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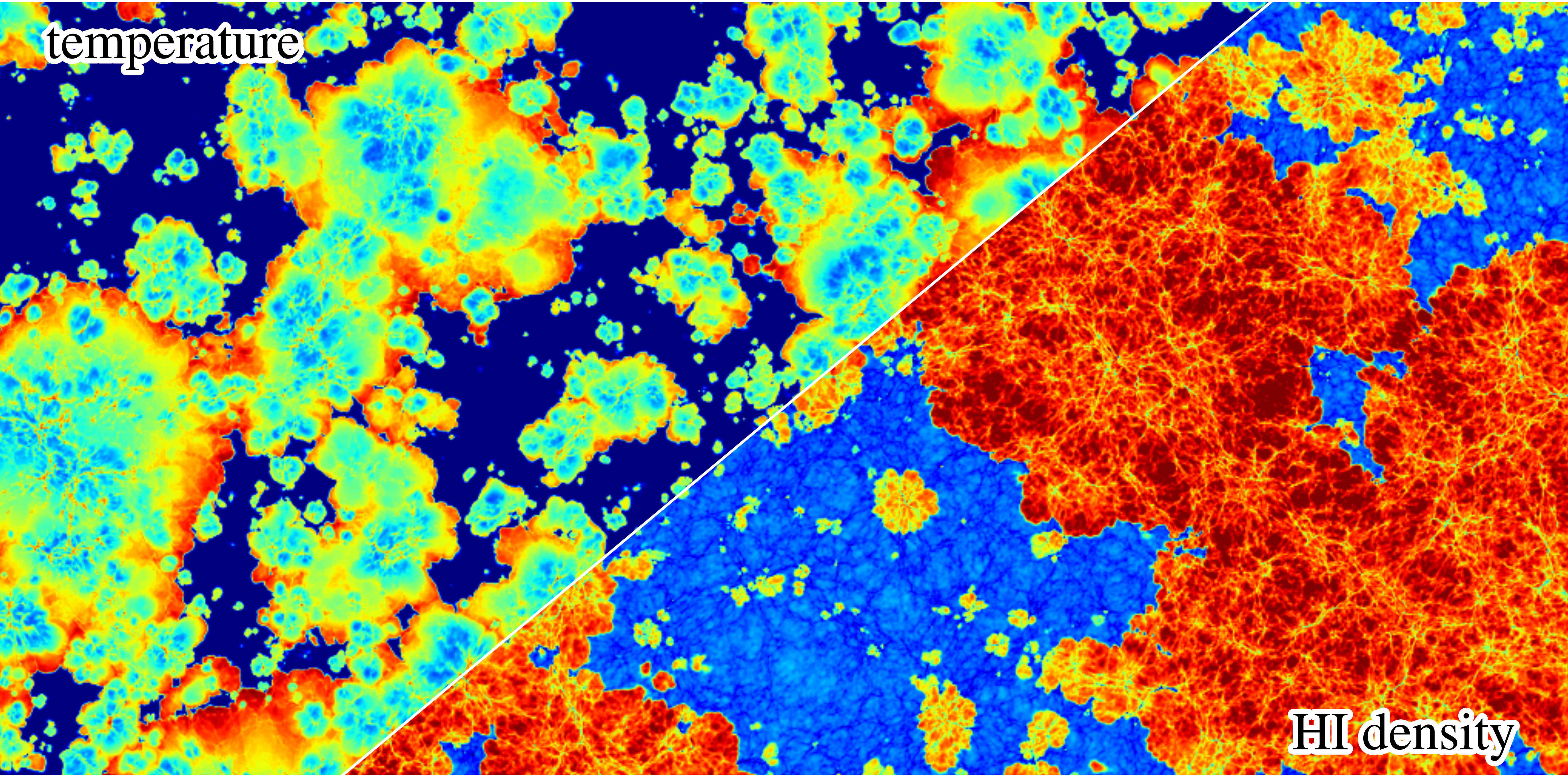


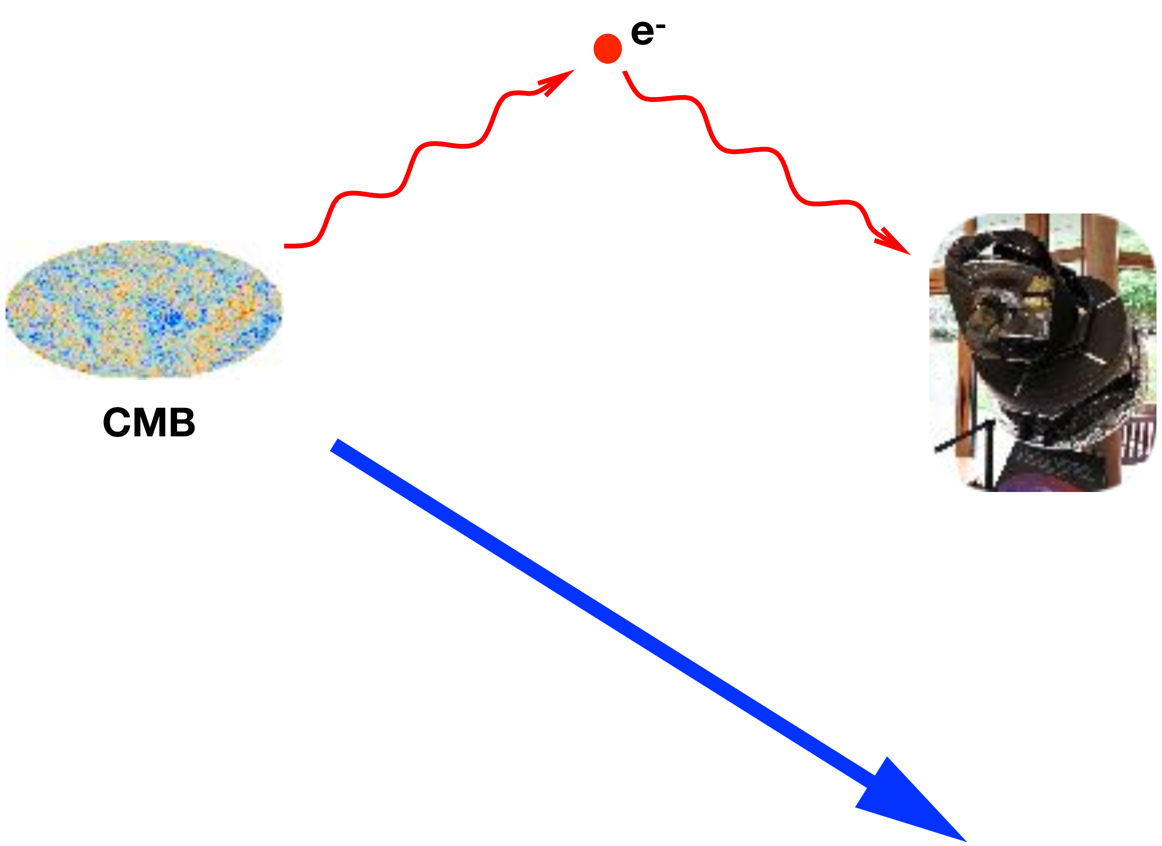
Relics of cosmic reionization in the high redshift IGM / Lyman-alpha forest & relevance for dark matter constraints

Ewald Puchwein, AIP

collaborators:
Girish Kulkarni, Laura Keating, James Bolton, Martin Haehnelt, Vid Irsic, Matteo Viel

Late and rapid cosmic reionization preferred by the data

Thomson scattering on free electrons



$$\tau = 0.0544^{+0.0070}_{-0.0081}$$

mid point: $z_{\rm re} = 7.68 \pm 0.79$

Planck 2018 VI

Lyman-alpha absorption by neutral hydrogen in the IGM

Lyman-alpha emitting galaxies

$$z_{\rm mid} \sim 7 - 7.5$$

e.g., Choudhury+15

QSO (near zones)

$$z_{\rm mid} \sim 7 - 7.5$$

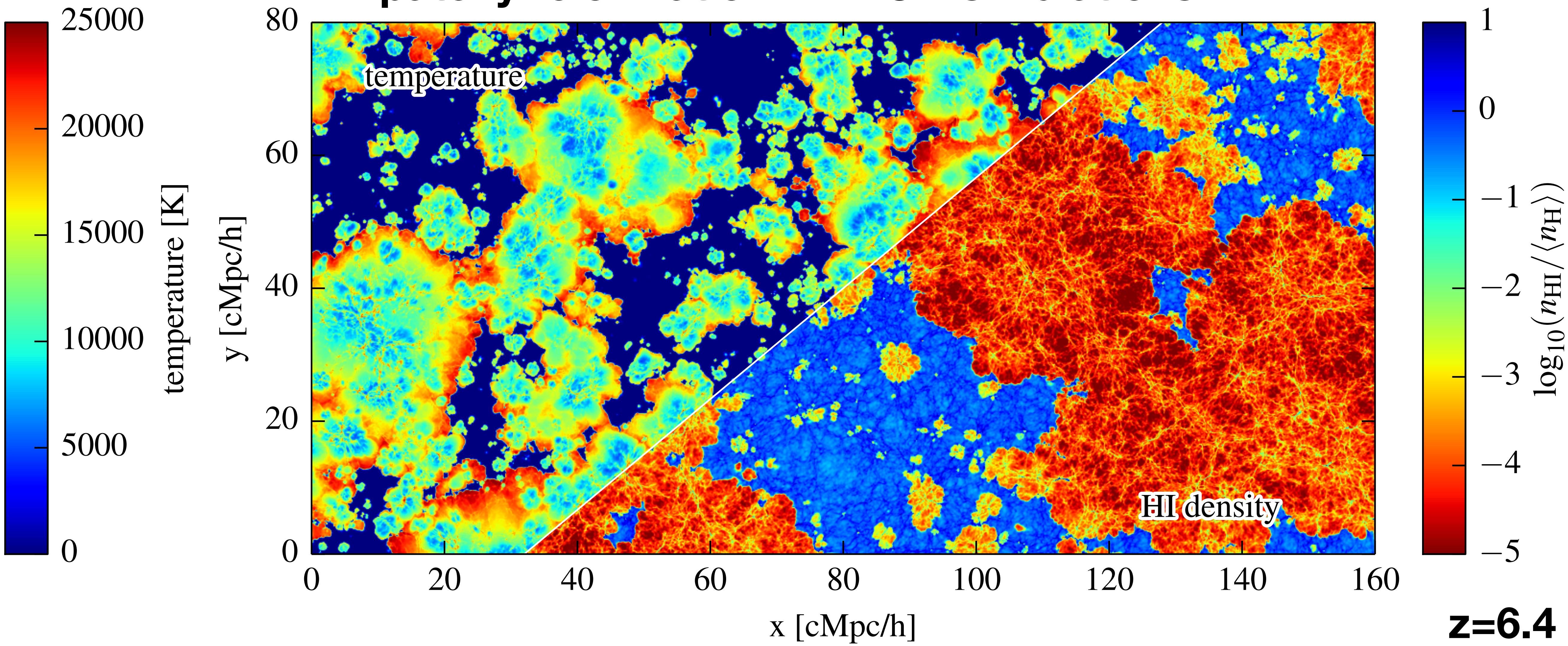
Davies+18

QSO (general IGM)

The IGM and Lyman-alpha forest in post-processing radiative transfer simulations

-> assign ionizing sources to halos
-> perform post-processing radiative transfer with the ATON code
-> calibrate source model to data (Lyman-alpha forest, CMB)
-> late reionization ending z~5.3 preferred (Kulkarni+19, Keating+19)

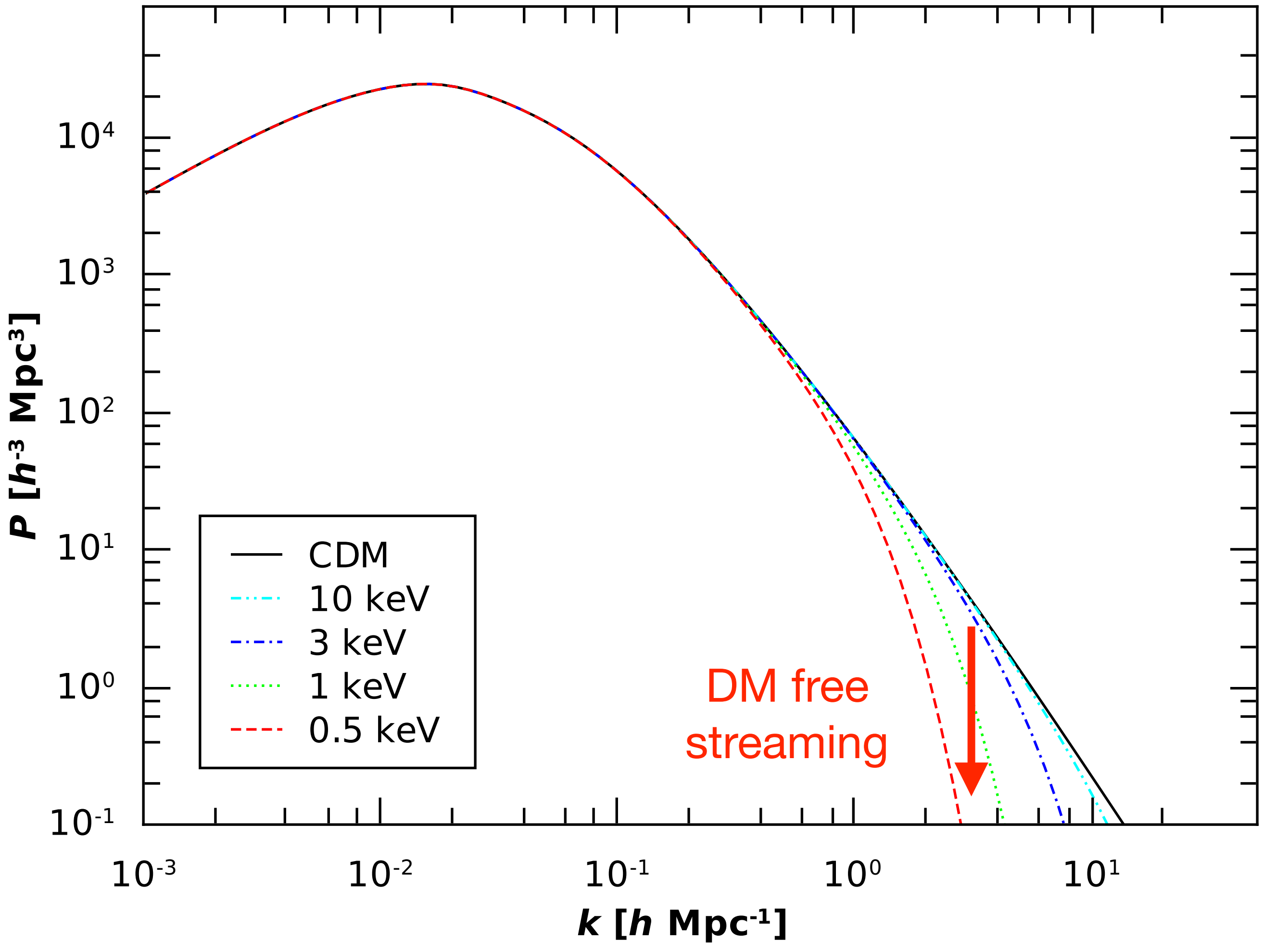
patchy reionization in ATON simulations



z=6.4

Constraining dark matter free streaming

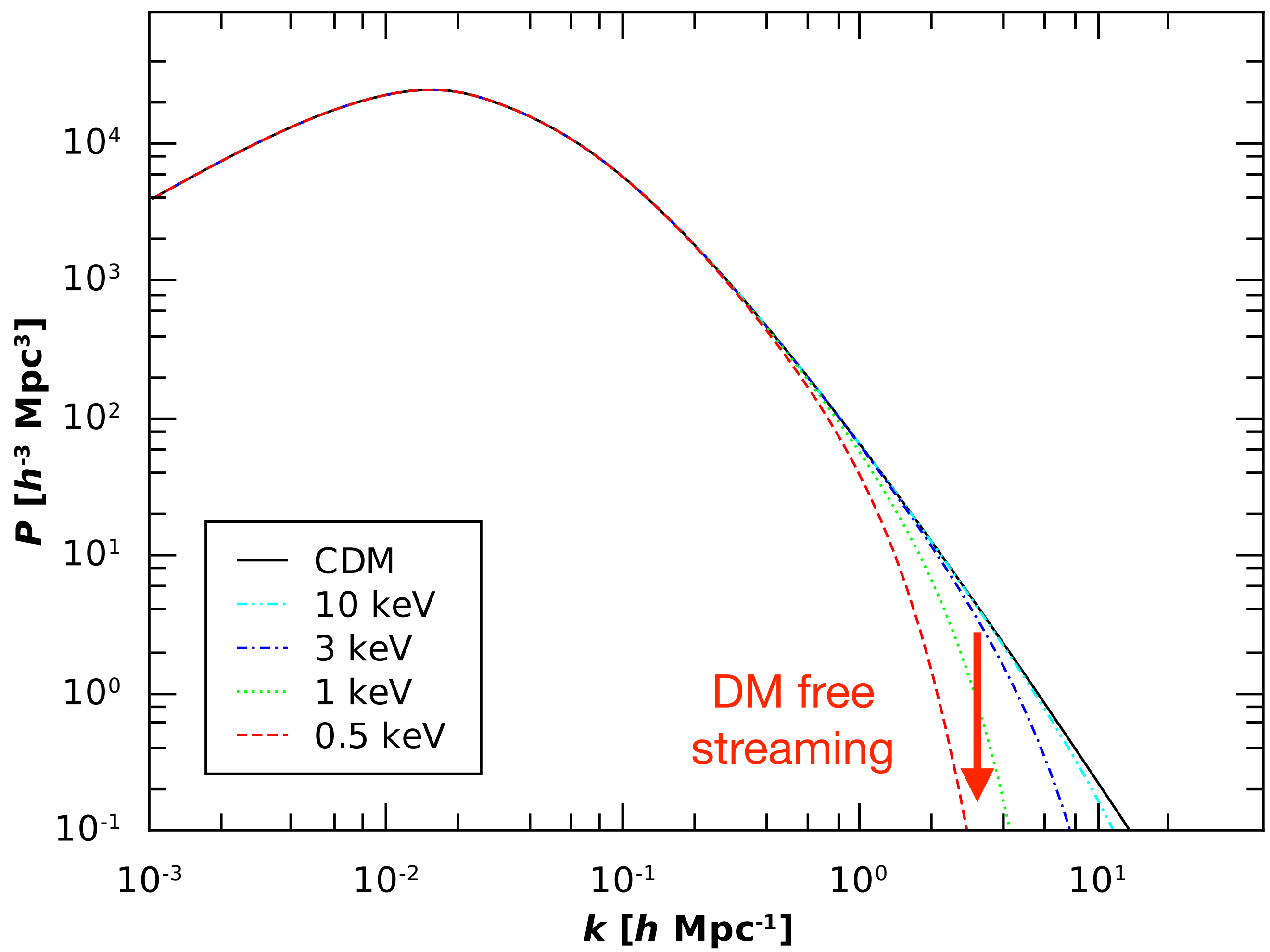
dark matter free streaming
suppresses small scale power



Dunstan et al. 2011

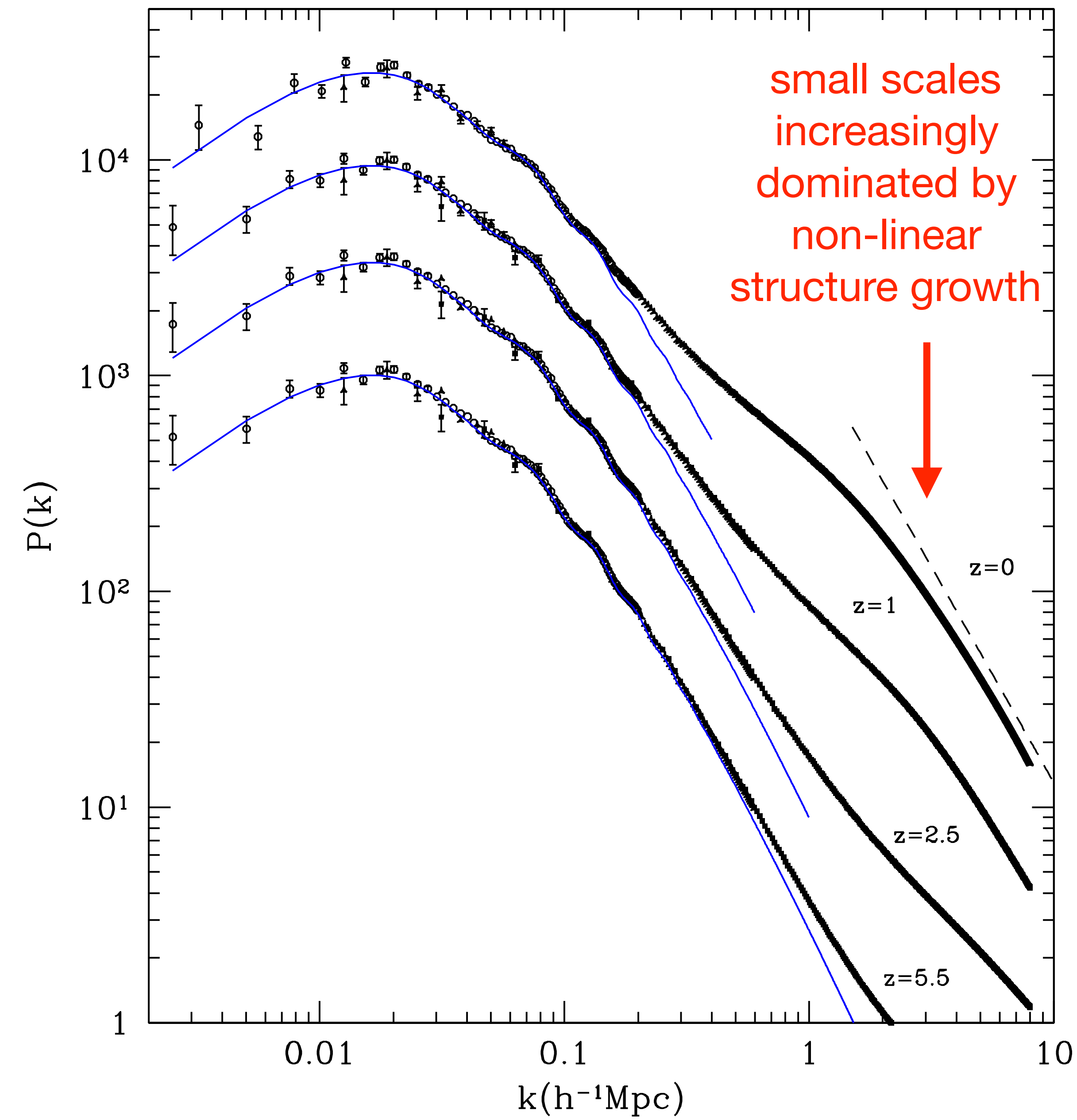
Constraining dark matter free streaming

dark matter free streaming suppresses small scale power



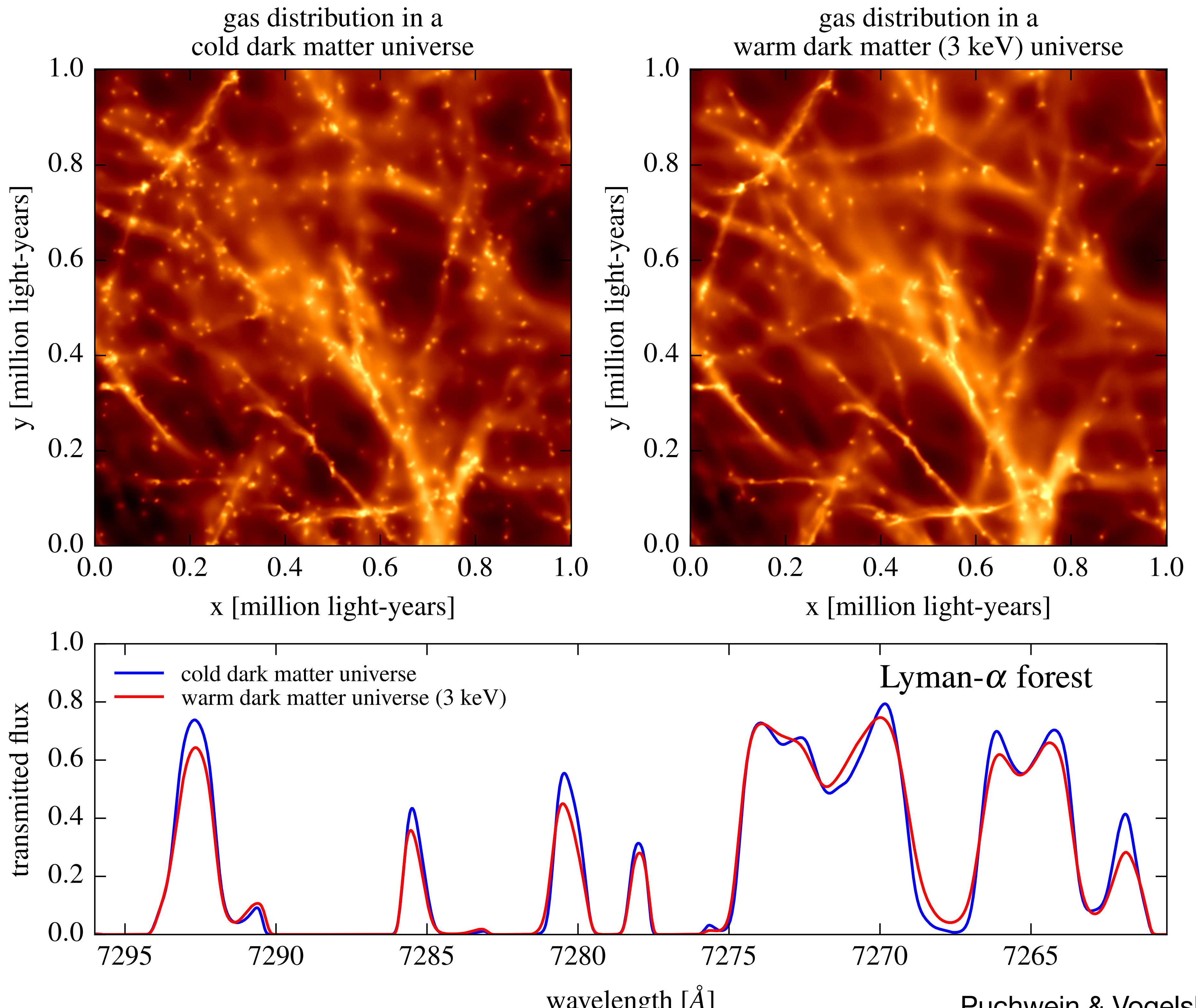
Dunstan et al. 2011

linear vs non-linear matter power spectrum



Klypin et al. 2016

The IGM in a cold and warm dark matter universe



z=5

Puchwein & Vogelsberger 2019, in prep.

Other effects on small scale Lyman-alpha forest

thermal broadening

Doppler broadening due to thermal motions of hydrogen atoms

mostly captured in post-processing radiative transfer

pressure smoothing

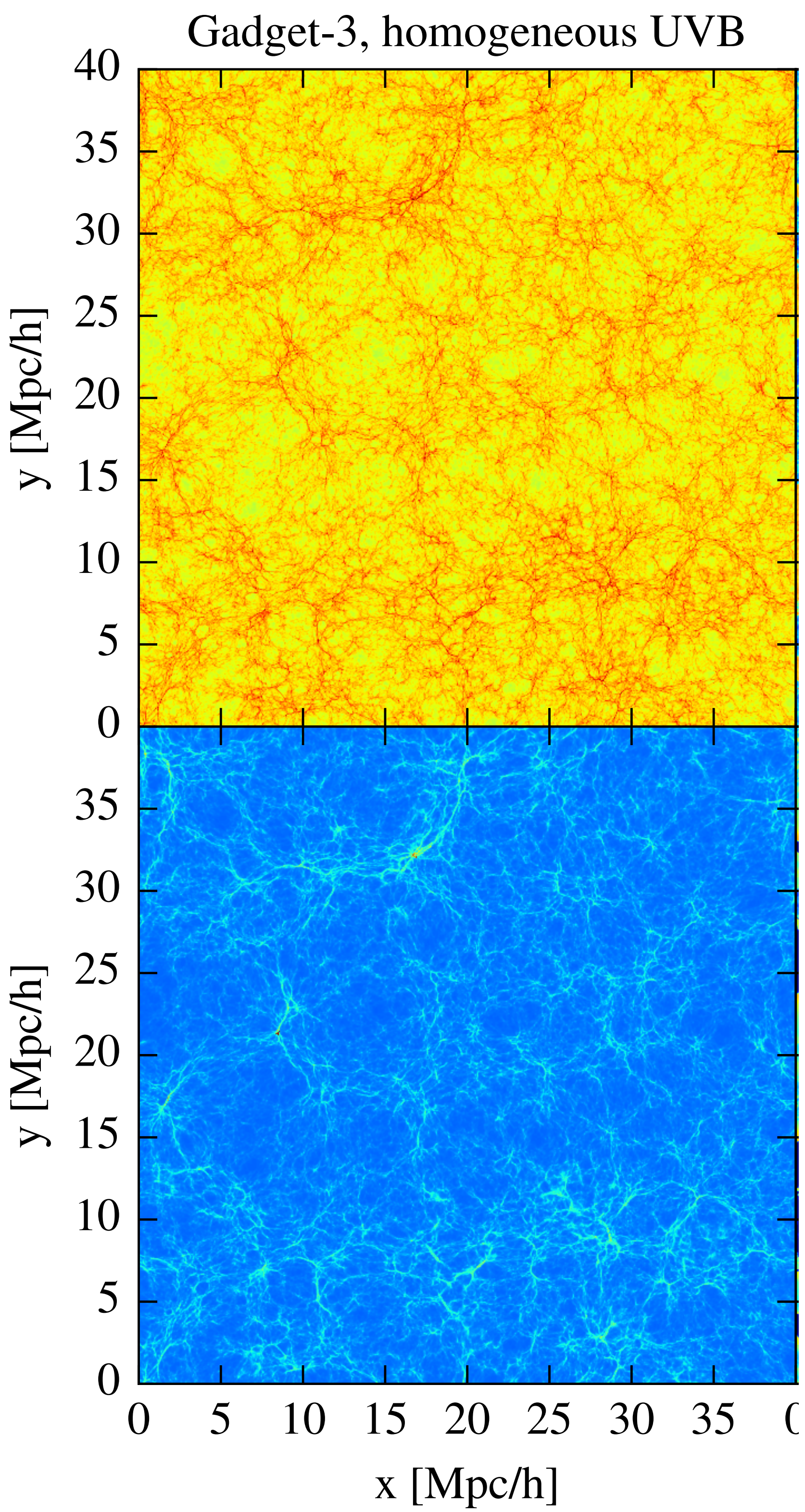
hydrodynamic reaction to photo-heating

not captured in post-processing radiative transfer

Hybrid radiative-transfer / hydrodynamical simulations

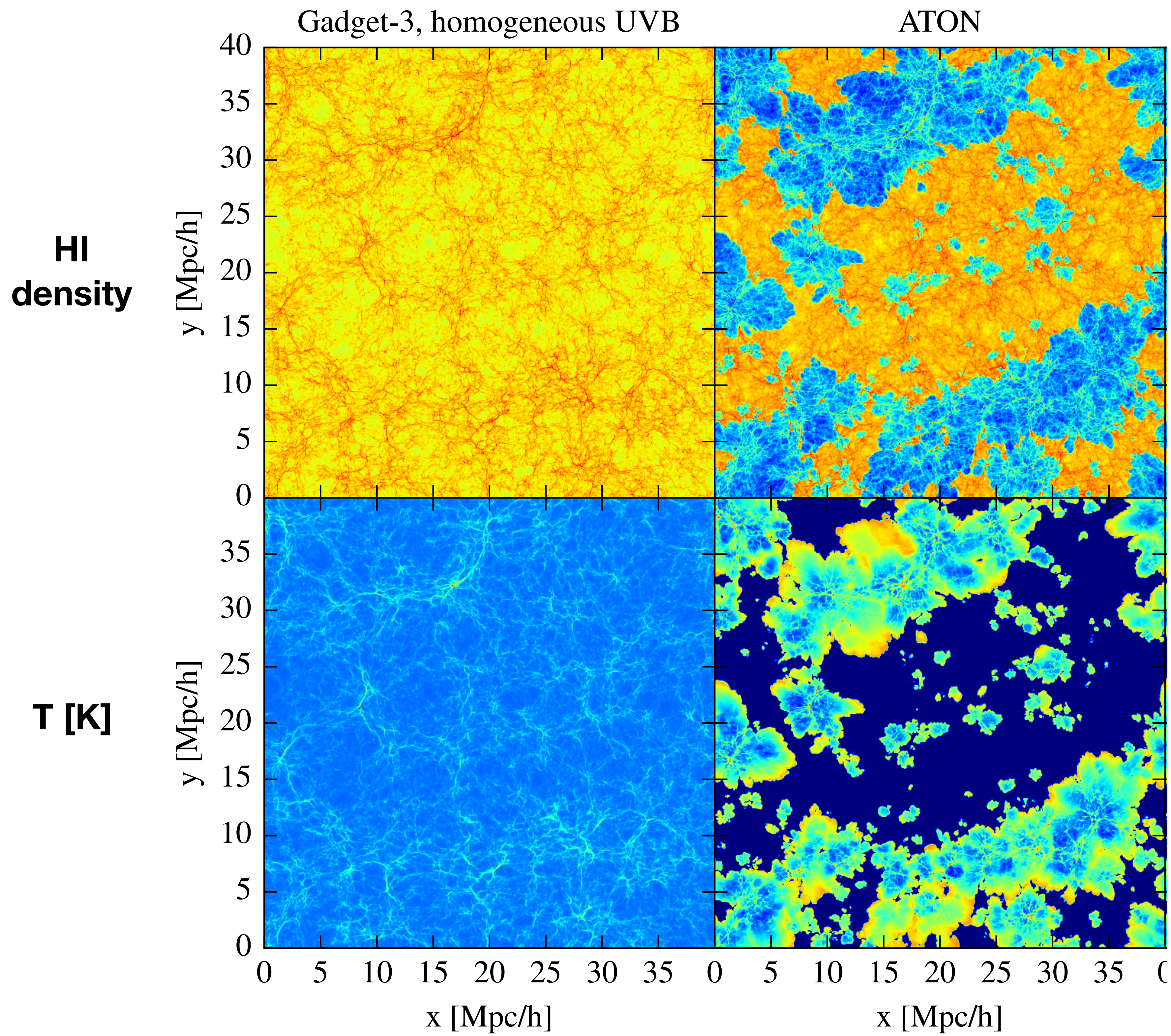
HI density

T [K]



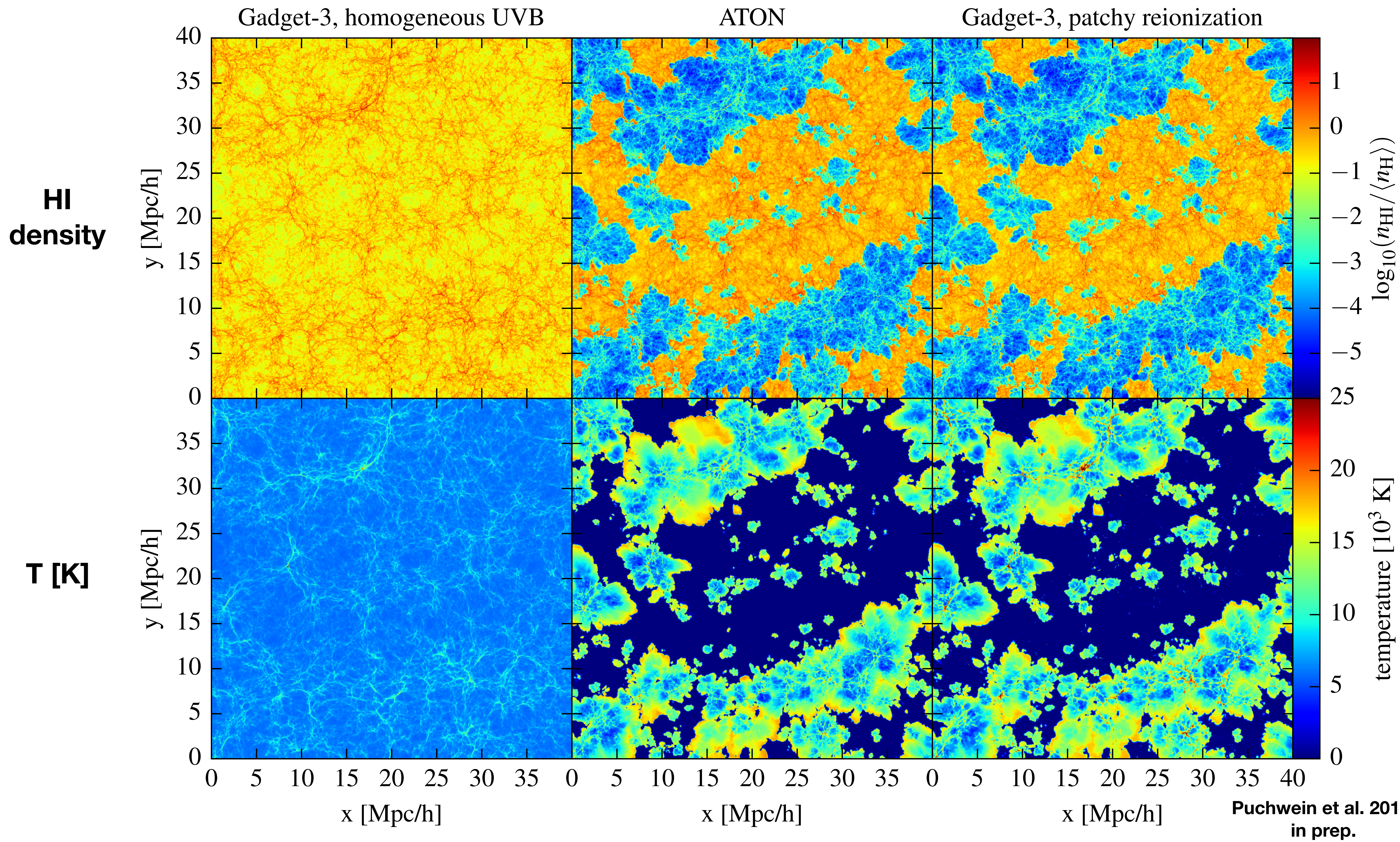
Puchwein et al. 2019, in prep.

Hybrid radiative-transfer / hydrodynamical simulations



Puchwein et al. 2019, in prep.

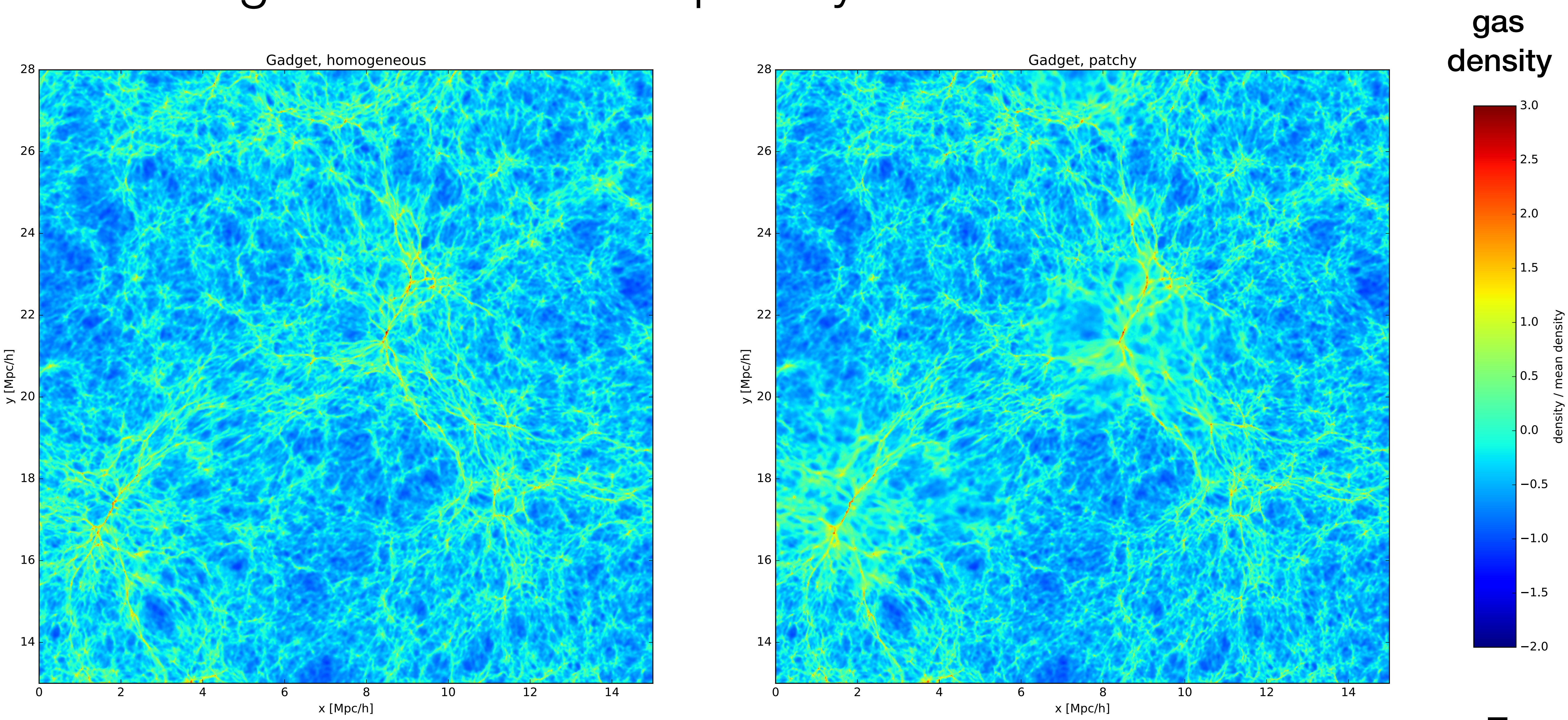
Hybrid radiative-transfer / hydrodynamical simulations



Puchwein et al. 2019, in prep.

Effect of pressure smoothing / patchy reionization on the density distribution of the IGM

homogeneous UVB | patchy UVB from RT simulation

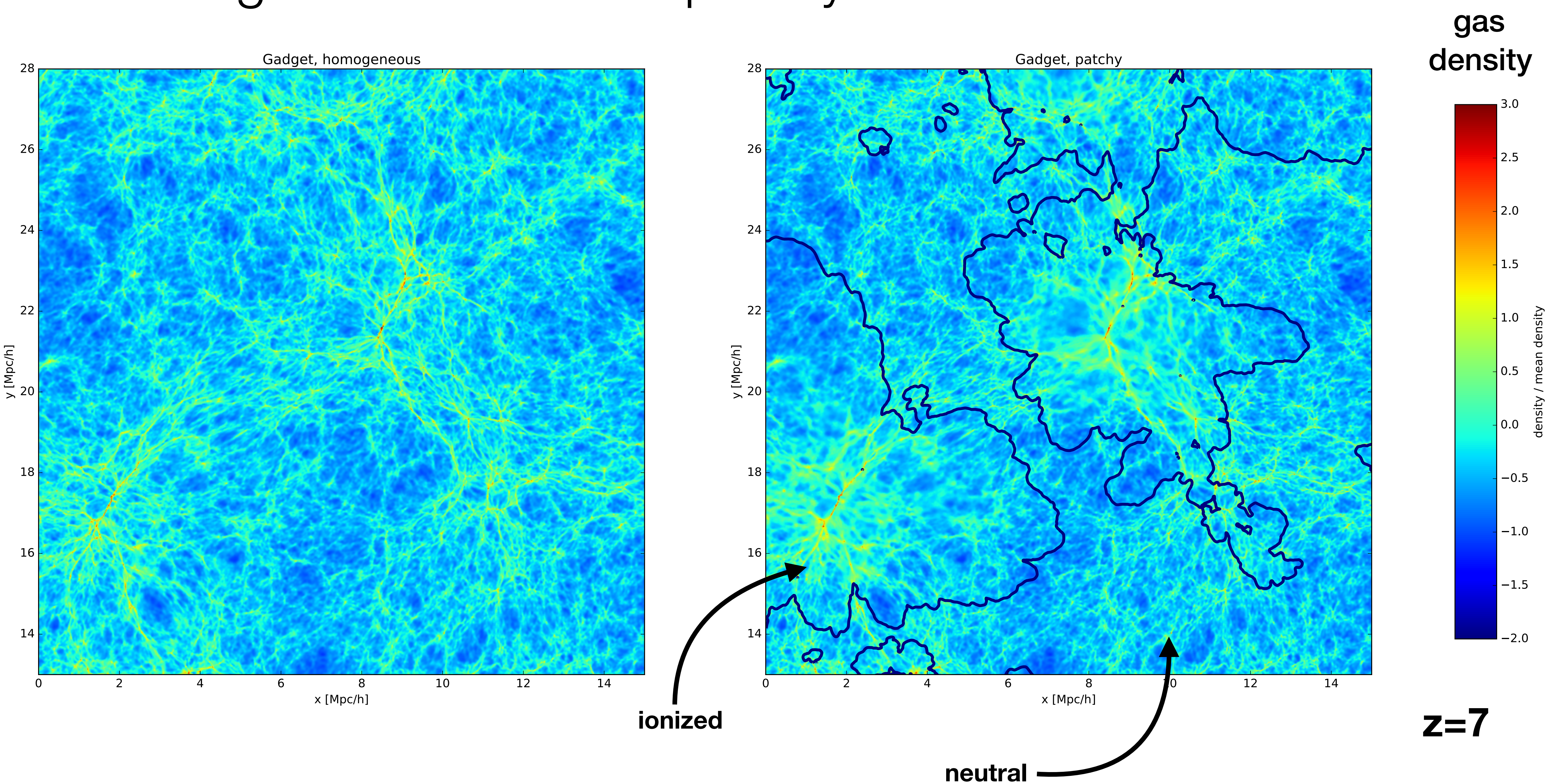


z=7

Puchwein et al. 2019, in prep.

Effect of pressure smoothing / patchy reionization on the density distribution of the IGM

homogeneous UVB — patchy UVB from RT simulation



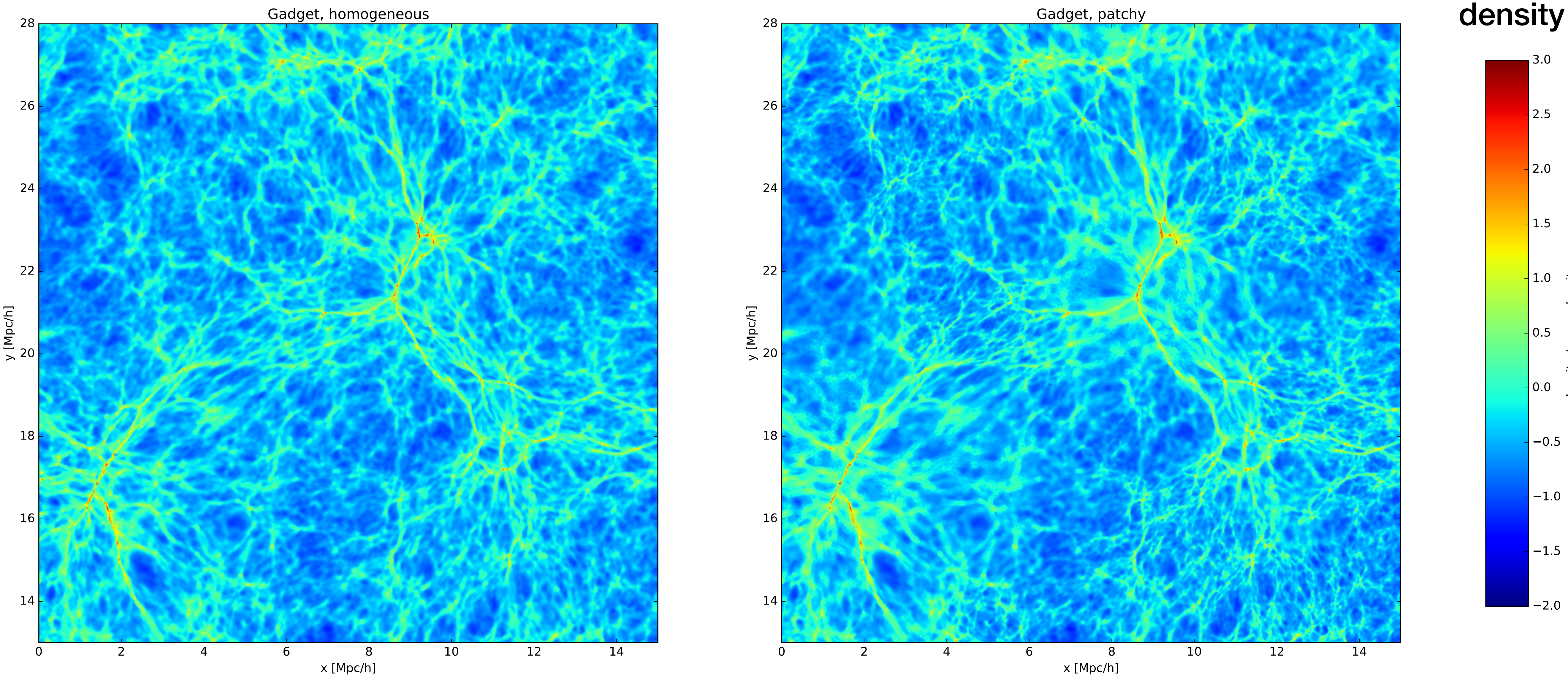
Puchwein et al. 2019, in prep.

Effect of pressure smoothing / patchy reionization on the density distribution of the IGM

homogeneous UVB

patchy UVB from RT simulation

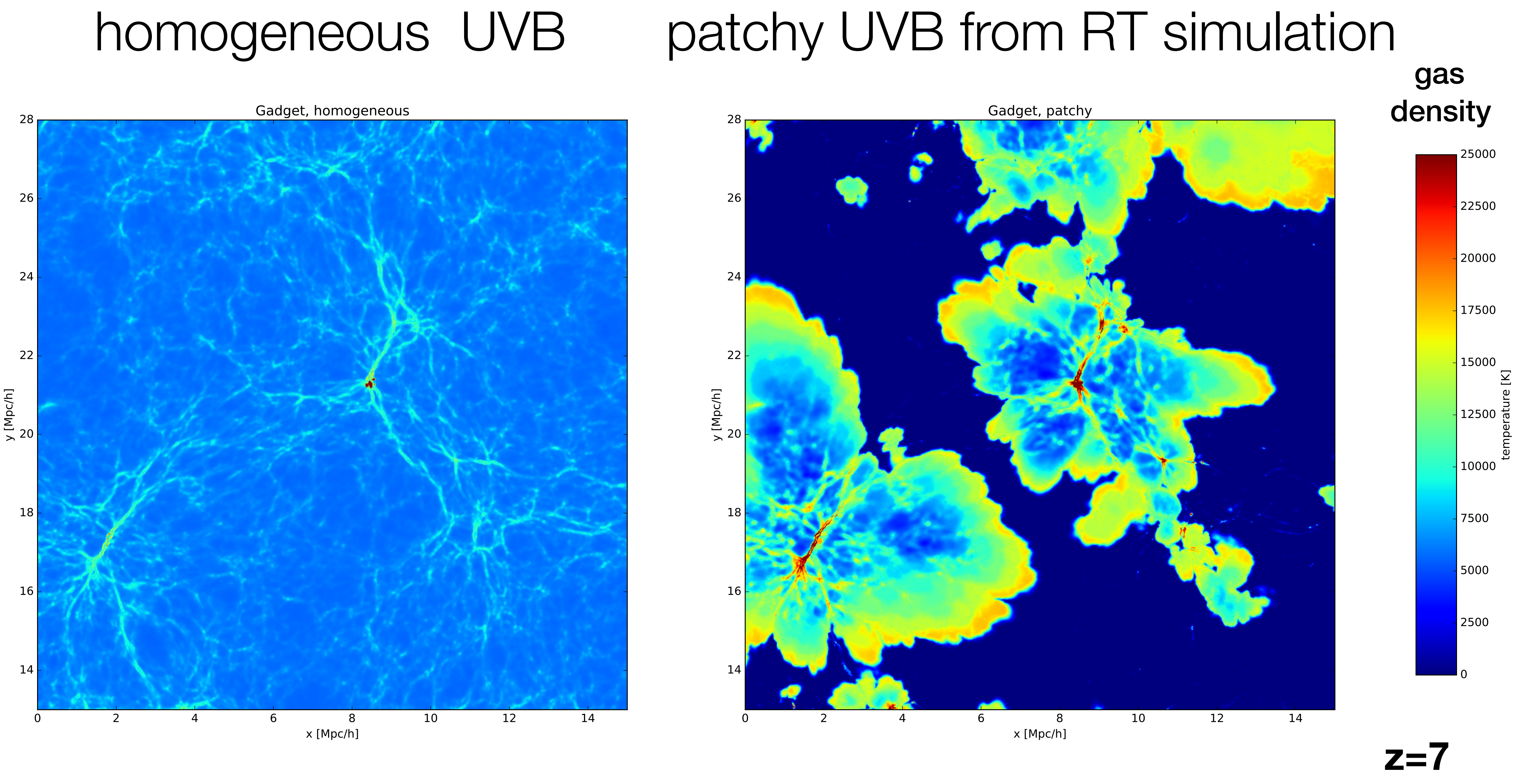
gas density



z=5

Puchwein et al. 2019, in prep.

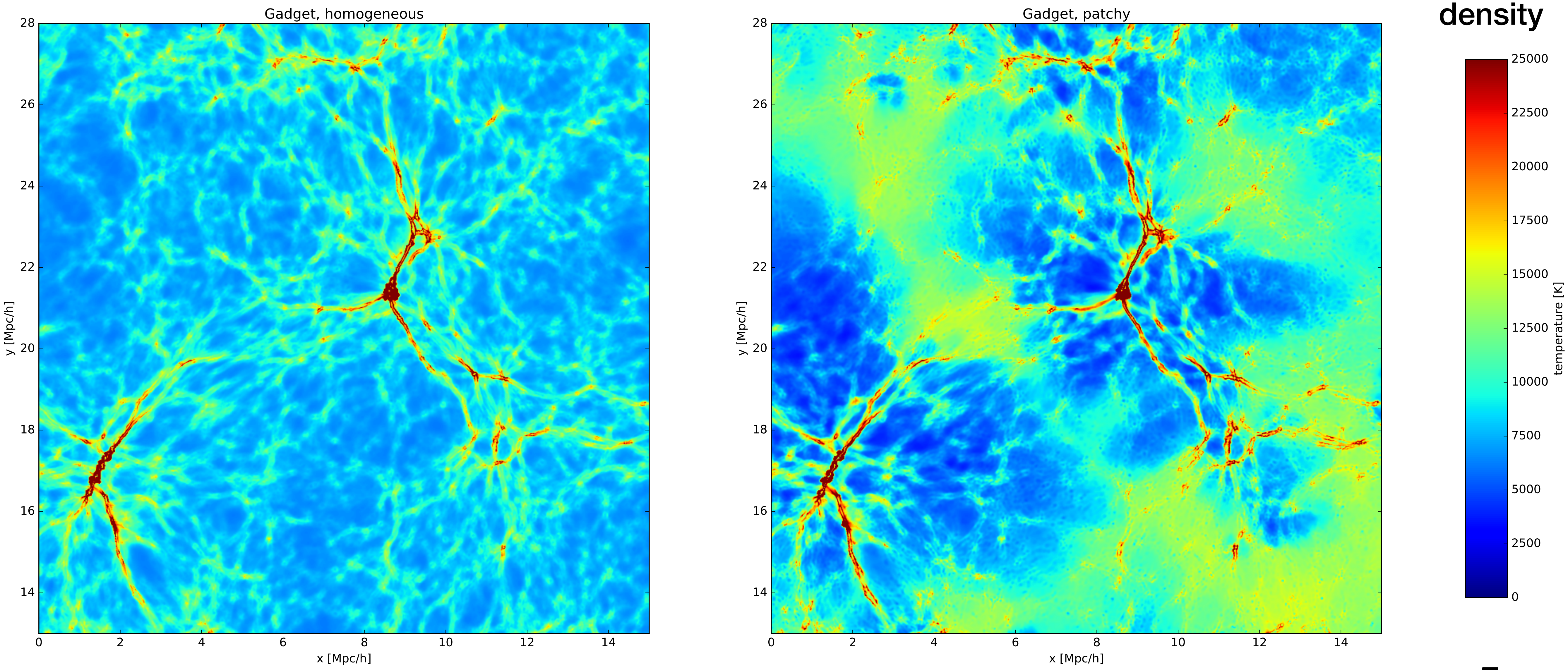
Effect of patchy reionization on the IGM temperature



Puchwein et al. 2019, in prep.

Effect of patchy reionization on the IGM temperature

homogeneous UVB   patchy UVB from RT simulation

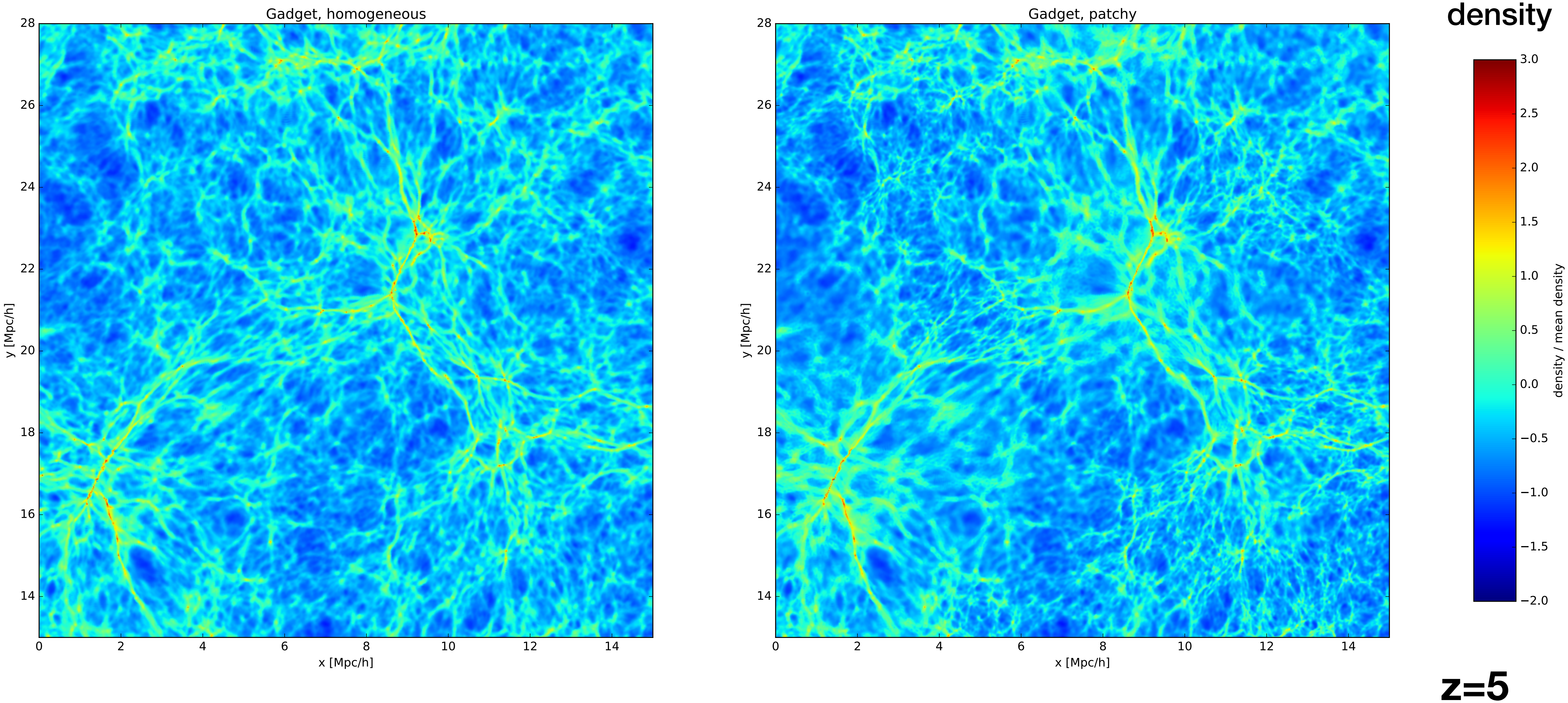


z=5

Puchwein et al. 2019, in prep.

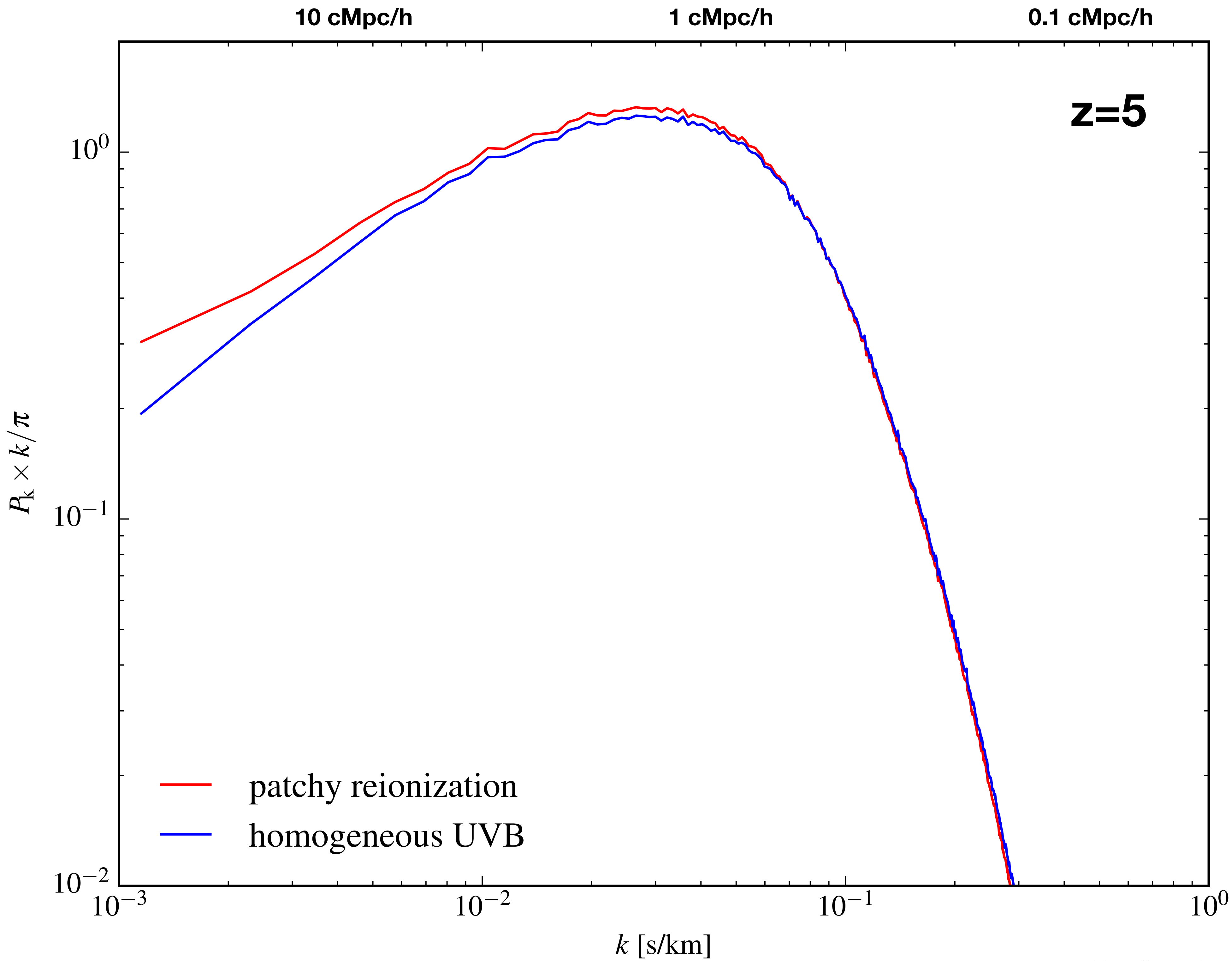
Effect of patchy reionization on the density distribution of the IGM

homogeneous UVB   patchy UVB from RT simulation



Puchwein et al. 2019, in prep.

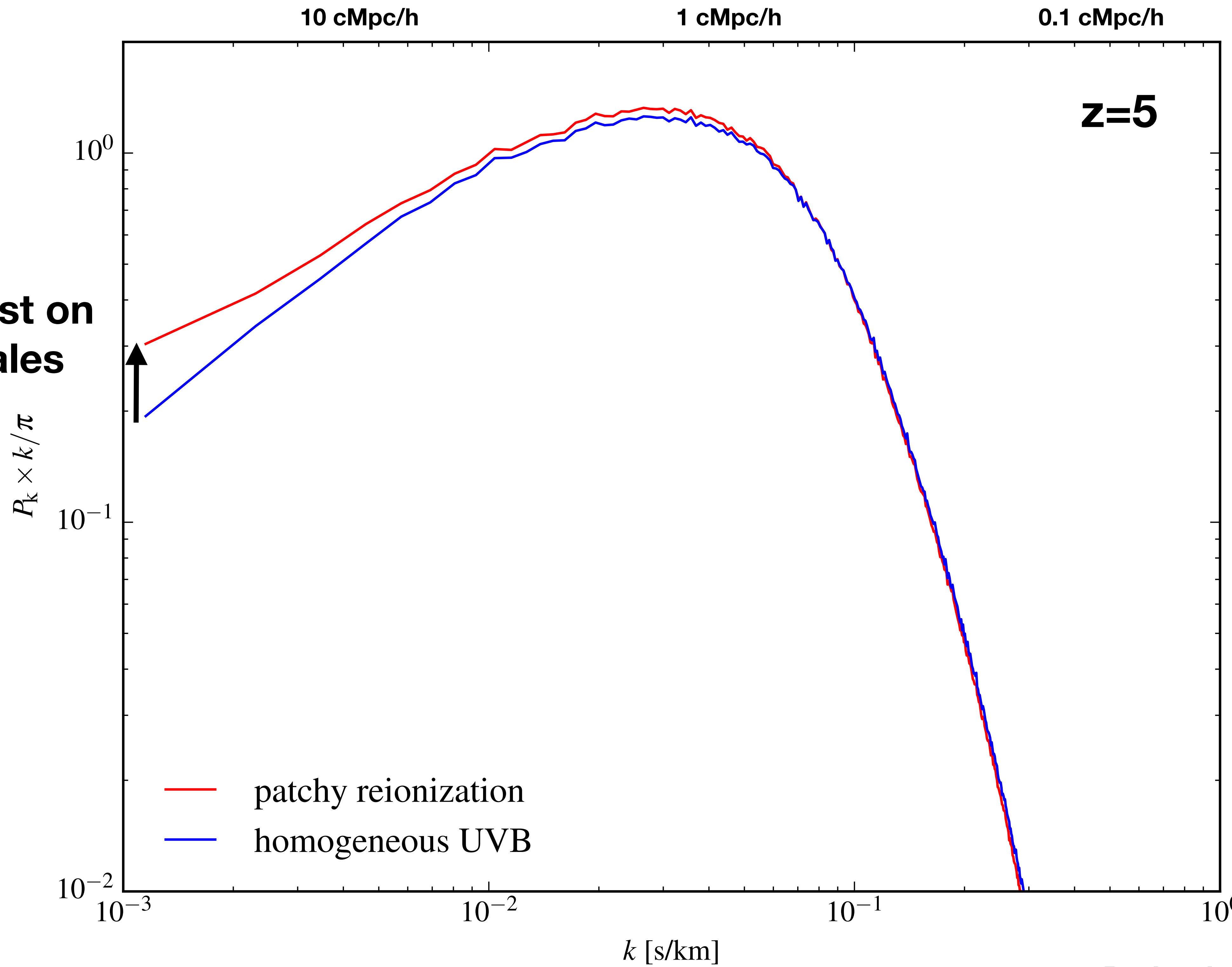
Flux power spectrum and impact of patchy reionization



Puchwein et al. 2019, in prep.

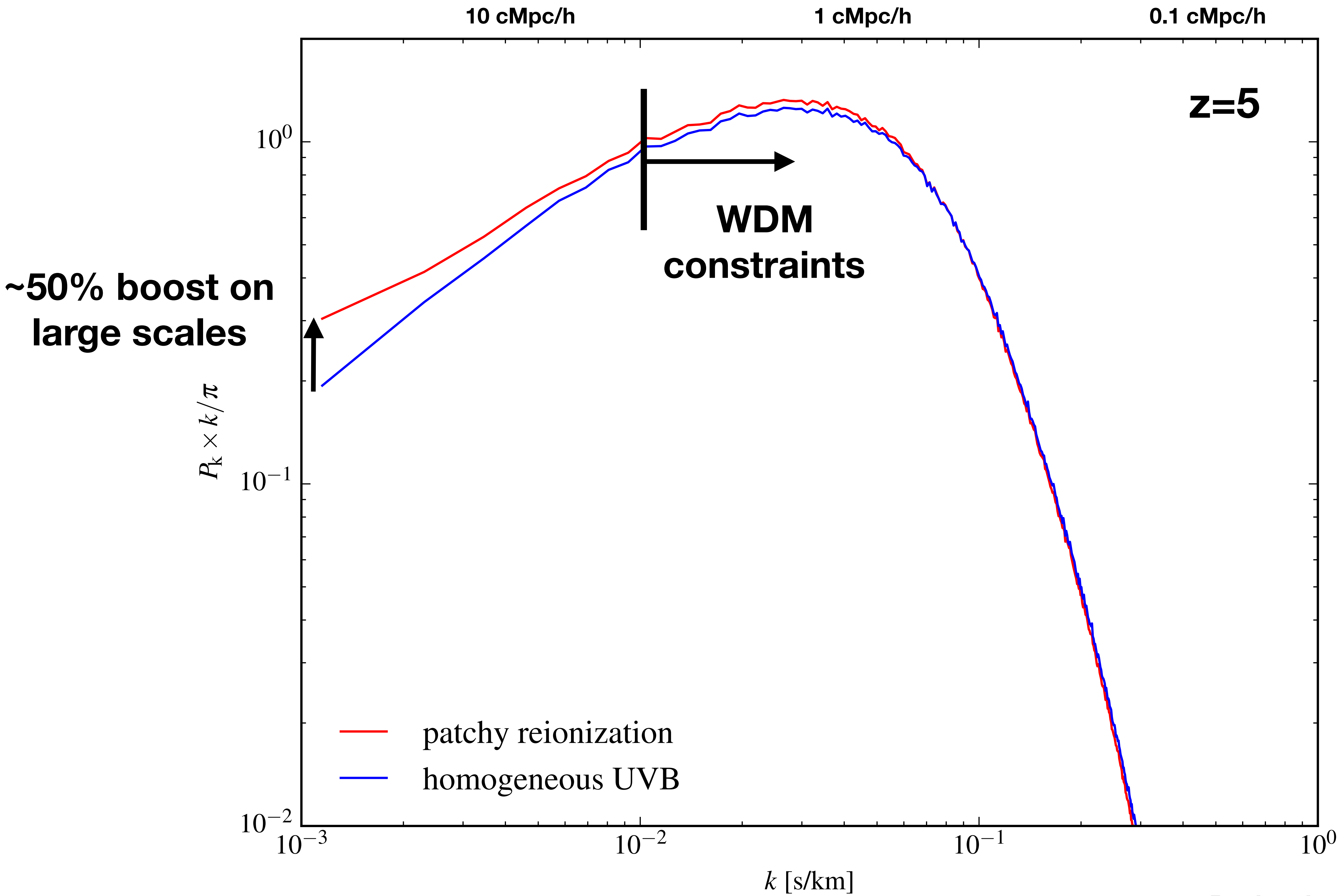
Flux power spectrum and impact of patchy reionization

~50% boost on large scales



Puchwein et al. 2019, in prep.

Flux power spectrum and impact of patchy reionization



Puchwein et al. 2019, in prep.

Summary

- Lyman-alpha forest fluctuations favour a very late hydrogen reionization ending at z~5.3 (see Laura Keating's talk)
  - ➡ close to sweet spot for constraining dark matter
- new simple method to model patchy reionizaion in cosmological hydrodynamical simulations
  - ➡ additional large scale power in the high-z Lyman-alpha forest
  - ➡ effects of fluctuations in pressure smoothing and thermal broadening (partly) cancel (consistent with Wu+19)
  - ➡ preliminary: probably minor effect for dark matter free streaming / warm dark matter constraints