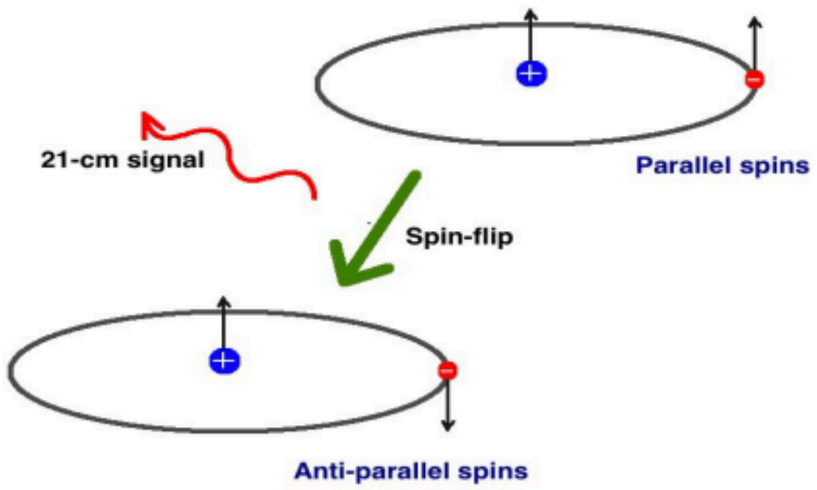
University of Zurich[UZH]

Simulating the 21cm signal during Cosmic Dawn and Reionisation

Timothée Schaeffer
with Sambit Giri and Aurel Schneider

The 21cm signal traces neutral Hydrogen in the IGM



What we measure :

$$dT_{\rm b} \propto x_{\rm HI}(1+\delta)(1-\frac{T_{\rm CMB}}{T_{\rm spin}})$$

- $x_{\rm HI}$: Neutral fraction
- $(1+\delta)$: Baryon Density
- $T_{\rm spin}$: Spin Temperature

—> dTb is sensitive to the **distribution**, **temperature** and **ionisation** state of the IGM gas

—> Hence, the signal is sensitive to both the **cosmology** and the **astrophysics**
(the properties of the first galaxies)

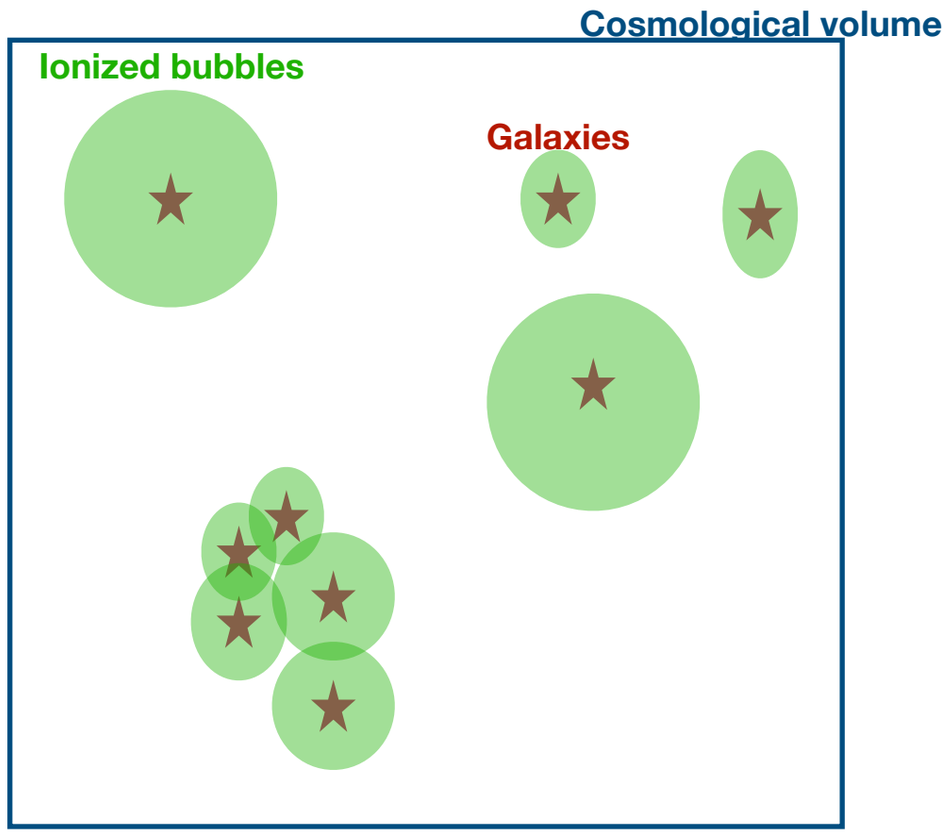
Modelling the 21cm signal : BEoRN

(**B**ubbles during the **E**poch **o**f **R**eionisation **N**umerical simulator)

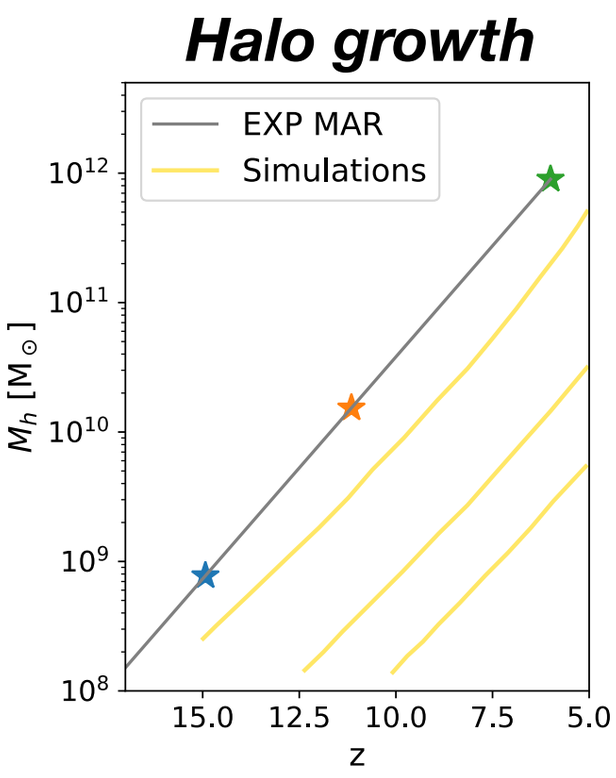
Goal : Produce 3D dTb maps

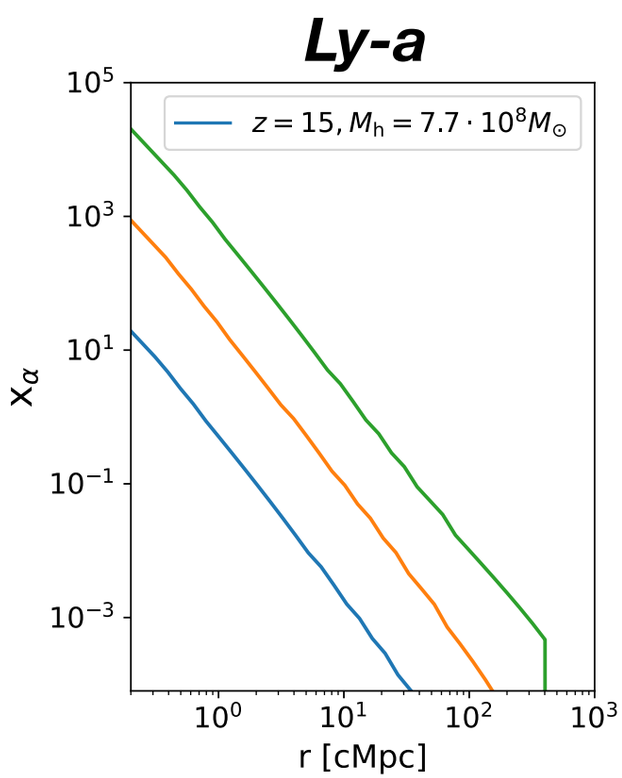
Methodology :

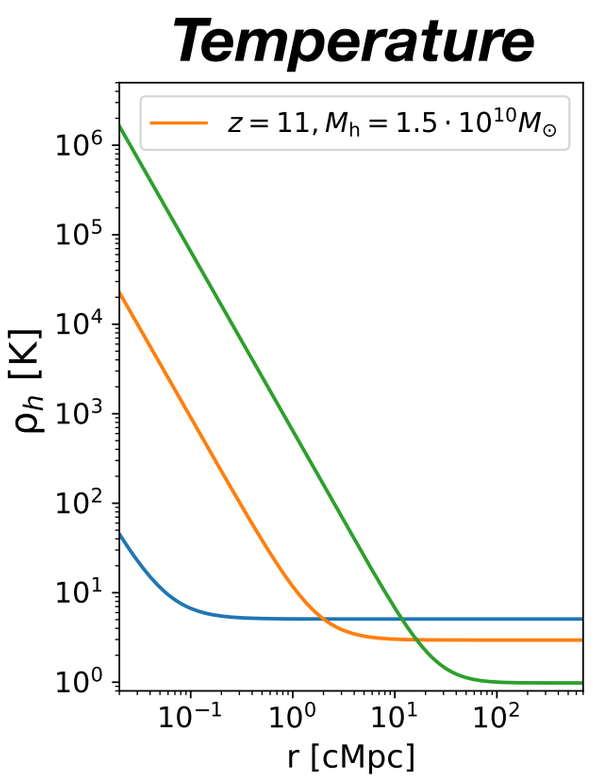
1. Use N-body or LPT solver for the non-linear matter field and DM halos
2. Populate halos with galactic sources
3. Compute 1D profiles for temperature, ionisation and Ly-α flux
4. Paint the profiles on 3D grids.
5. Deal with overlap of ionised bubbles
6. Tk, xHII, dTb maps

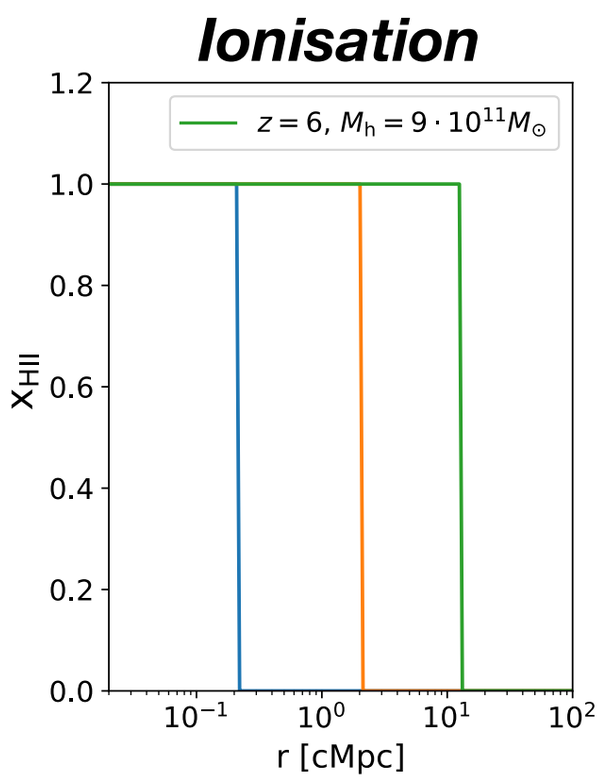


1D profiles





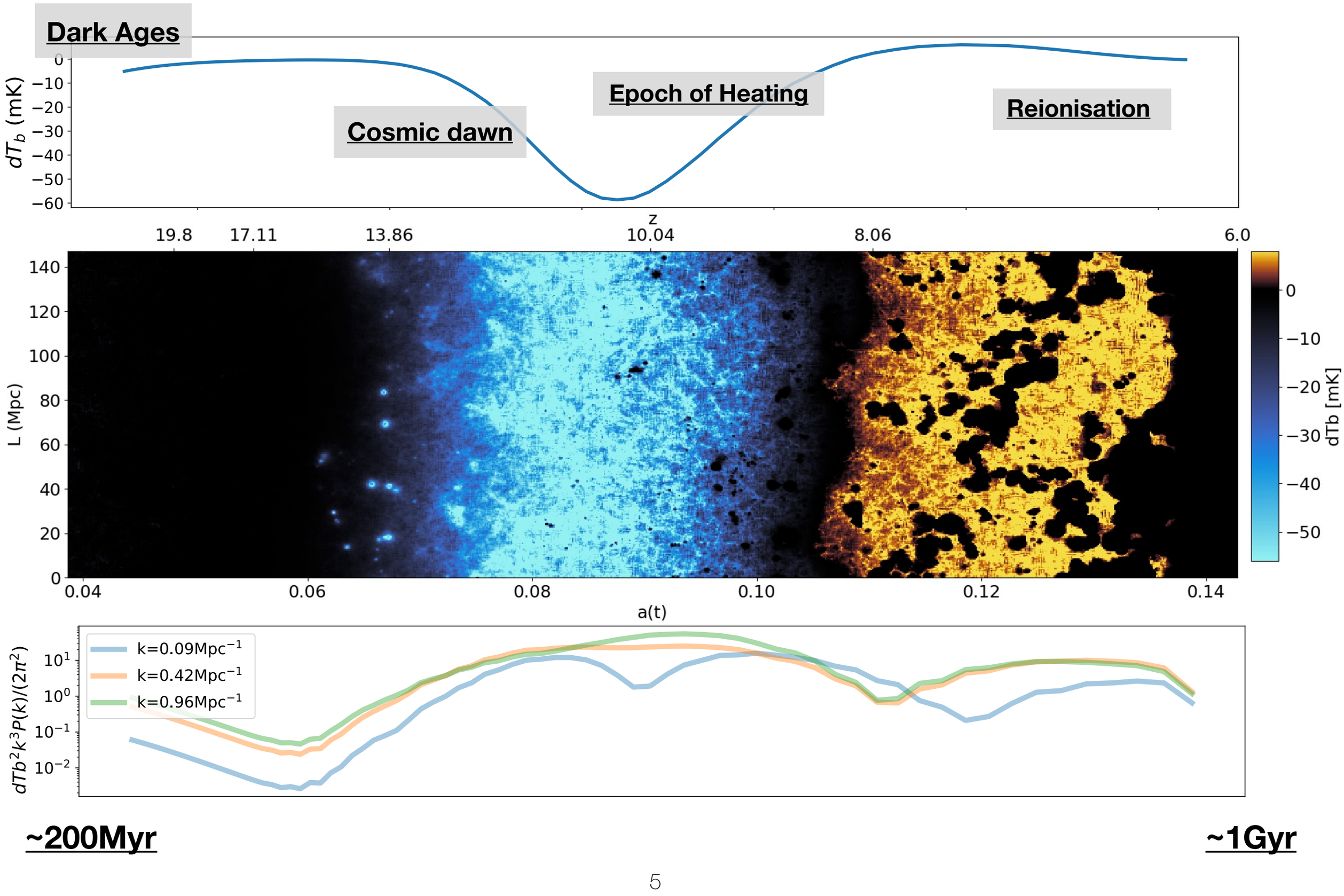




As a halo accretes mass, the SFR increases and the profiles evolve

These profiles are painted on 3D maps.

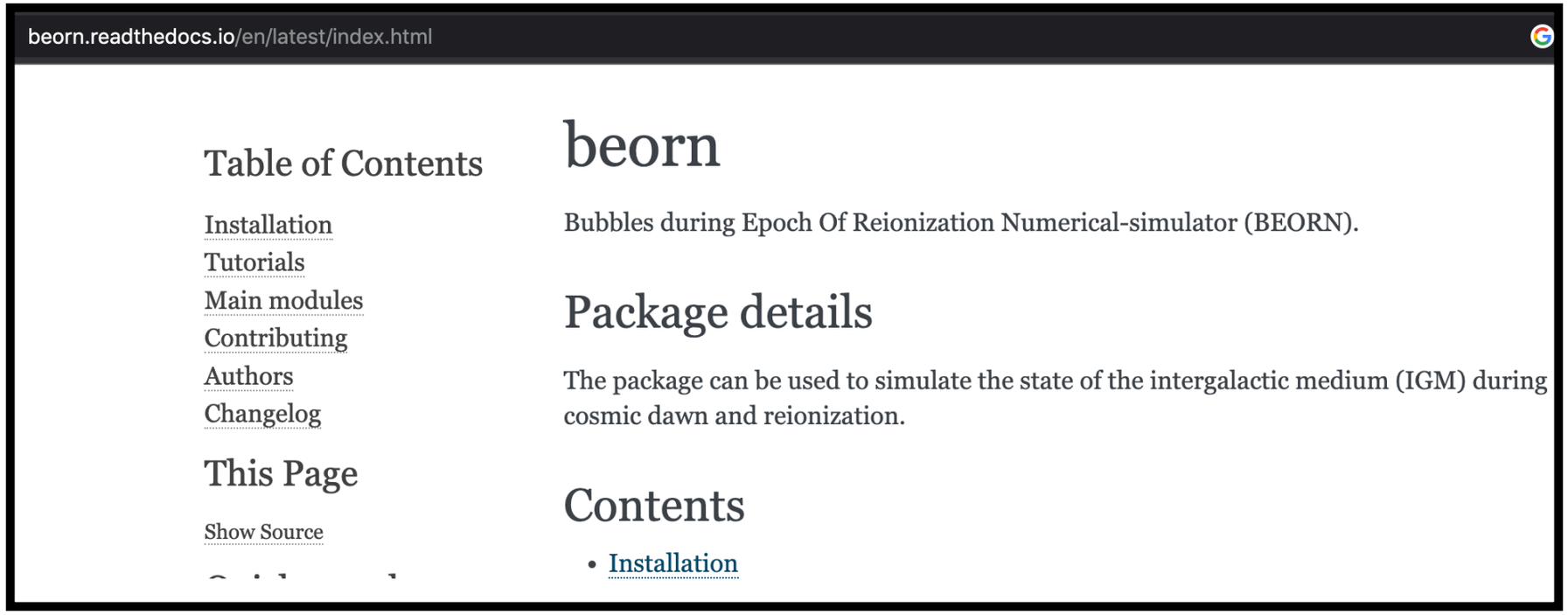
Final product : 3D dTb maps, power spectrum



BEoRN

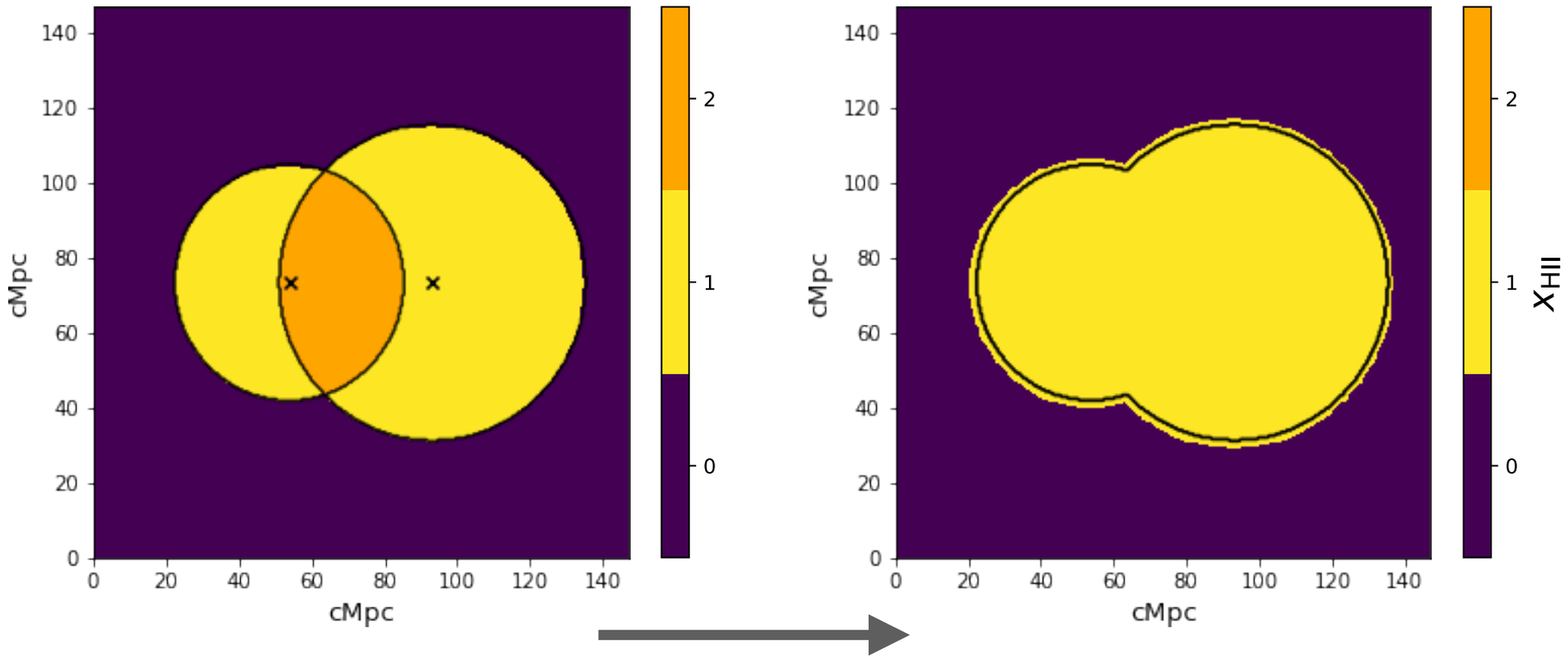
(**B**ubbles during the **E**poch **o**f **R**eionisation **N**umerical simulator)

Publicly available, flexible, user-friendly



(in development)

Dealing with the overlap of ionised bubbles



Redistributing the "over-ionised pixels"

To go further

- Need Fast gravity solver/halo finder algorithms

- More accurate galactic SED (pop.II/pop.III stars)

- Modelling of X-ray sources (Qasars/ HMXBs)

- Constraints on the ionising photon escape fraction.

Modelling the 21cm signal : BEoRN

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Methodology :

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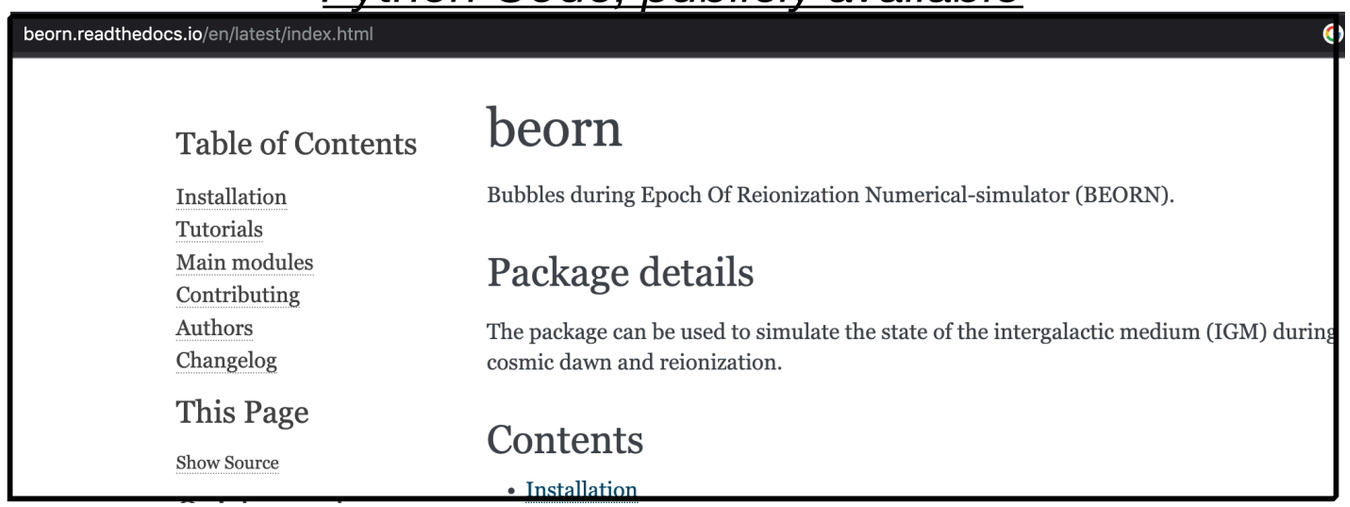
5. Paint the profiles on 3D grids.

Python Code, publicly available



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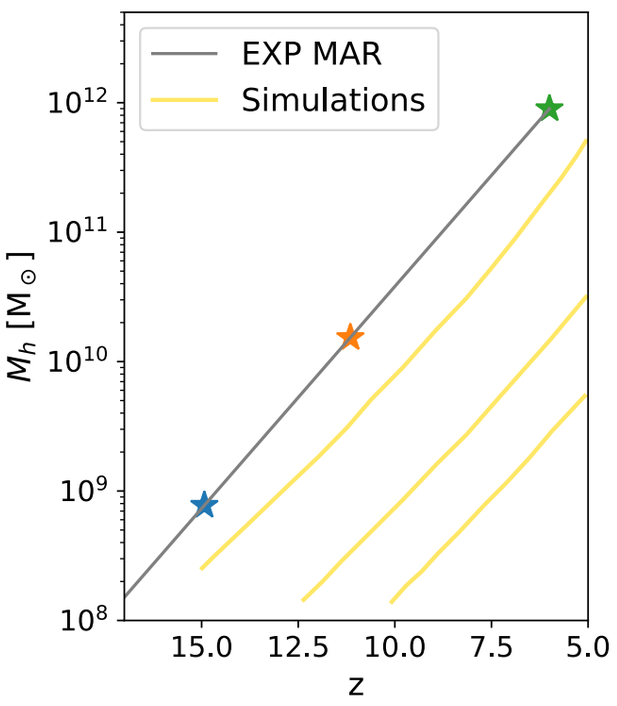
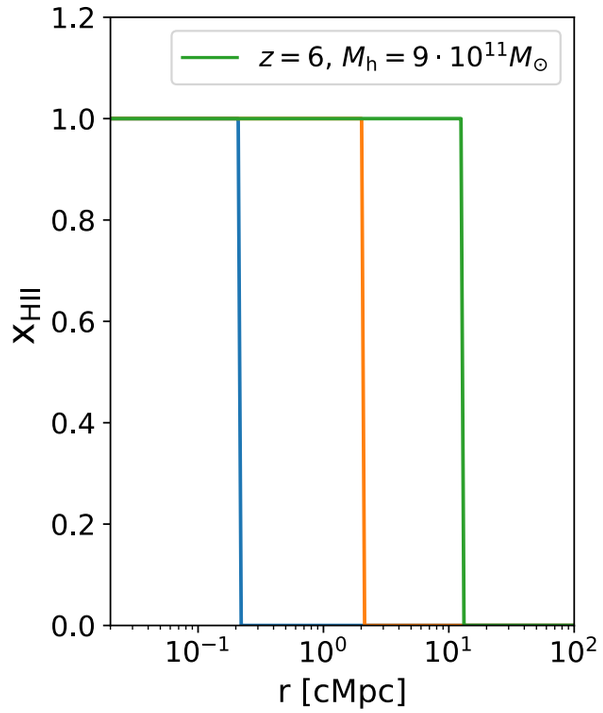
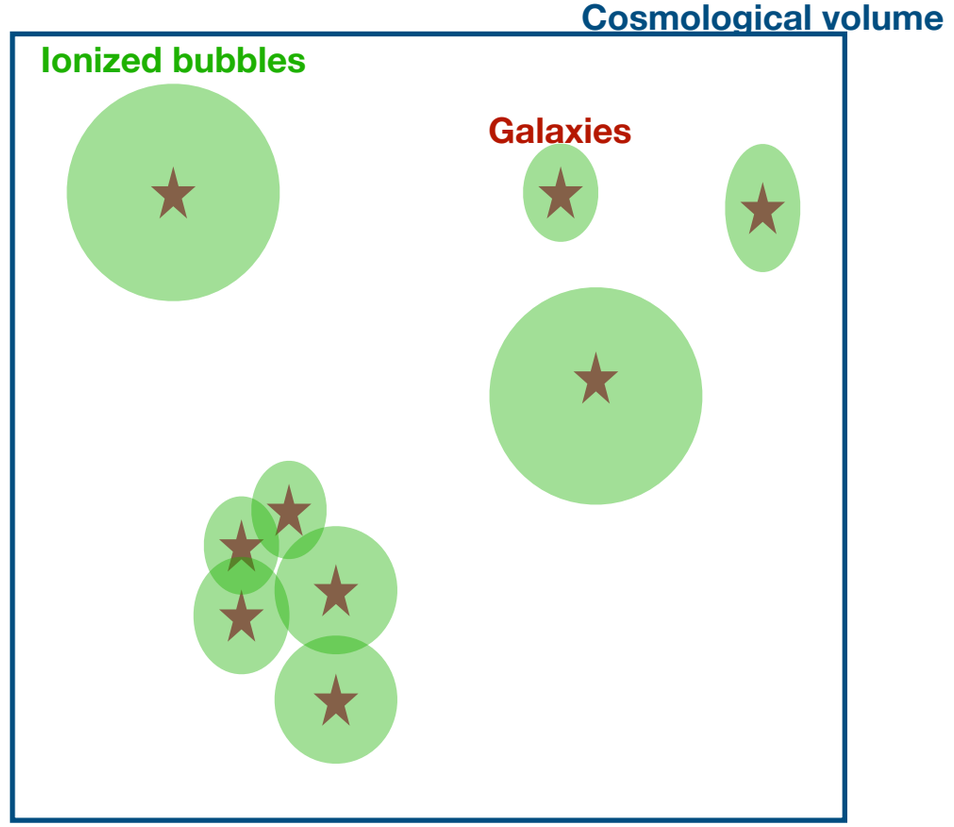
Halo growth



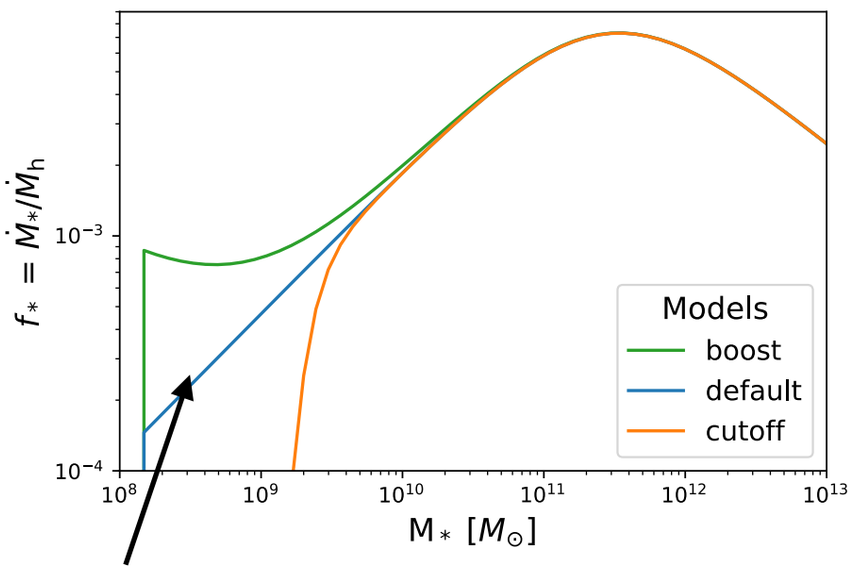
Ionised bubble





3 realistic scenarios for the Cosmic Dawn

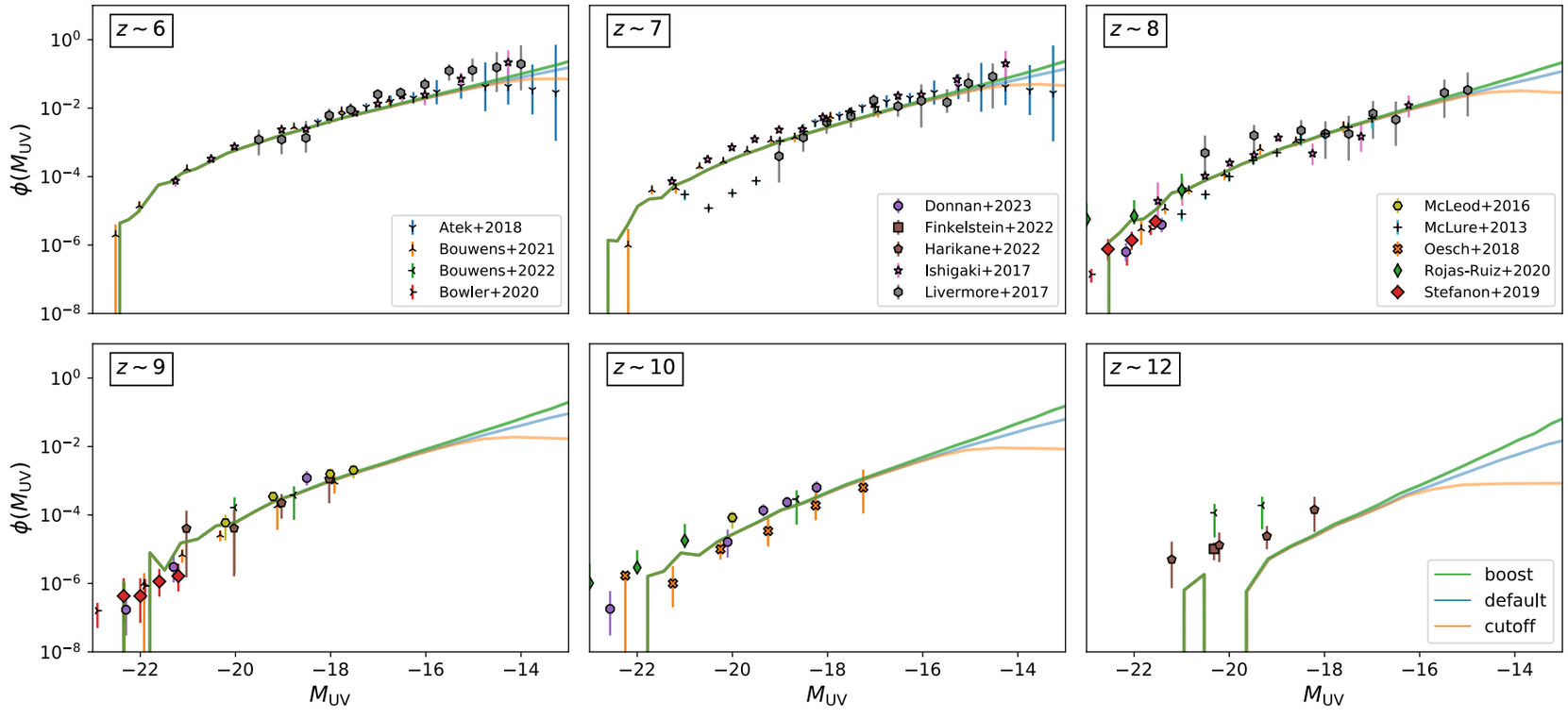
Stellar-to-halo



Unconstrained at small scales

The UV **luminosity function** constraints the **stellar-to-halo relation**

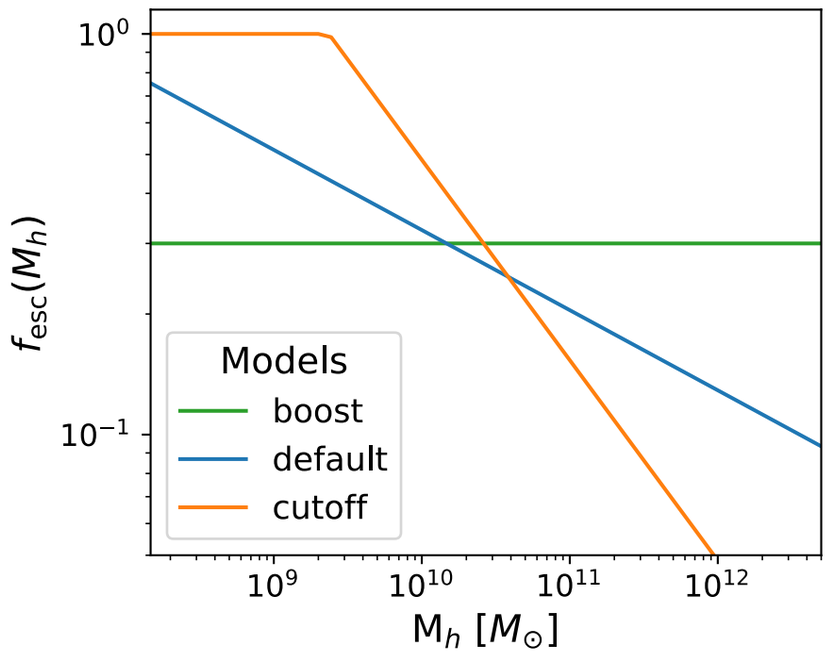
Luminosity function : theory vs data



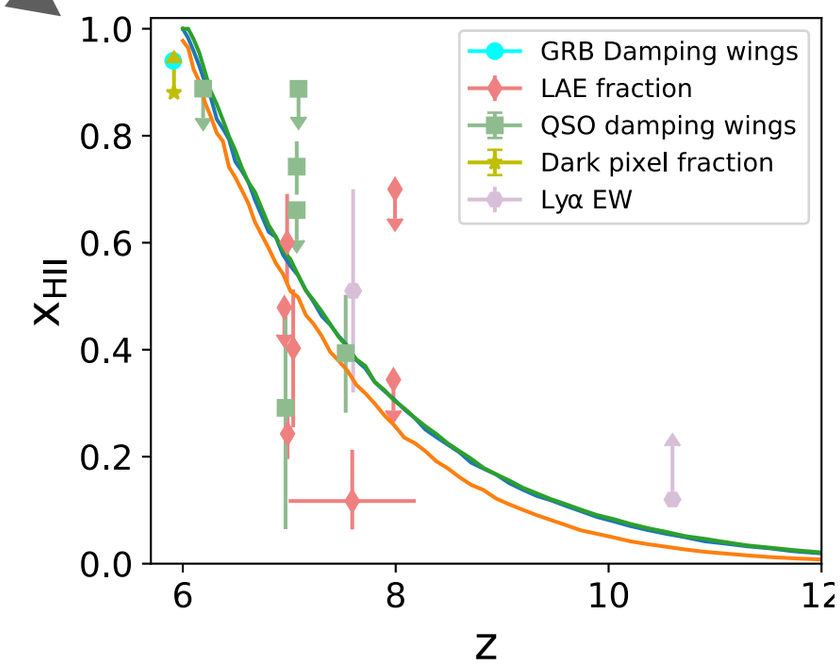
3 realistic scenarios for the Cosmic Dawn

Mean ion fraction observations constraints the **escape fraction** of ionising function

Escape fraction



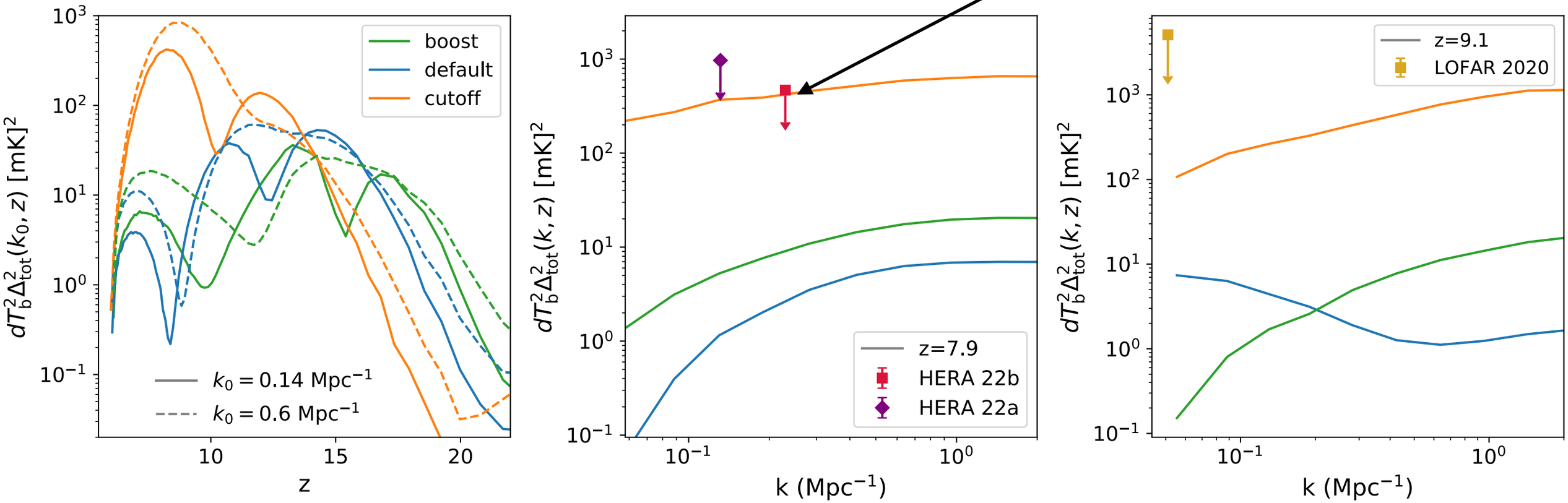
Reionisation history



3 realistic scenarios for the Cosmic Dawn

21cm signal (Power spectrum)

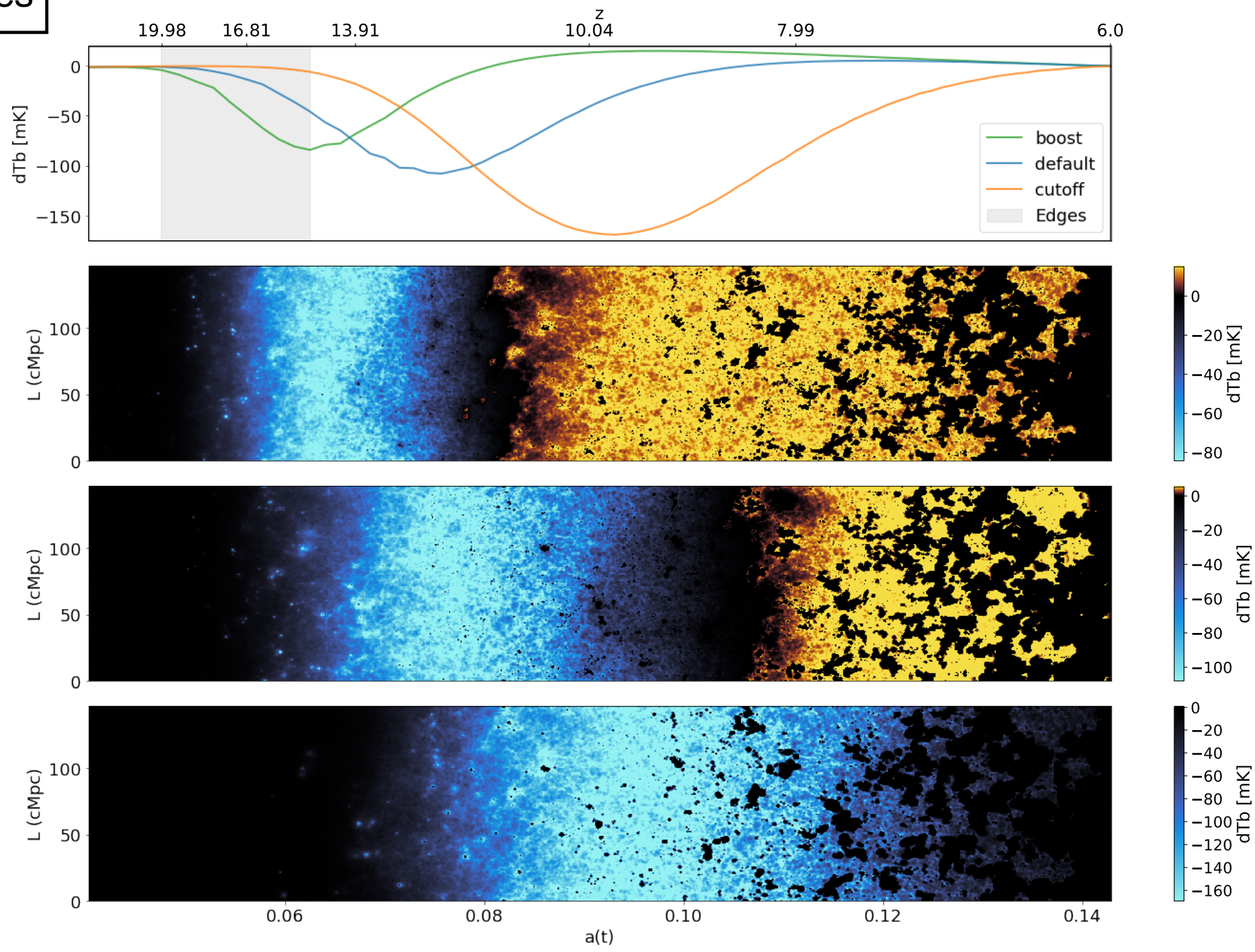
Current data : Upper limits on the signal



21cm signal (Power spectrum)

3 realistic scenarios for the Cosmic Dawn

Lightcones



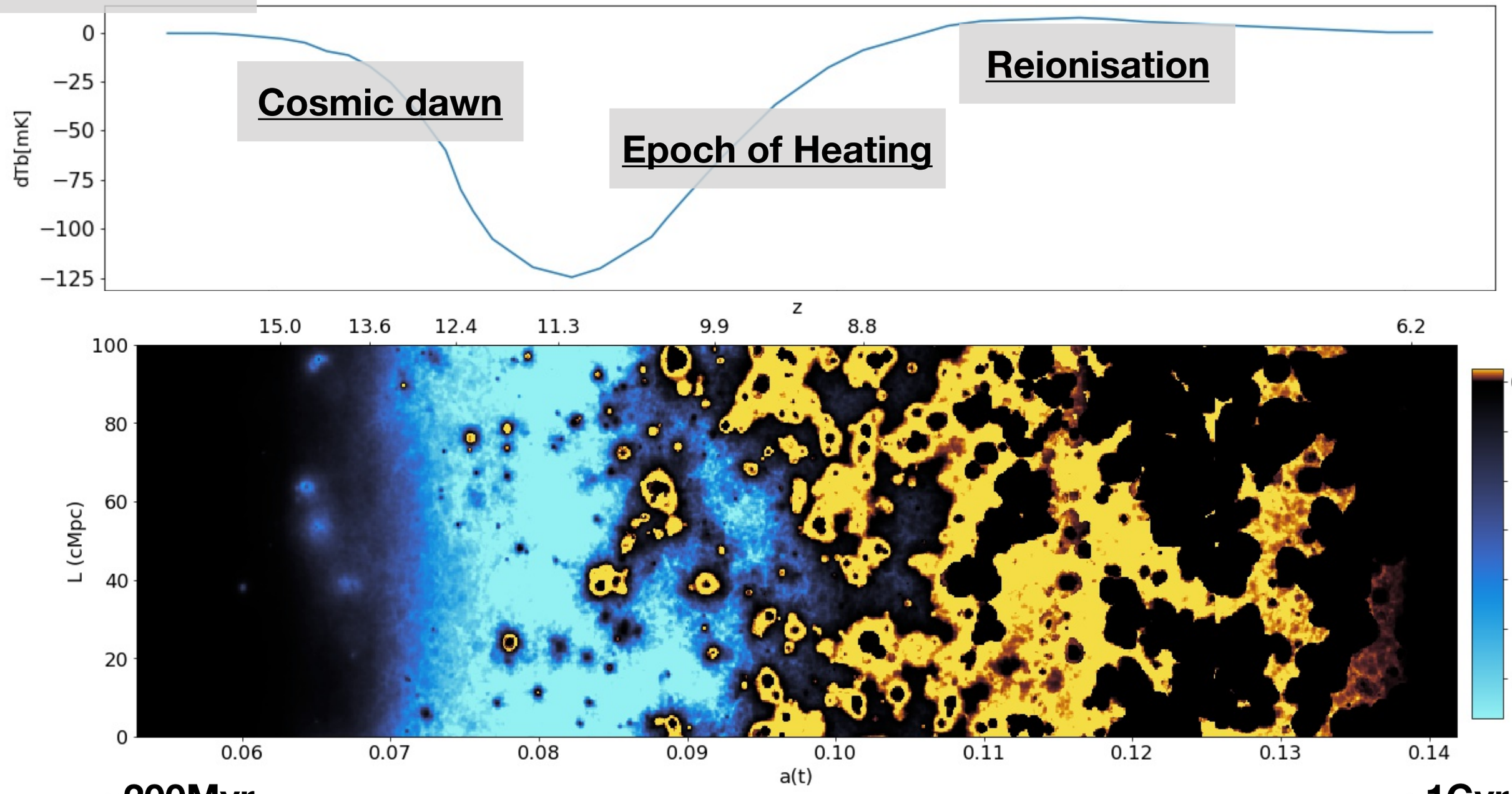
Outcome of the code

Dark Ages

Cosmic dawn

Epoch of Heating

Reionisation

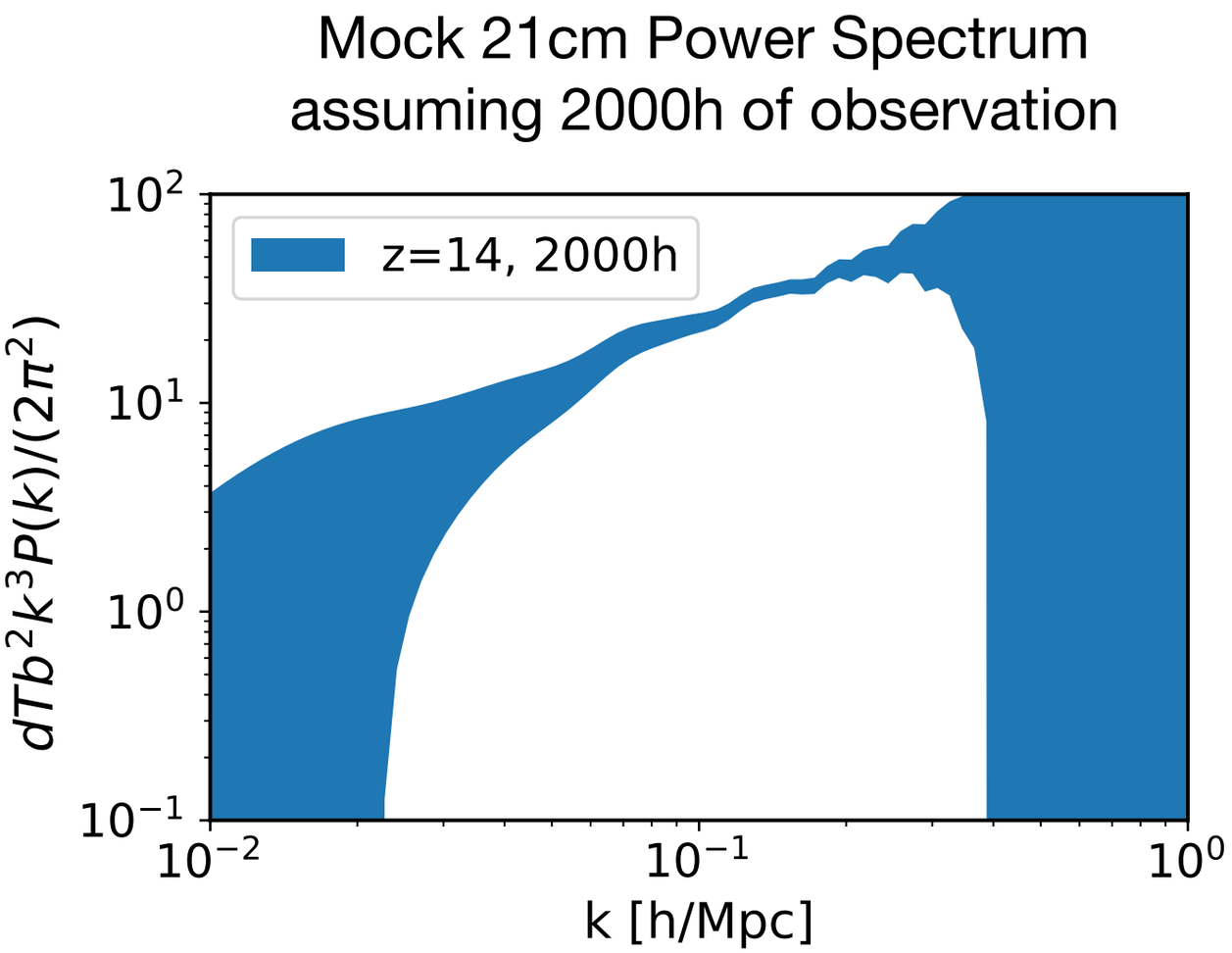


~200Myr

~1Gyr

SKA-low will provide data (~2029)

SKA-low in Australia (50–350 MHz)
z~25-3



(see 1903.01294)

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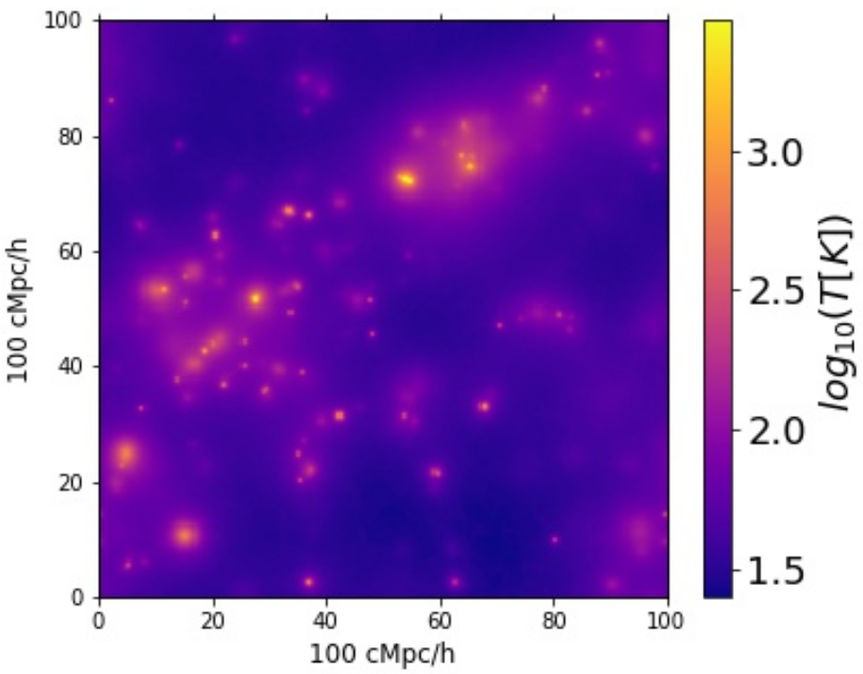
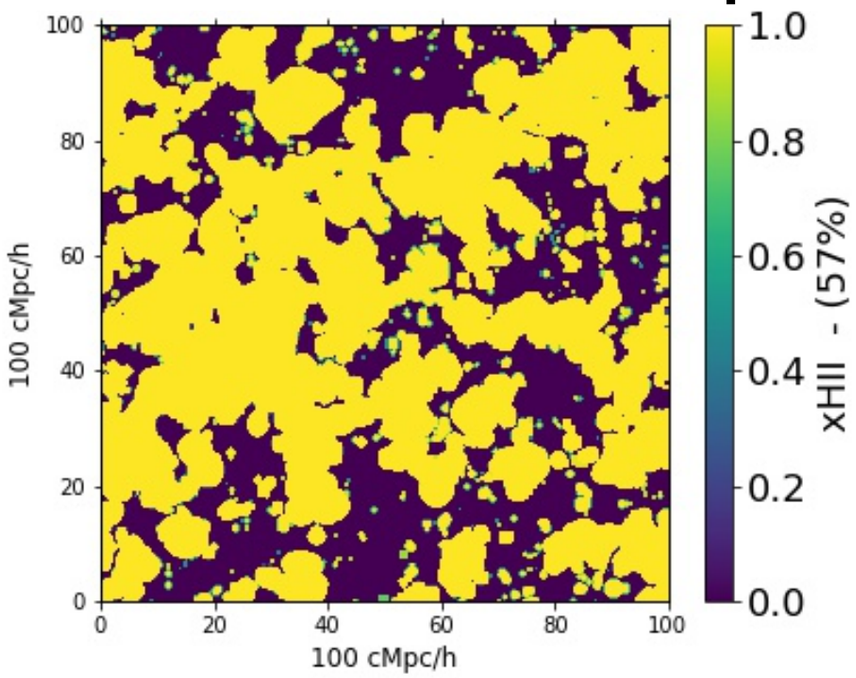
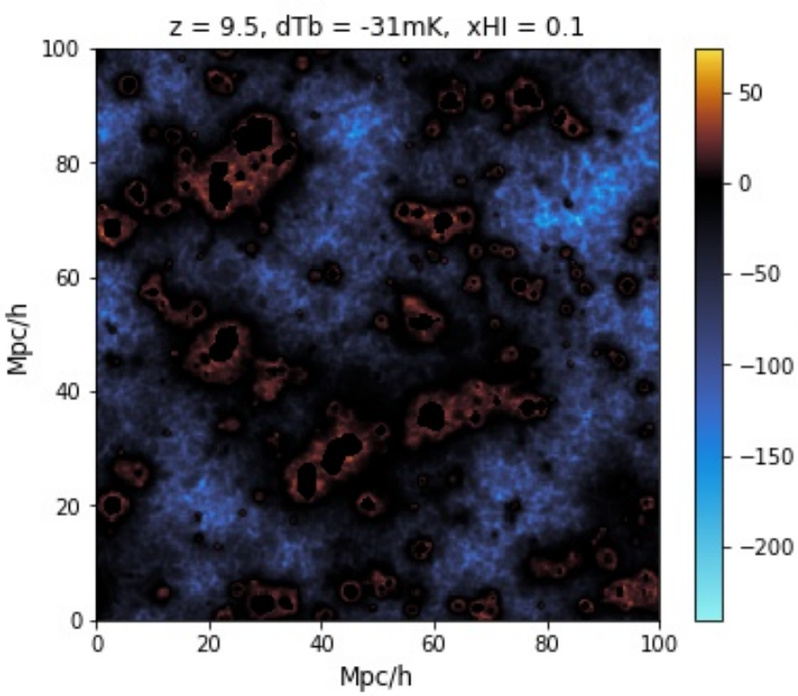
Temperature maps



Ionisation fraction maps



dTb maps



Modelling the 21cm signal : BEoRN

(**B**ubbles during the **E**poch **o**f **R**eionisation **N**umerical simulator)

- Python Code, publicly available, easy to use

- Can be coupled to any N-body output

- Flexible source model

beorn.readthedocs.io/en/latest/index.html

Table of Contents

Installation
Tutorials
Main modules
Contributing
Authors
Changelog

This Page

Show Source

beorn

Bubbles during Epoch Of Reionization Numerical-simulator (BEORN).

Package details

The package can be used to simulate the state of the intergalactic medium (IGM) during cosmic dawn and reionization.

Contents

- Installation

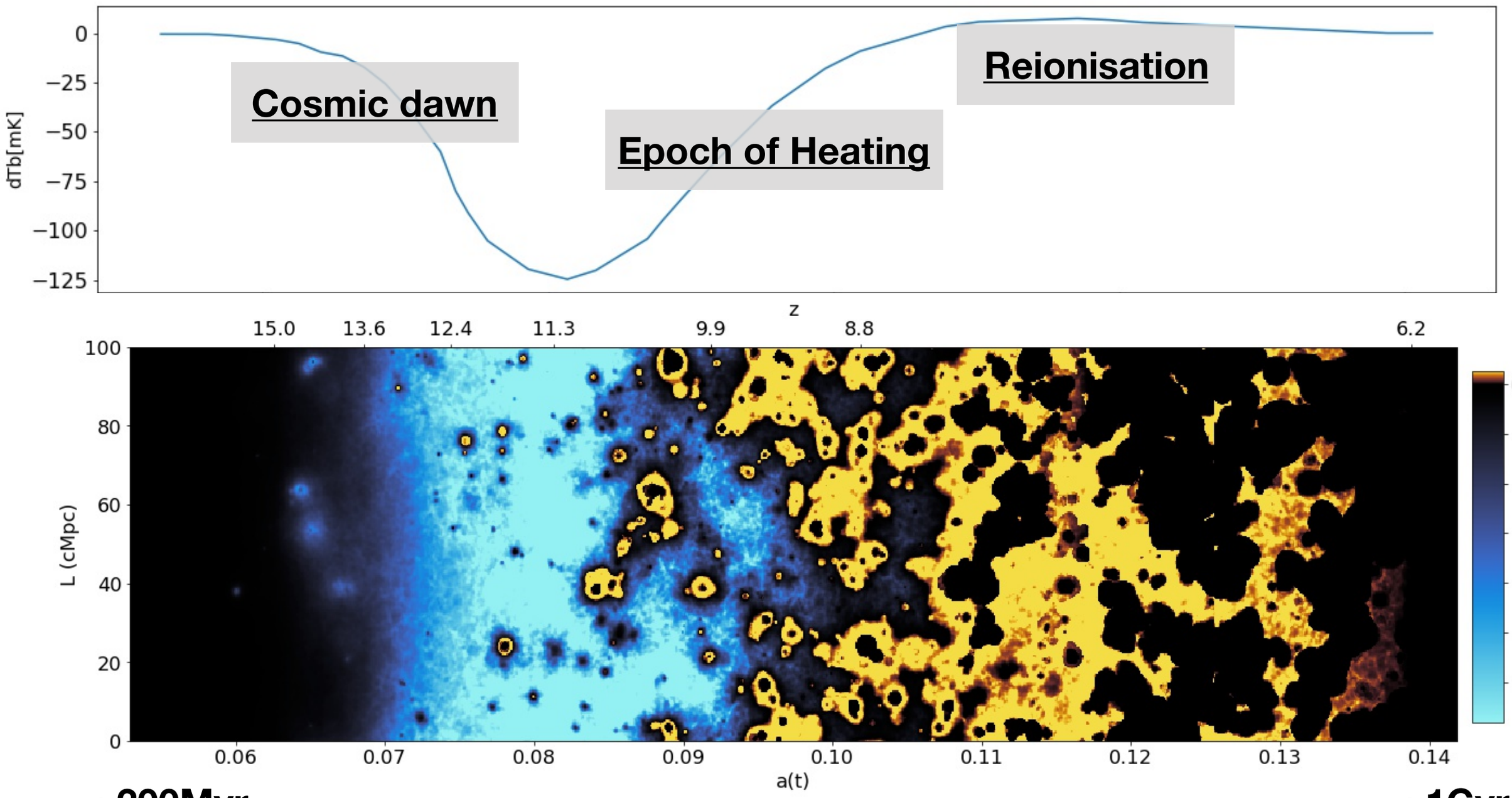
What kind of 21cm signal can we expect ?

Current z > 6 observation :

- Can be coupled to any N-body output

- Flexible source model

21cm signal probes various epochs of the early universe



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