Constraining Temperature Fluctuations using WEAVE survey

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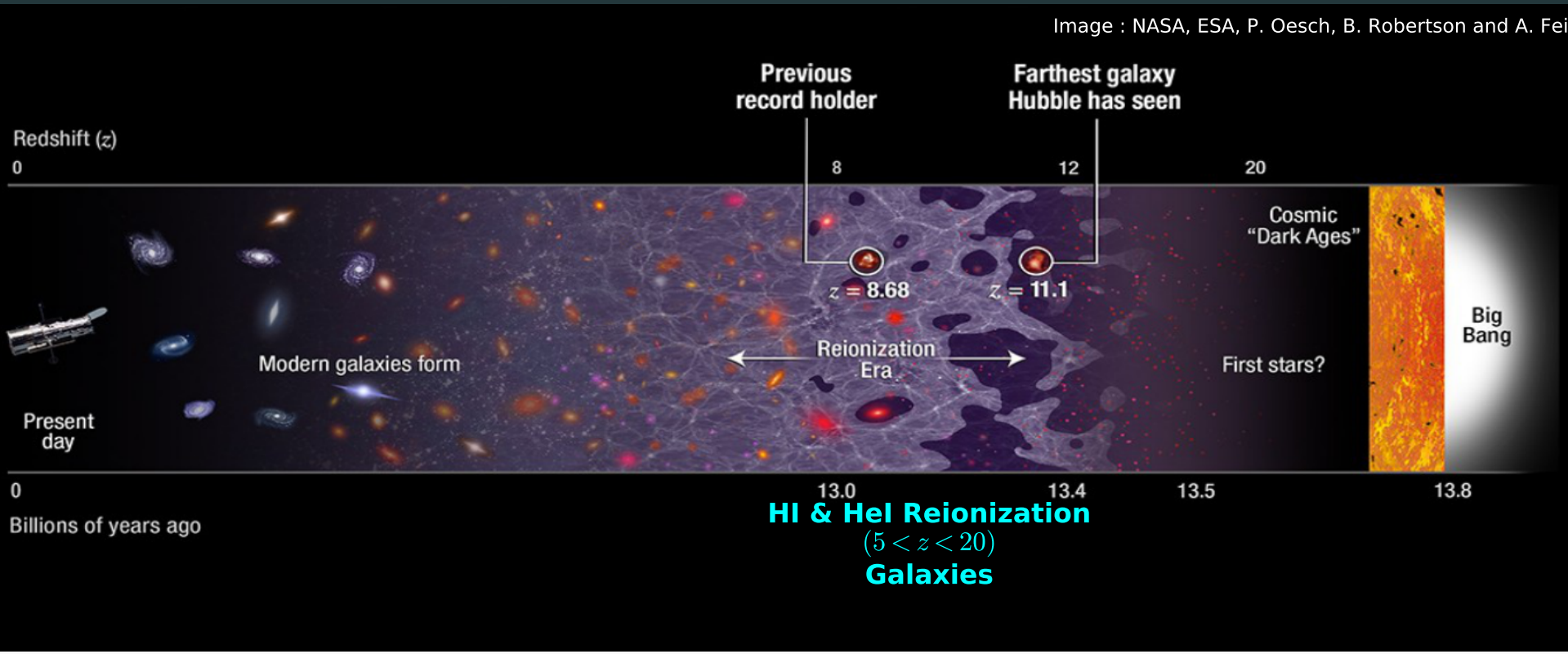
Dec, 2023

Outline

- Introduction
- Motivation
- Simulations
- Signatures of Temperature Fluctuations
- How WEAVE survey can detect?
- Summary

Introduction



- Reionization is a two step process.
- H I and He I Reionization ($z \sim 6$), Stars and Early type Galaxies

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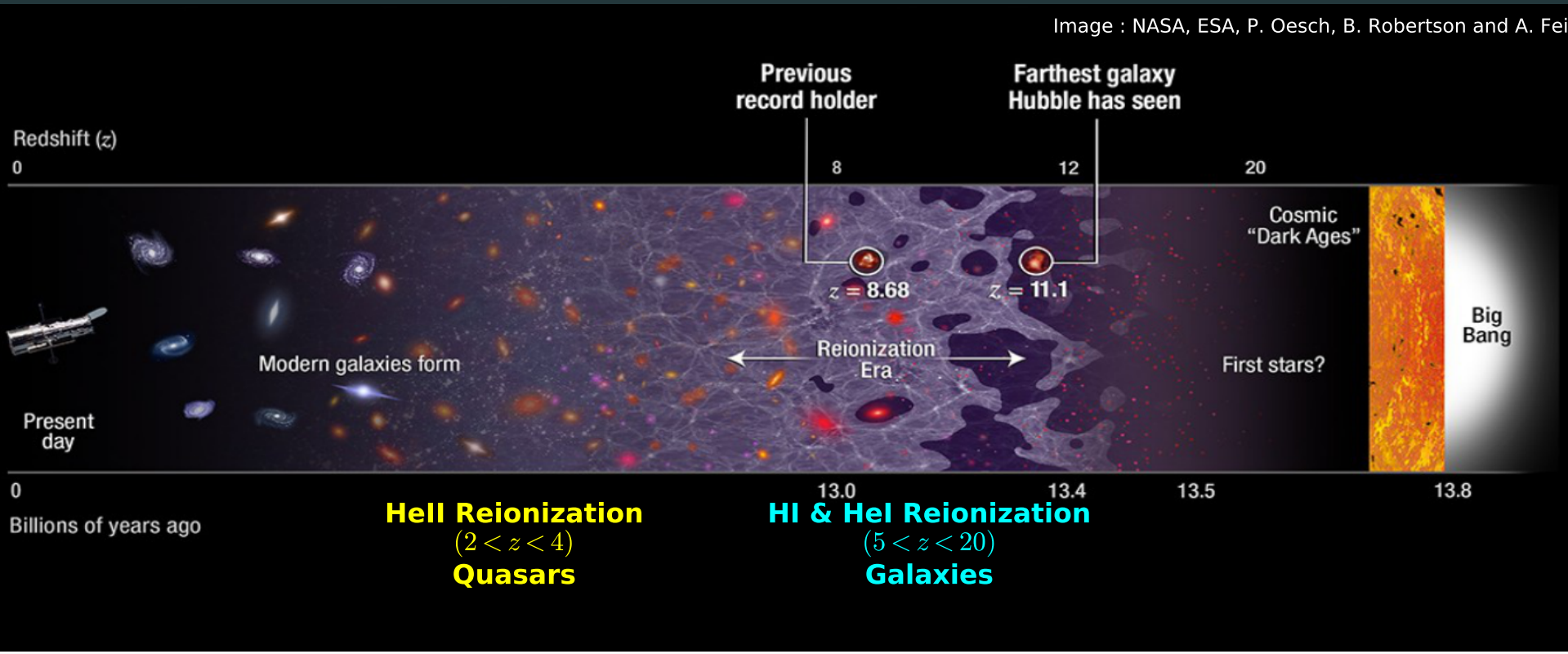

- Reionization is a two step process.
- H I and He I Reionization ($z \sim 6$), Stars and Early type Galaxies
- He II Reionization ($z \sim 3$), AGN (QSO)

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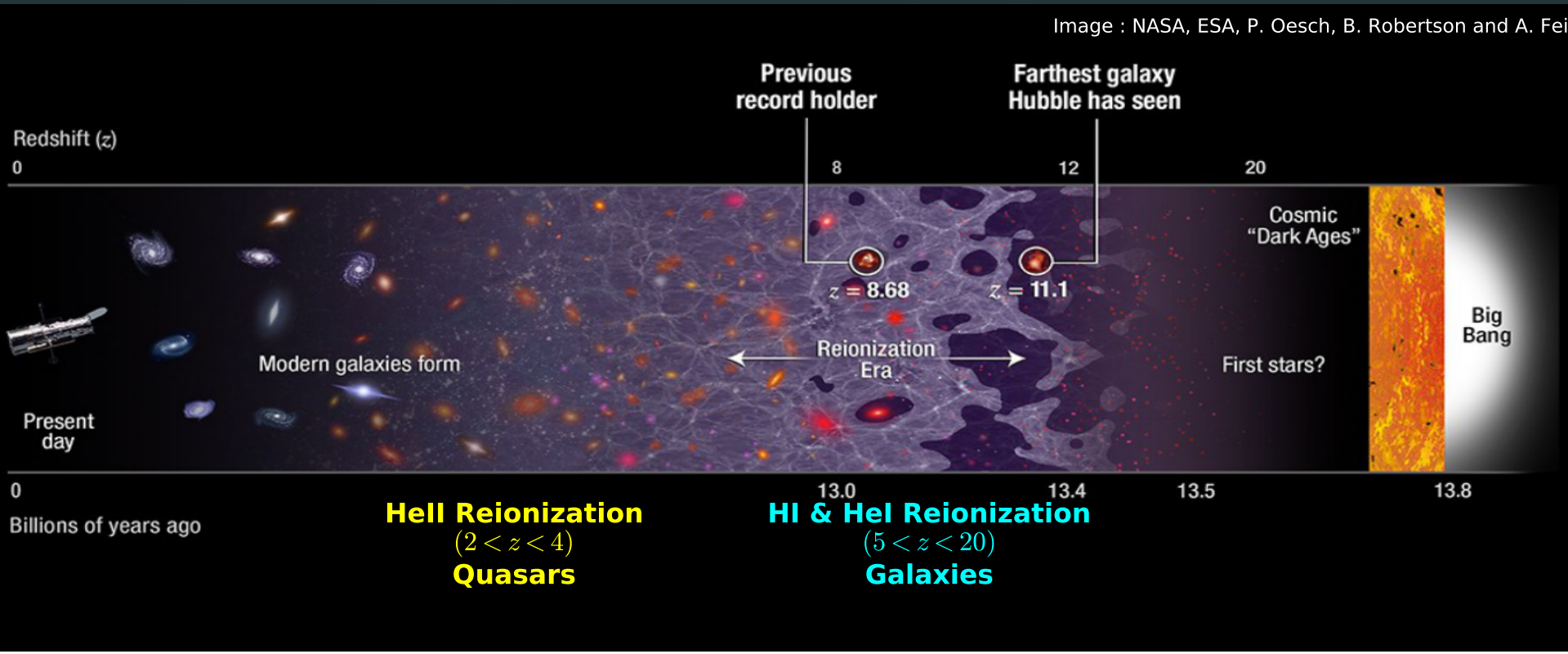

- Four important question about Reionization
- Sources of reionization? $\Rightarrow$ Galaxies (Small or Large mass, $f_{\rm esc}$), QSOs?
- Nature of reionization? $\Rightarrow$ Slow vs Rapid, Uniform vs Fluctuating UVB

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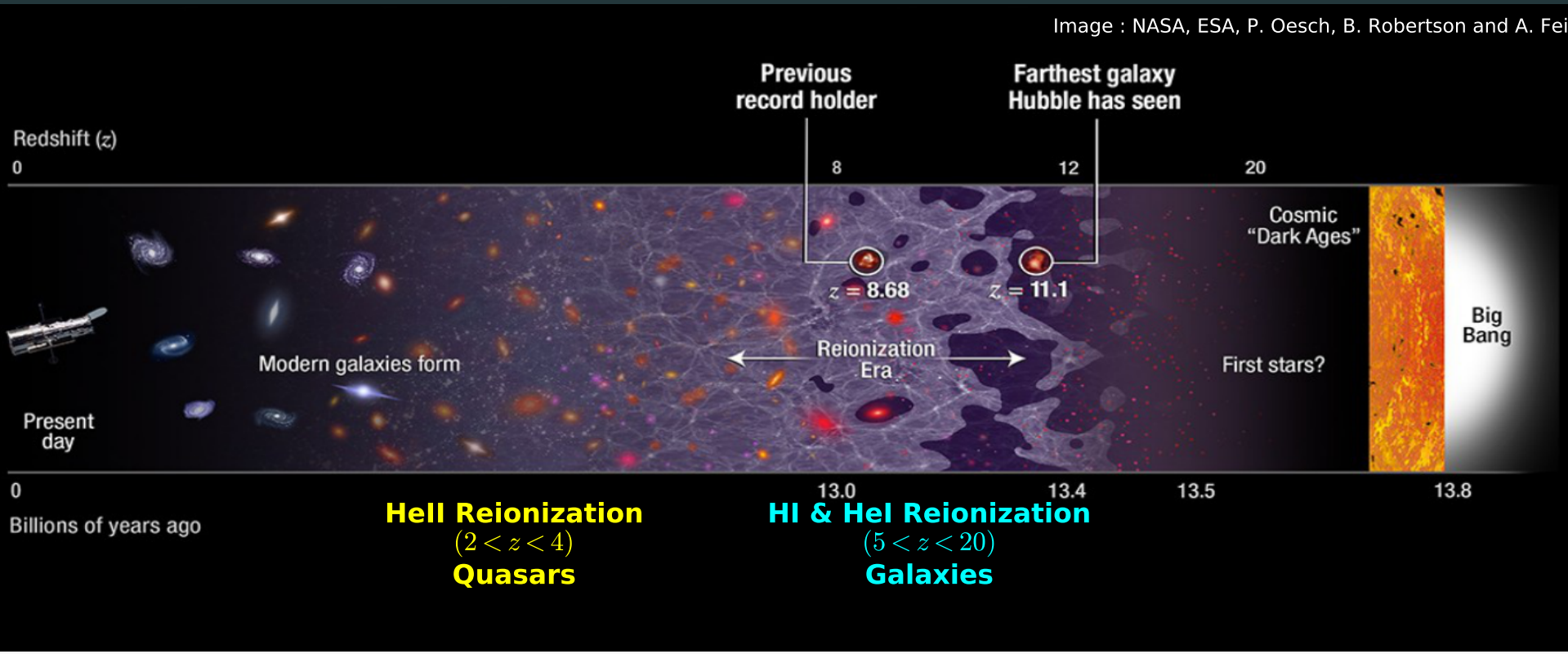

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- Timing of reionization? $\Rightarrow$ Early vs Late reionization
- Effects of reionization? $\Rightarrow$ Ionization and thermal state of IGM

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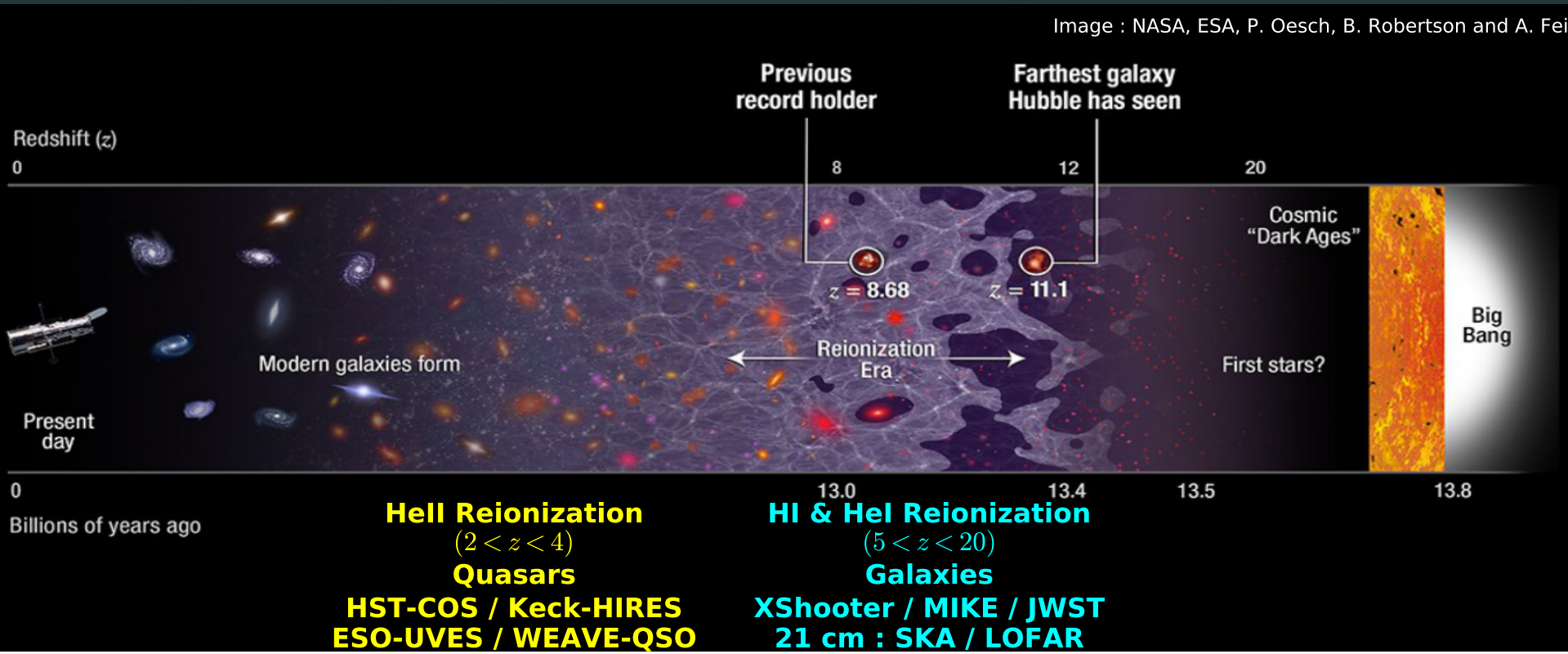

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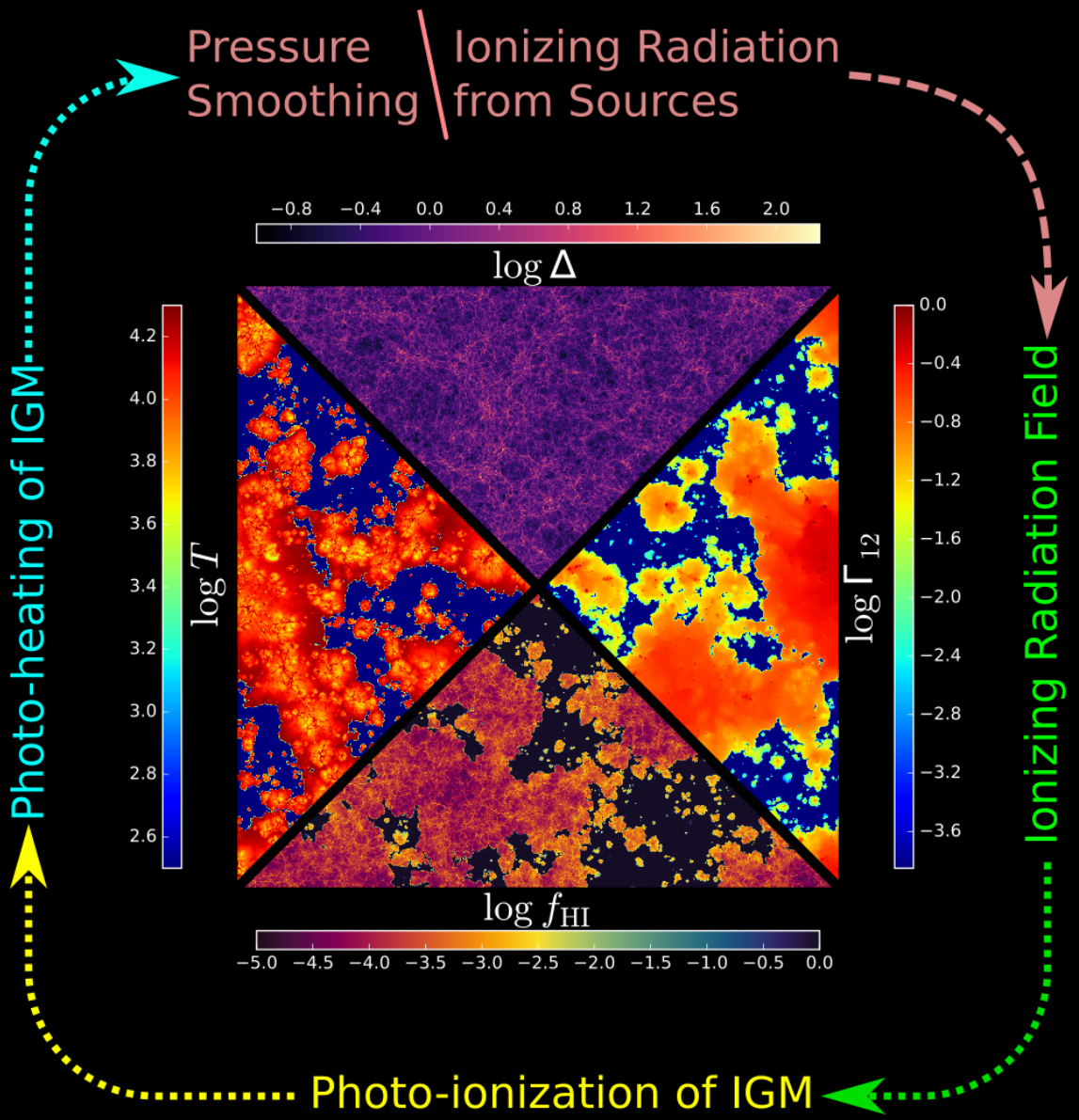
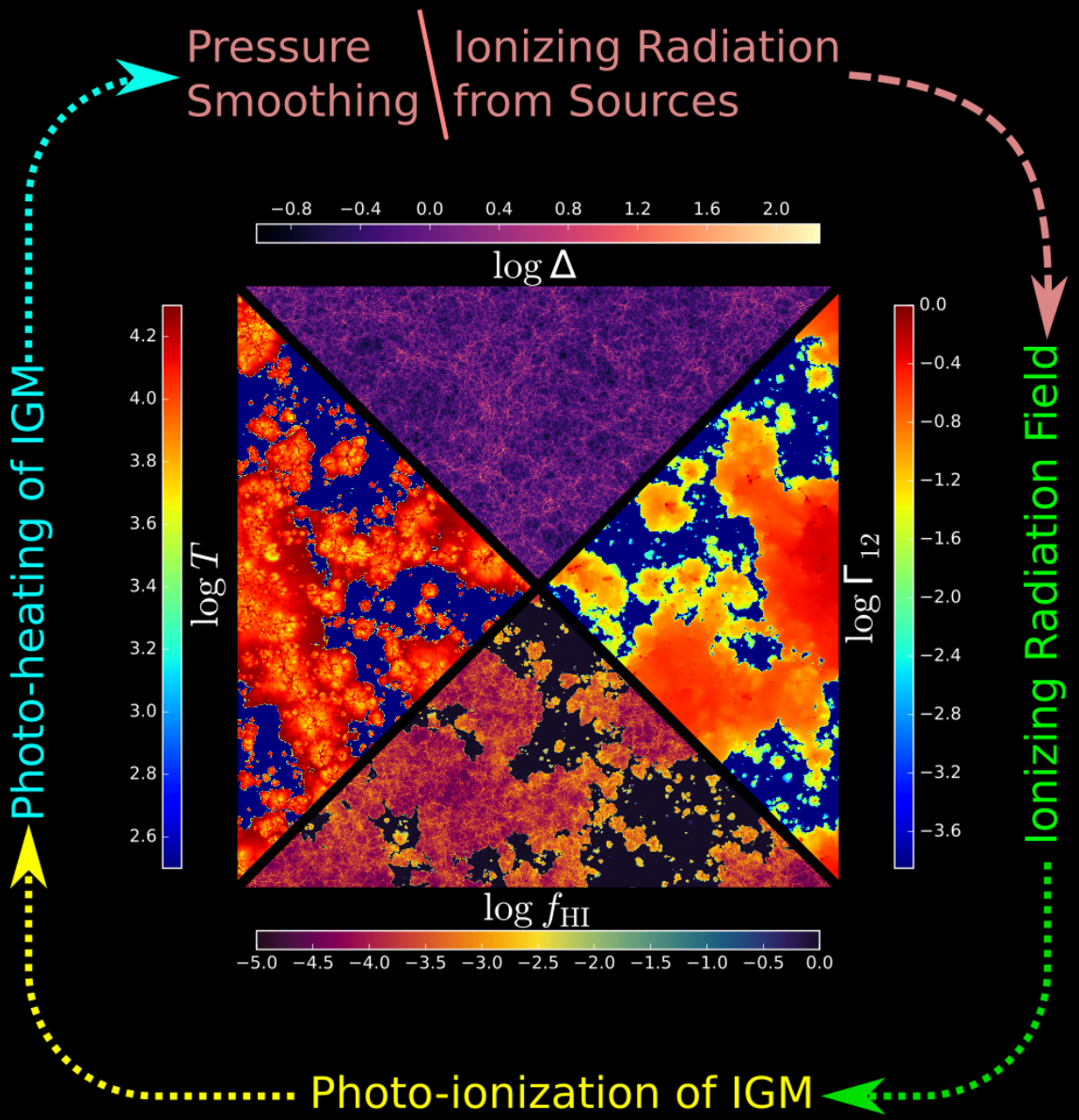
- Nature of reionization? $\Rightarrow$ Slow vs Rapid, Uniform vs Fluctuating UVB
- Timing of reionization? $\Rightarrow$ Early vs Late reionization
- Effects of reionization? $\Rightarrow$ Ionization and thermal state of IGM
- Nature and Timing of Reionization using WEAVE survey?

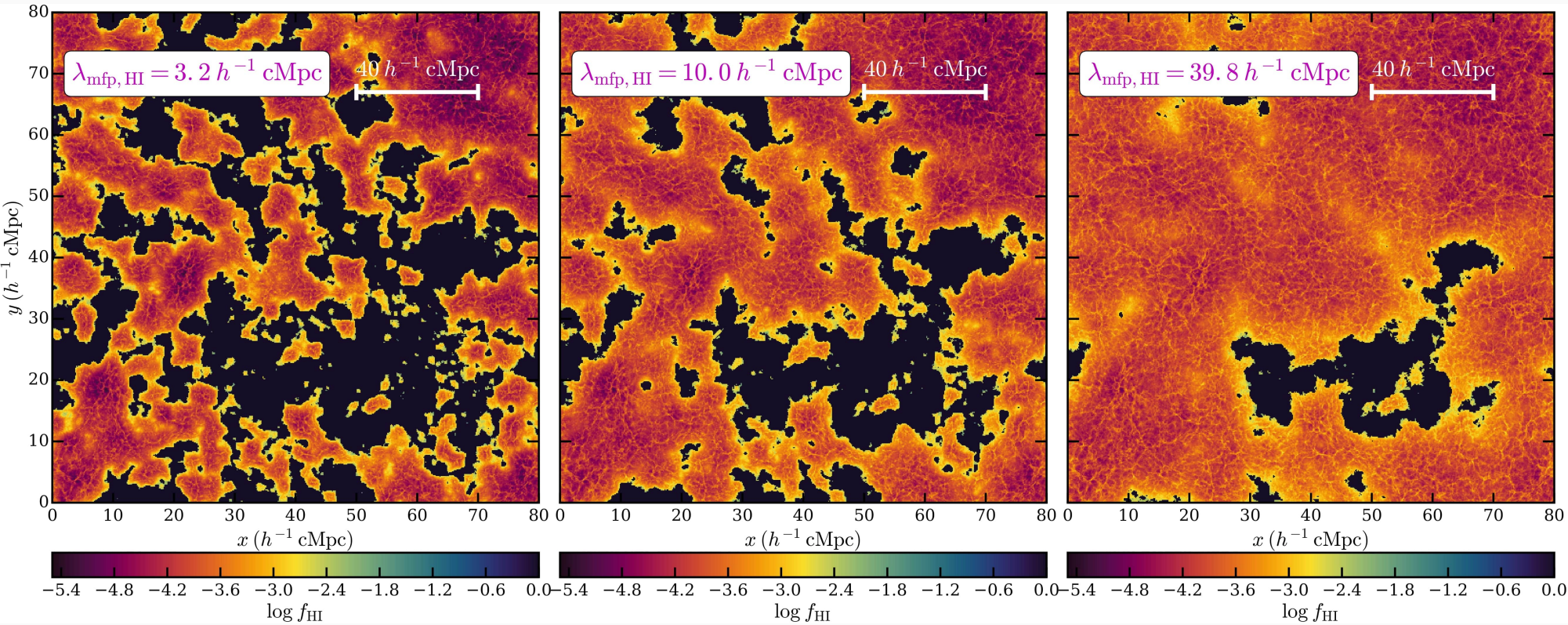

Pressure Smoothing
Ionizing Radiation from Sources
Photo-heating of IGM
Ionizing Radiation Field
Photo-ionization of IGM
log Δ
−0.8 −0.4 0.0 0.4 0.8 1.2 1.6 2.0
log T
4.2 4.0 3.8 3.6 3.4 3.2 3.0 2.8 2.6
log Γ12
0.0 −0.4 −0.8 −1.2 −1.6 −2.0 −2.4 −2.8 −3.2 −3.6
log fHI
−5.0 −4.5 −4.0 −3.5 −3.0 −2.5 −2.0 −1.5 −1.0 −0.5 0.0

Motivation



- Can we detect these temperature fluctuations? $\Rightarrow$ Observations + Modeling Reionization

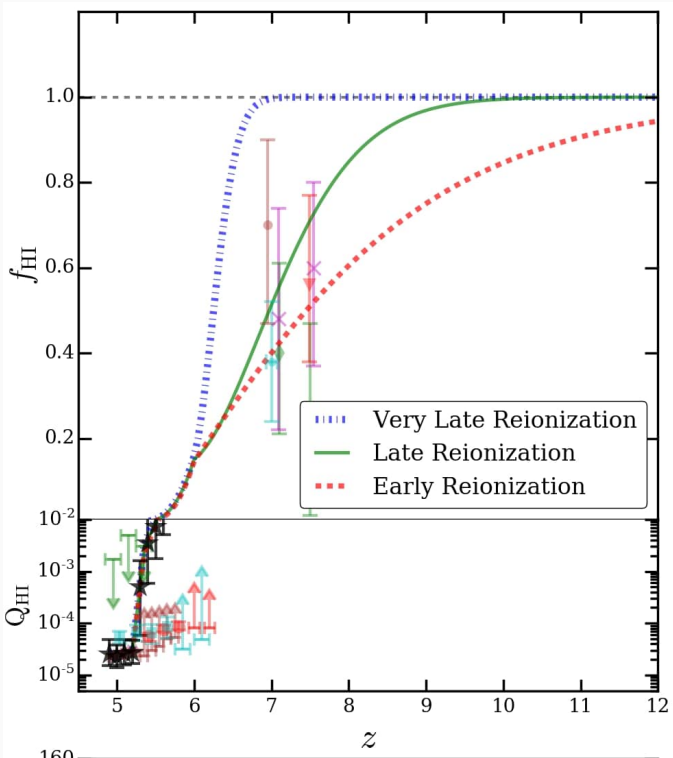
Parameter Variation

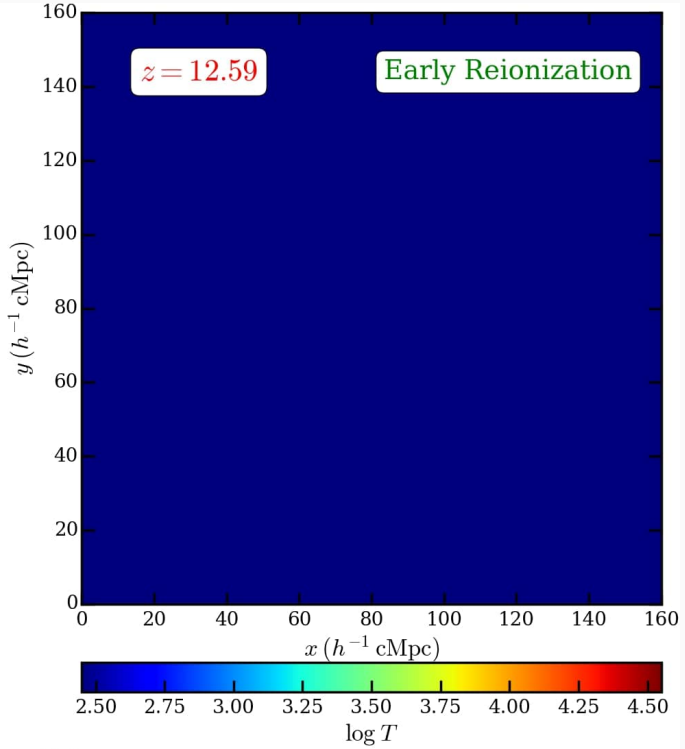


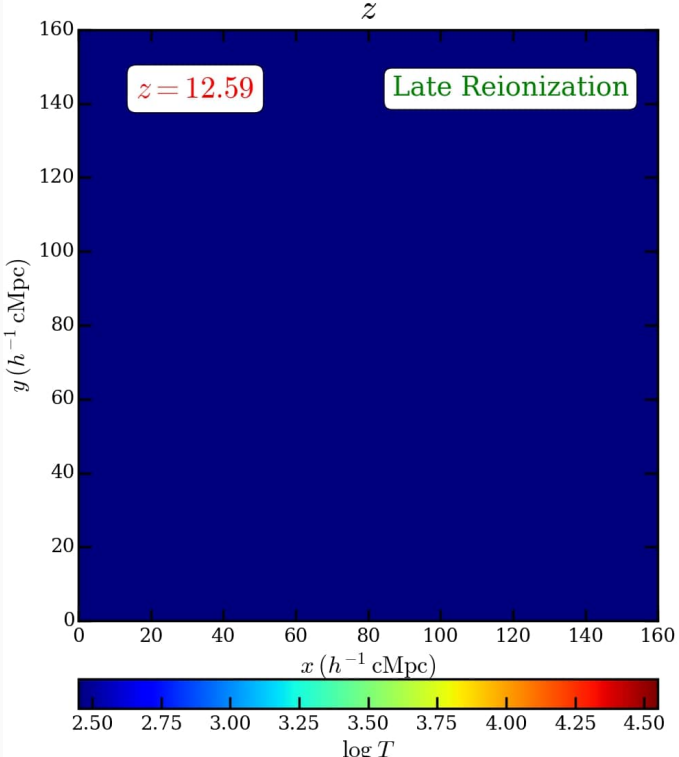
- Mean free path ⇒ Average distance travel by ionizing photons before absorption
- Mean free path affects morphology of reionization
- Small Mean free path ⇒ More patchy reionization
- Large Mean free path ⇒ More uniform reionization
- Evolution of Mean Free Path depends on reionization history

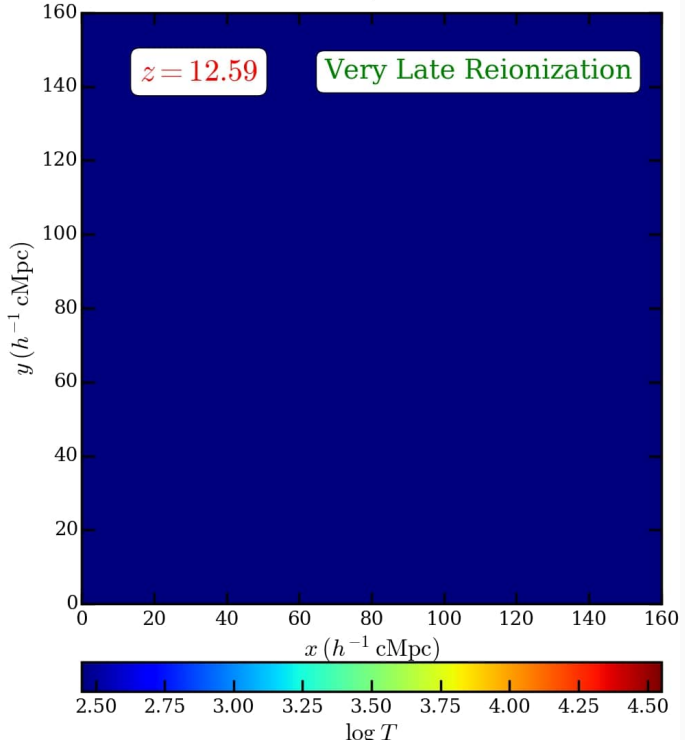
Temperature Fluctuations

Reionization starts at $z \sim 13$









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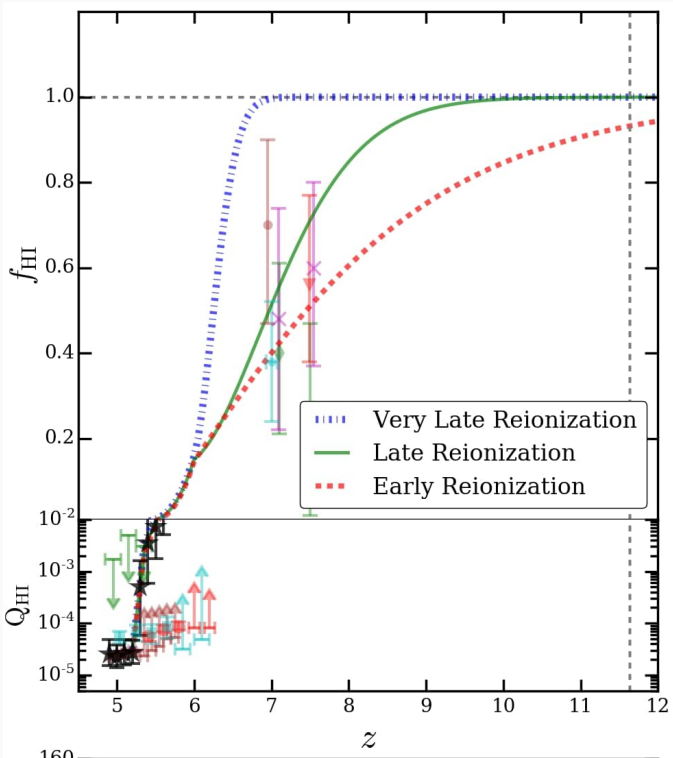
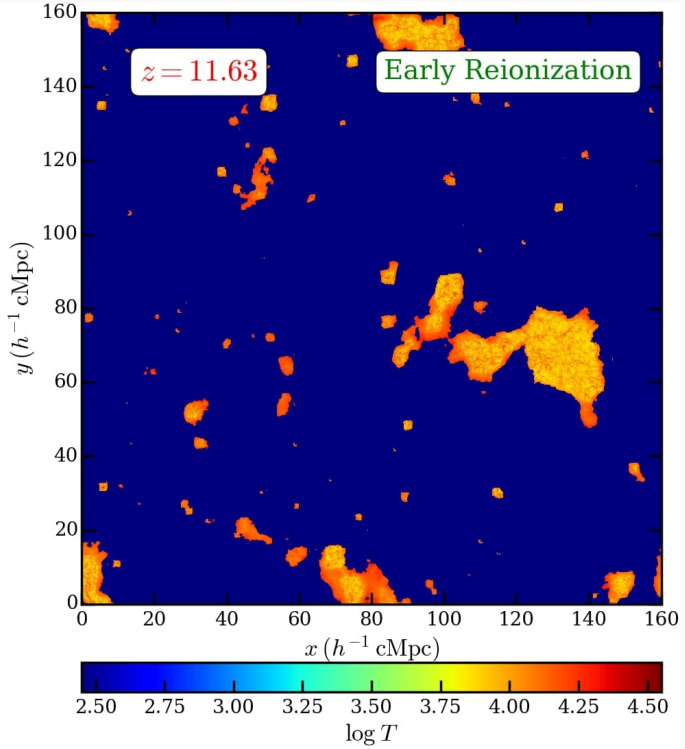
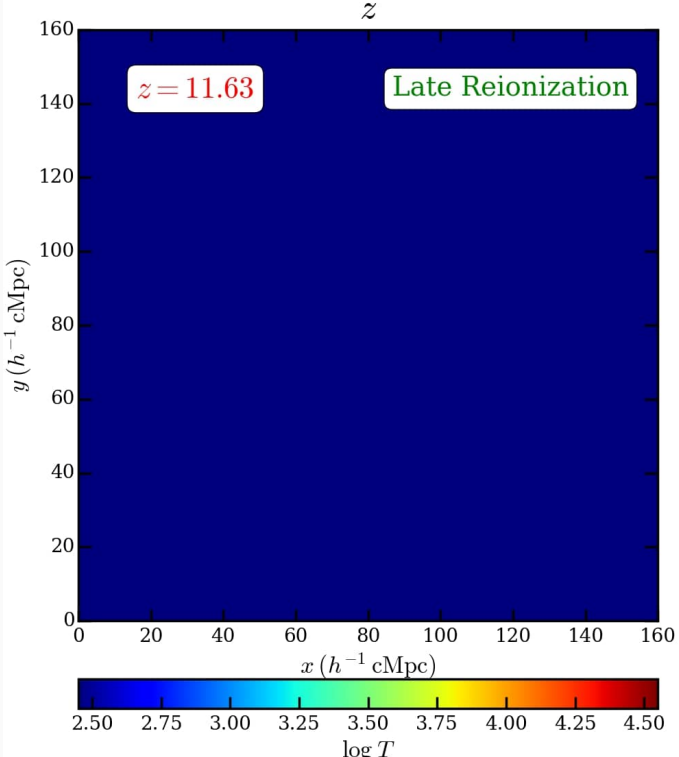
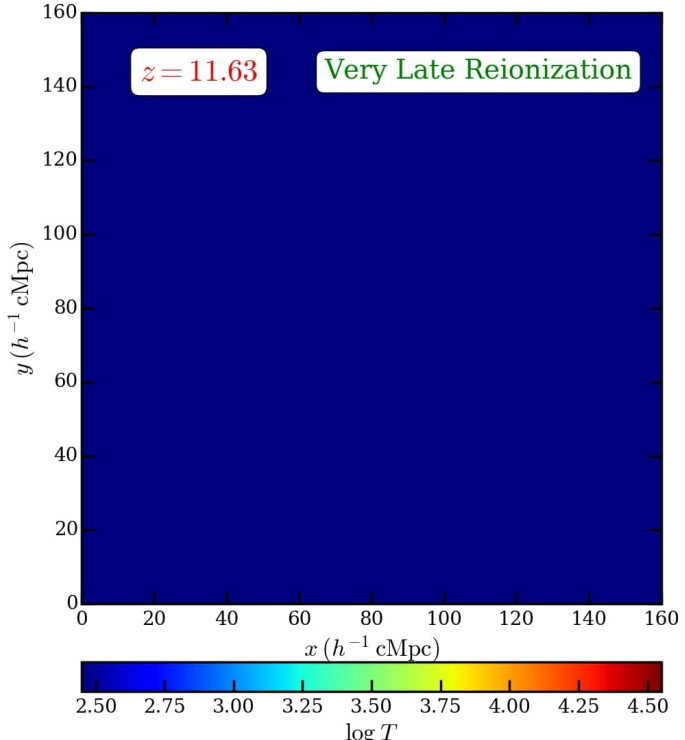
Reionization starts at $z \sim 13$

Region close to sources ionizes and increases IGM temperature









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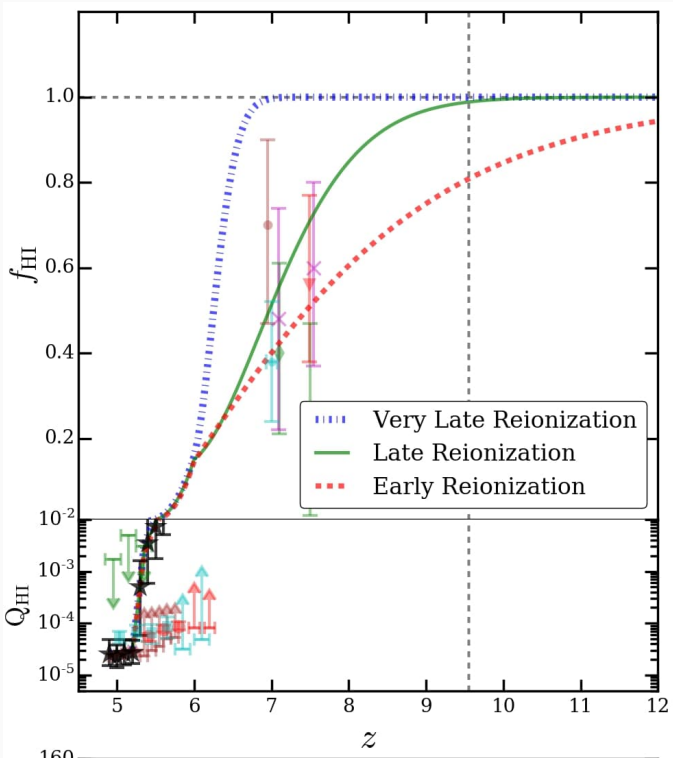

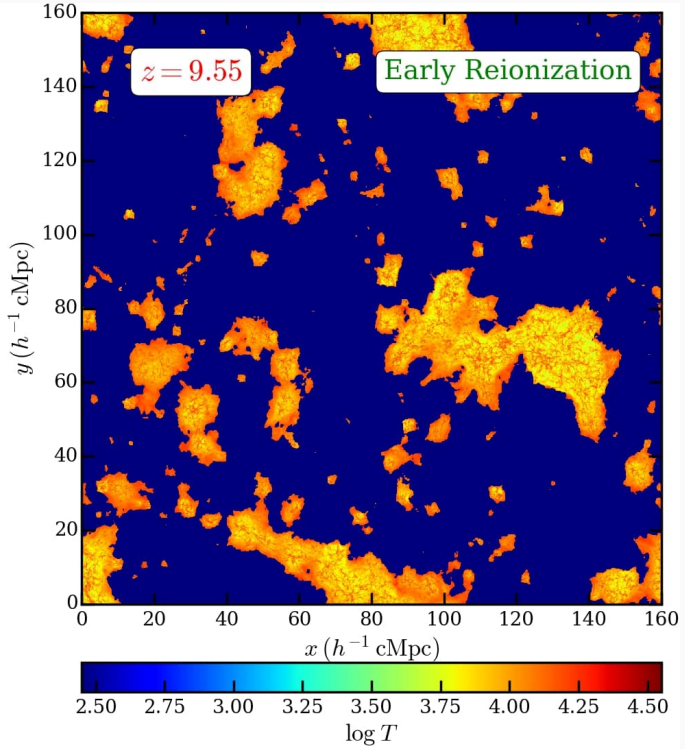

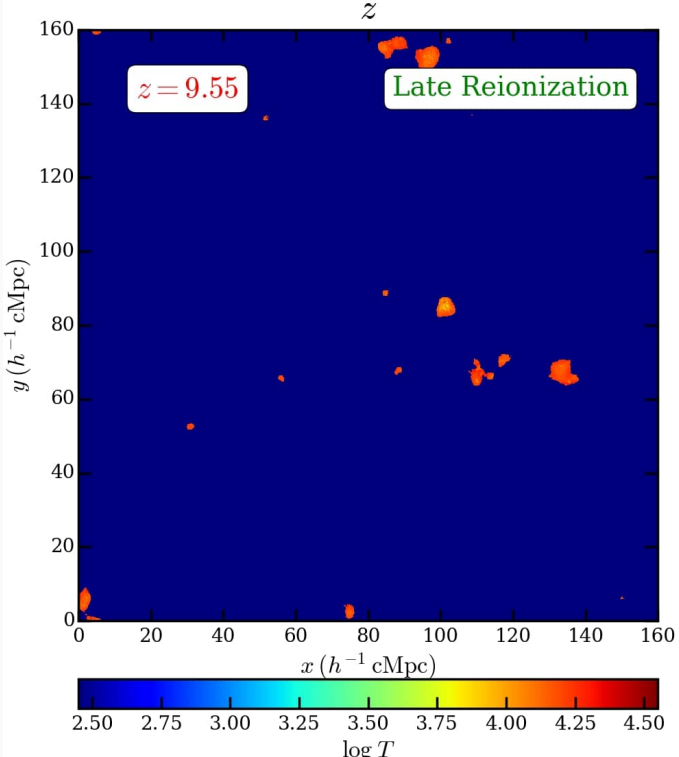

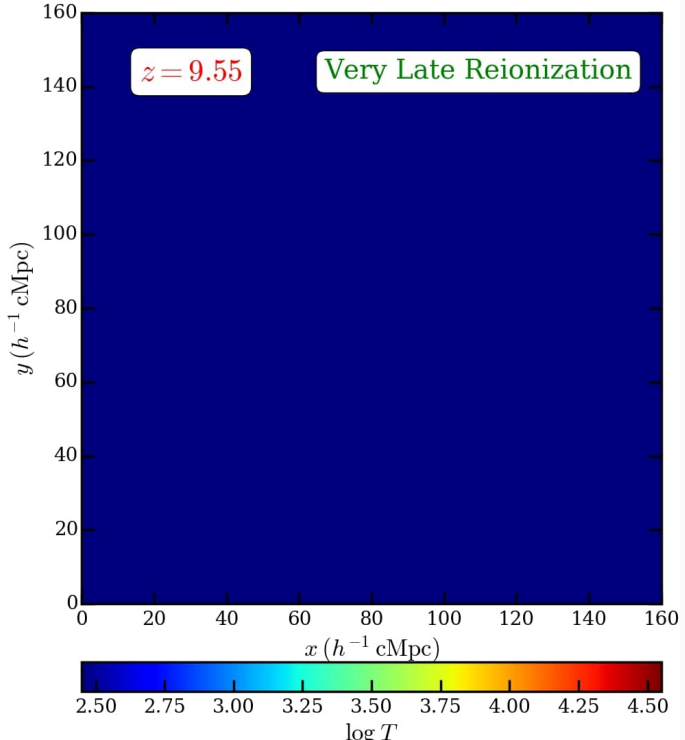

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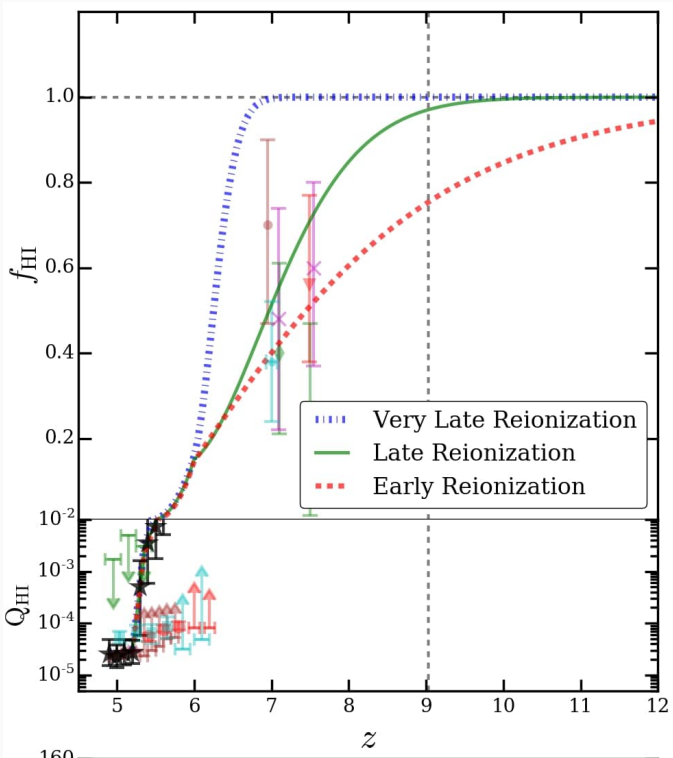

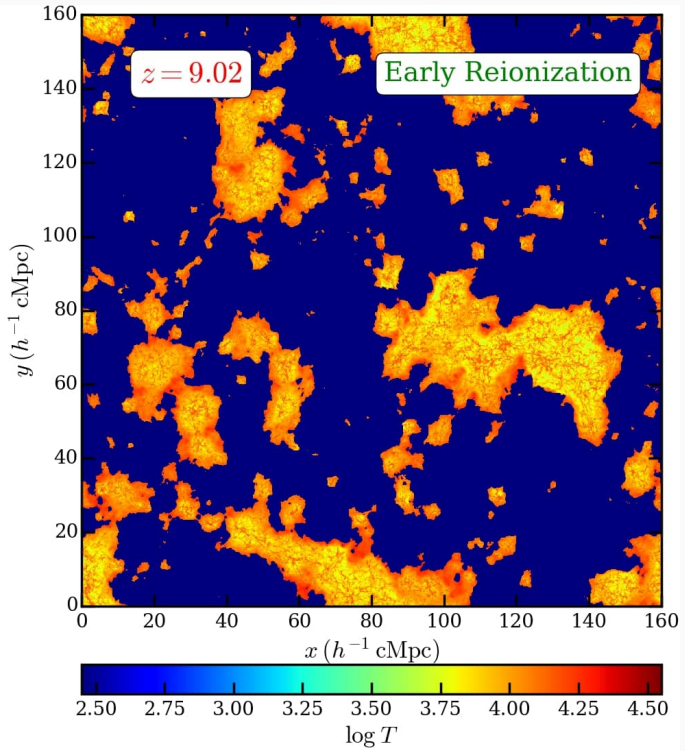

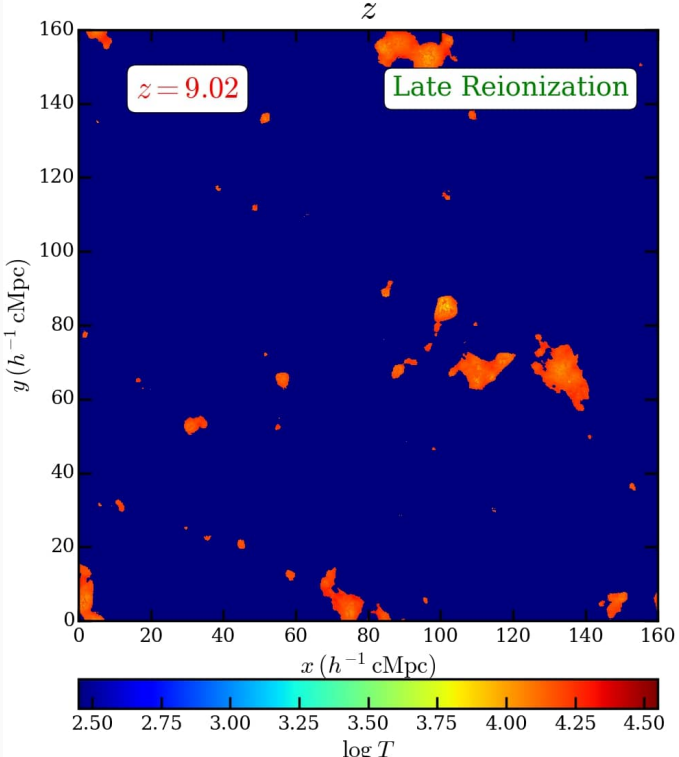

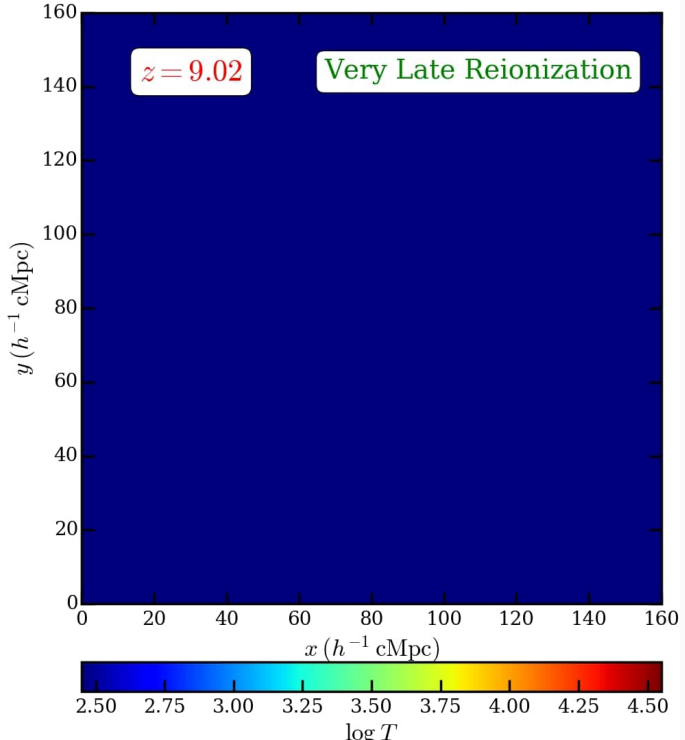

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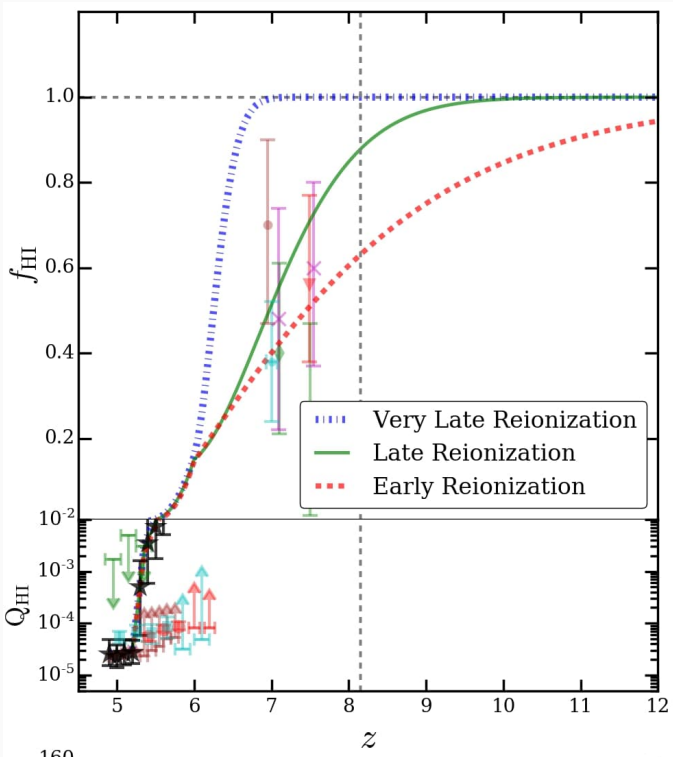

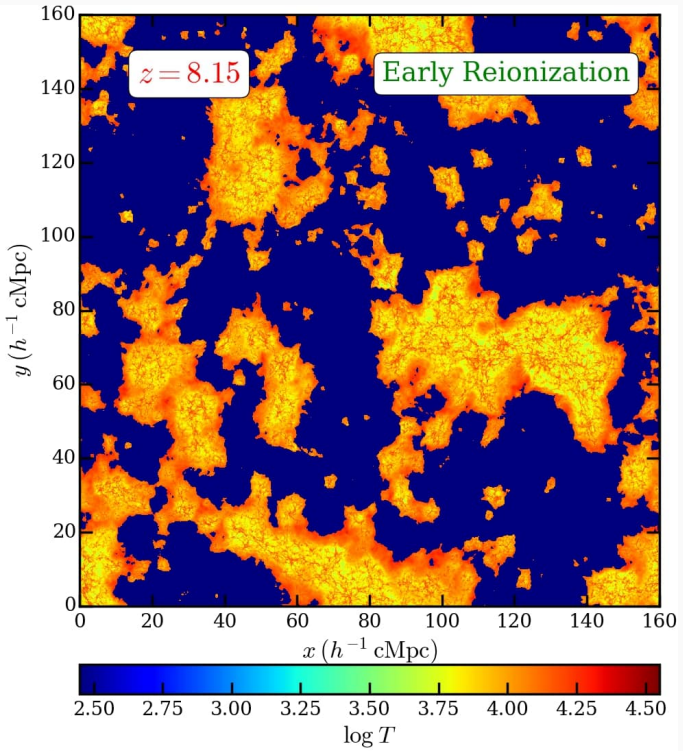

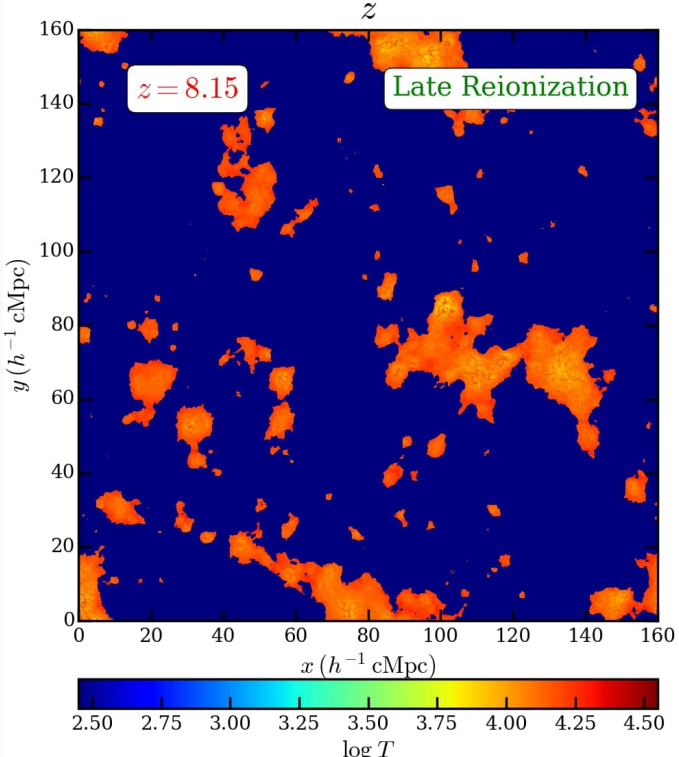

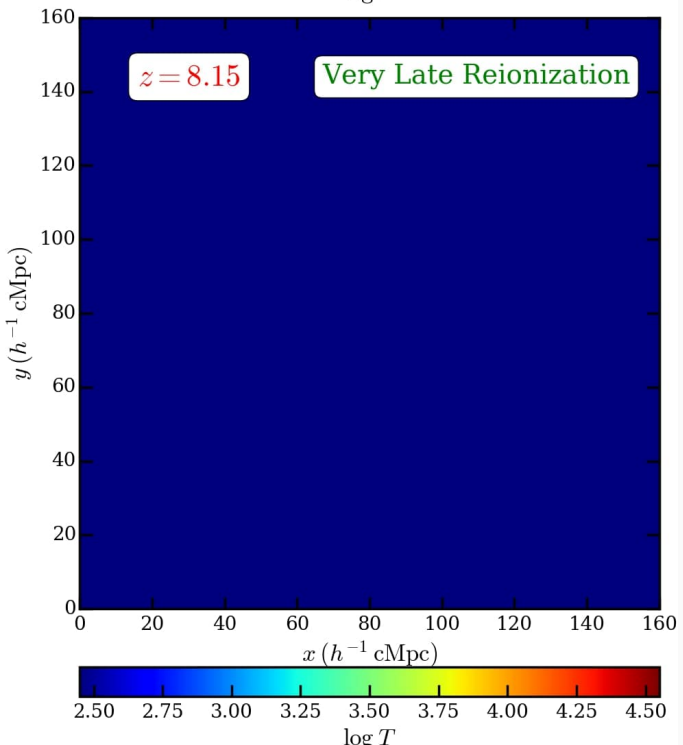

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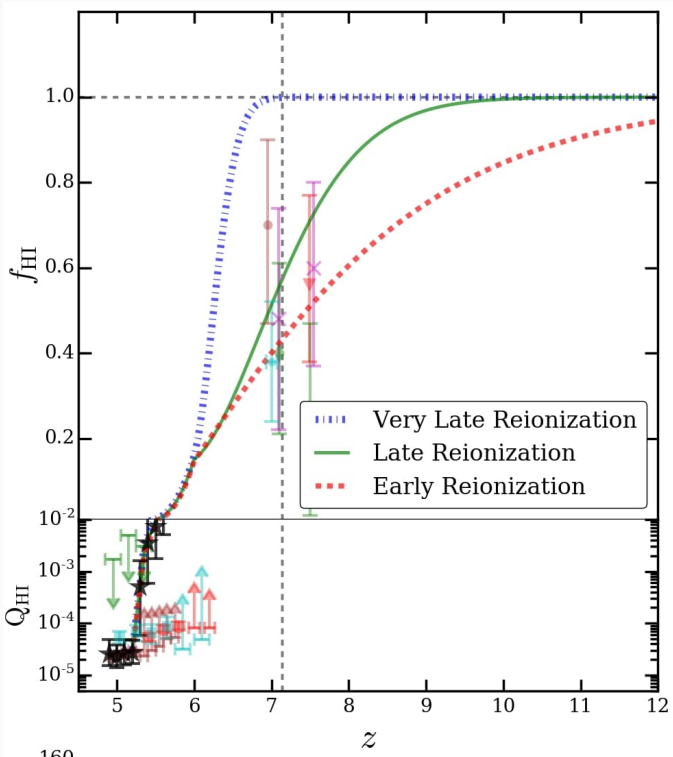

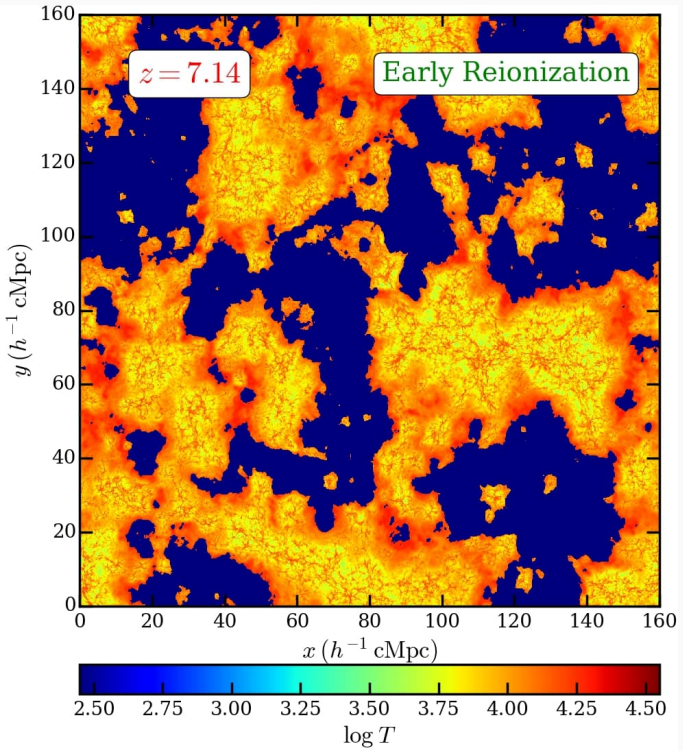

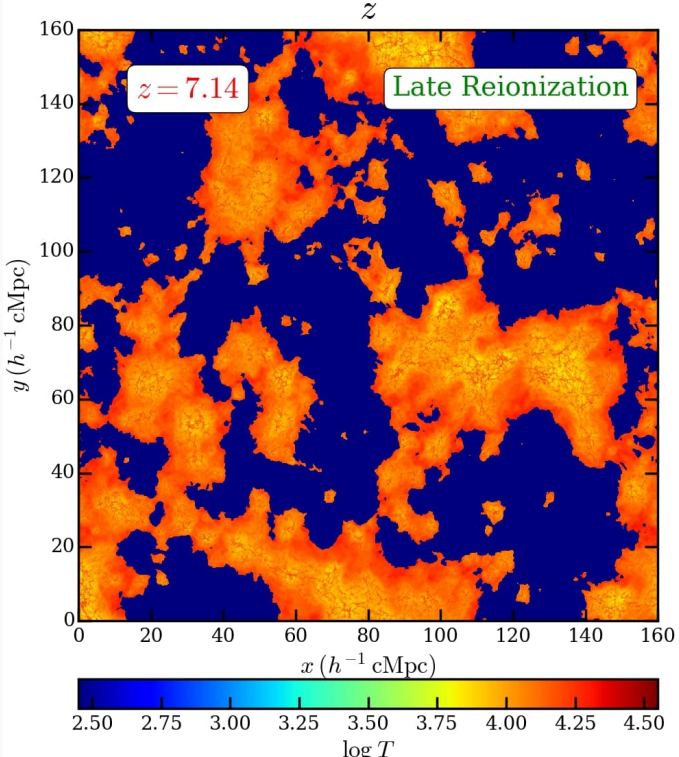

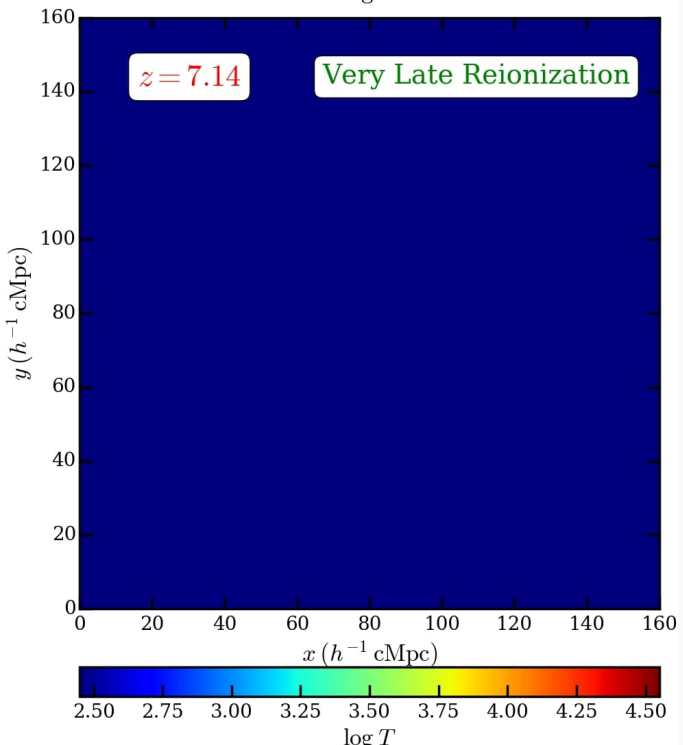

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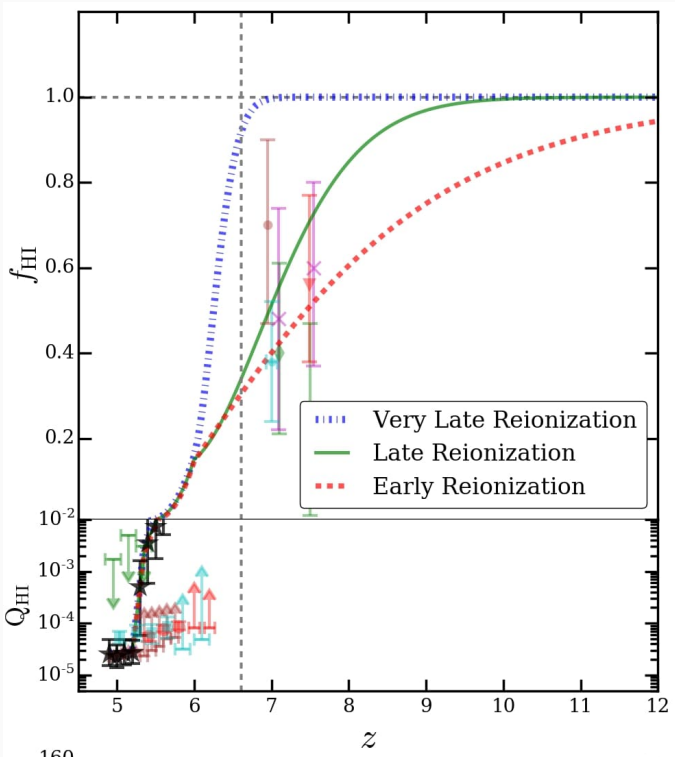
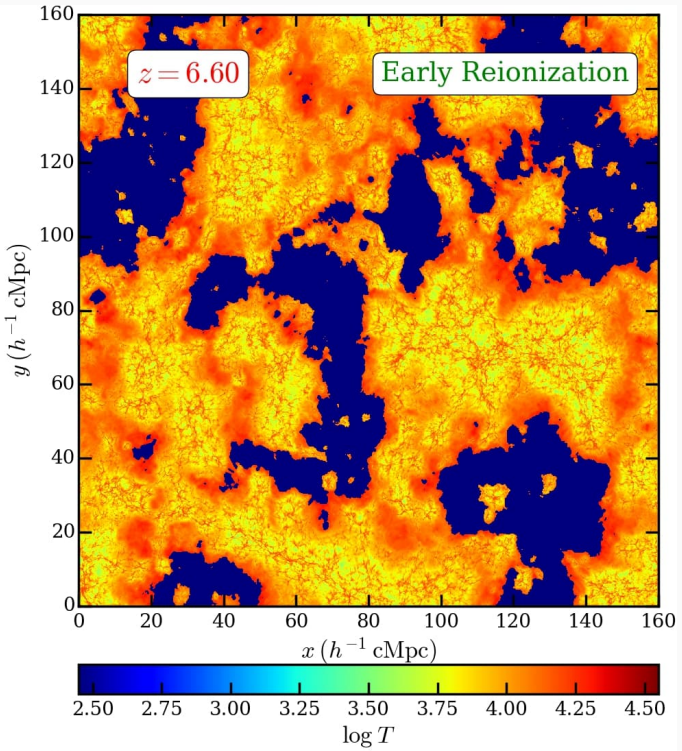
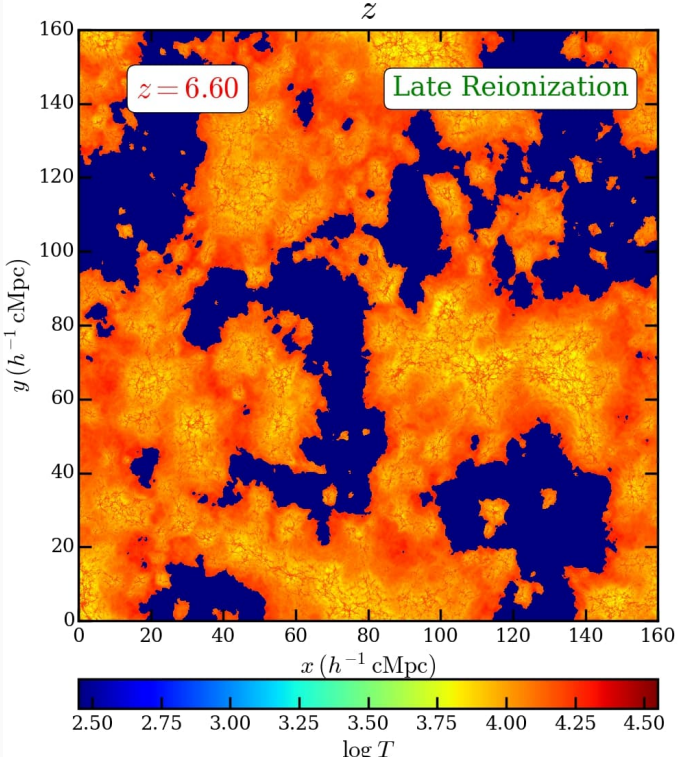
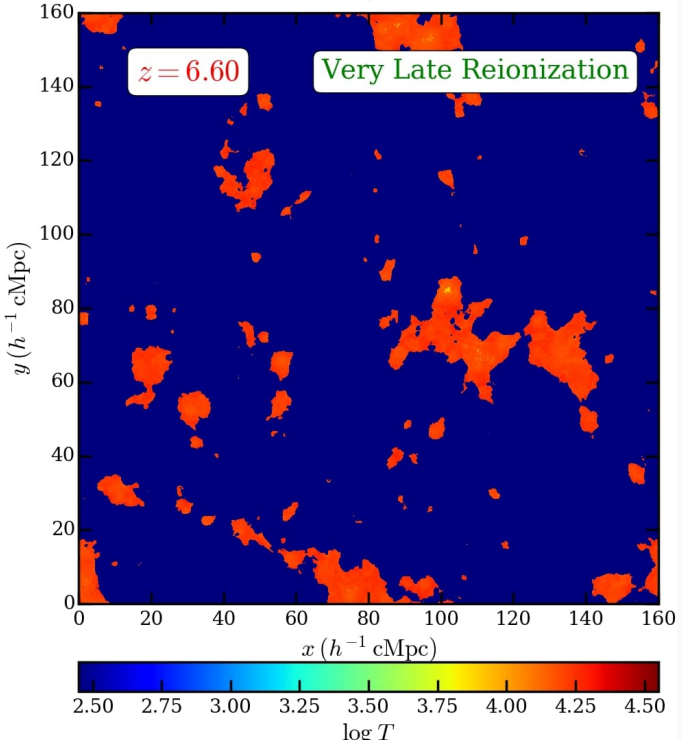
Region close to sources ionizes and increases IGM temperature

Regions ionized earlier starts to cool down due to cooling processes and Hubble expansion









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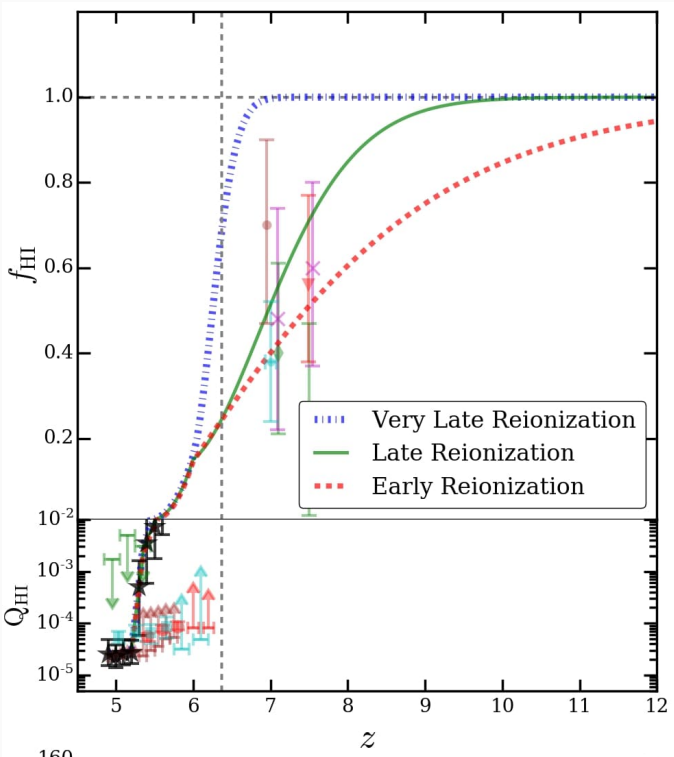

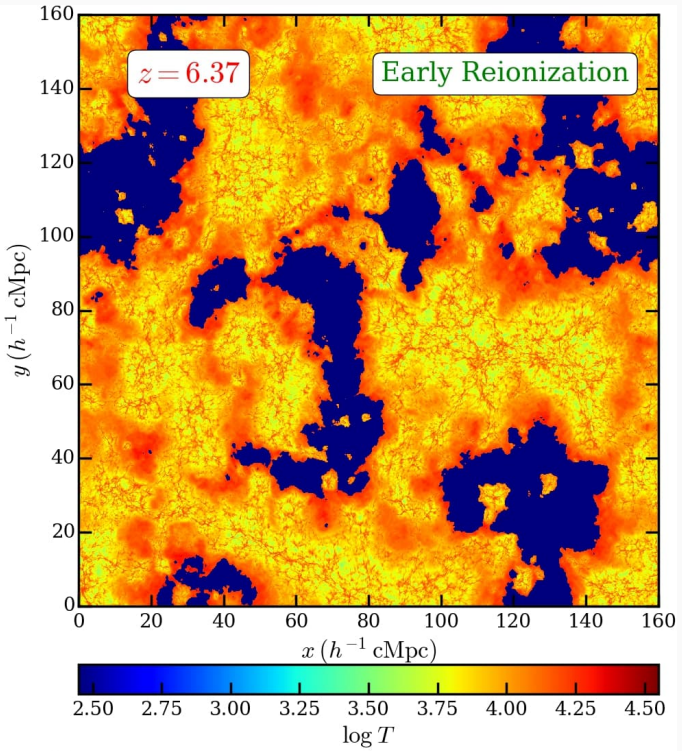

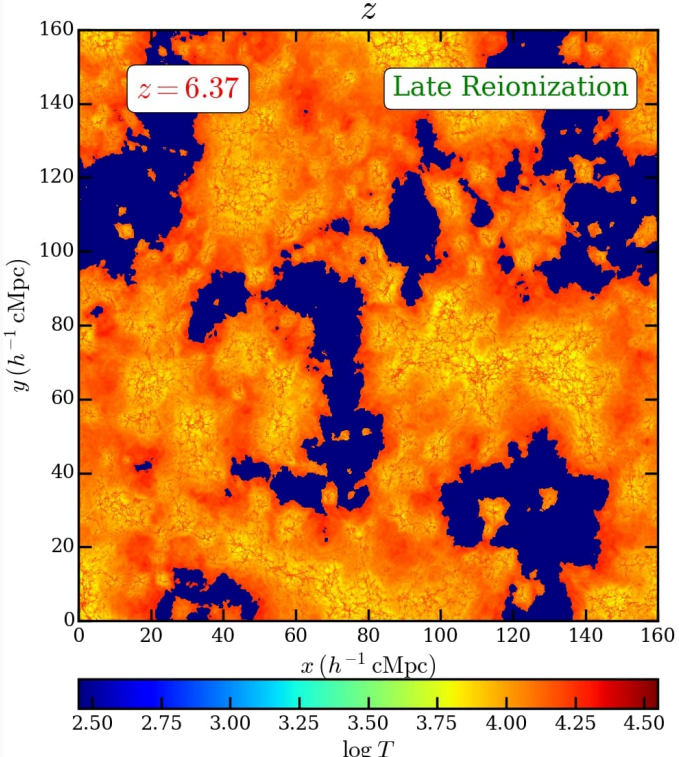

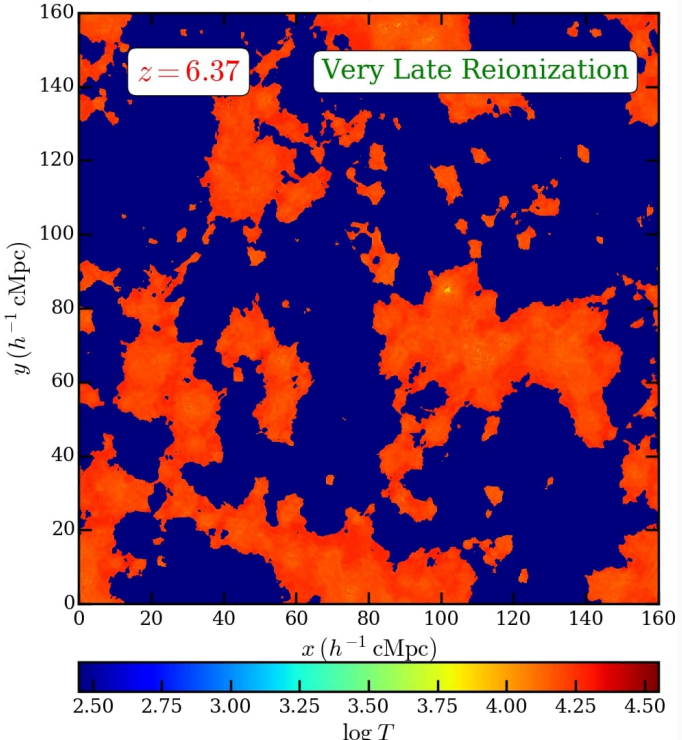

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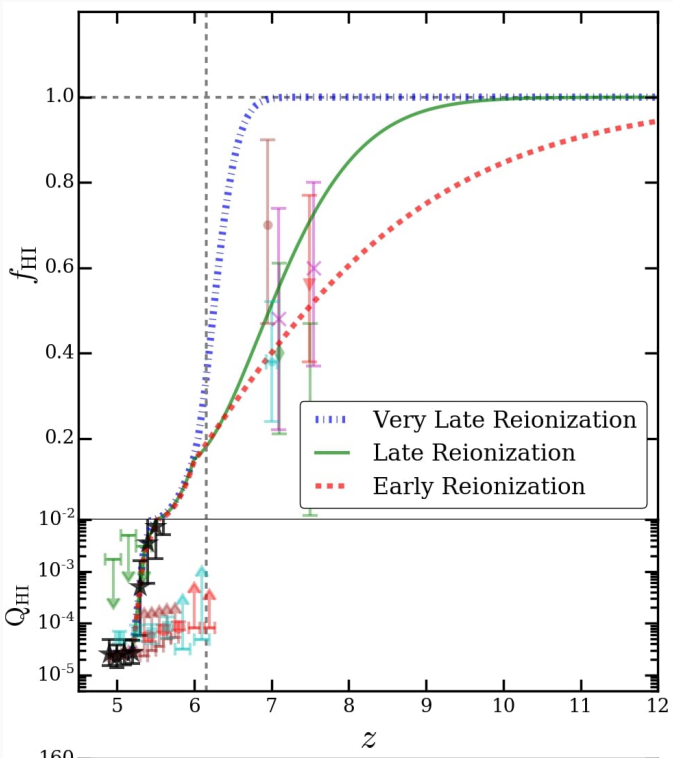

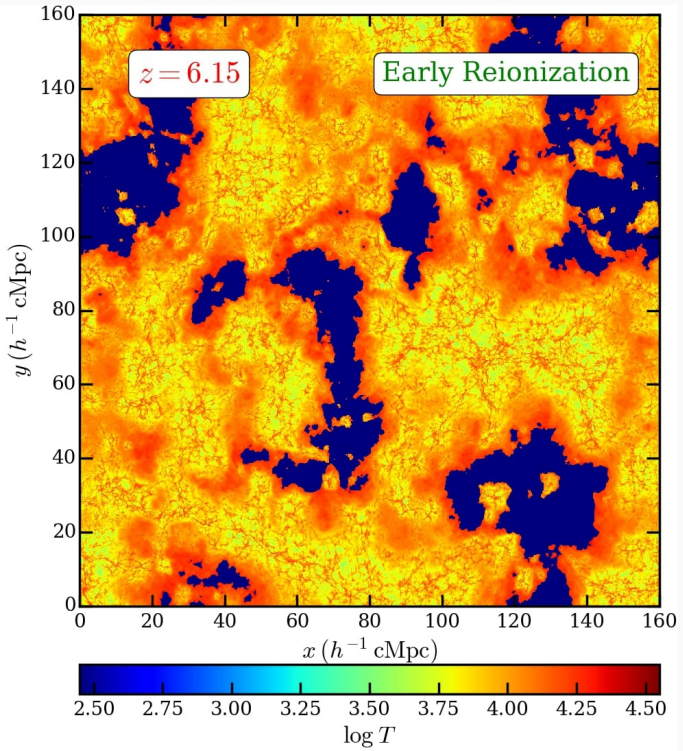

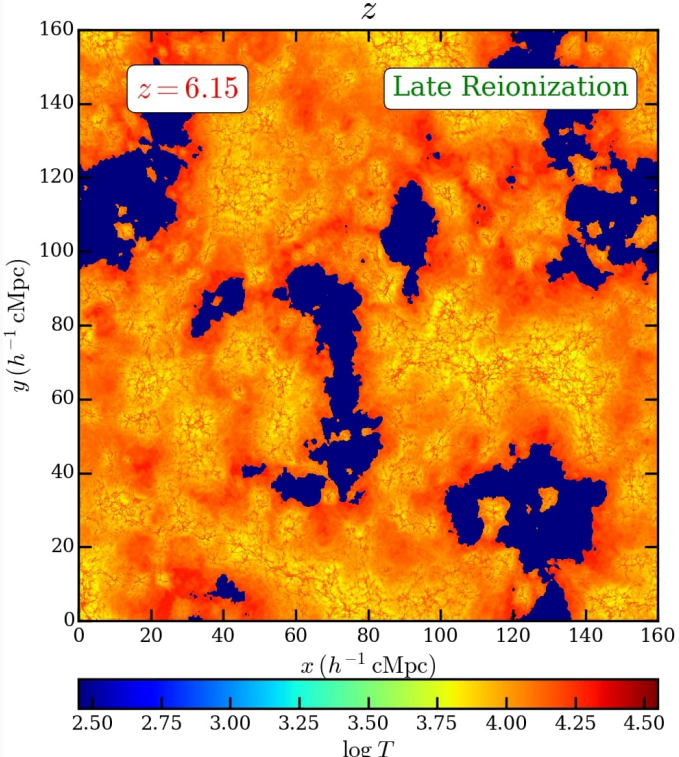

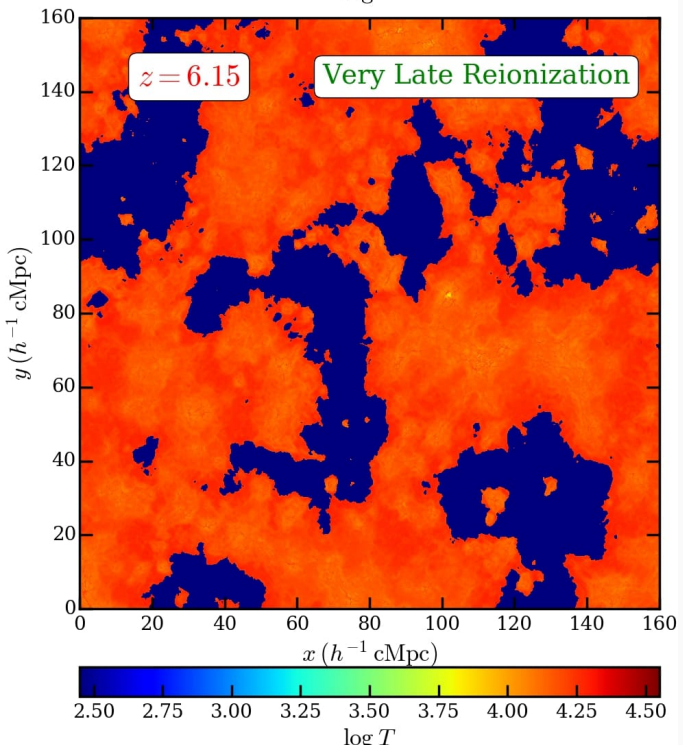

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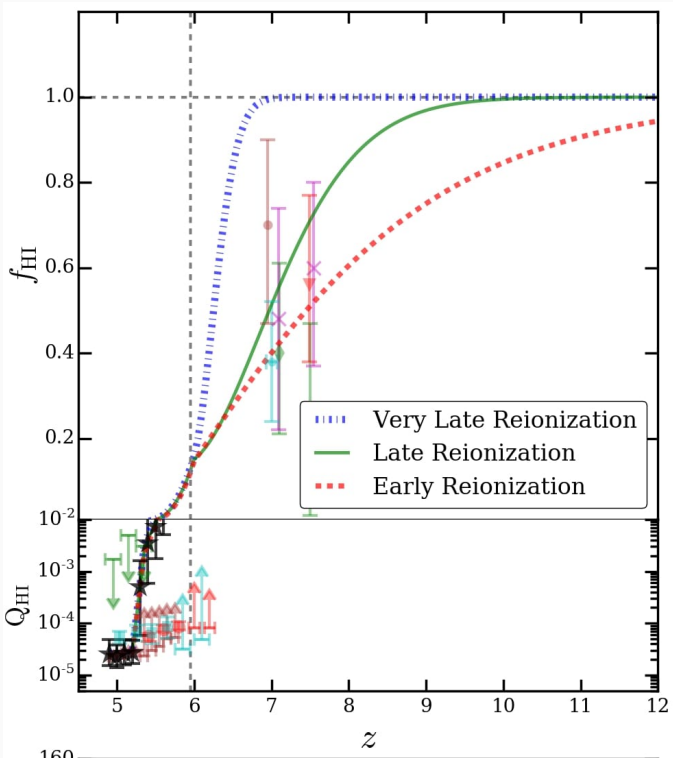
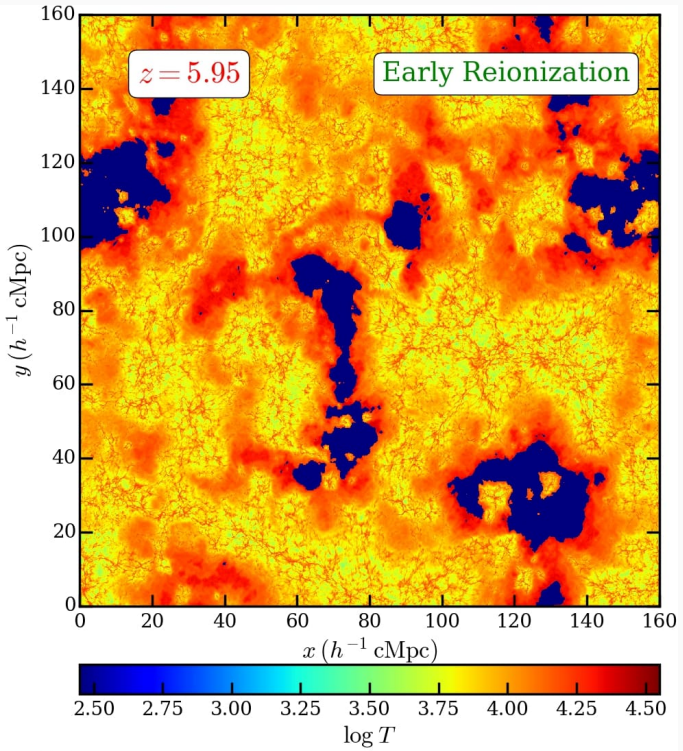
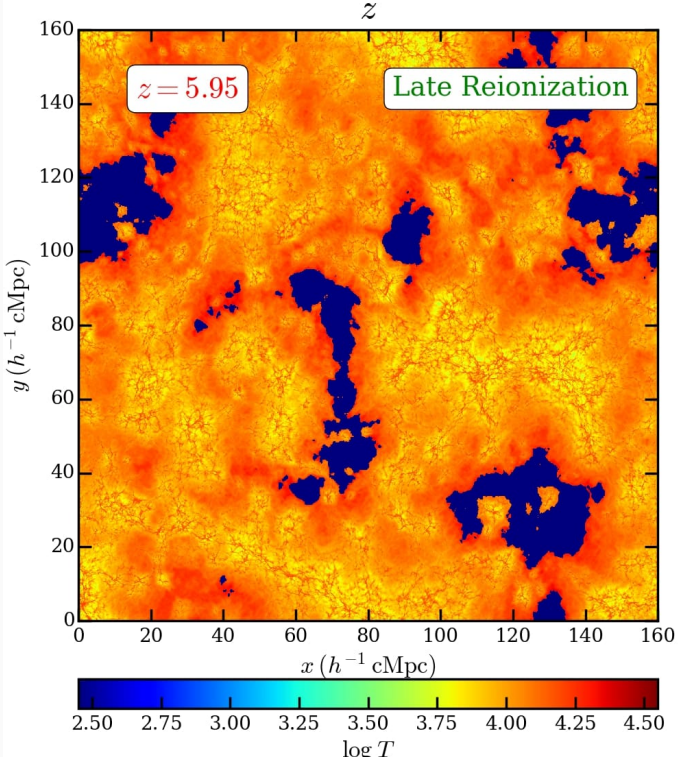
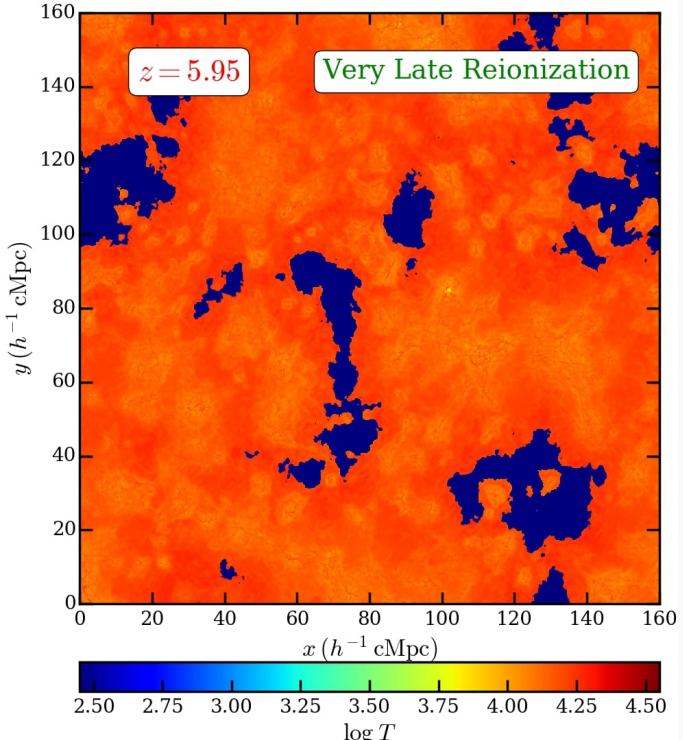
Recently ionized regions are hot while previously ionized regions are relatively cold









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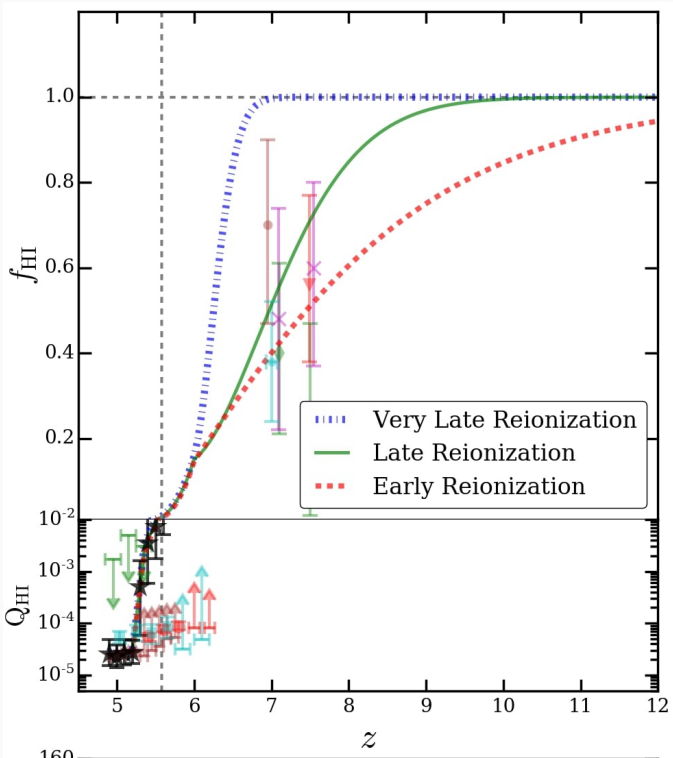

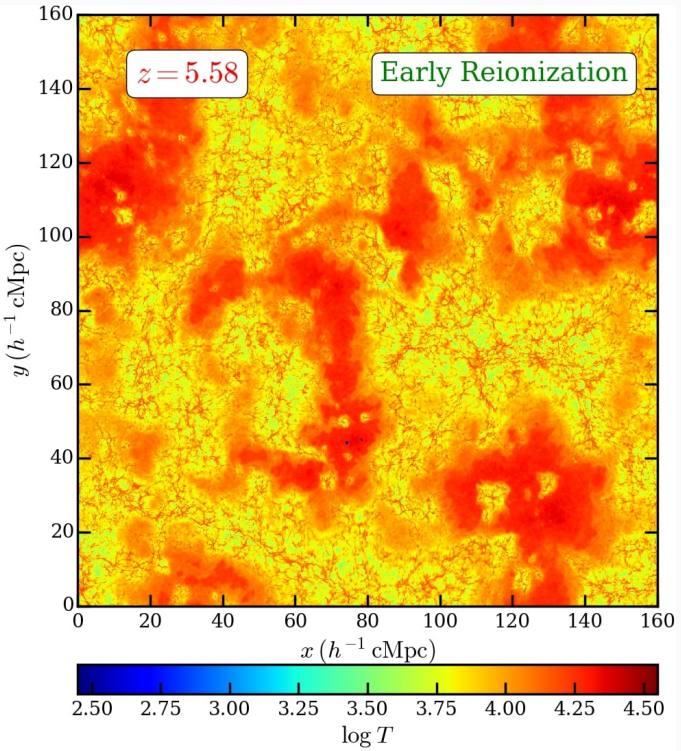

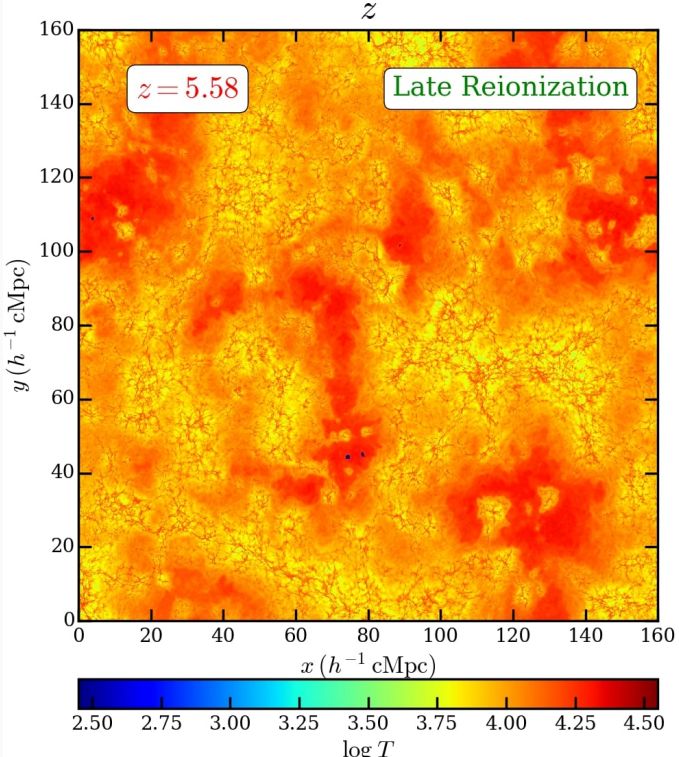

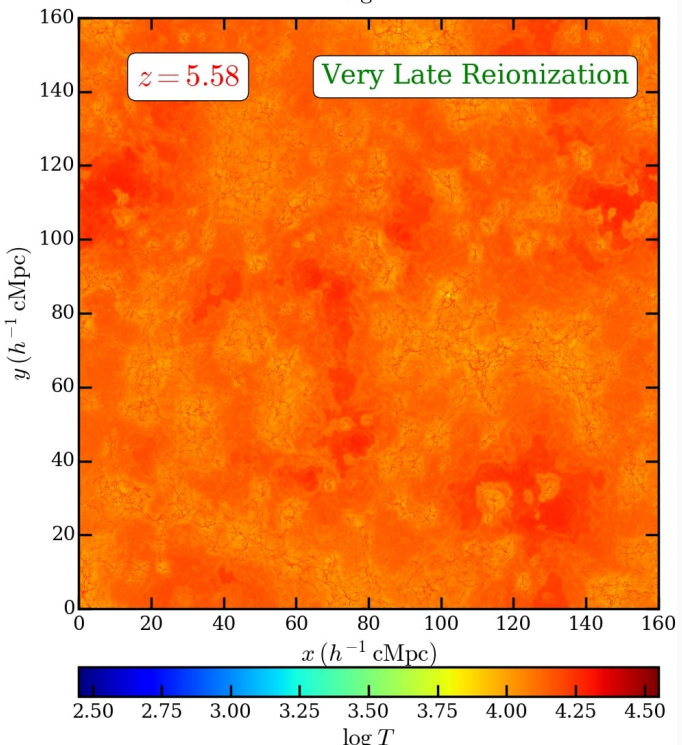

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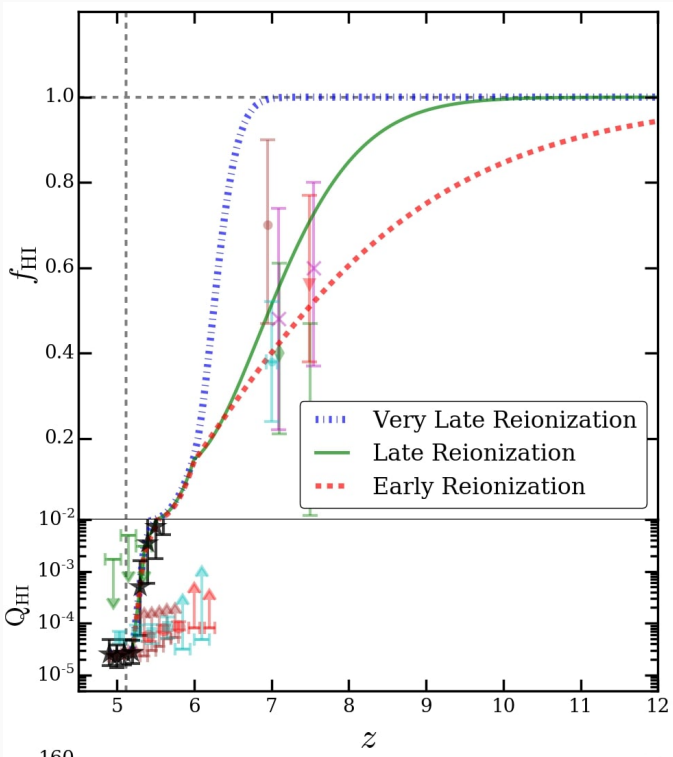

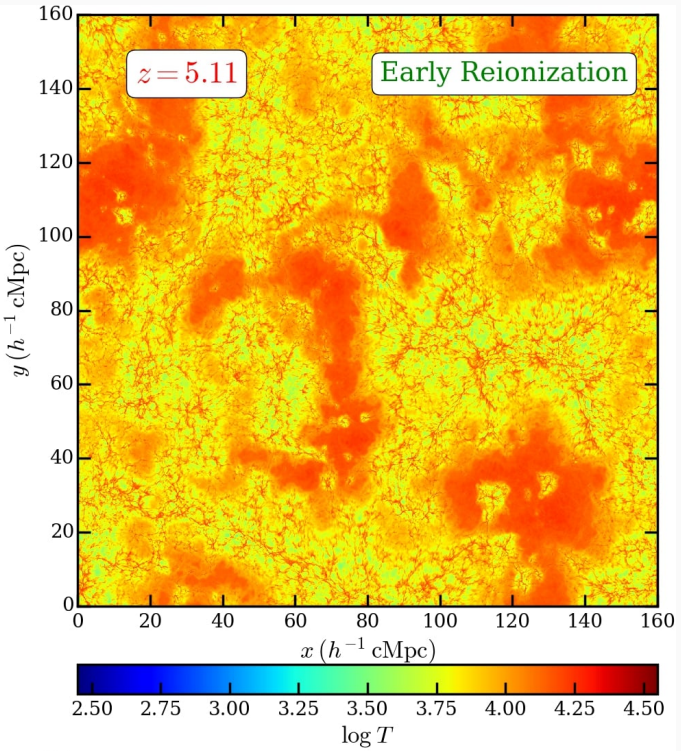

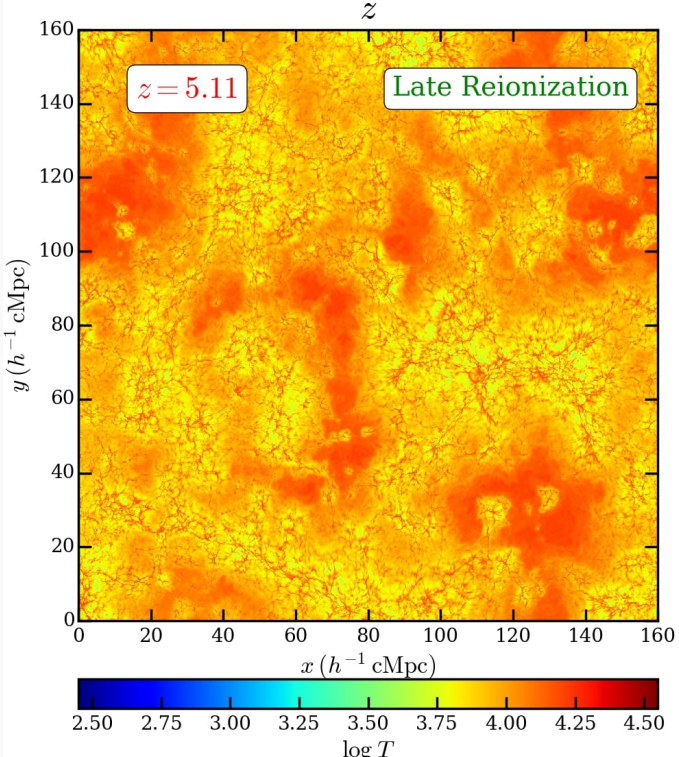

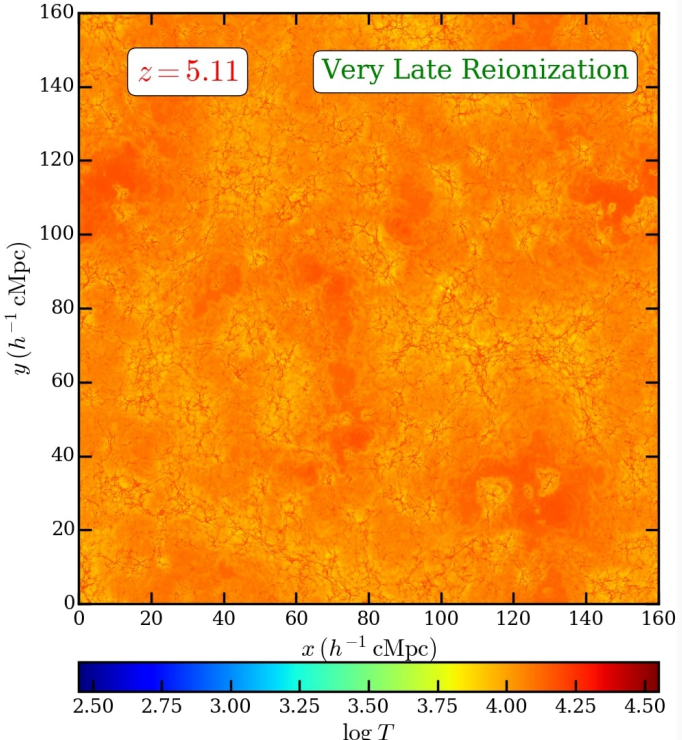

Temperature Fluctuations

Reionization starts at $z \sim 13$

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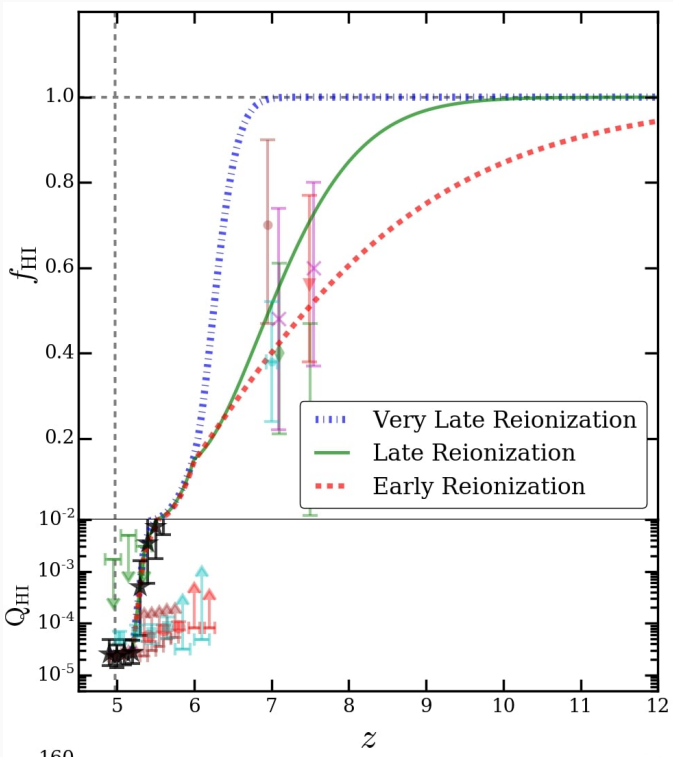

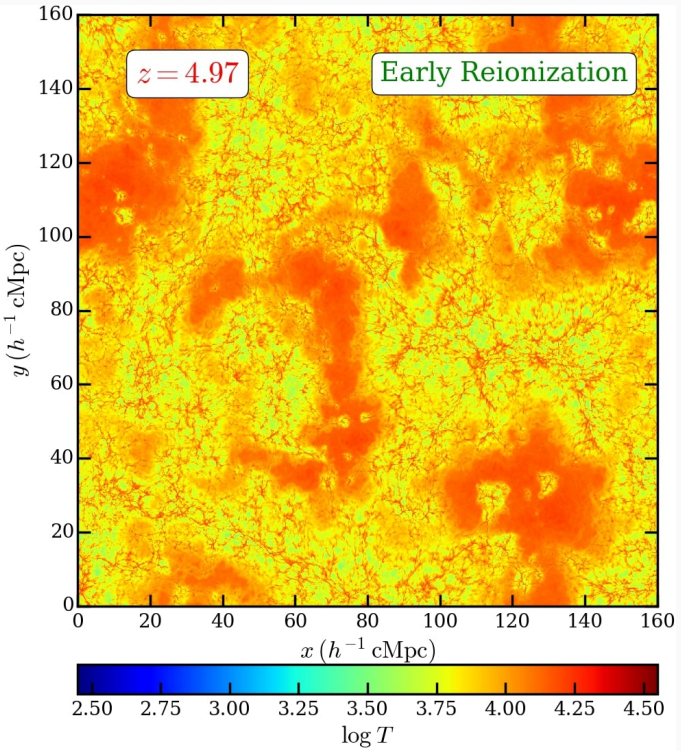

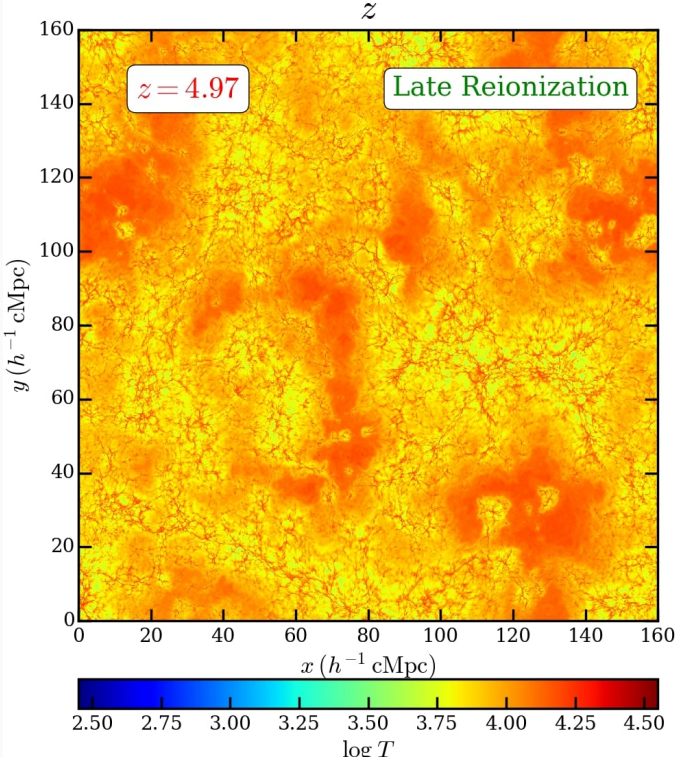

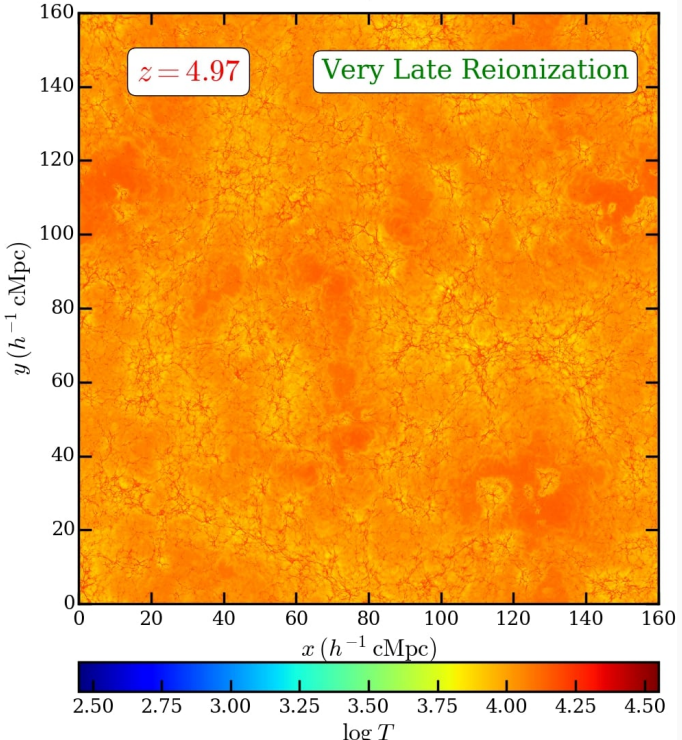

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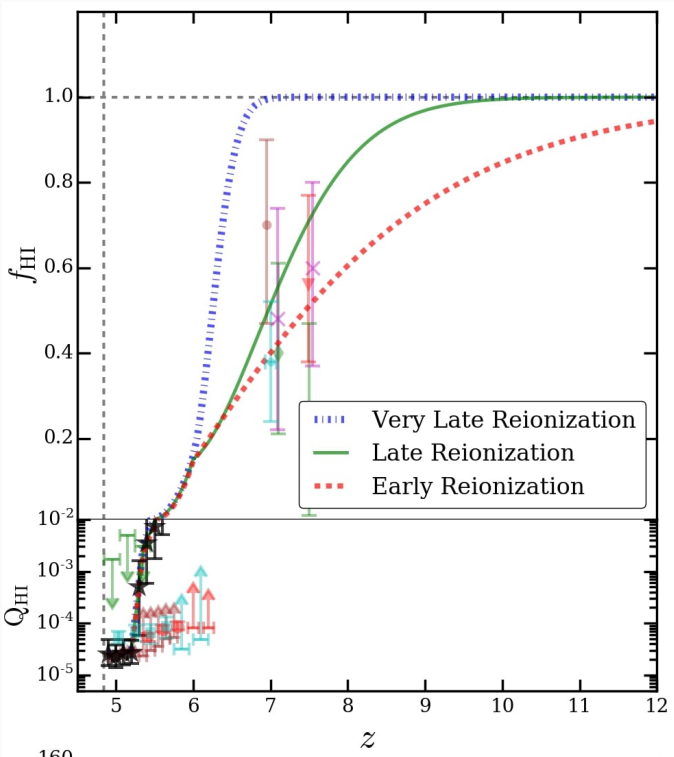

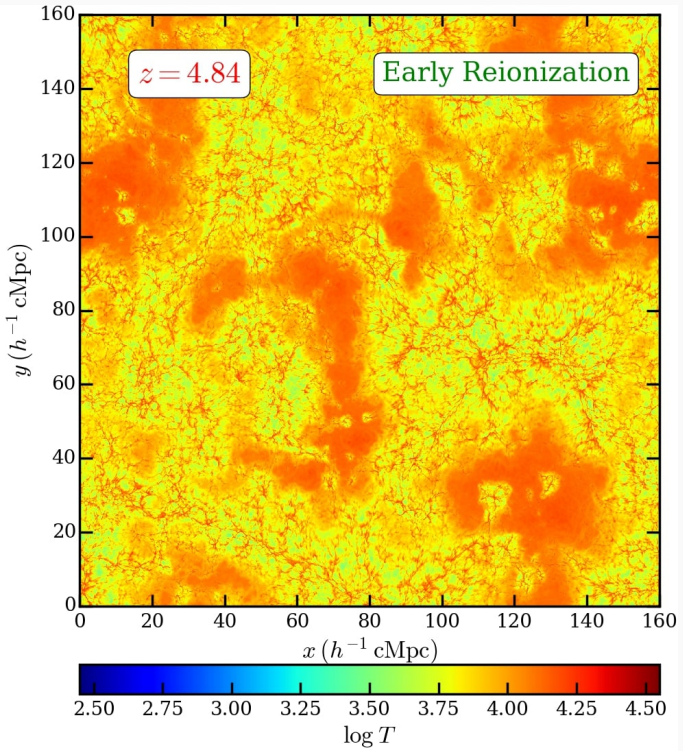

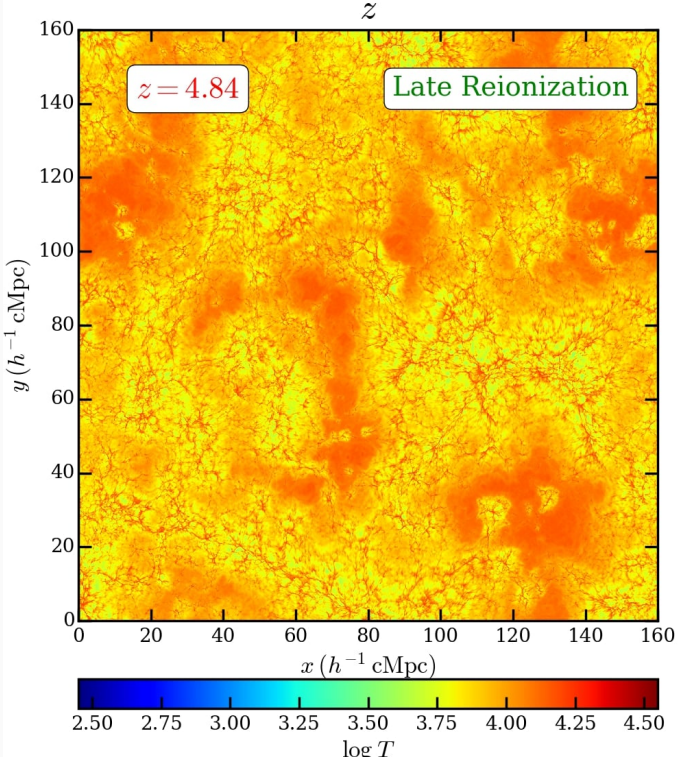

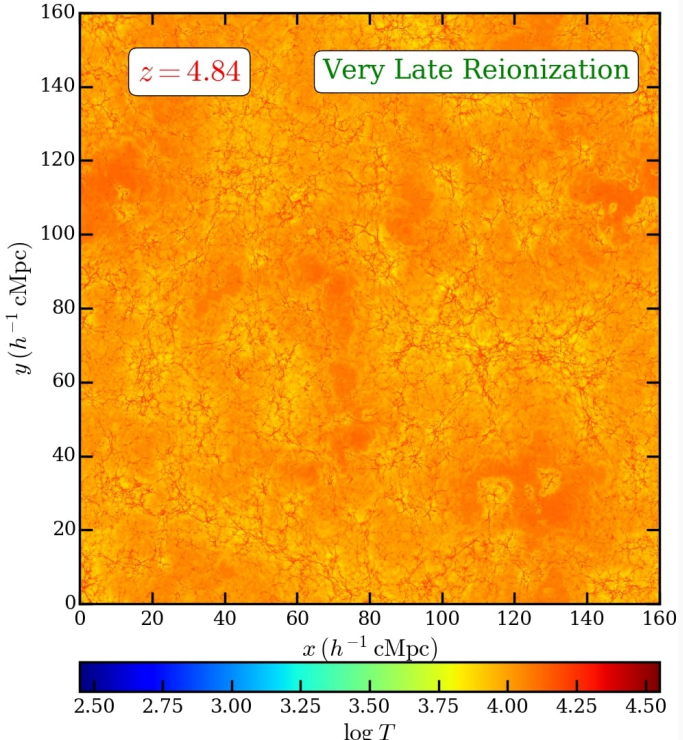

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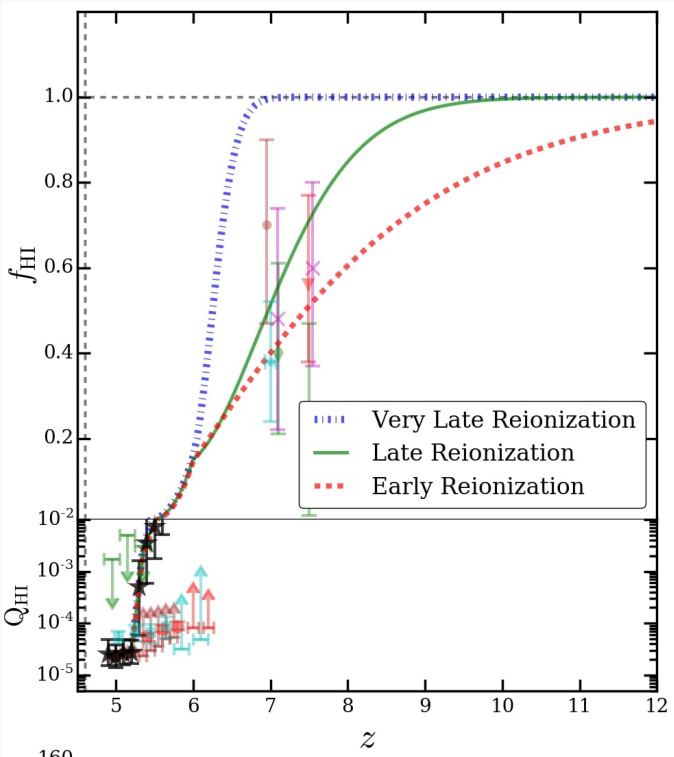
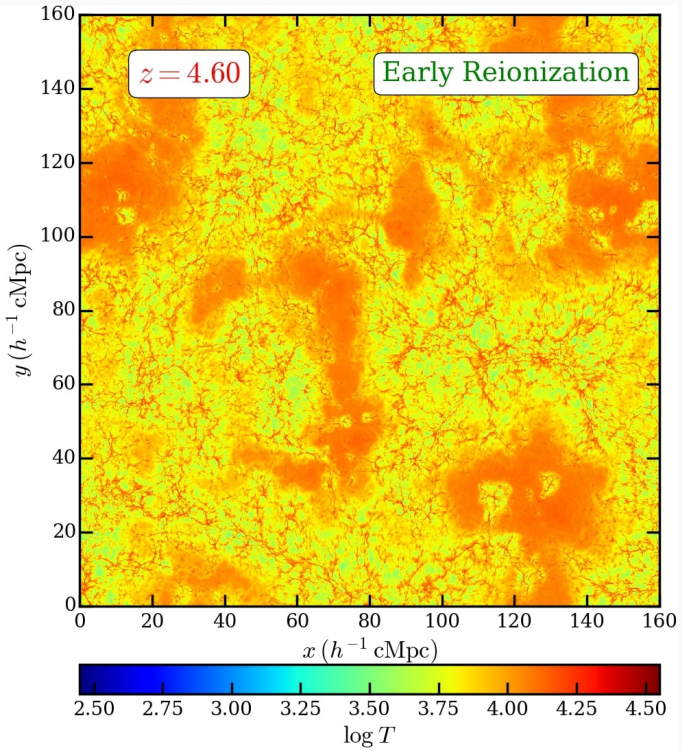
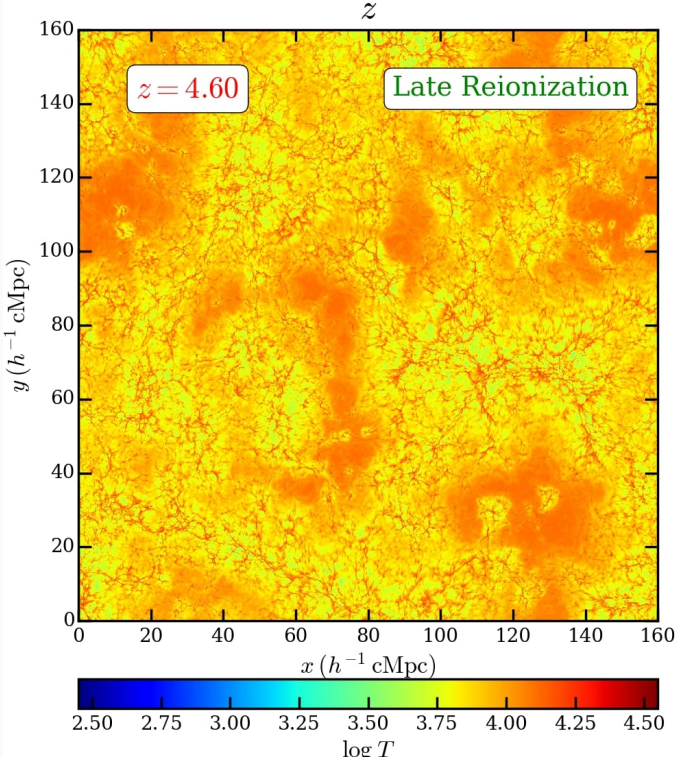
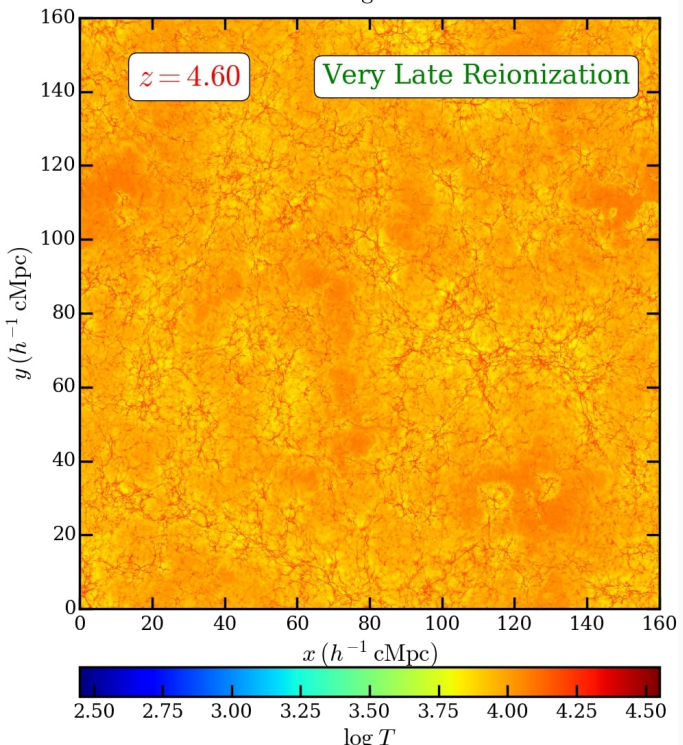
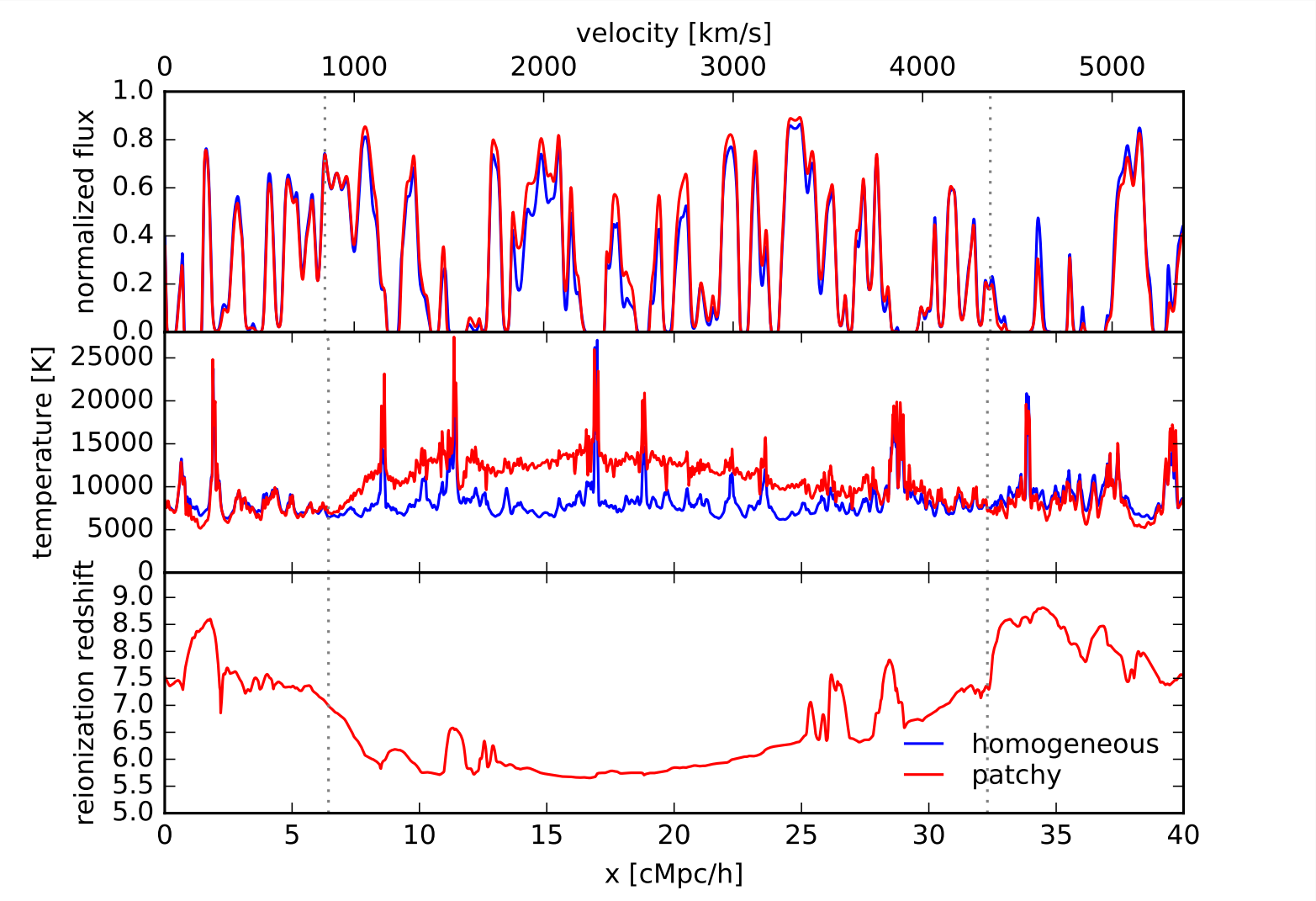








Effect of Temperature fluctuations on P1D (Molaro+2023,Puchwein+2023)

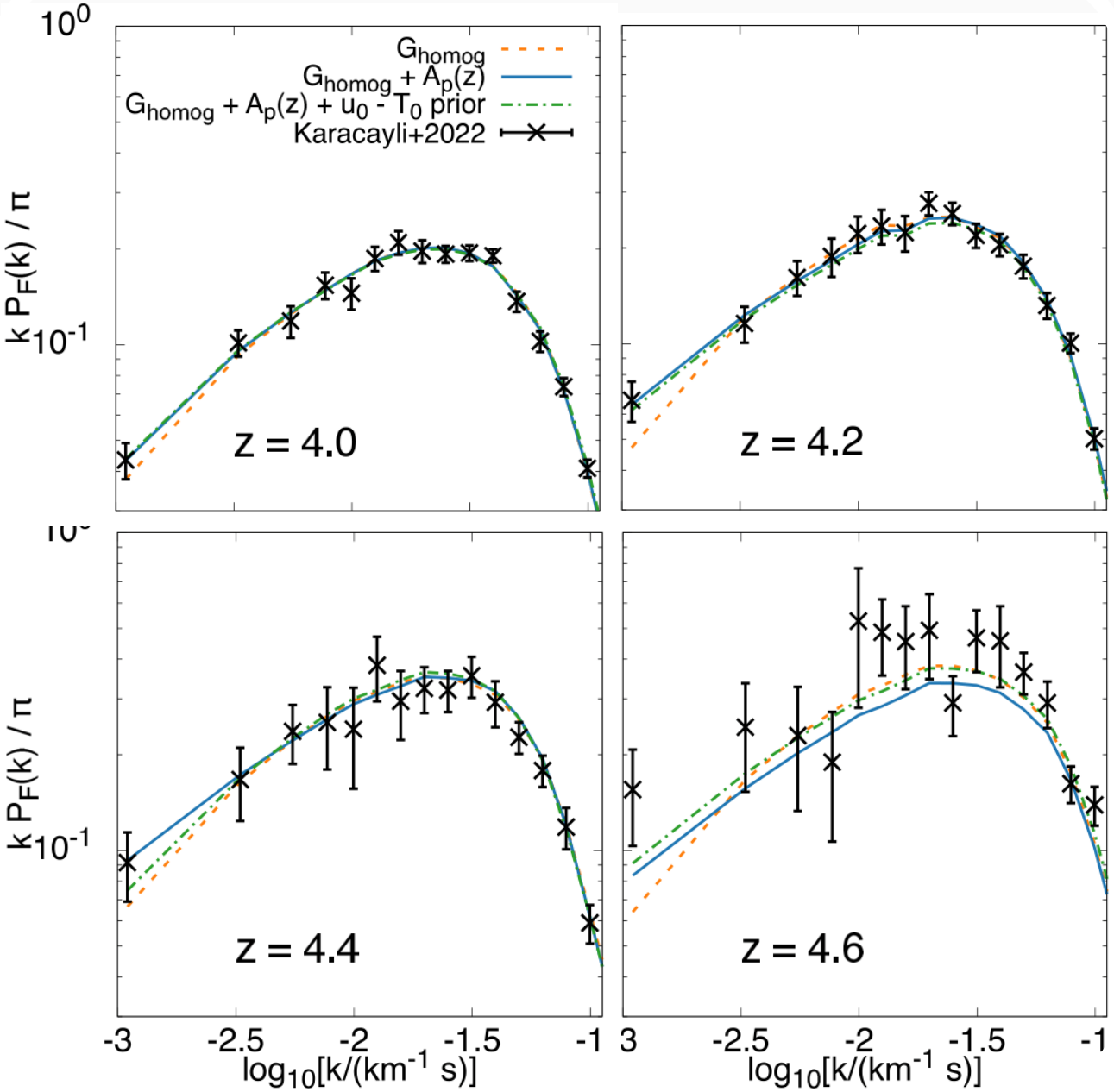


Large scale variation in temperature along sightline

Flux increases due to temperature dependence of recombination rate

Lines are broader in the hotter regions

Effect of Temperature fluctuations on P1D (Molaro+2023,Puchwein+2023)



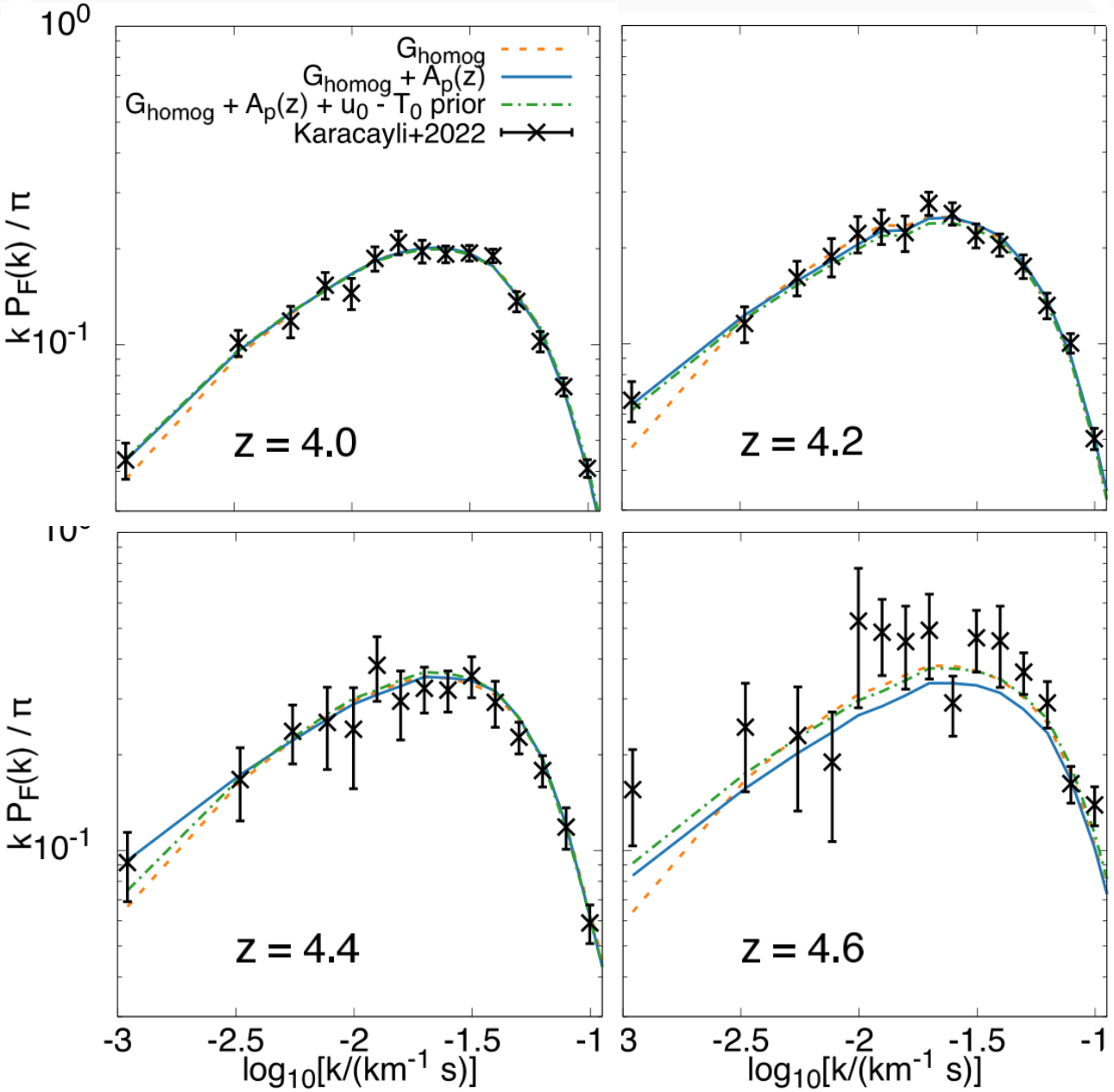
Increase in power on large scale in P1D

Large number of QSO spectra with in WEAVE-LR at $z > 4$

Continuum fitting uncertainty

Similar effects at $2 < z < 4$ due to He II reionization

Summary



Patchy reionization introduces fluctuations in temperature.

Early reionization model ⇒ large temperature fluctuations

Large scale power enhancement P1D

Work in progress: How many QSO of what magnitude to be observed with WEAVE-LR to detect signal?

WEAVE-LR data could be useful

Good Continuum fitting is desirable