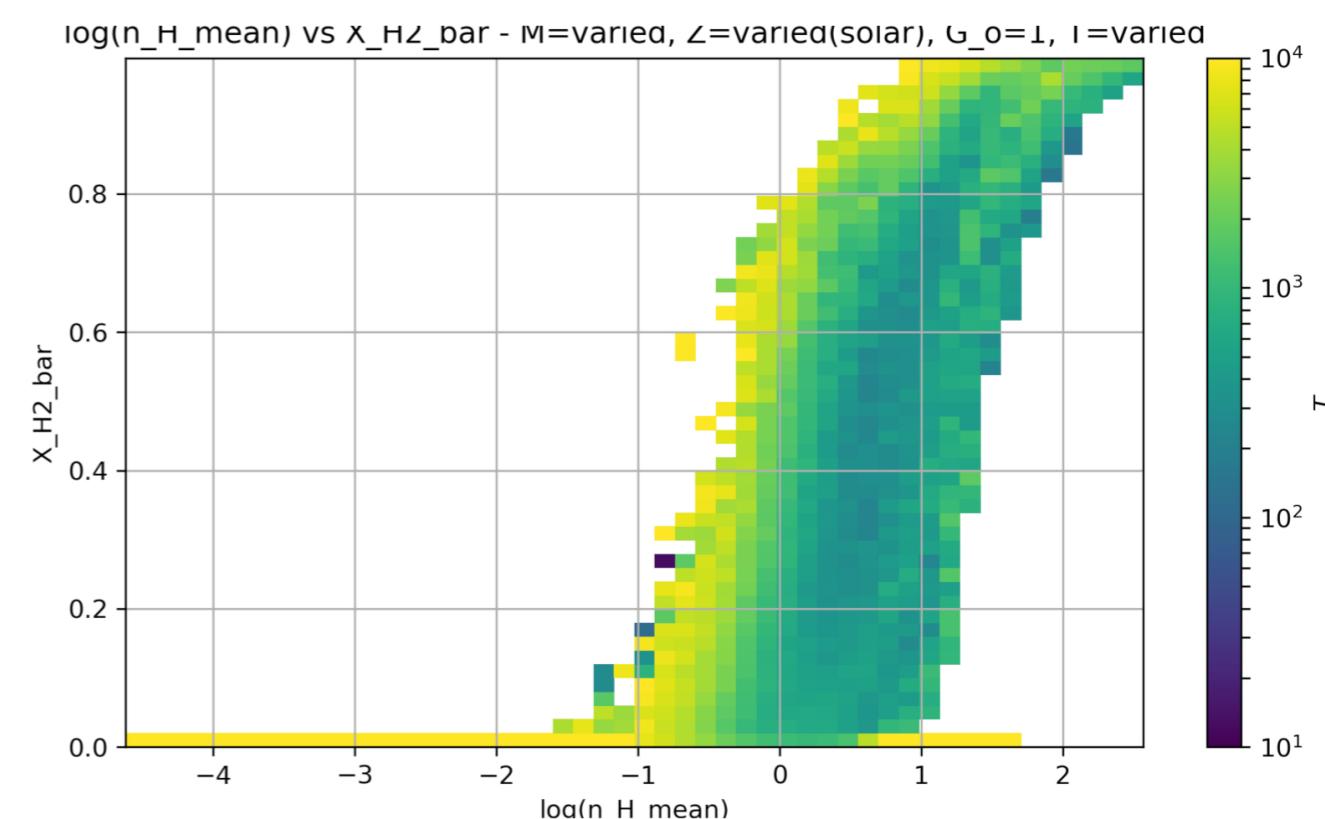
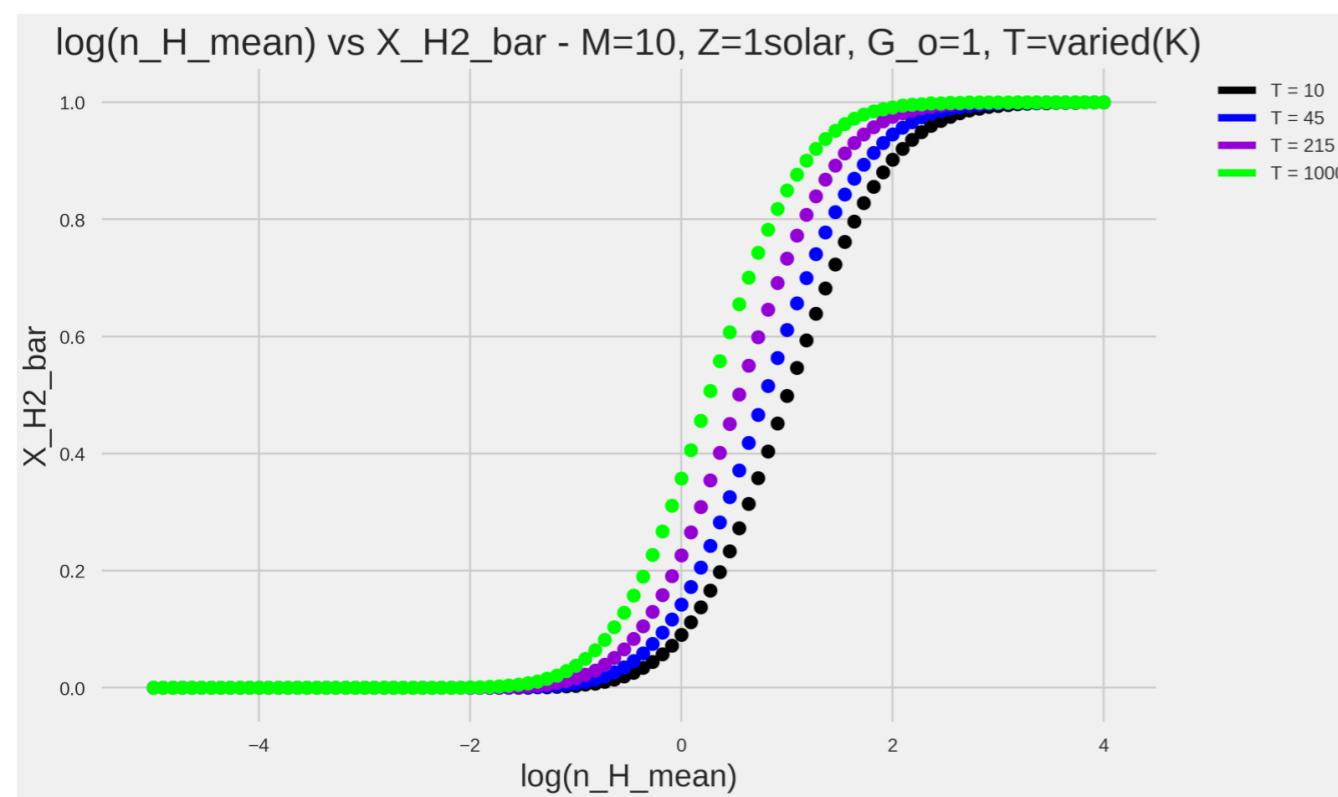
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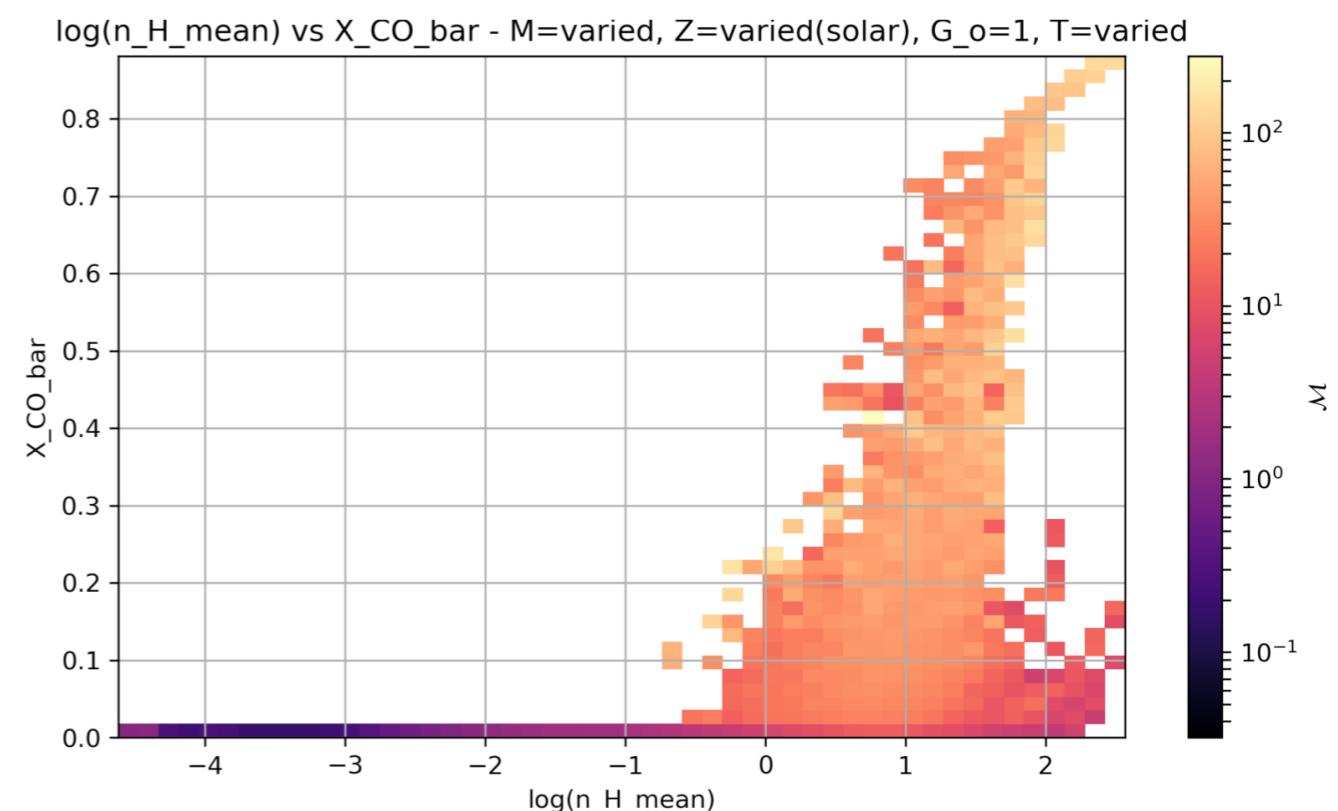
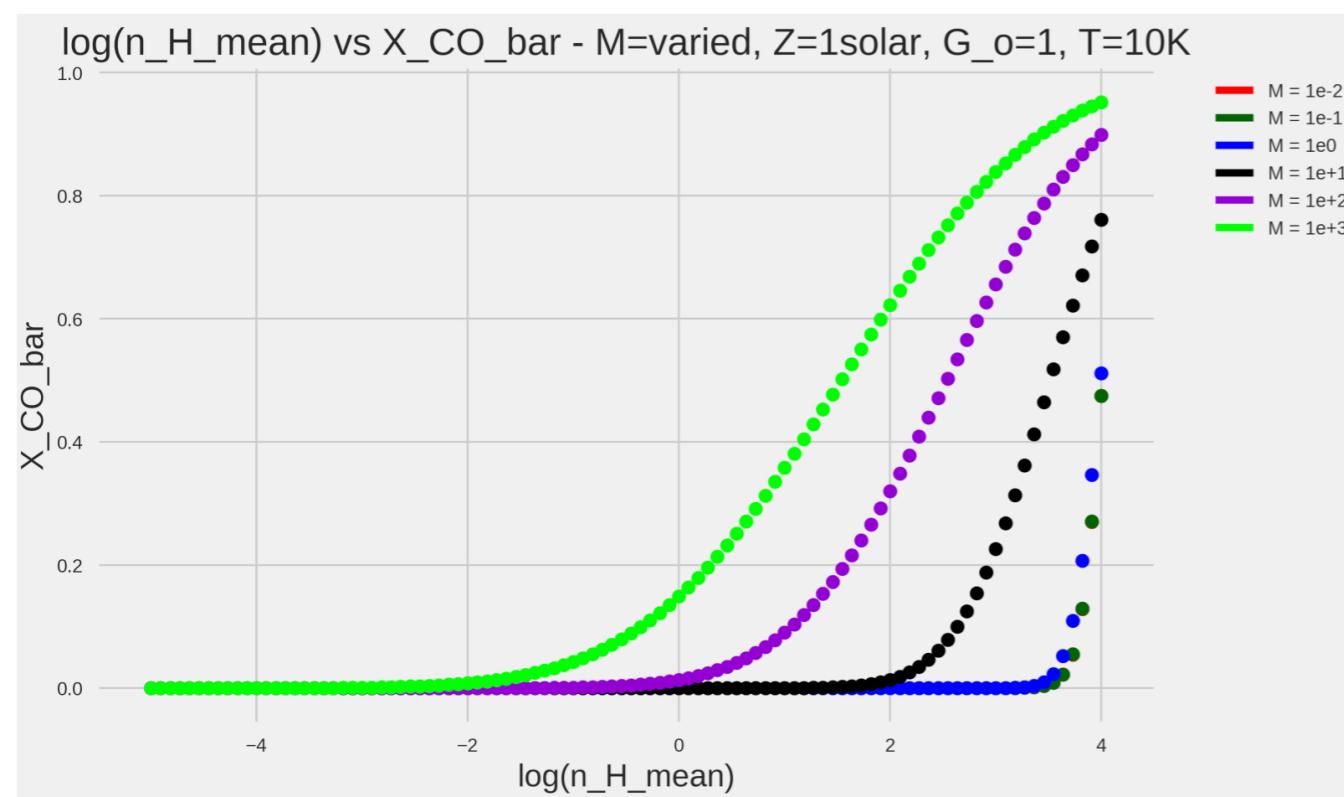
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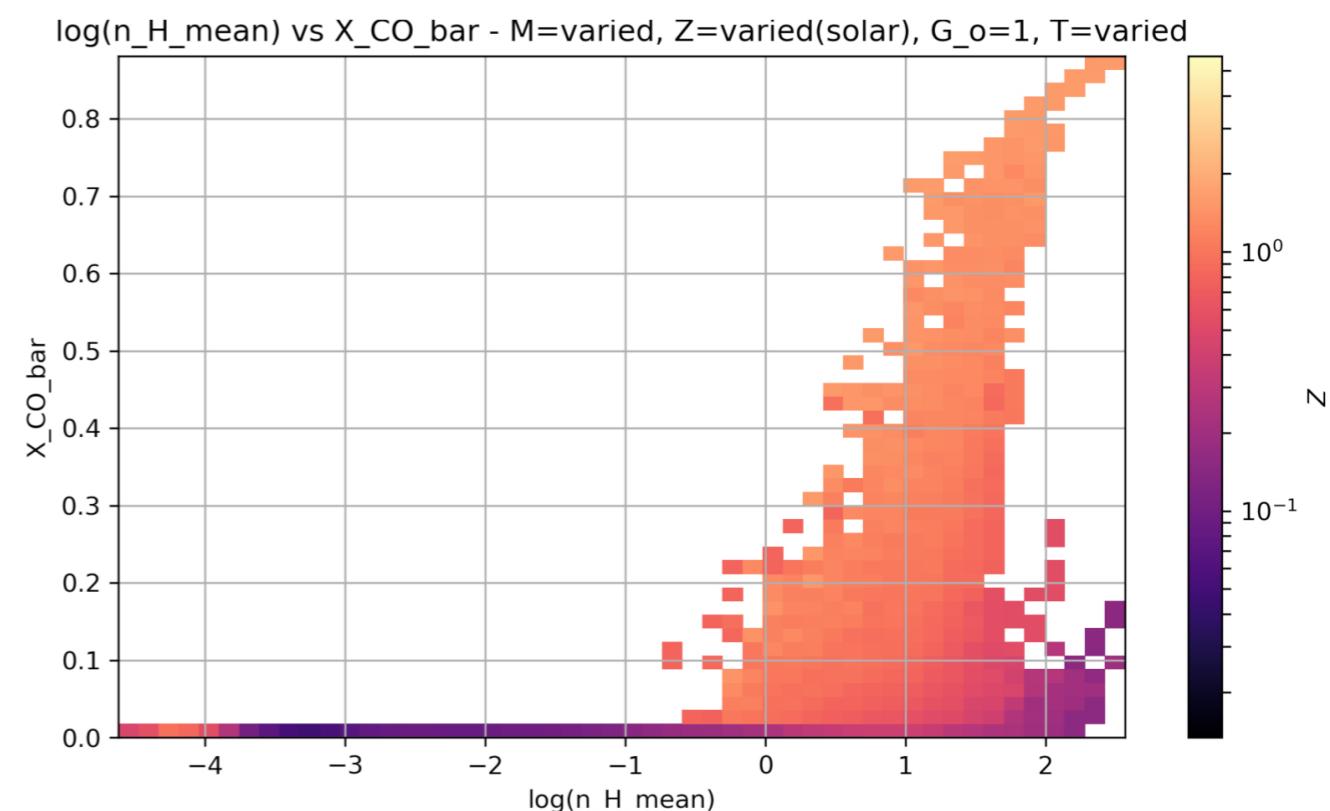
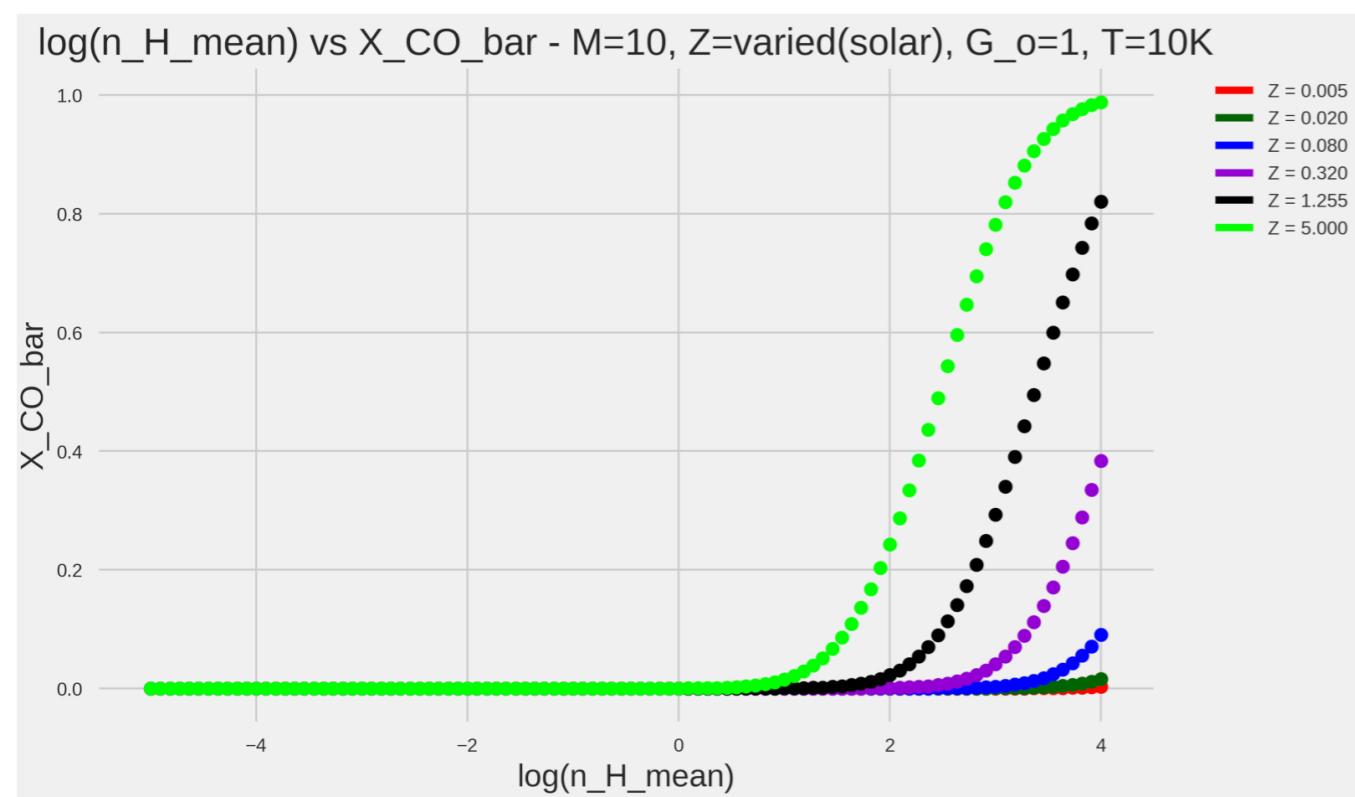
COMPARISON:



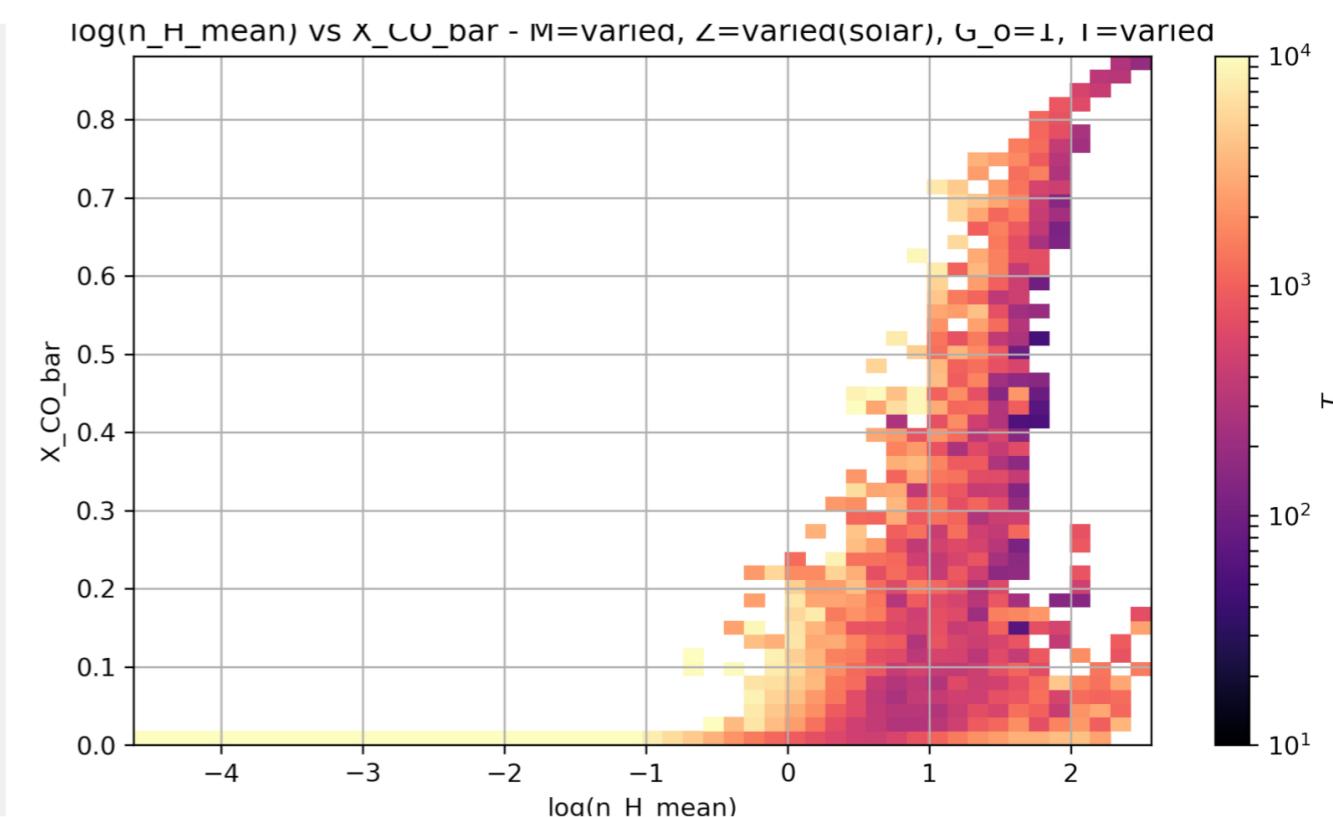
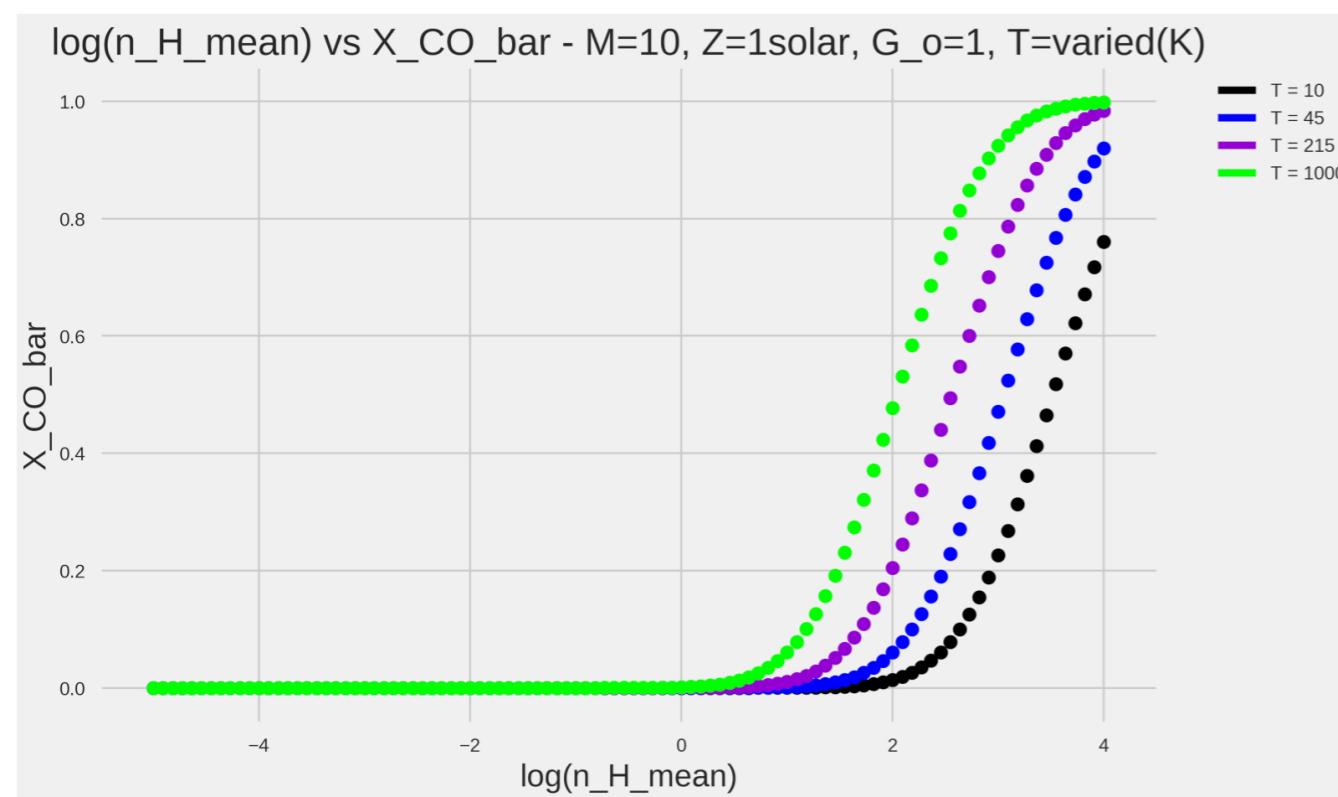
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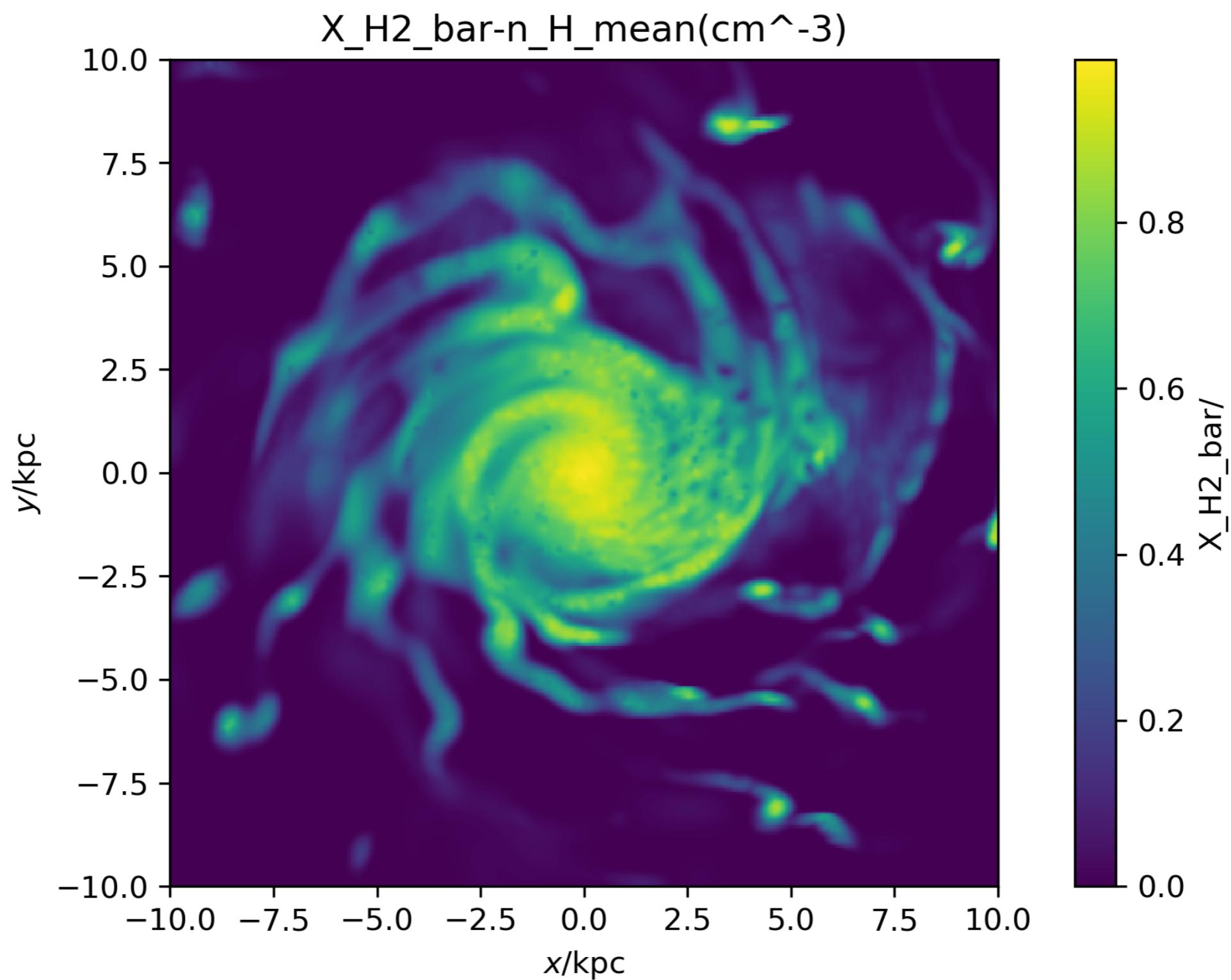
COMPARISON:



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GALAXY MAPS:



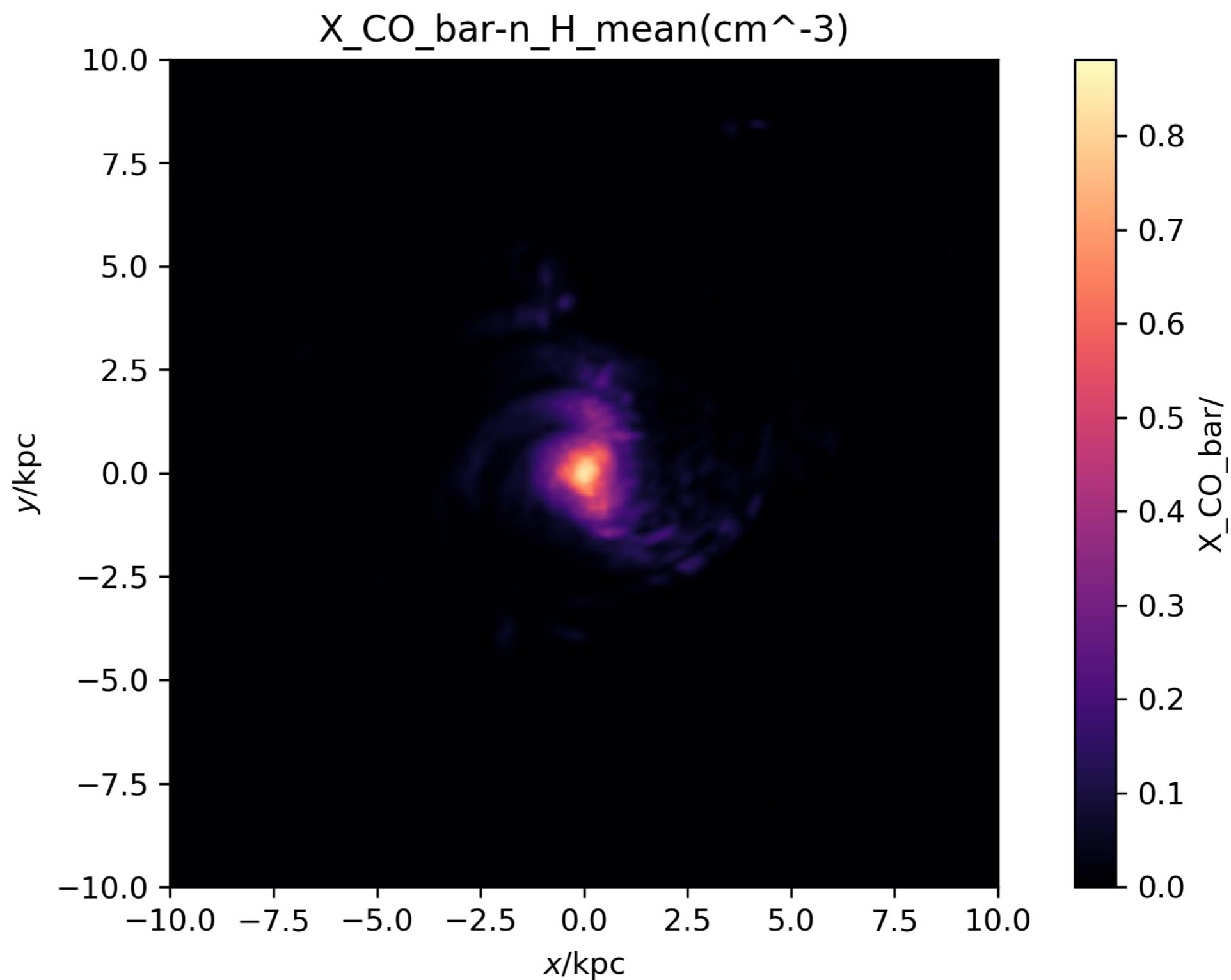
DOWN THE LINE...

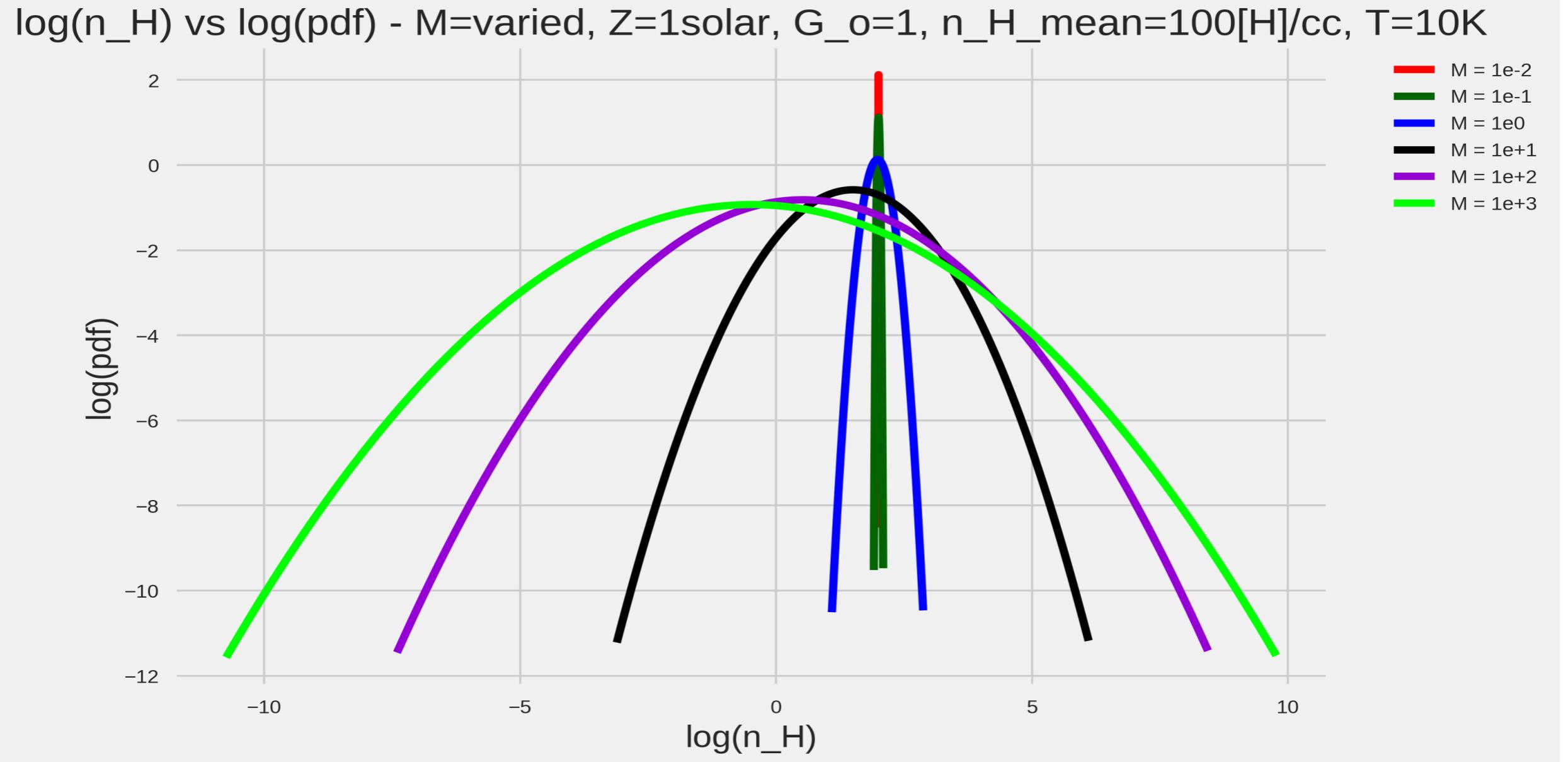
- ✓ CO emission lines - radiative transfer
- ✓ Comparing with observations from ALMA

FIN.

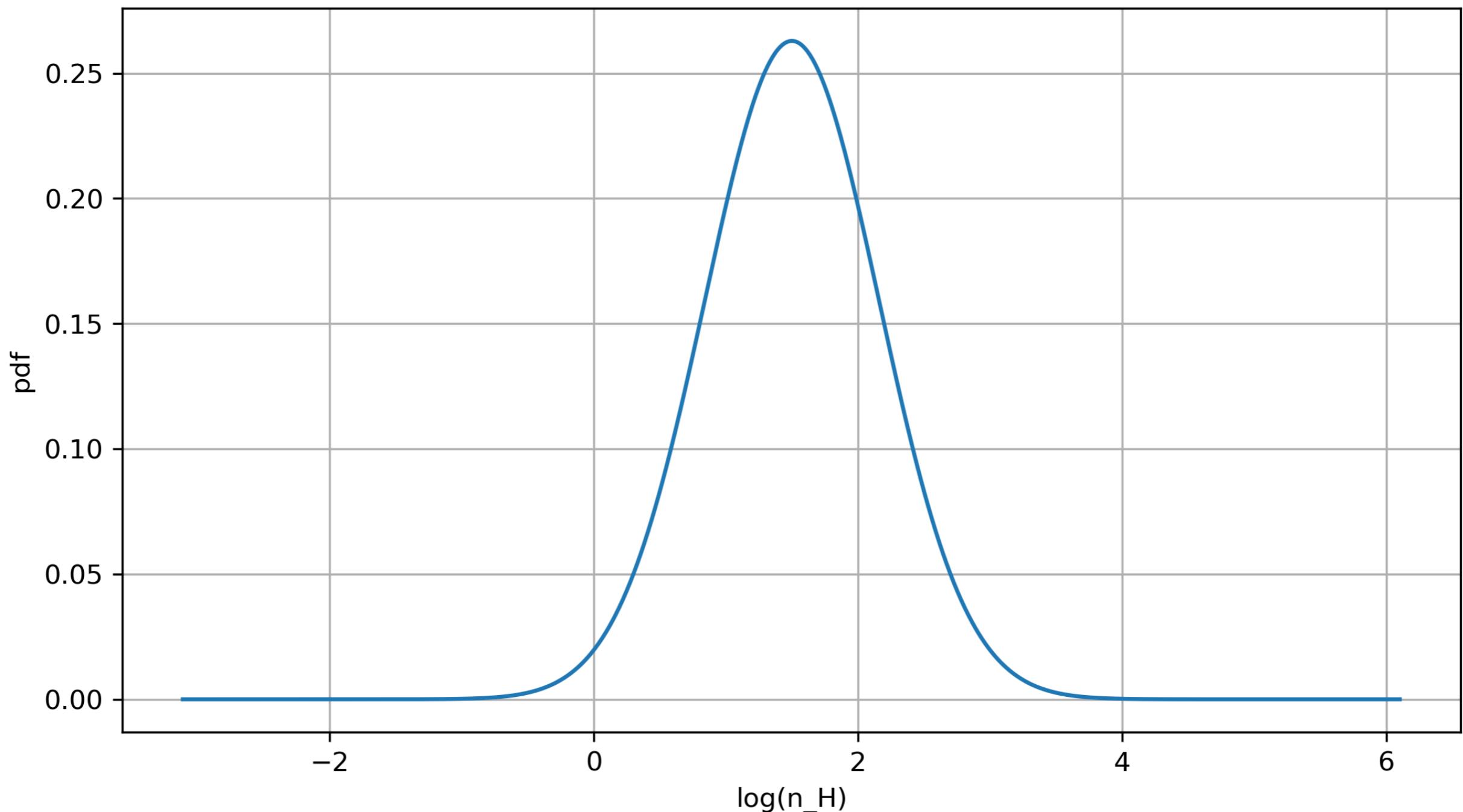
AFTER-LIFE

GALAXY MAPS:





$\log(n_H)$ vs pdf - $M=10$, $Z=1\text{solar}$, $G_o=1$, $n_H\text{mean}=100[H]/\text{cc}$, $T=10\text{K}$



$\log(n_H)$ vs pdf - $M=10$, $Z=1\text{solar}$, $G_o=1$, $n_H\text{mean}=100[H]/\text{cc}$, $T=10\text{K}$

