Probing the physical state of the high-redshift intergalactic medium using cosmological simulations

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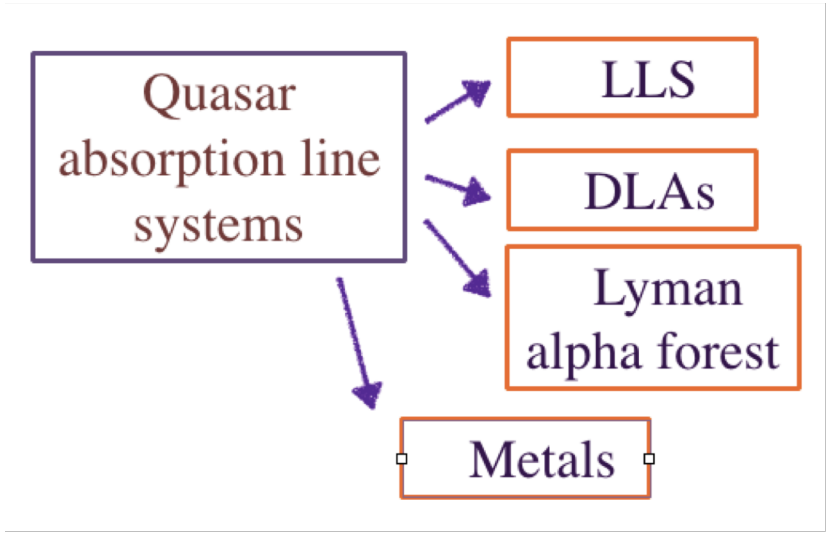
The Intergalactic Medium at the Epoch of Reionisation

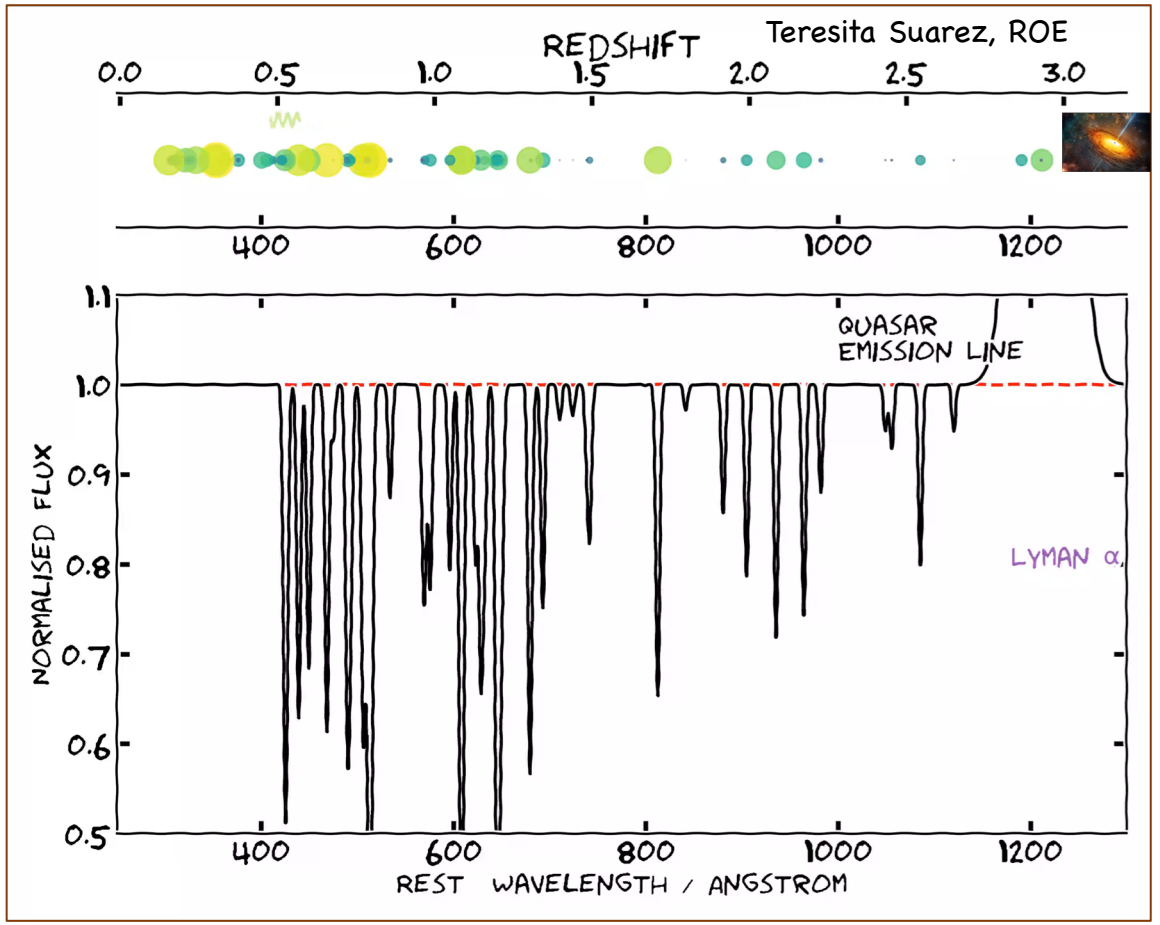
- Metagalactic UV background :: Abundances of individual ionisation species present in the IGM allow us to model the metagalactic UV background and the physical properties (temperature and density) of the gas, in particular at the epoch of reionisation.

- High-quality quasar absorption spectra :: Studies of high-quality quasar absorption spectra :: a lot of information regarding the distribution of heavy elements in the high-redshift IGM.



Absorption Lines

- Quasar absorption lines
  - Produced by clouds of gas
  - powerful probe of the IGM
  - High-redshifts >> used to study the evolution of the IGM
- abundance patterns of quasar absorption systems:
  - nucleosynthetic origins
  - dust content of the gas
  - build-up of metals with cosmic time
- Redshift evolution



Common QSO absorption line systems

HI, CII, CIV, OVI, MgII, SiIV

The balance between ionisation and recombination

- ➢ Density and temperature of the absorbing gas
- ➢ Intensity of the ionising photons

$T \sim 10^4$ K → HI, CII, MgII :: low ionization

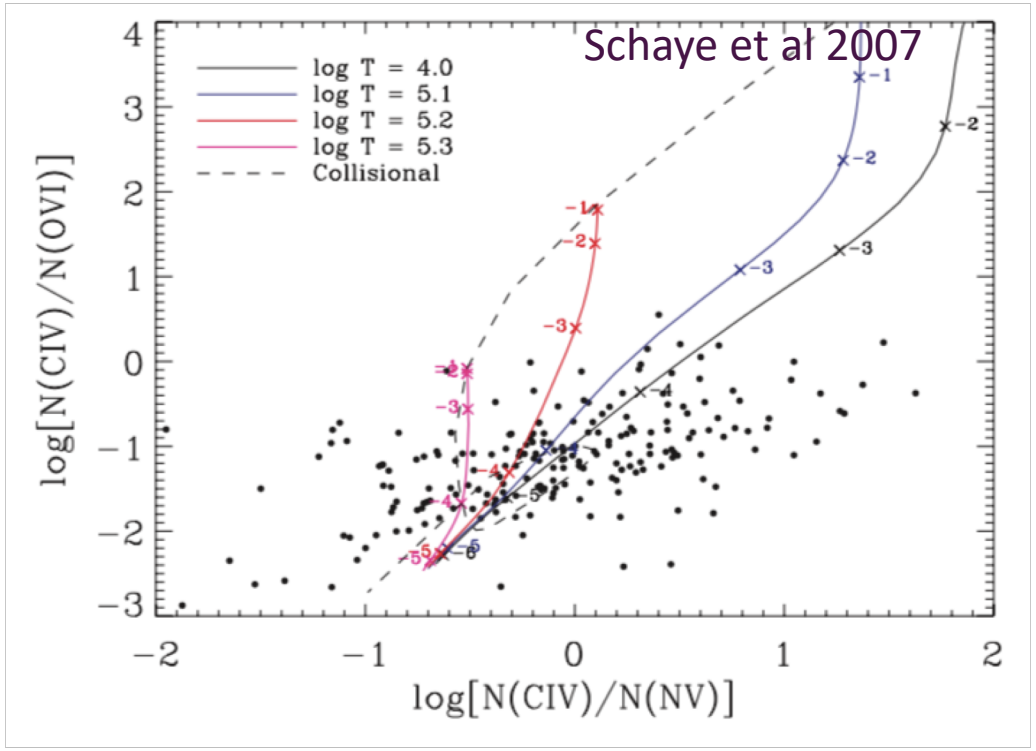
If $T > 10^5$ K → CIV and OVI :: highly ionized species

The relative strengths of different absorption lines

- ➢ information about abundance ratios
- ➢ thermal and ionisation state of the absorbing gas

Surveys: populations of IGM absorbers

- **Highly enriched gas clouds** are regularly found in surveys for quasar absorption lines, for a **wide range of *z* and *N*(HI)**
- Metal lines at z ~6 as **potential probes of H reionization**:: high density peaks>> last pockets of neutral gas
- low-ionization absorption lines [**OI, SiII, CII**] :: last phase of reionisation
- **CIV tracer** of highly ionized metals at z<5 :: may remain abundant out of z~6



Photoionization models

Series of photoionization models
[cloudy (Ferland et al. 1998; Ferland 2006)]

Small clouds of constant density gas irradiated by

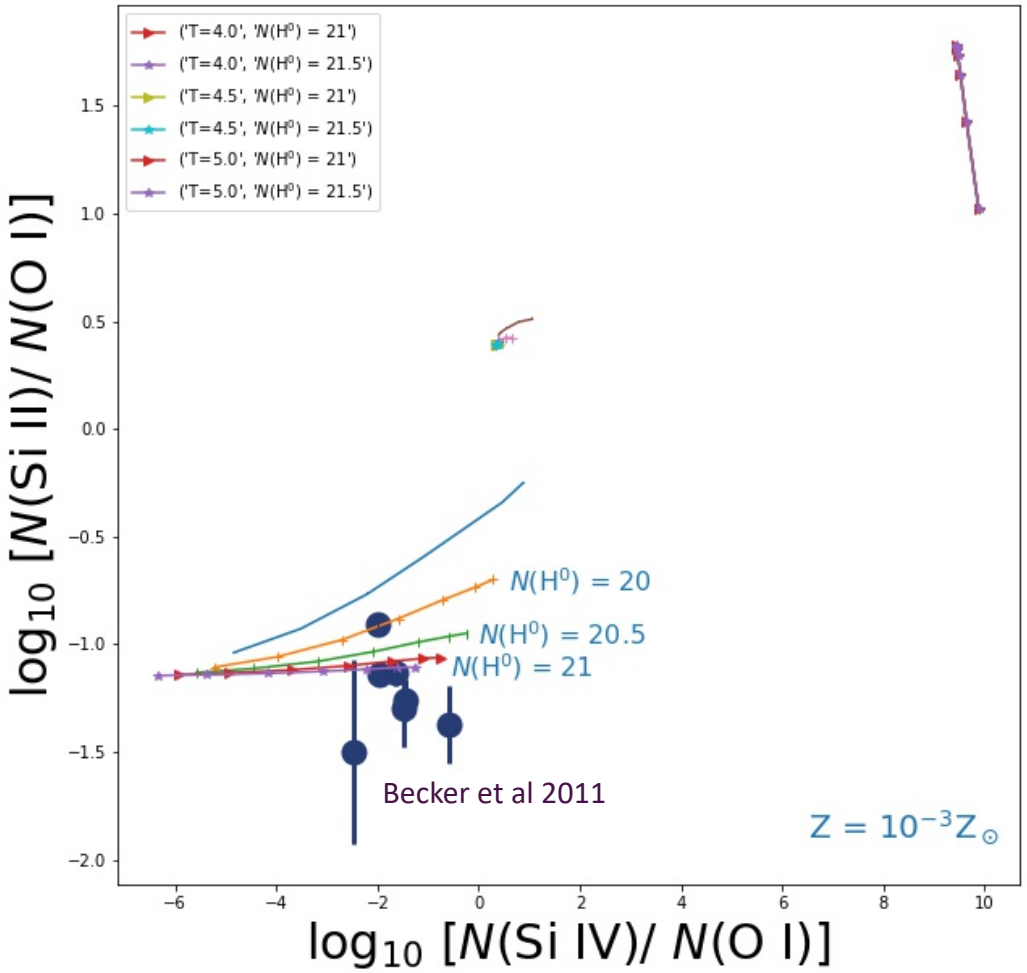
- the metagalactic ionising background (Haardt & Madau 2001, 2005)
- the cosmic microwave background

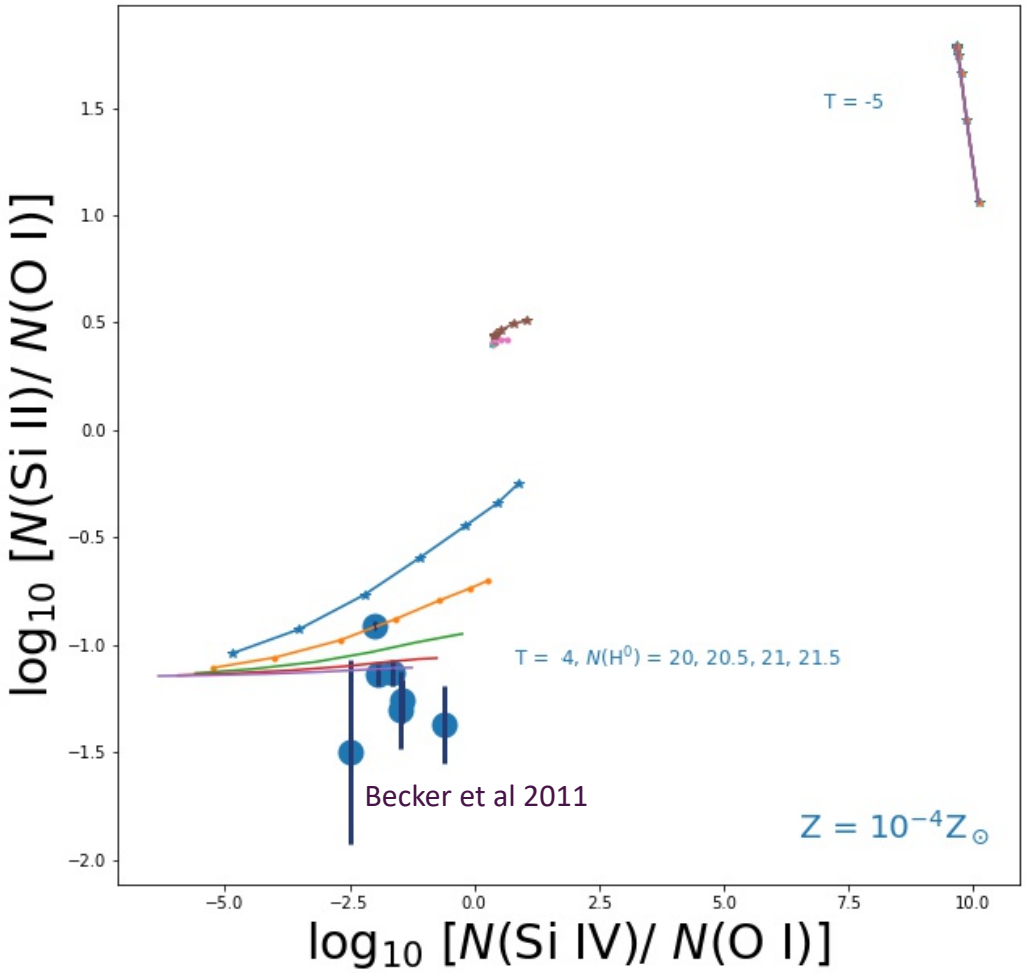
***Z* =1/1000 [&10^{-4}] solar**

Gas volume density from **log[n(H)/cm−3] = −4 to -1**
Stopped the calculation when the measured column density of neutral gas was reached
= 16.5 to 21.5

Temperatures **log[T] = 4, 4.5, 5**

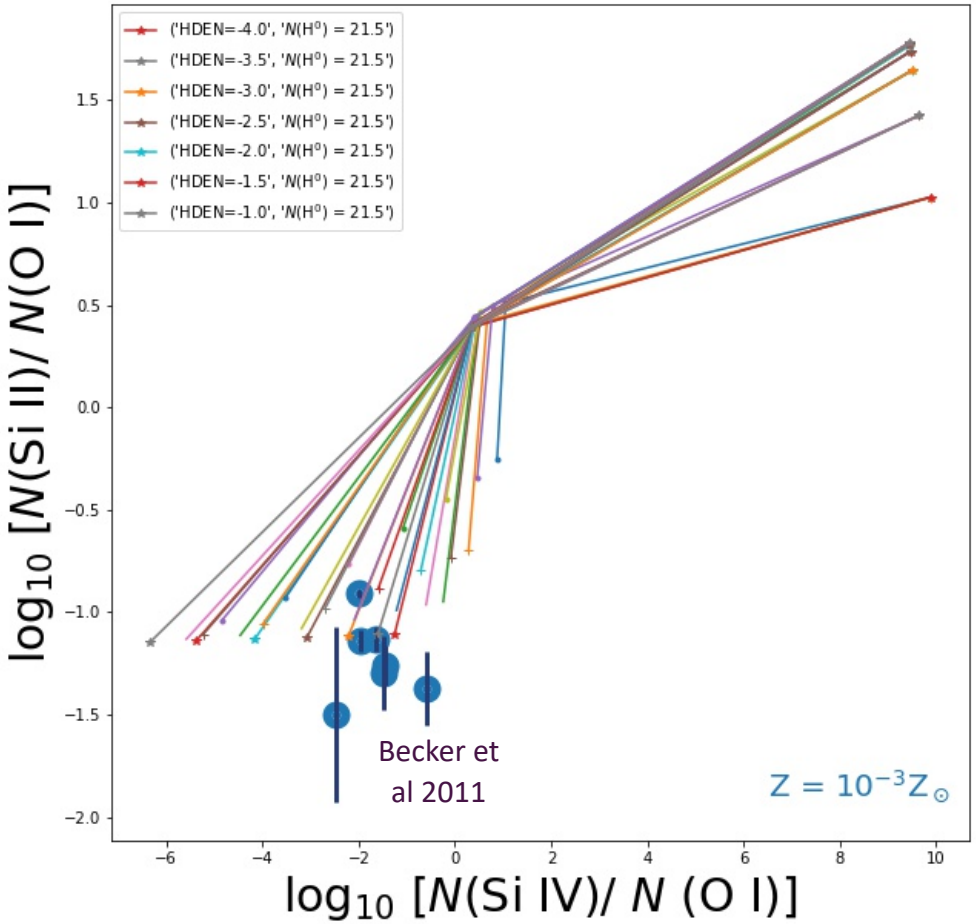
Column densities
log[T/K] = 4 to 5

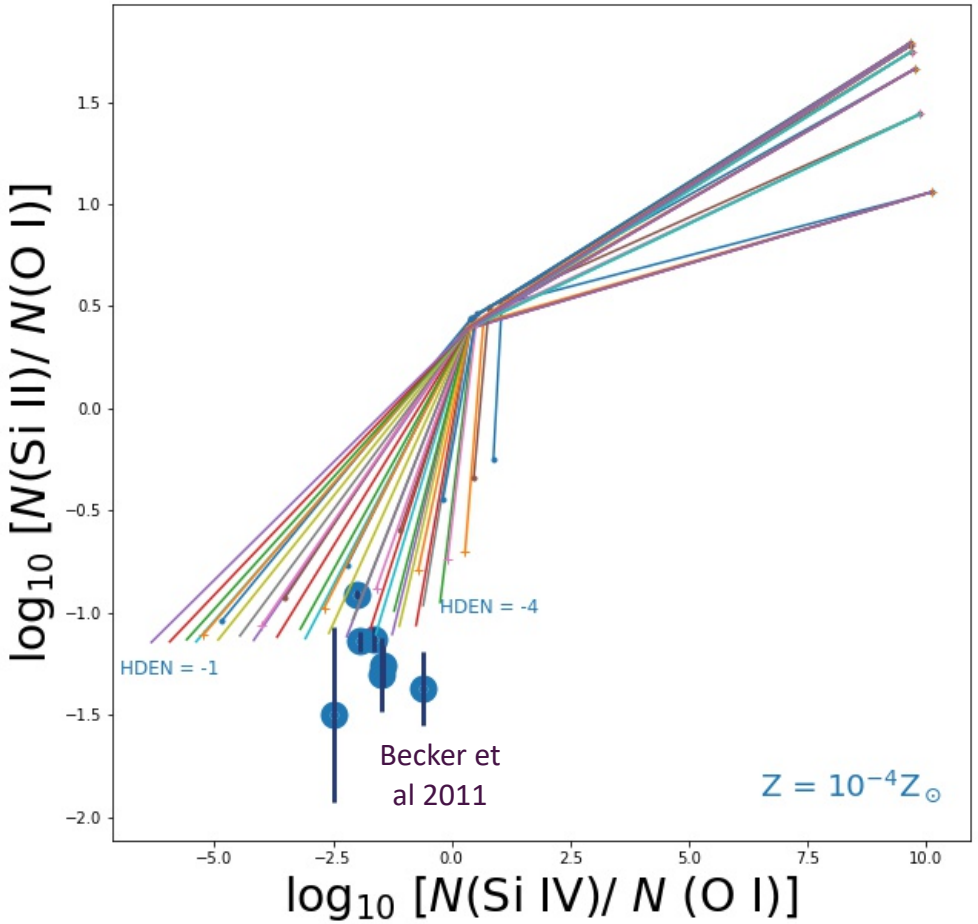




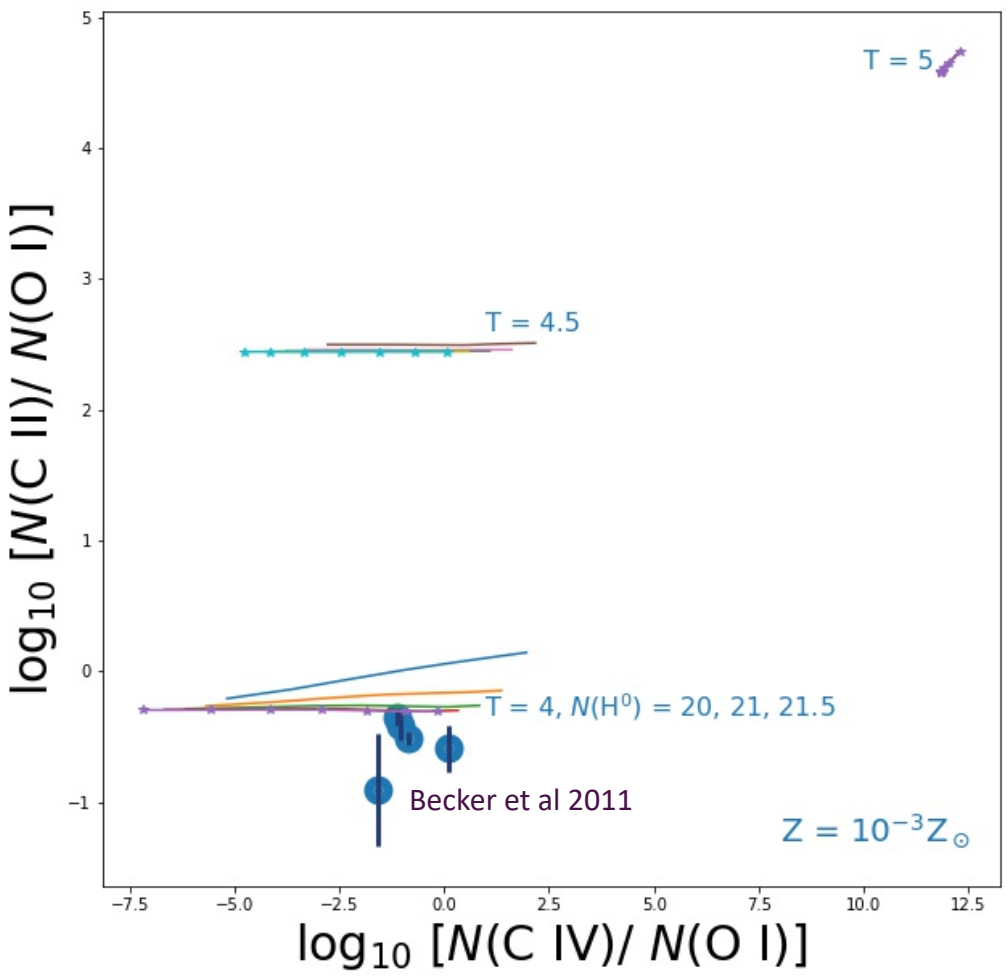
Column Densities

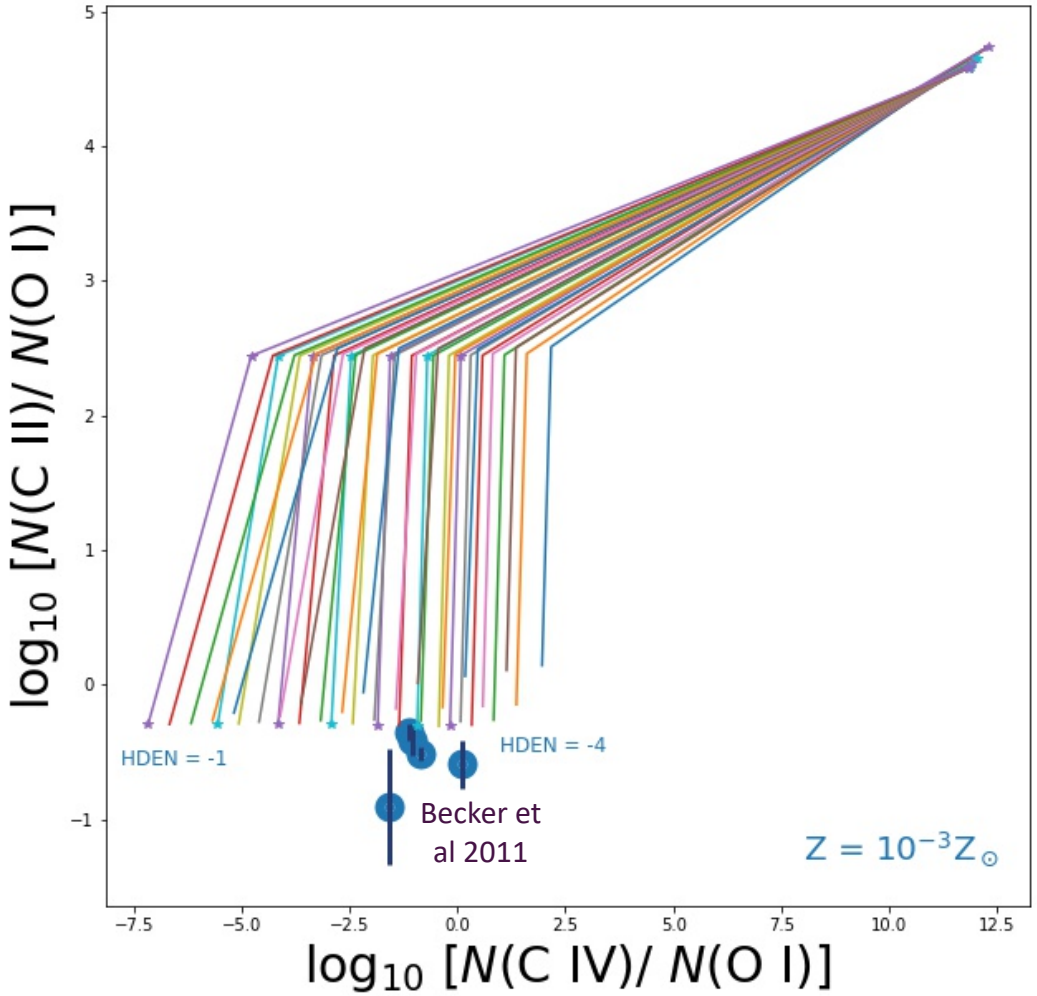
gas volume density log[n(H)/cm−3] = −4 to -1





CIV Column densities log[T/K] = 4 to 5





Some conclusions and more to do…

1. Inference of the size of the absorbers :: about few pc [8.5 pc to 0.03pc]

2. Simulations need that resolution EAGLE, Illustris, Sherwood,…

3. Are clouds in collisional equilibrium? Photoionized?

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