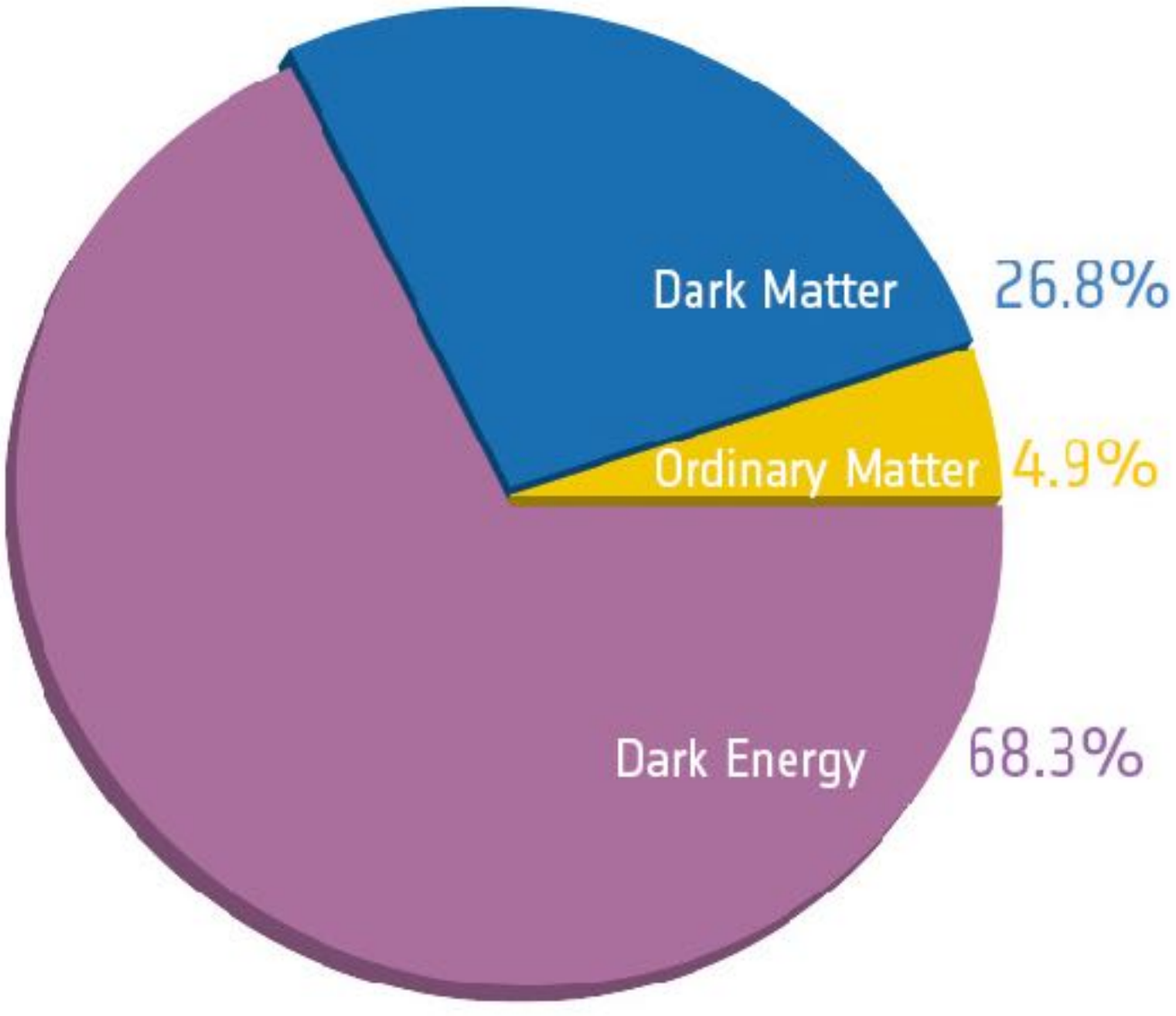
Cosmic neutral hydrogen as large scale structure tracer

Isabella Paola Carucci (SISSA)

Astro - TS 2017

Trieste, September 26th 2017

Cosmology



- **DM:** sets galaxy potential wells
- **Atoms:** ordinary matter, what we can directly observe
- **DE:** sets the accelerated expansion of the Universe

where is matter ?

where is matter ?

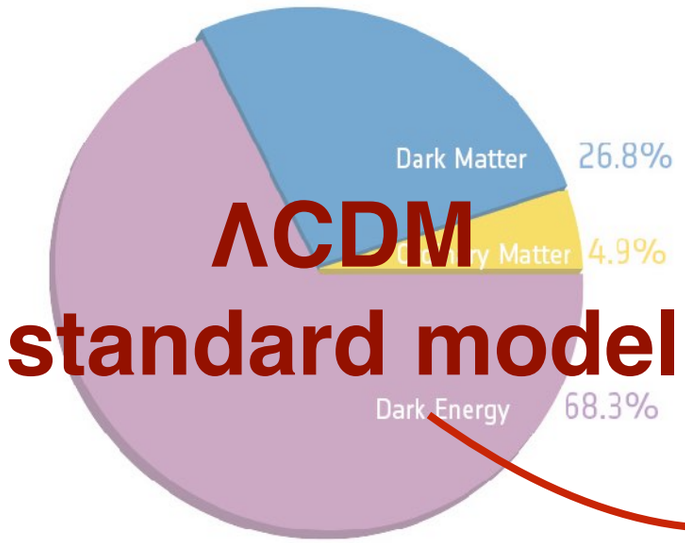
- Galaxies (stars)
- Clusters of galaxies
- Absorption features in quasars' spectra (Lya forest)
- Voids
- velocity fields, lensing, …

biased tracers

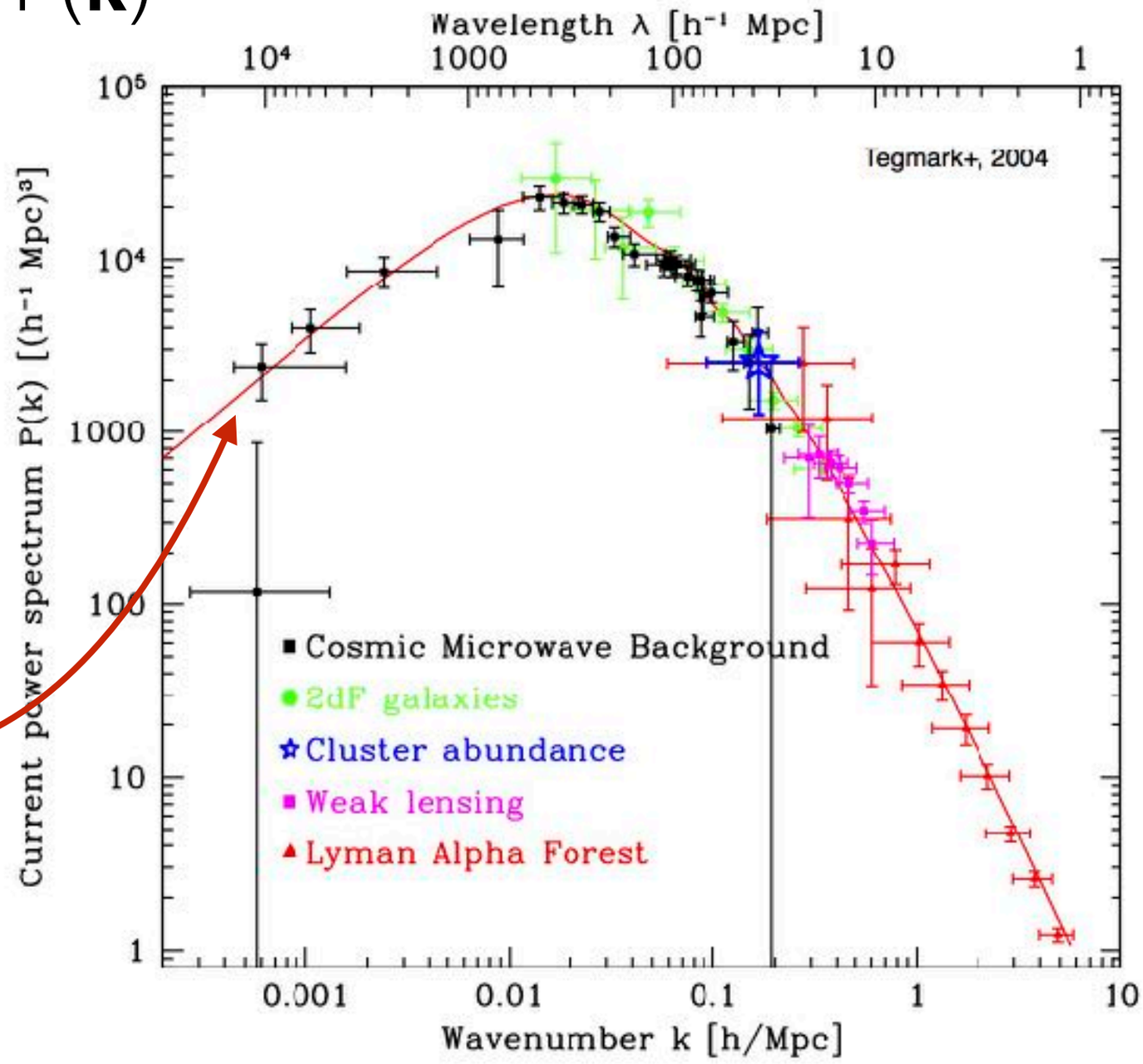
the matter power spectrum

$$\langle \delta(\mathbf{k})\, \delta(\mathbf{k'}) \rangle = \delta_D(\mathbf{k}+\mathbf{k'})\, P(\mathbf{k})$$

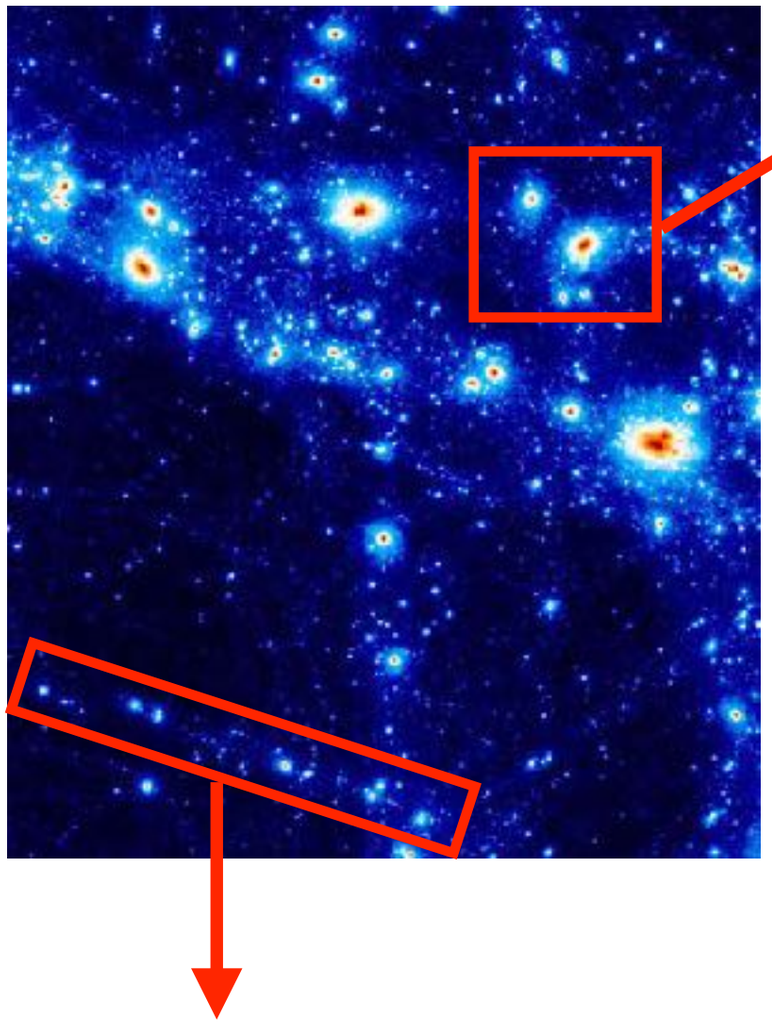
$$\delta = \frac{\Delta\rho}{\rho}$$



ΛCDM standard model



neutral hydrogen in the Universe



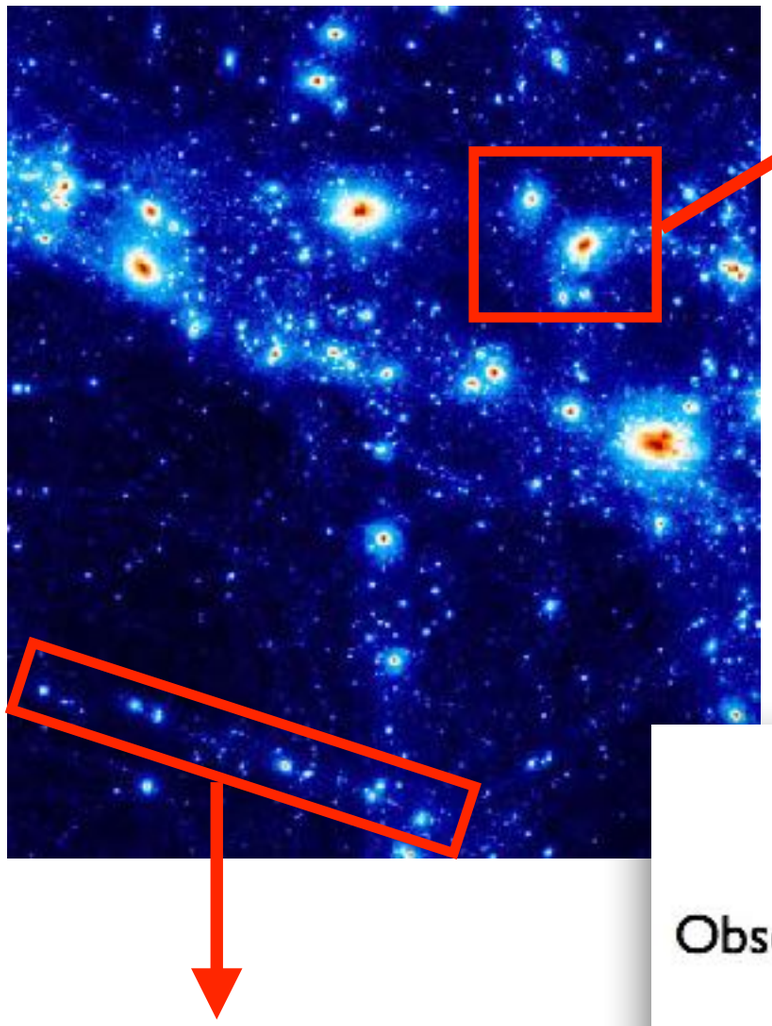
Galaxies (DLAs)

Dense, self-shielded HI

Filaments

H mostly ionised

neutral hydrogen in the Universe



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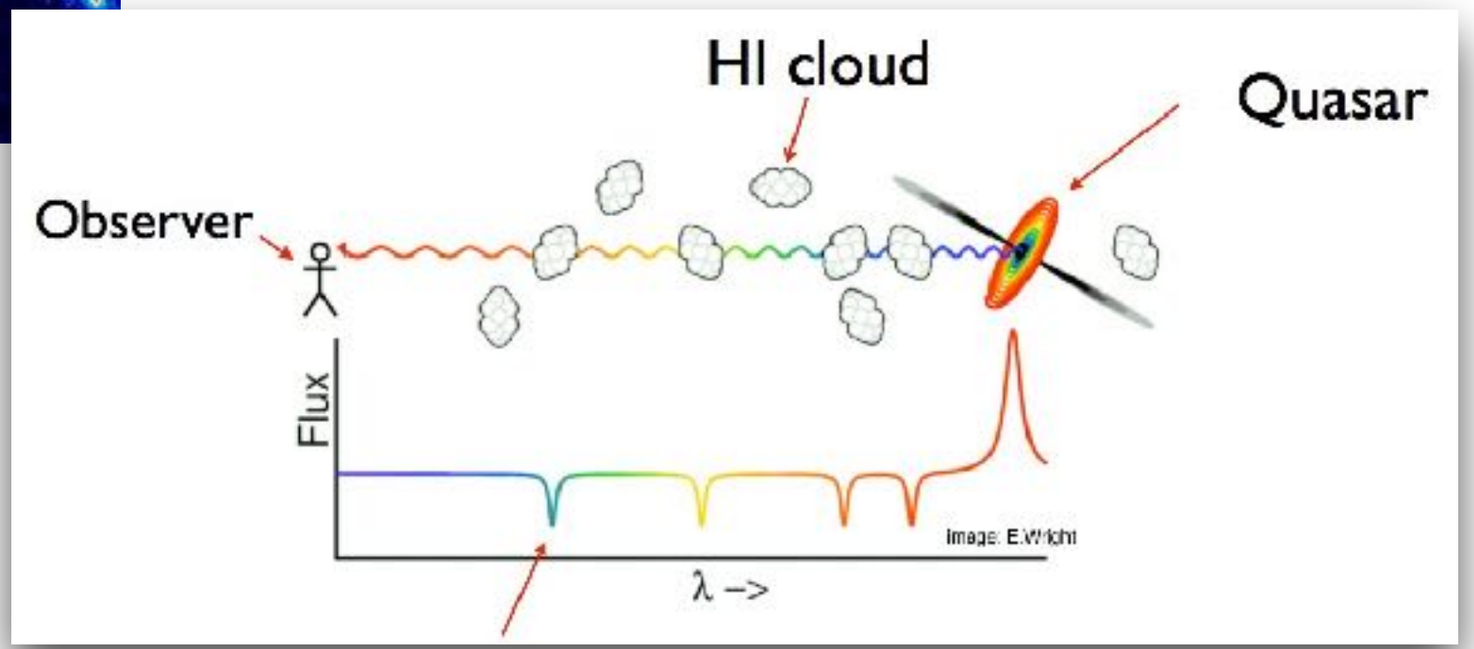
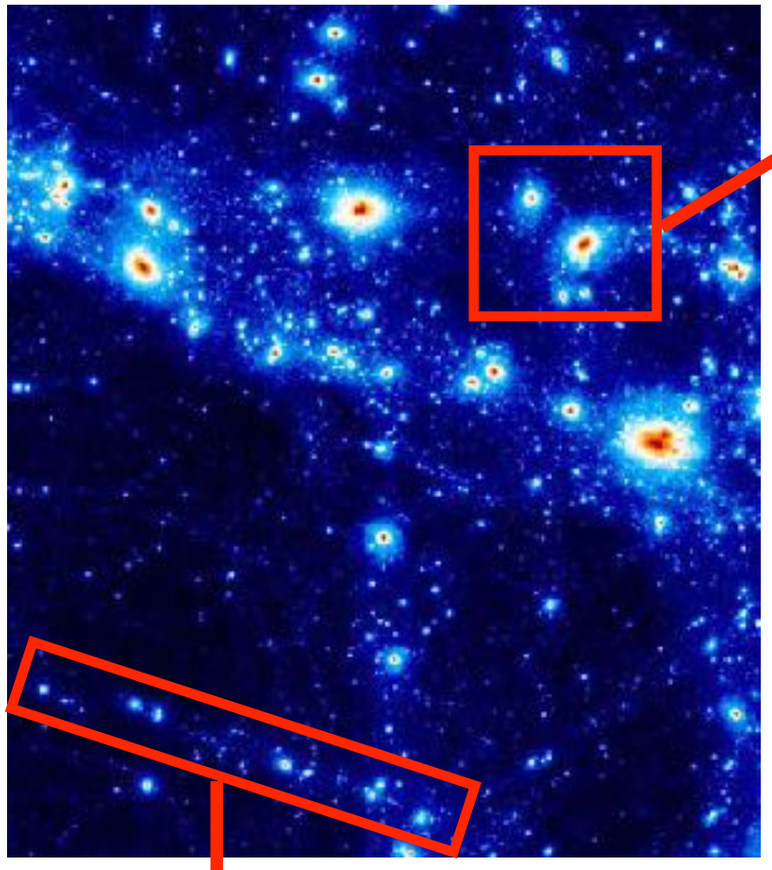


neutral hydrogen in the Universe



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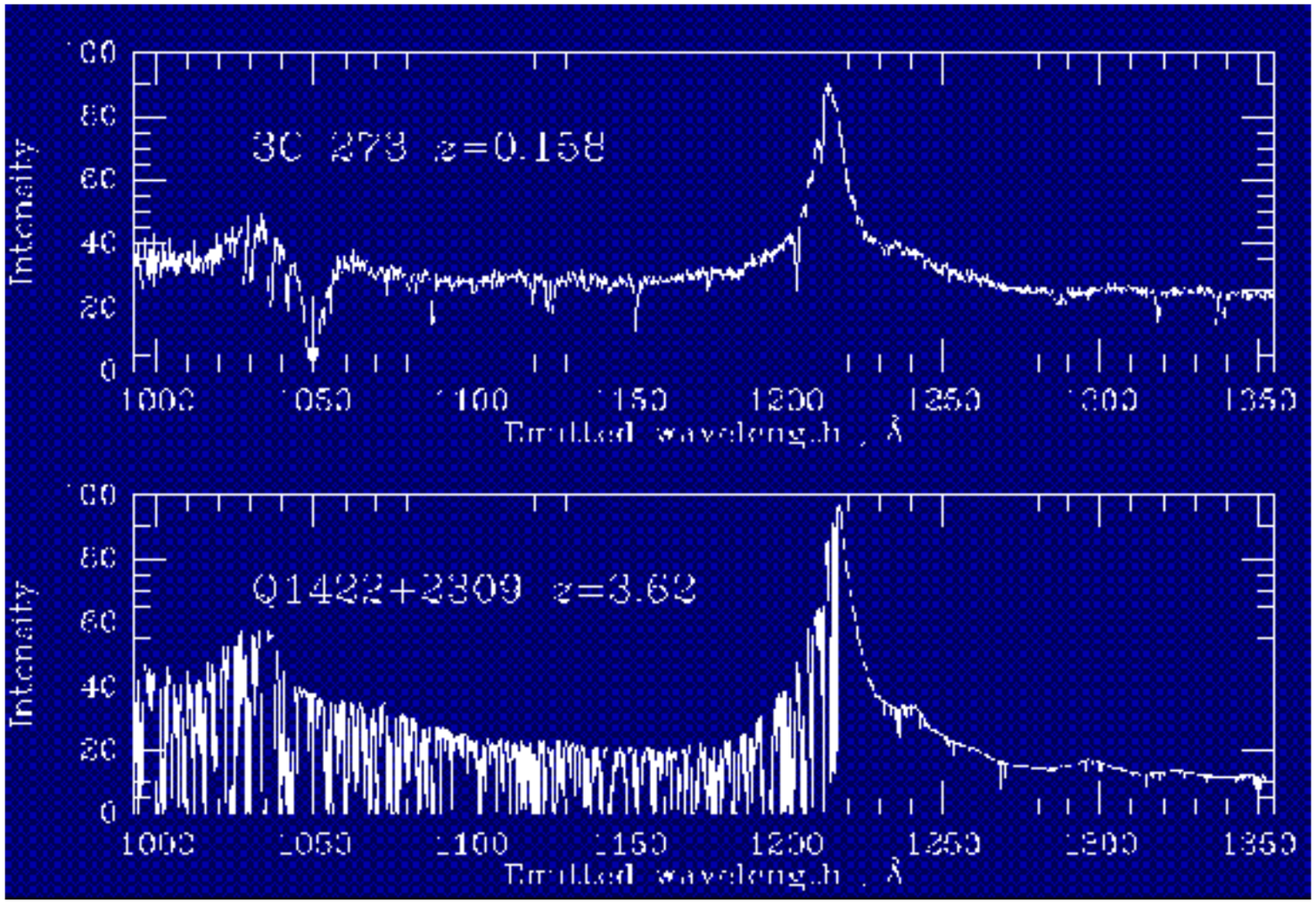
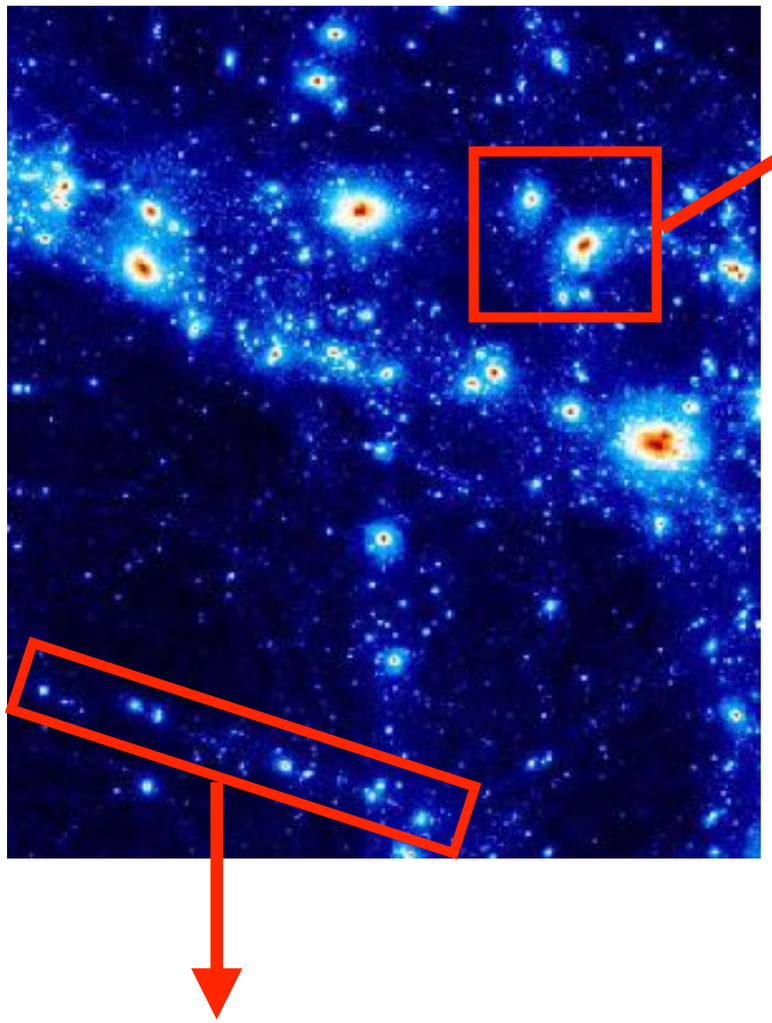


neutral hydrogen in the Universe



Galaxies (DLAs)

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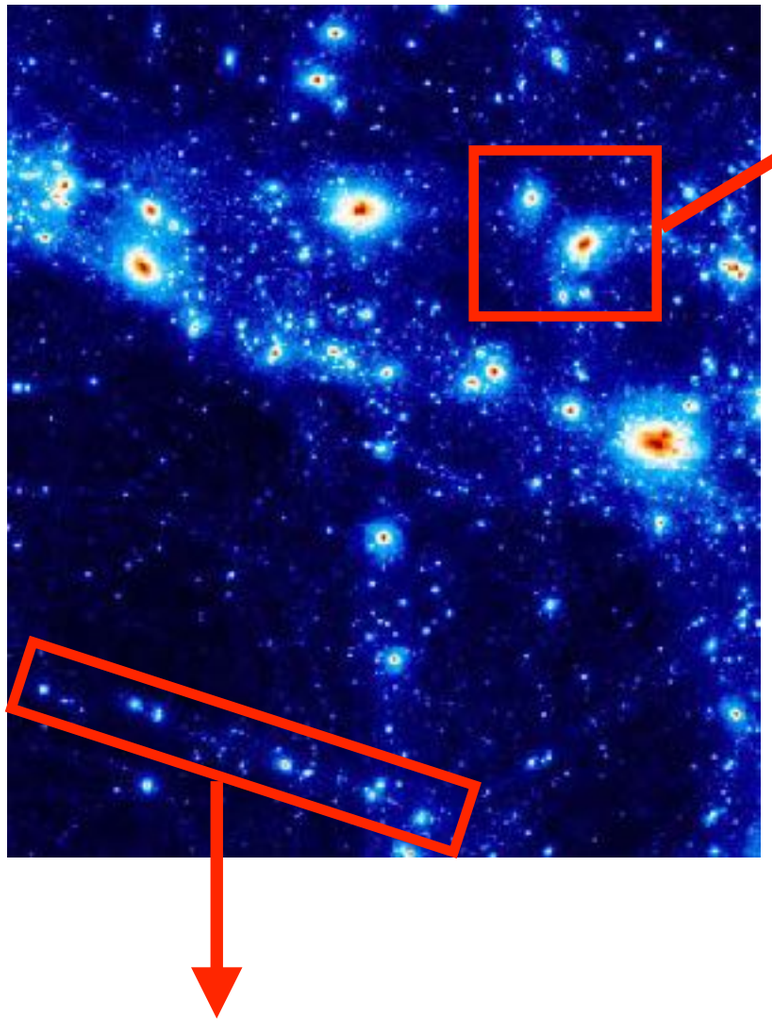
neutral hydrogen in the Universe



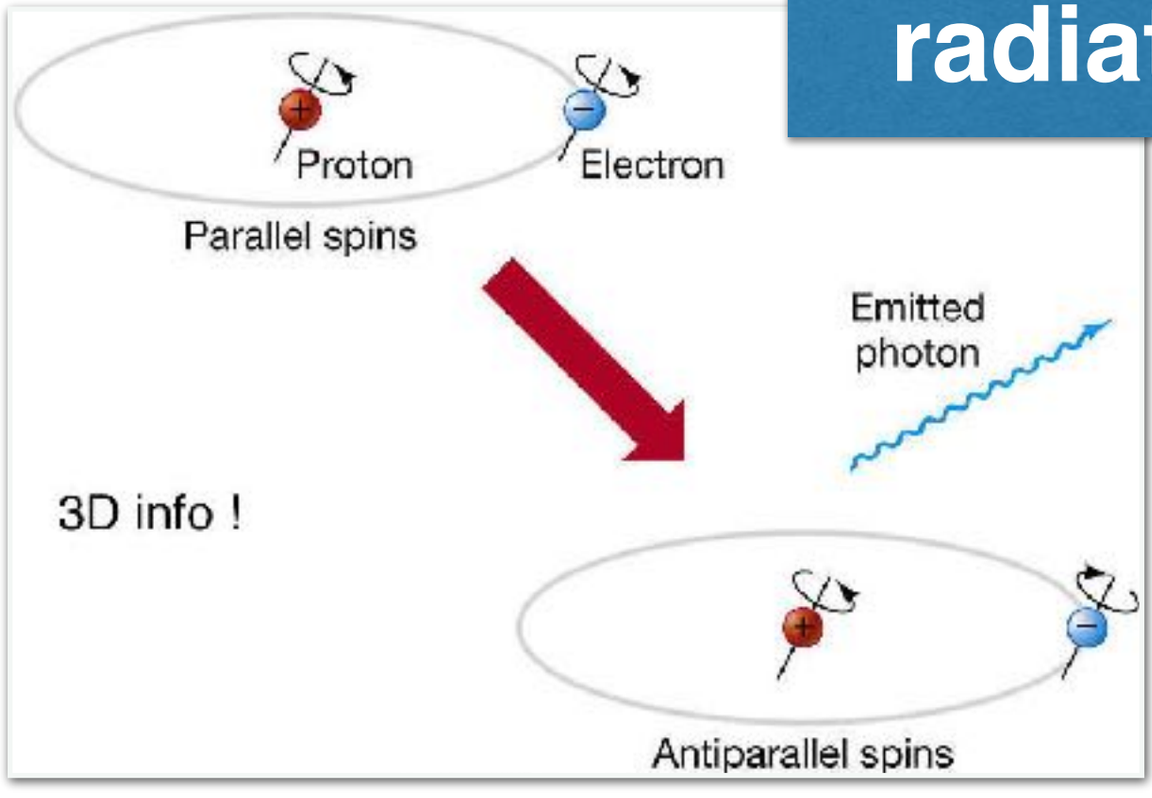
Galaxies (DLAs)

Dense, self-shielded HI

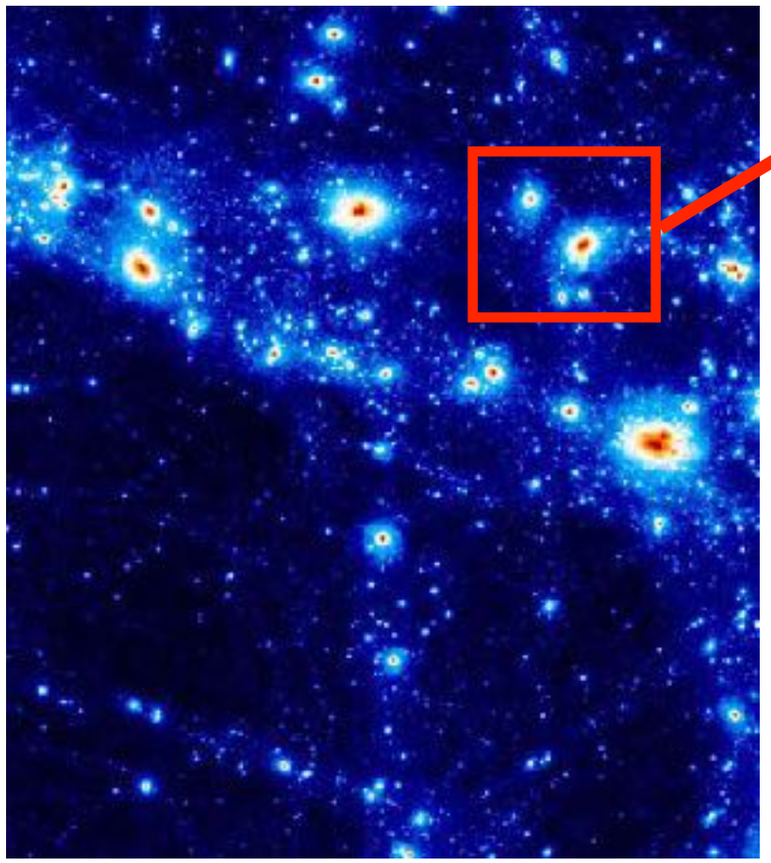
Filaments

H mostly ionised

21cm radiation

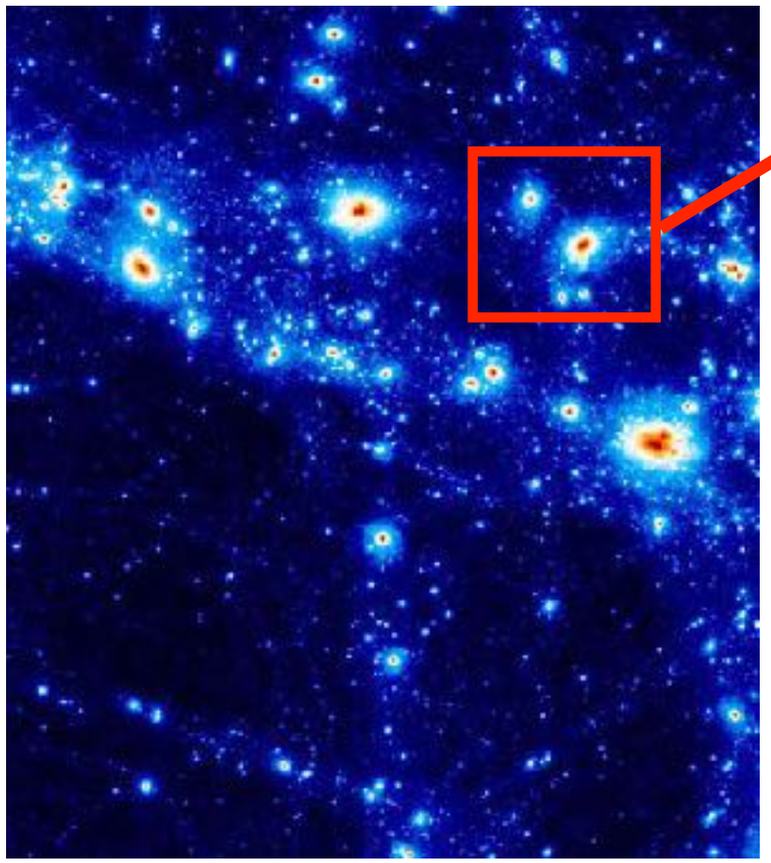


neutral hydrogen in the Universe



21cm radiation signal

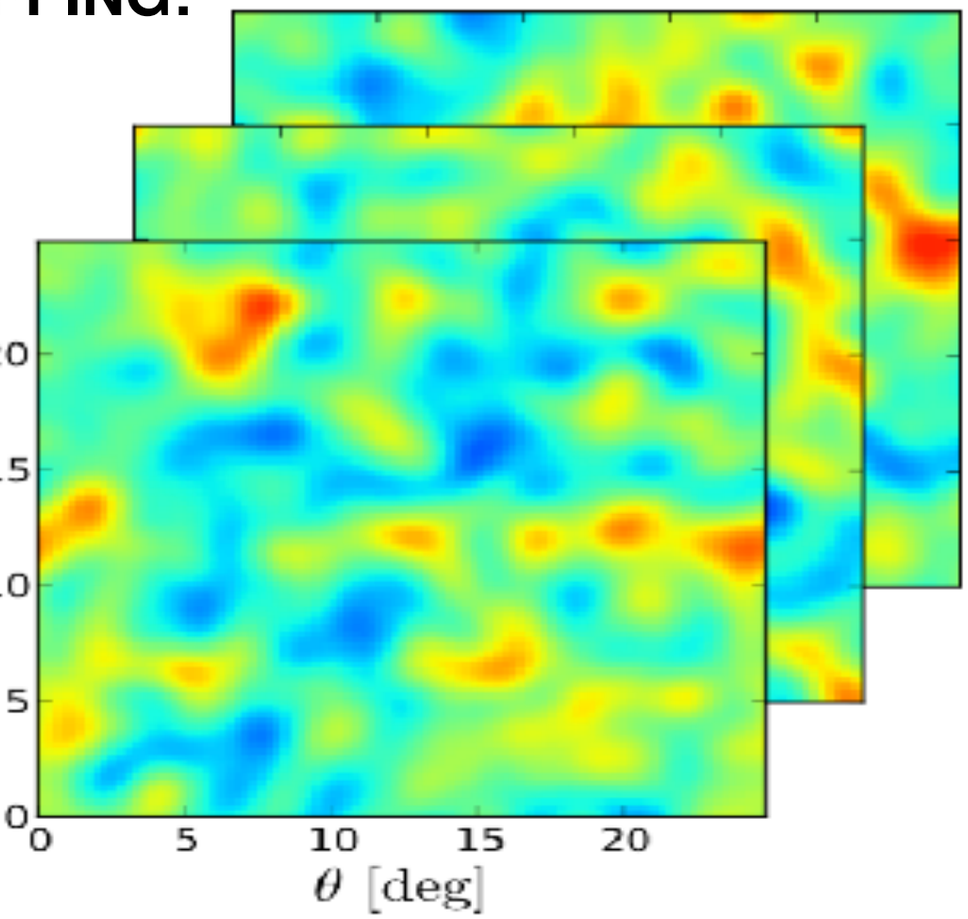
neutral hydrogen in the Universe



21cm radiation signal

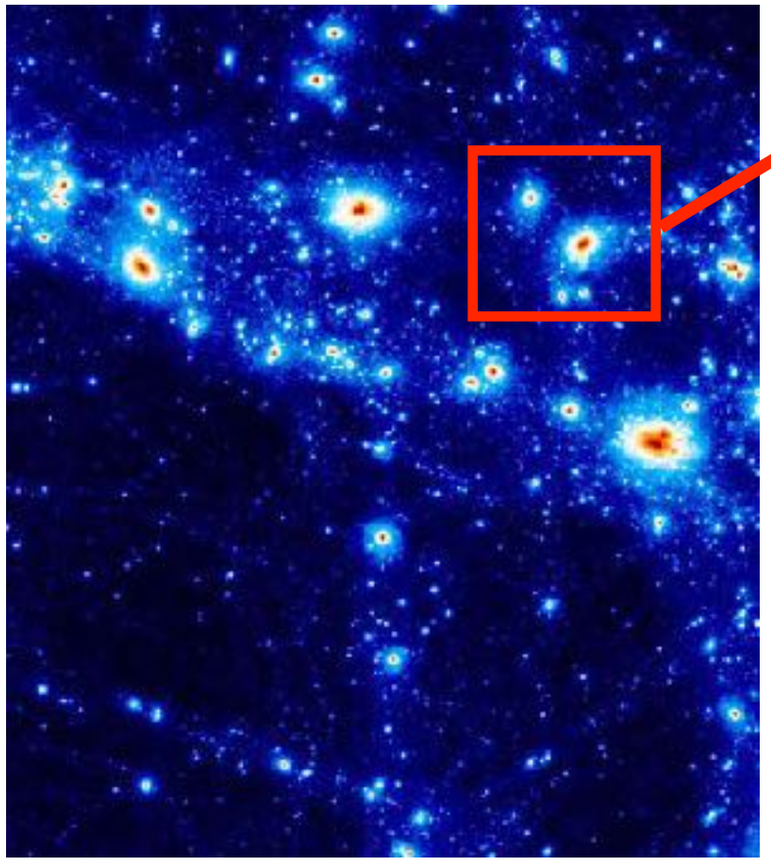
INTENSITY MAPPING:

mapping the collective HI 21cm radiation background without resolving the individual sources



spectroscopic nature
large volumes

neutral hydrogen in the Universe



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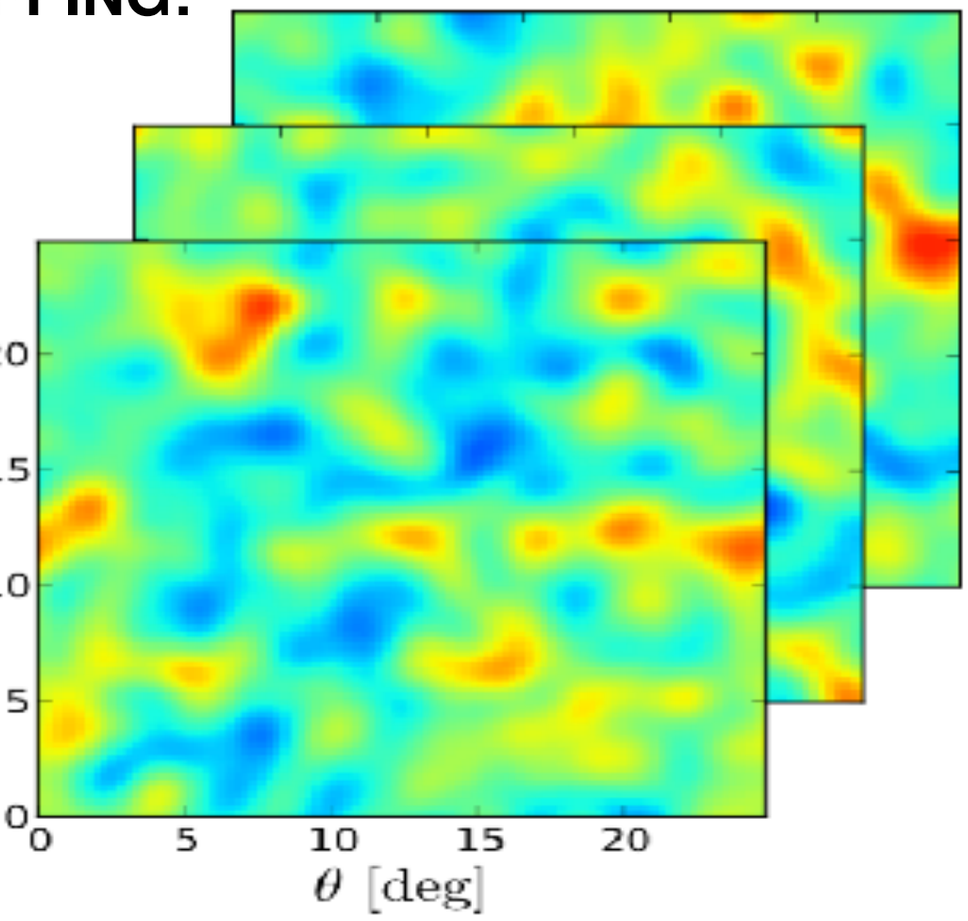
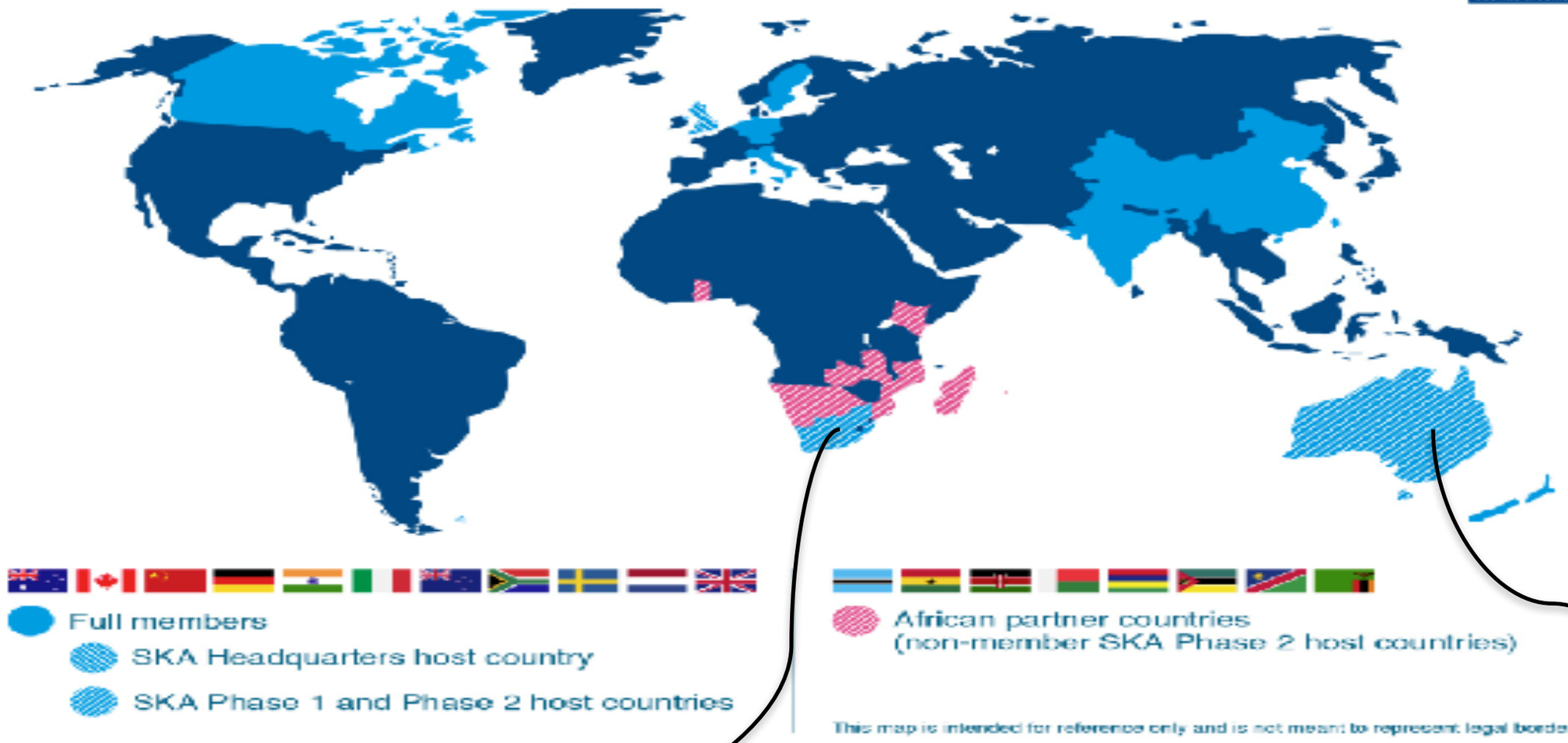


- There's a lot of HI!
- Promising observational efforts!

spectroscopic nature
large volumes



Phase I

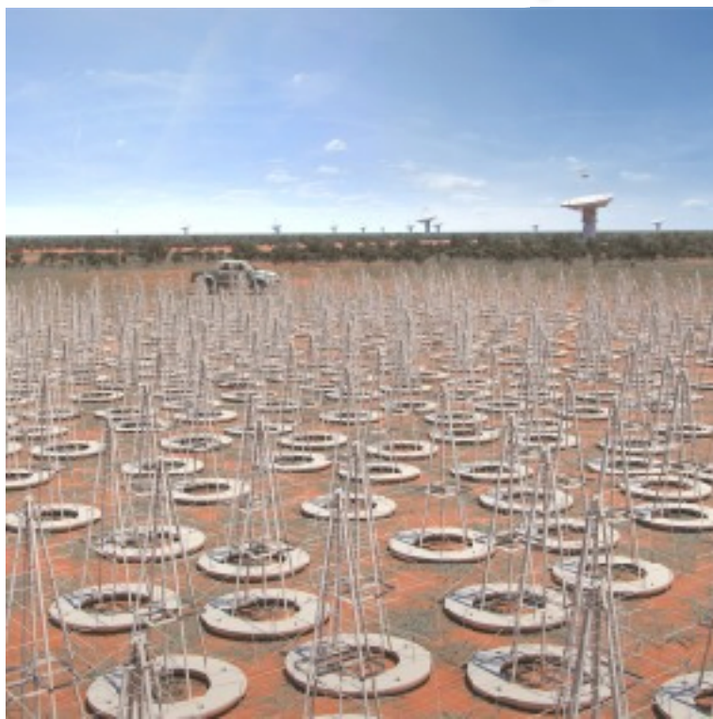
SKA1-MID

- 0<z<3
- 200 dishes; 15m
- South Africa

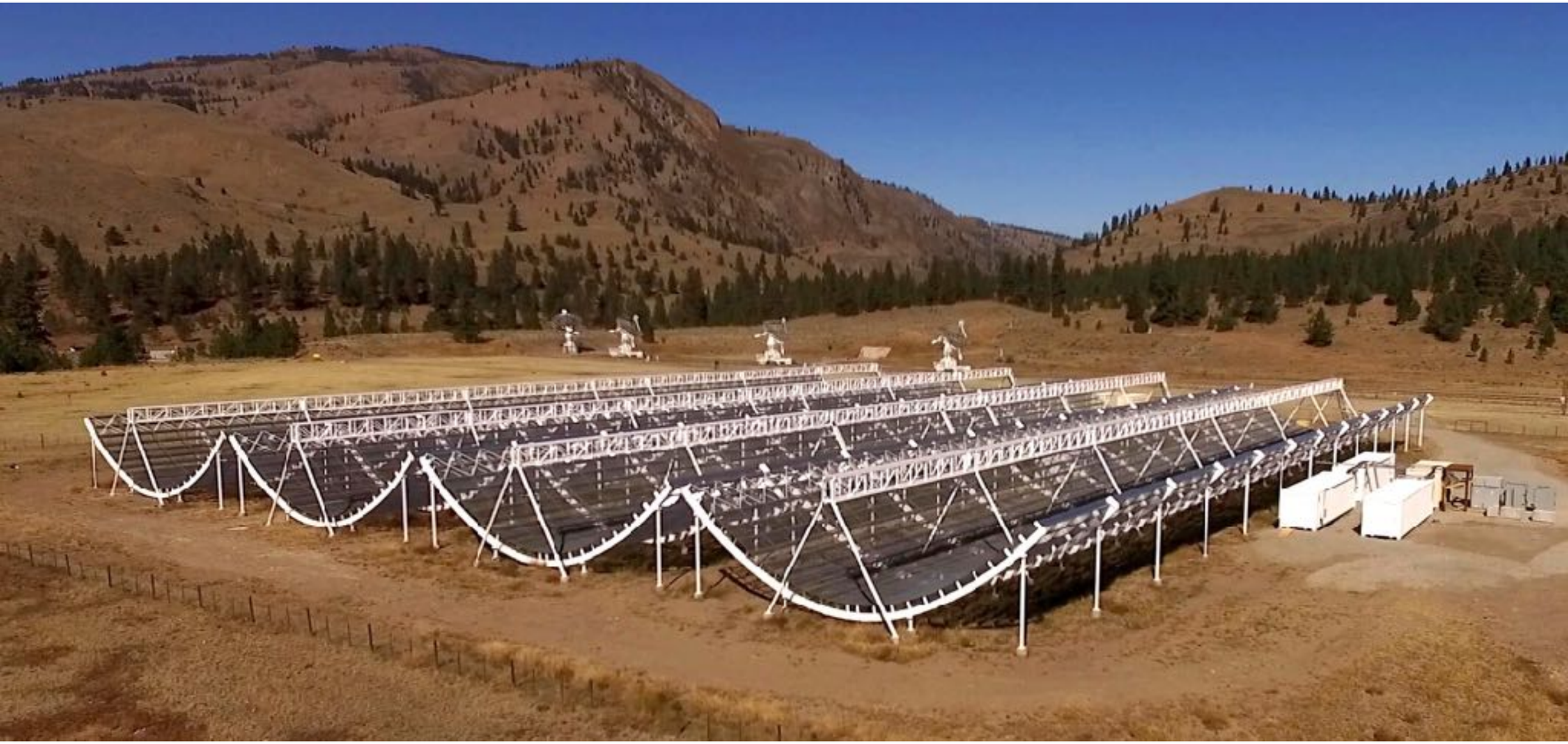
SKA1-LOW

- 3<z<27
- 911 antennae
- Australia

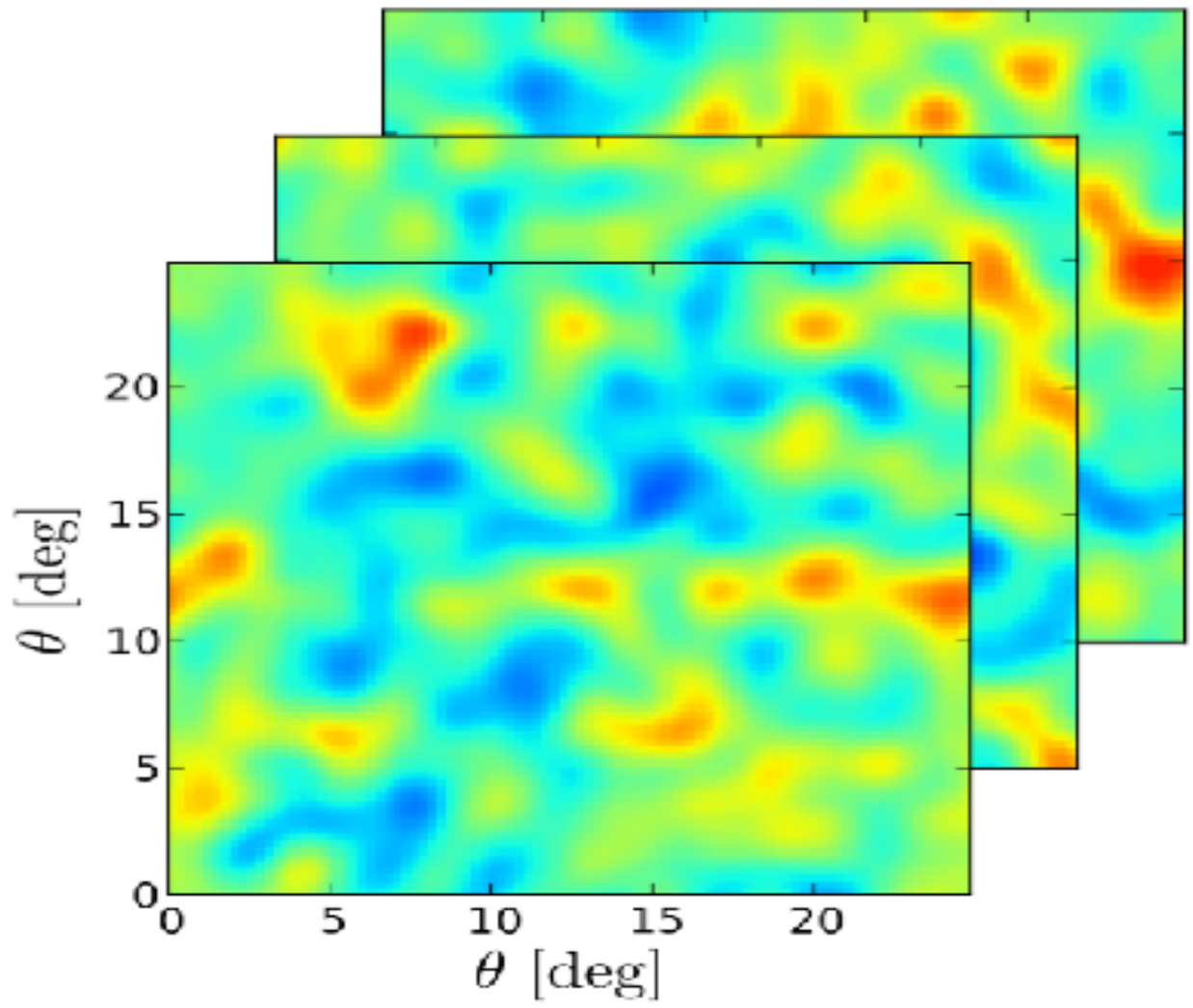
Very isolated places to avoid RIF



CHIME



The Canadian Hydrogen Intensity Mapping Experiment



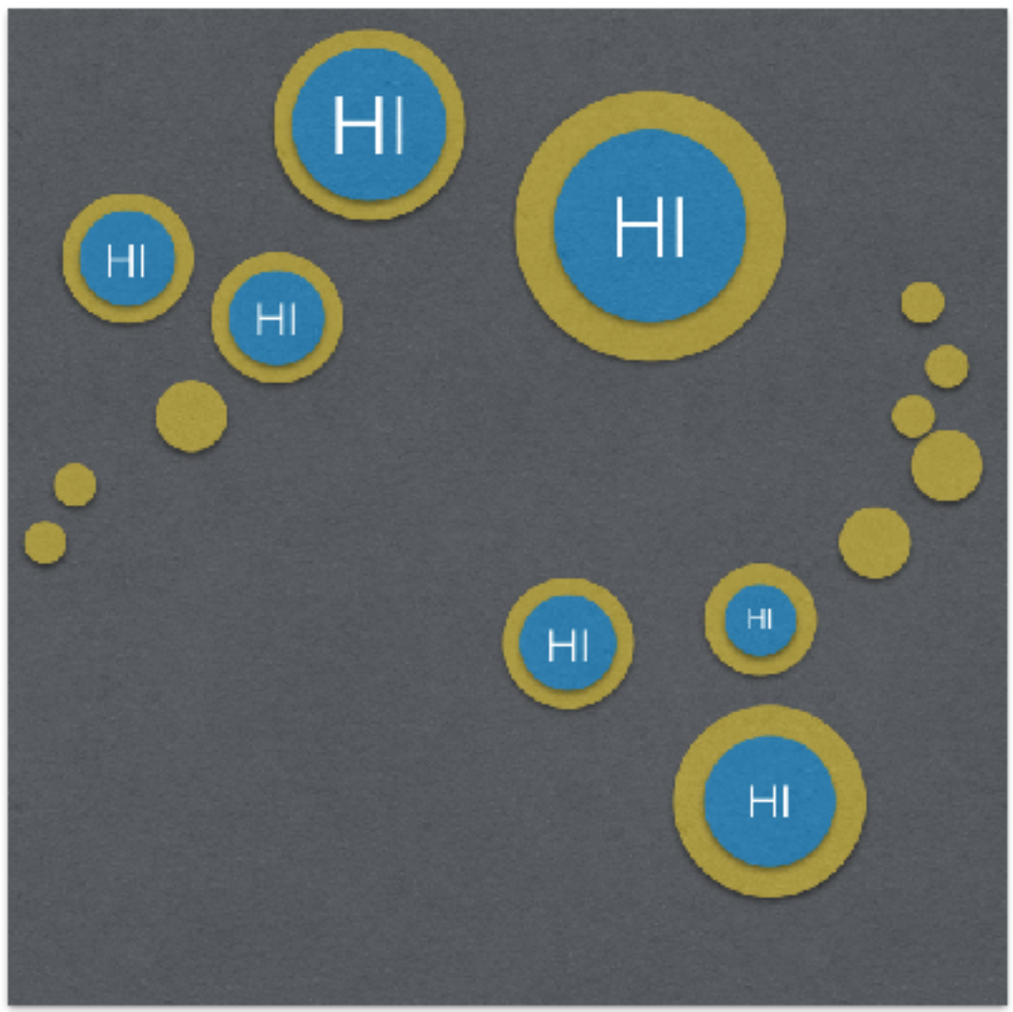
how is distributed atomic neutral hydrogen (HI)
in the Universe?

modelling the HI distribution

halo based method

(Bagla 2010) (Villaescusa-Navarro 2016)

HI resides only in DM halos



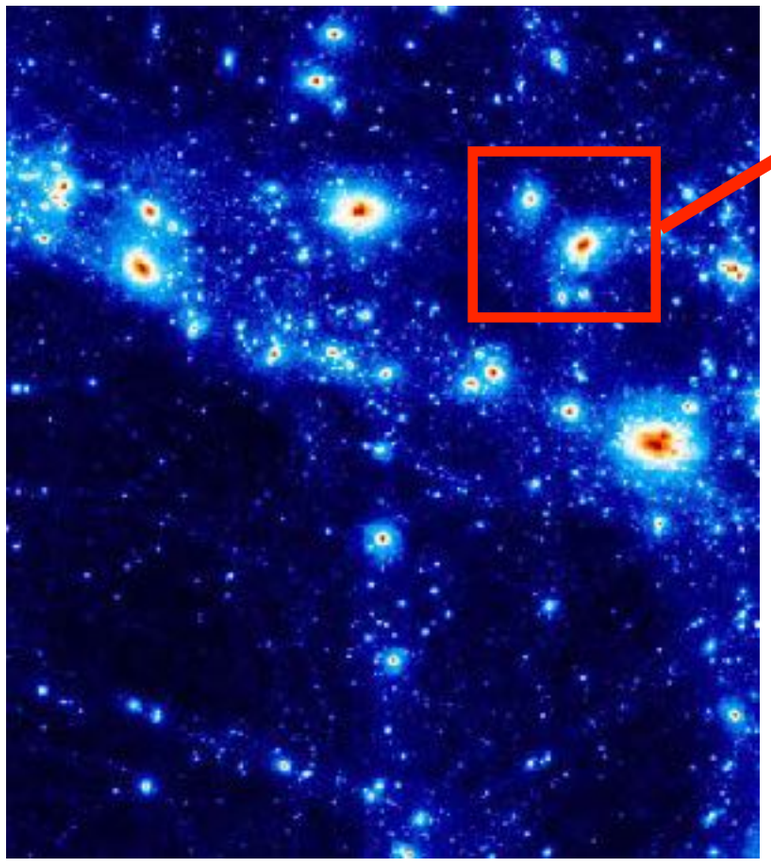
particle based method

(Dave 2013)

HI assigned to all gas particles, according to their properties

- assuming photo-ionization equilibrium, setting the HI/H fraction in order to reproduce the Lyman-α mean transmission flux
- mimicking HI self-shielding for high enough density regions
- letting H_2 forming for even denser regions

neutral hydrogen in the Universe



21cm radiation signal

Outline:

- Constraining the **nature of dark matter** with the 21cm power spectrum

- **Imprint of dark energy** on the 21cm power spectrum

how much warm dark matter is

see Riccardo Murgia's talk
of yesterday

- lighter mass → faster particle
- resist longer to gravitational collapse
- later formation times
- small scale perturbations erased → less sub-structures

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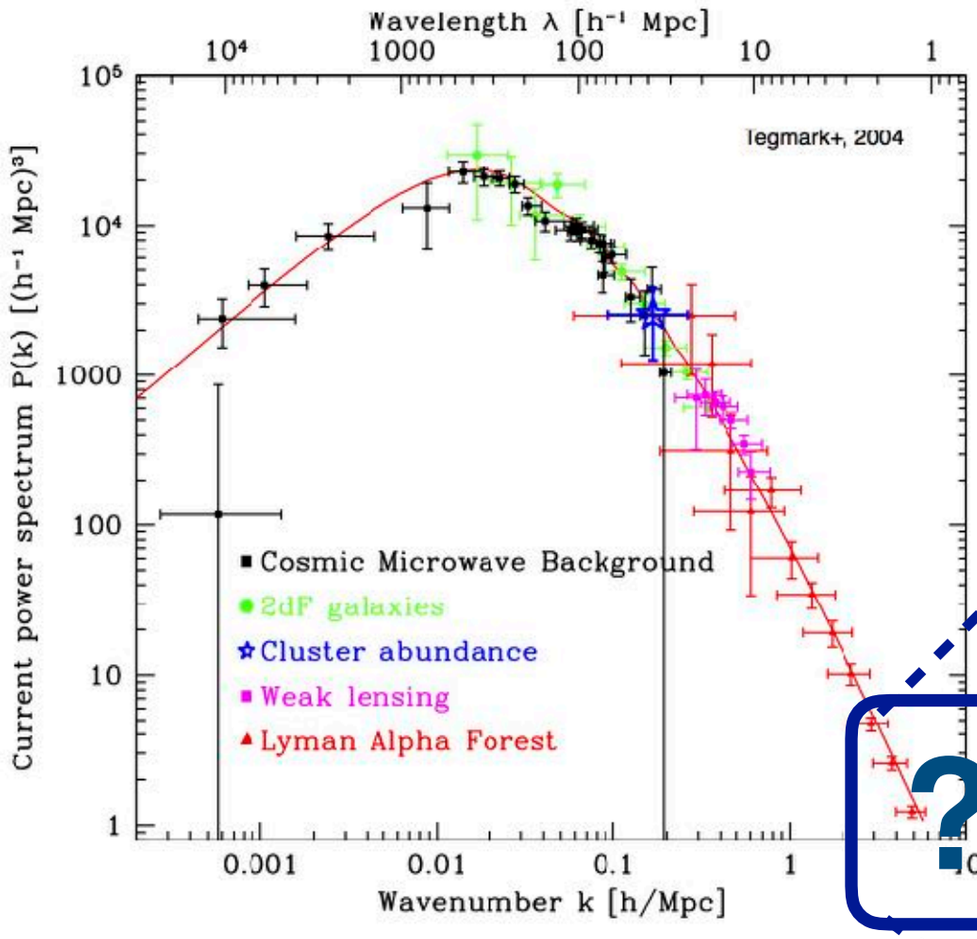

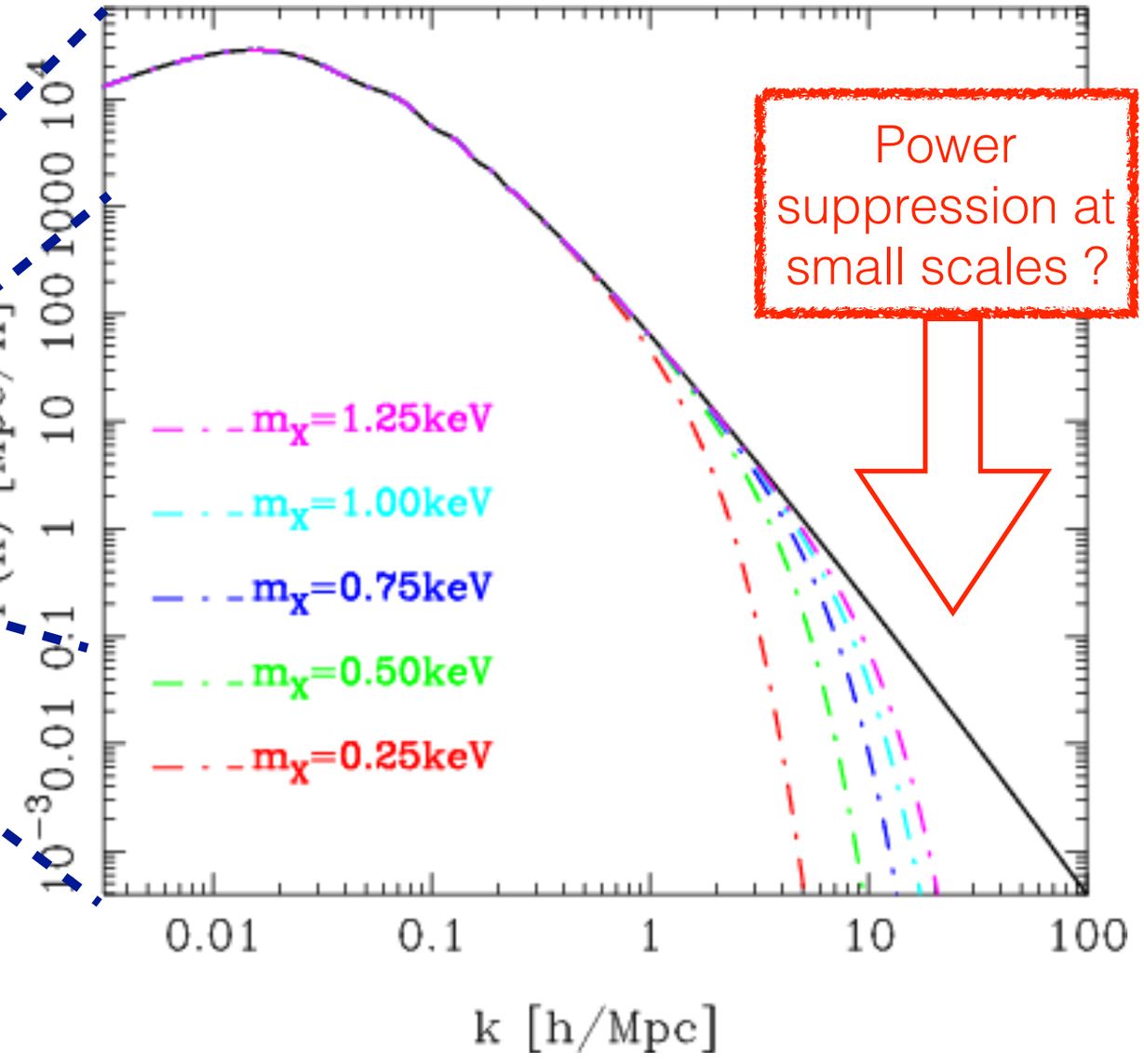

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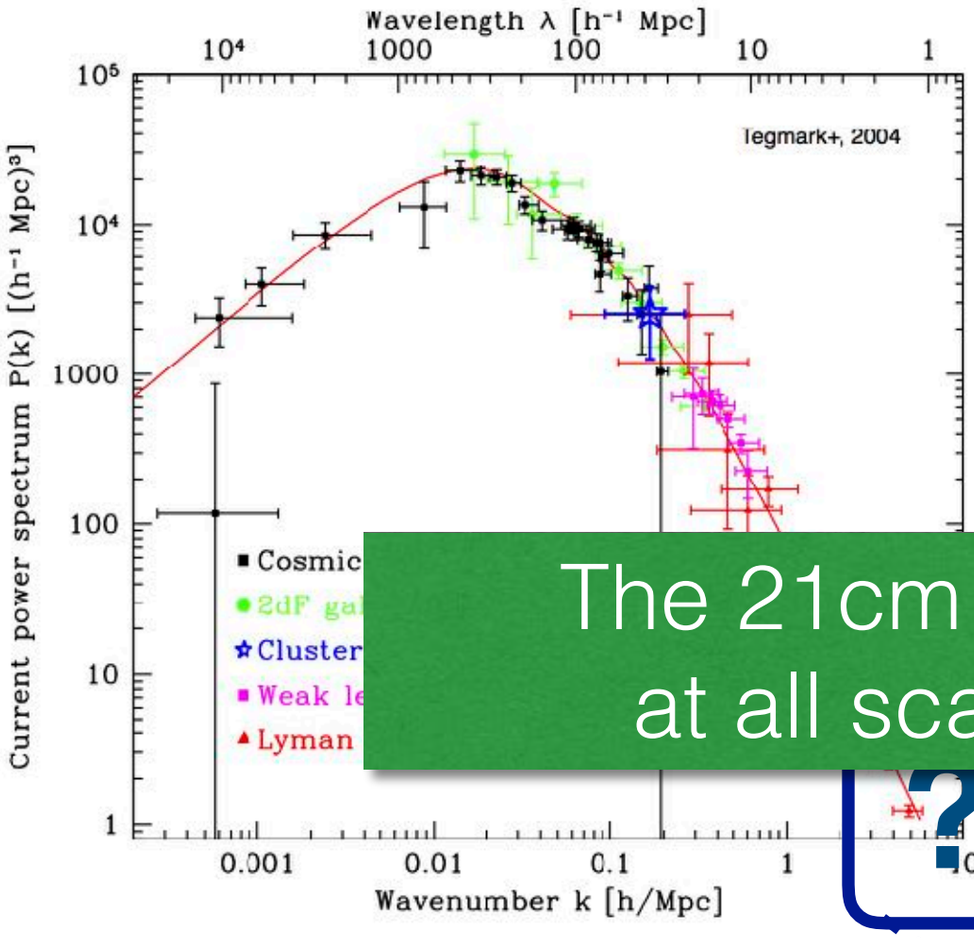
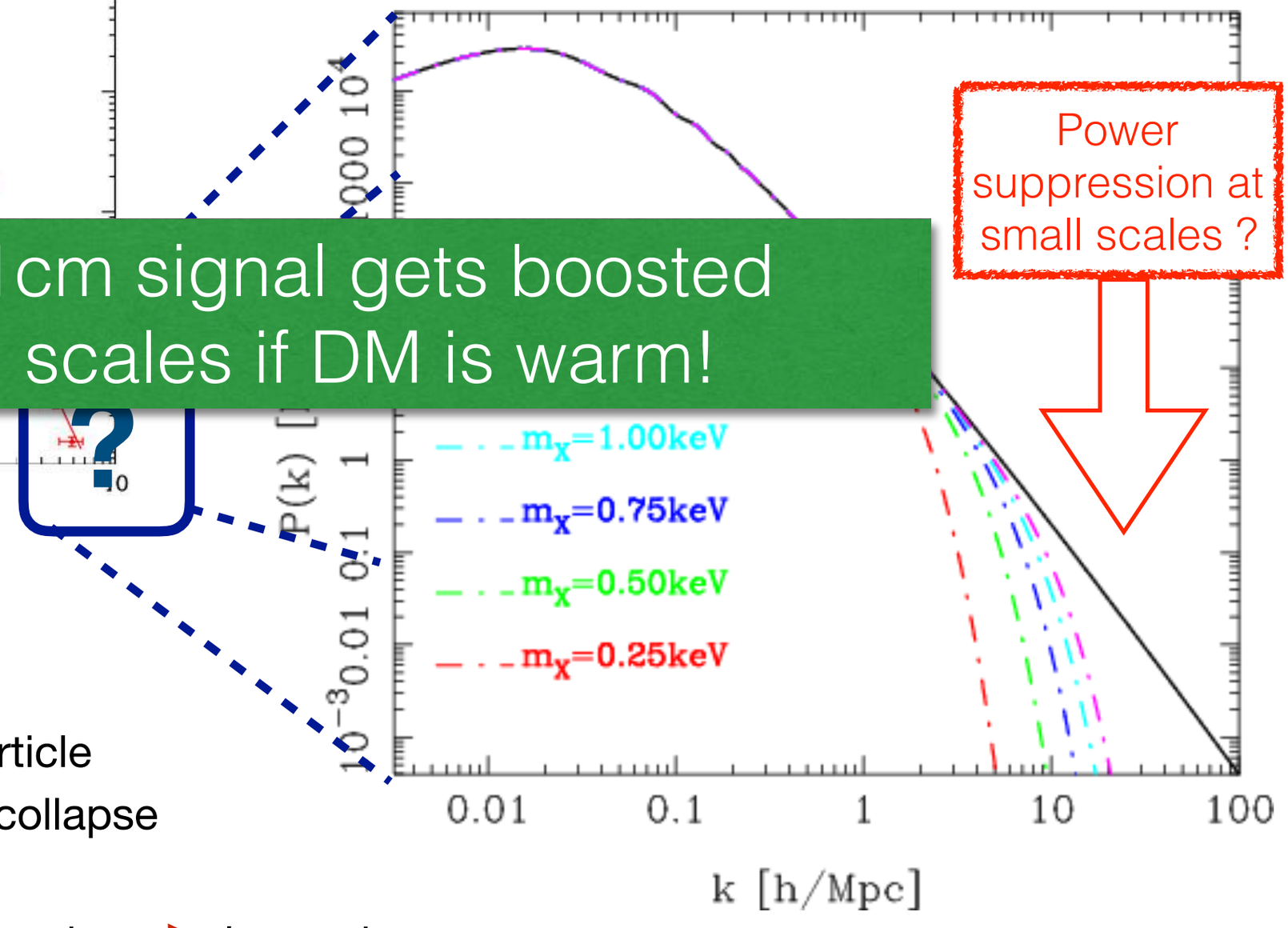




?

The 21cm signal gets boosted
at all scales if DM is warm!

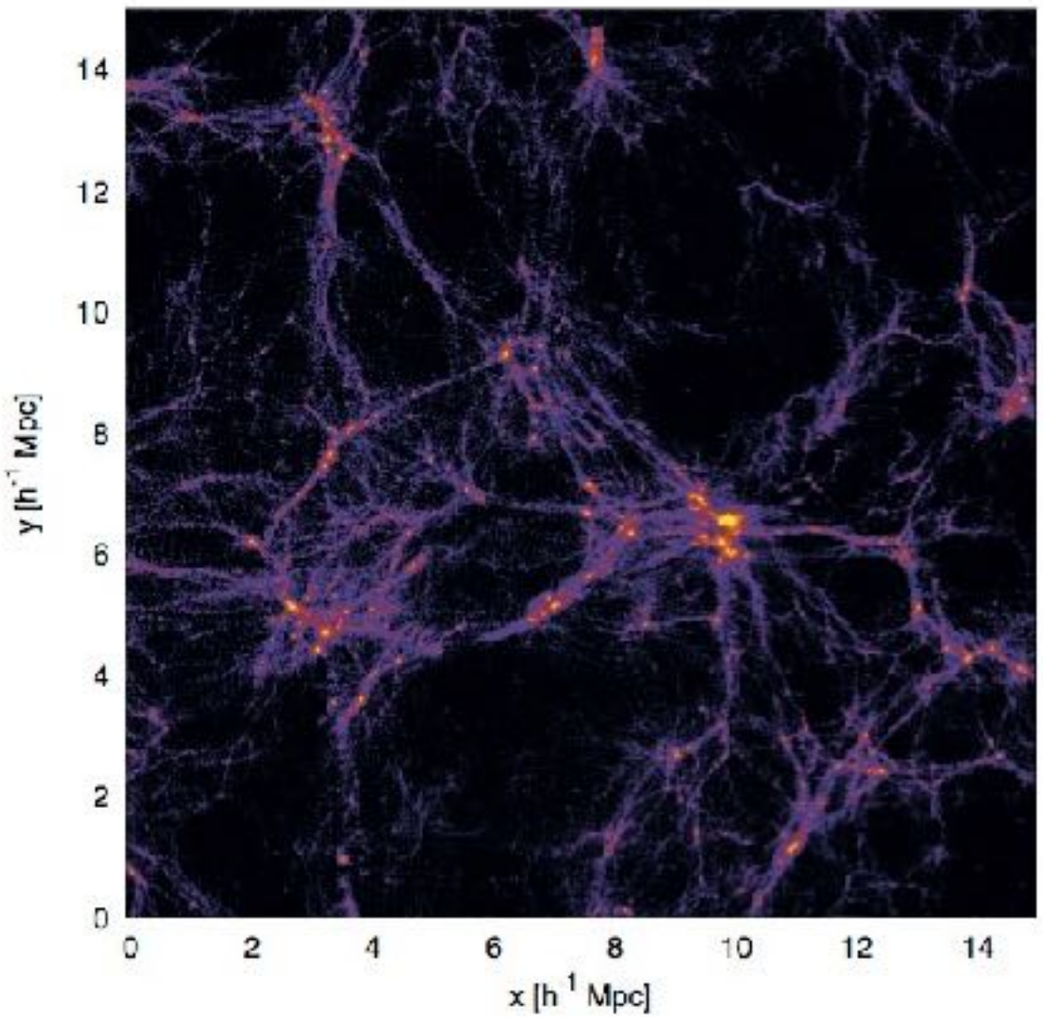
Power
suppression at
small scales ?

- lighter mass → faster particle
- resist longer to gravitational collapse
- later formation times
- small scale perturbations erased → less sub-structures

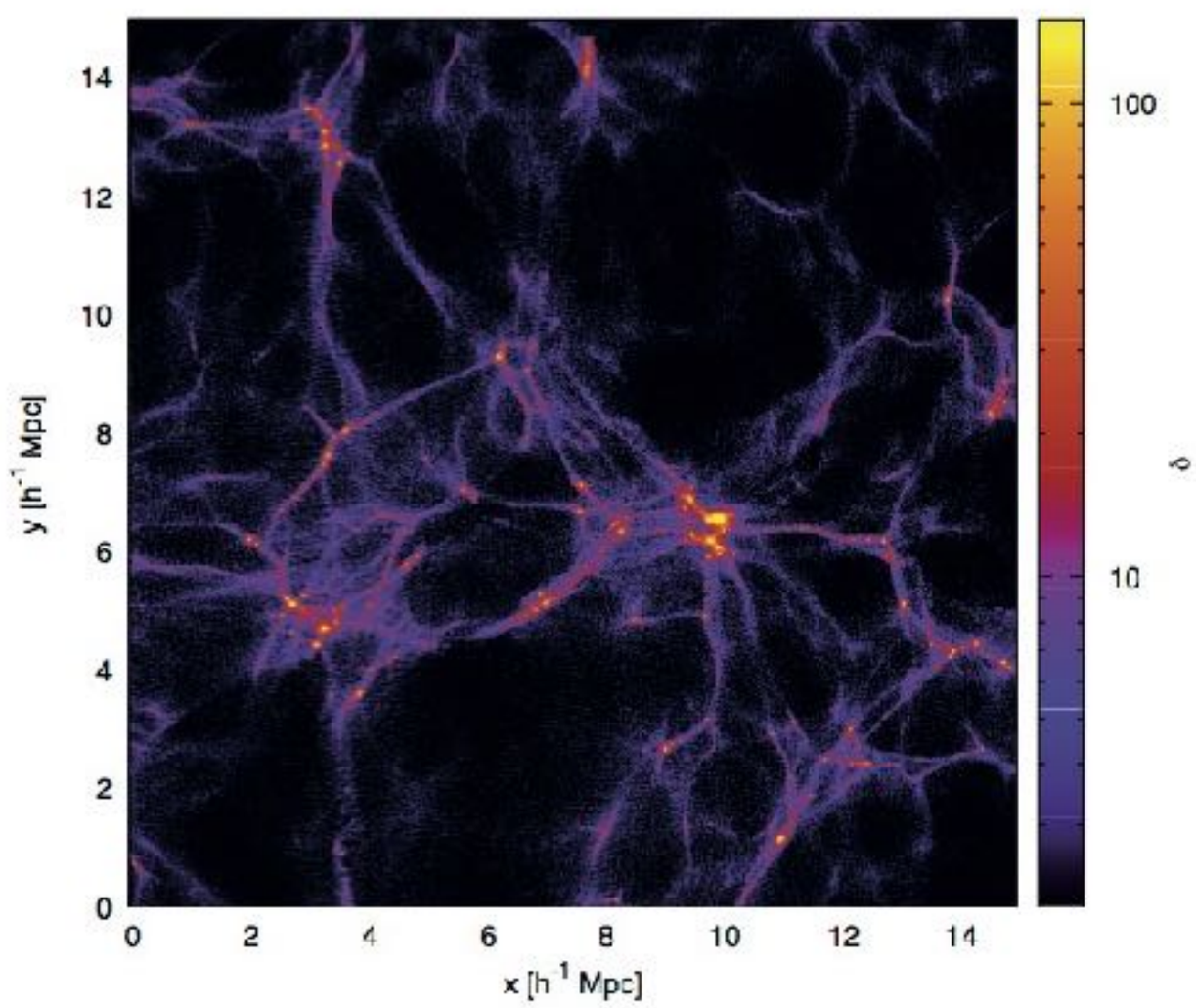
cosmological simulations:

what is the impact of WDM on the matter distribution?

cold CDM



1 keV WDM warm

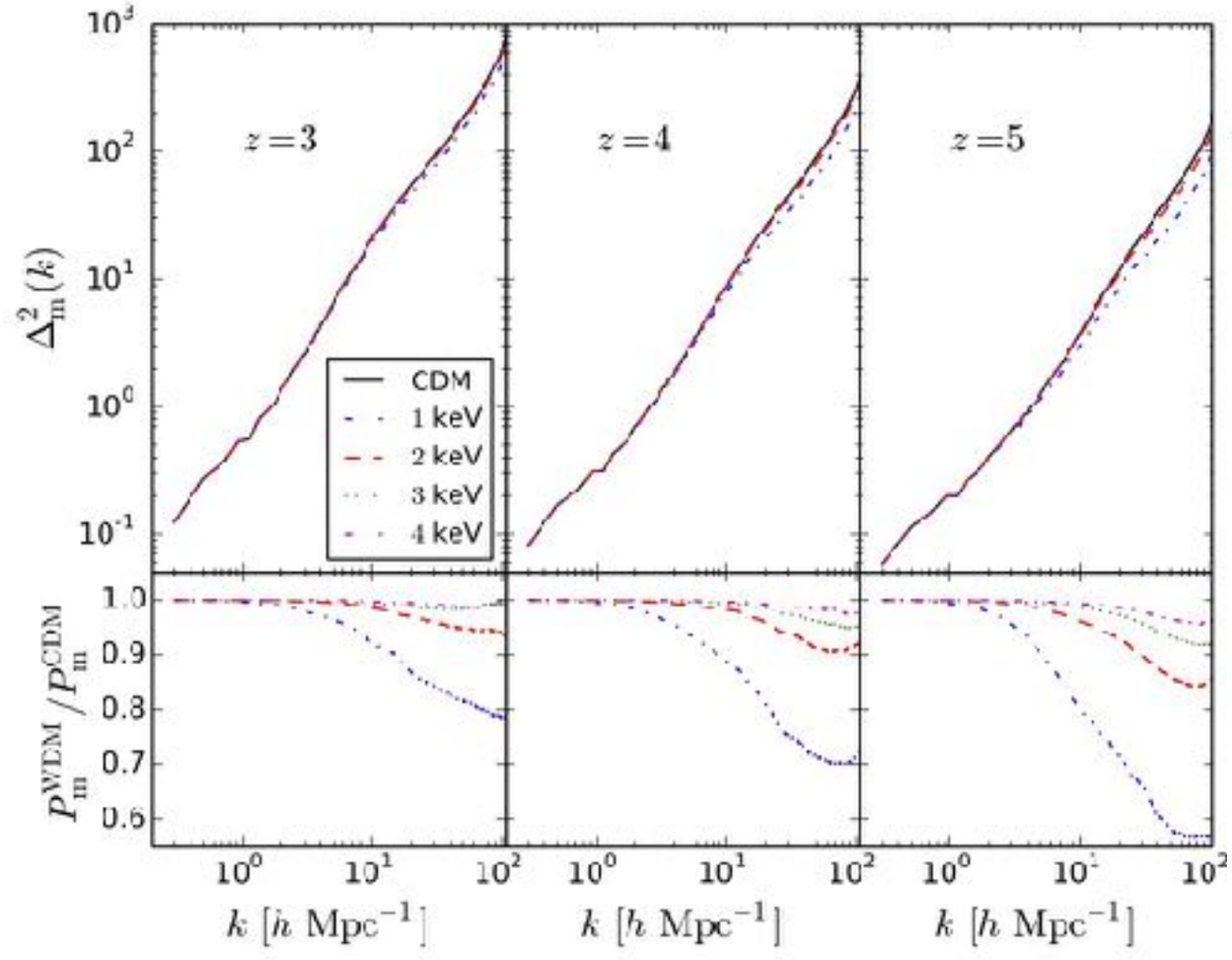


Gadget3 (hydro). Box size = 30 Mpc/h 512^3 DM + 512^3 baryons particles,
5 cosmologies: CDM and 1, 2, 3 and 4 keV WD, from z=99 to z=3, (snapshot at 3, 4 and 5)

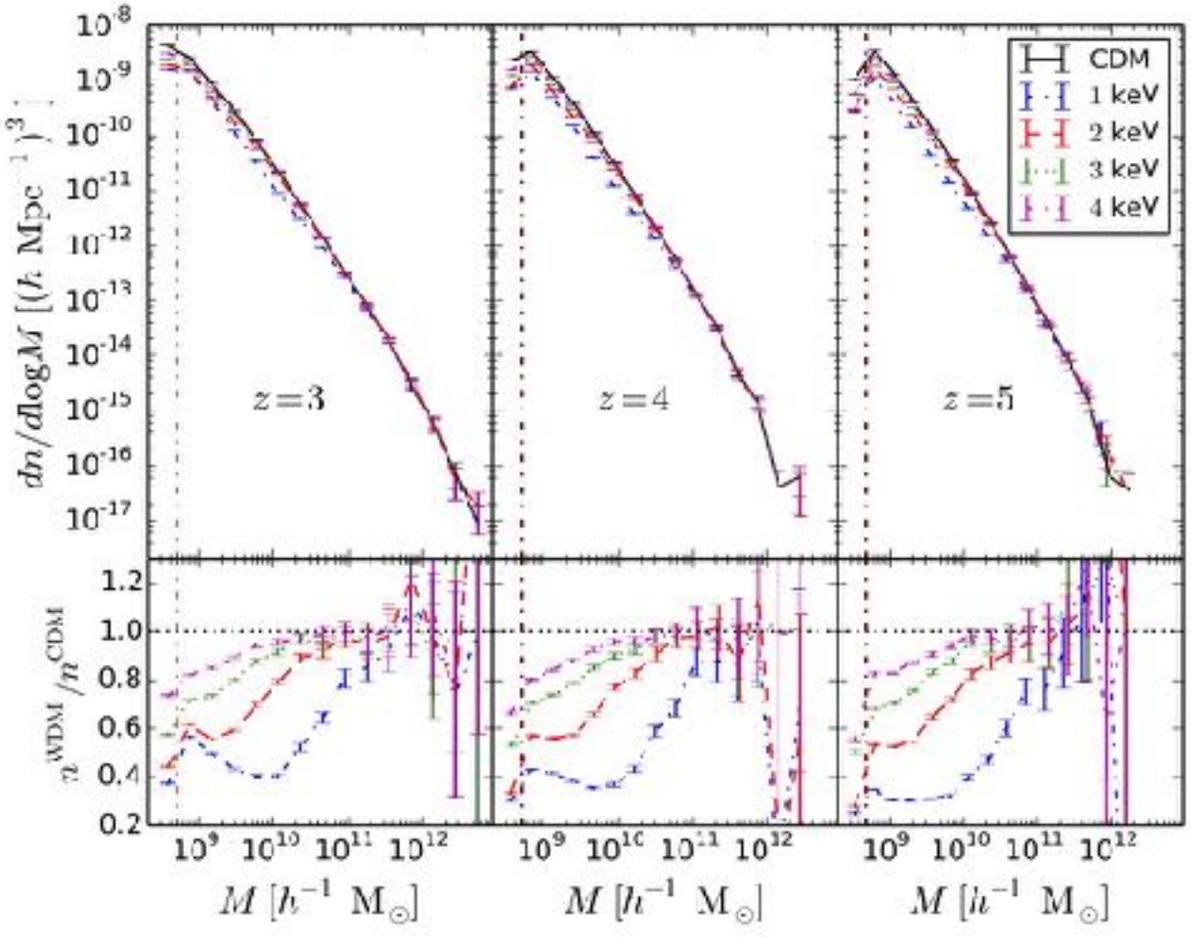
cosmological simulations:

what is the impact of WDM on the matter distribution?

Matter power spectrum



Halo mass function



The warmer DM, the higher the suppression of power at small scales:
for DM mass = 3 - 4 keV we observe ~10% suppression on small scales ...

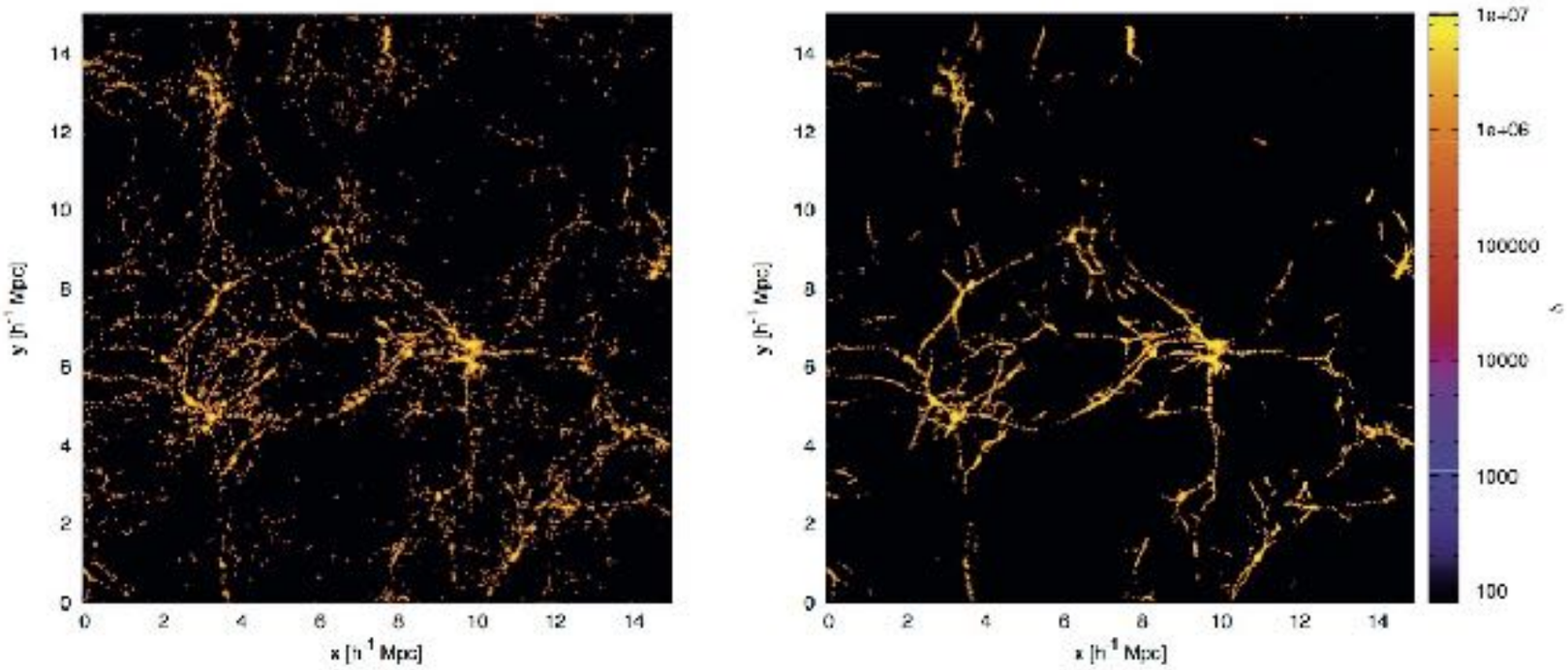
... and a reduction in the number of 10^9 $h^{-1}M_\odot$ halos of the order of ~ 20 – 40% compared to the CDM (cold) case.

modelling the HI distribution

cold CDM

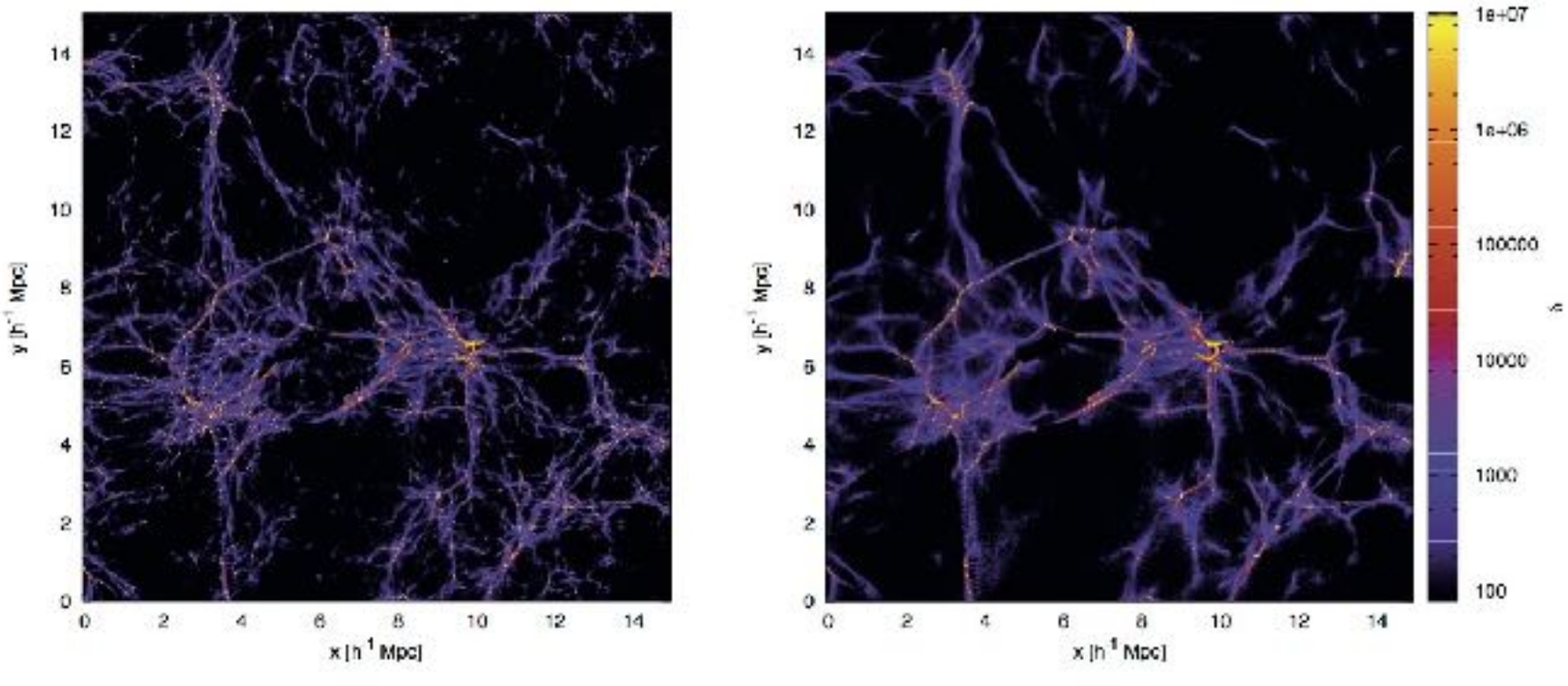
1 keV WDM warm

HI halo based



HI resides only in DM halos

HI particle based



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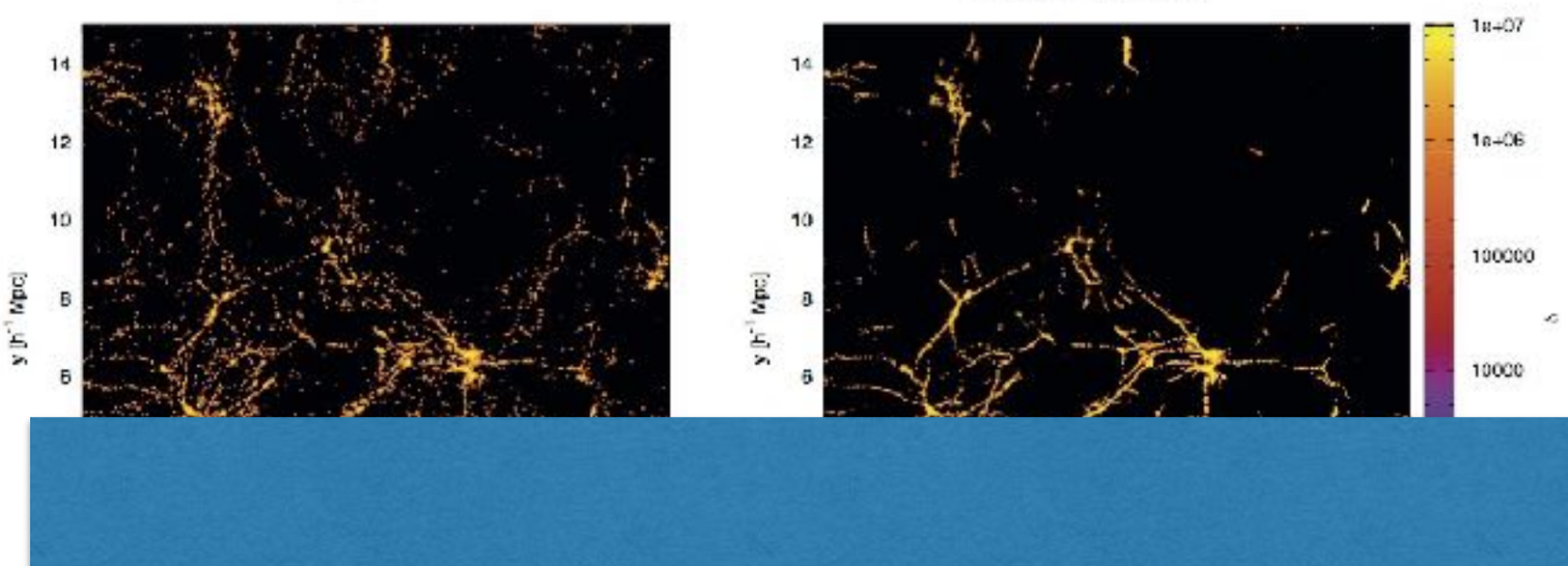
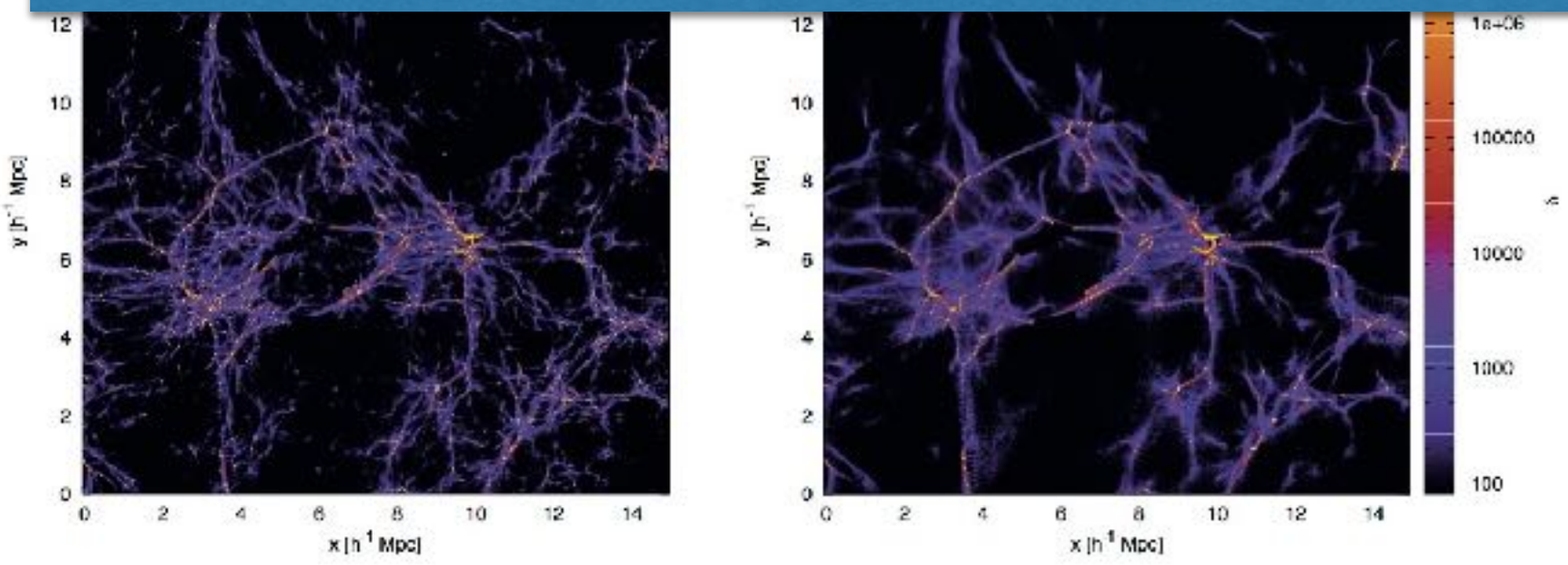


HI resides only in DM halos

ρ_{HI} —> RSD —> δT_b —> $P_{21cm}(k)$

HI particle based



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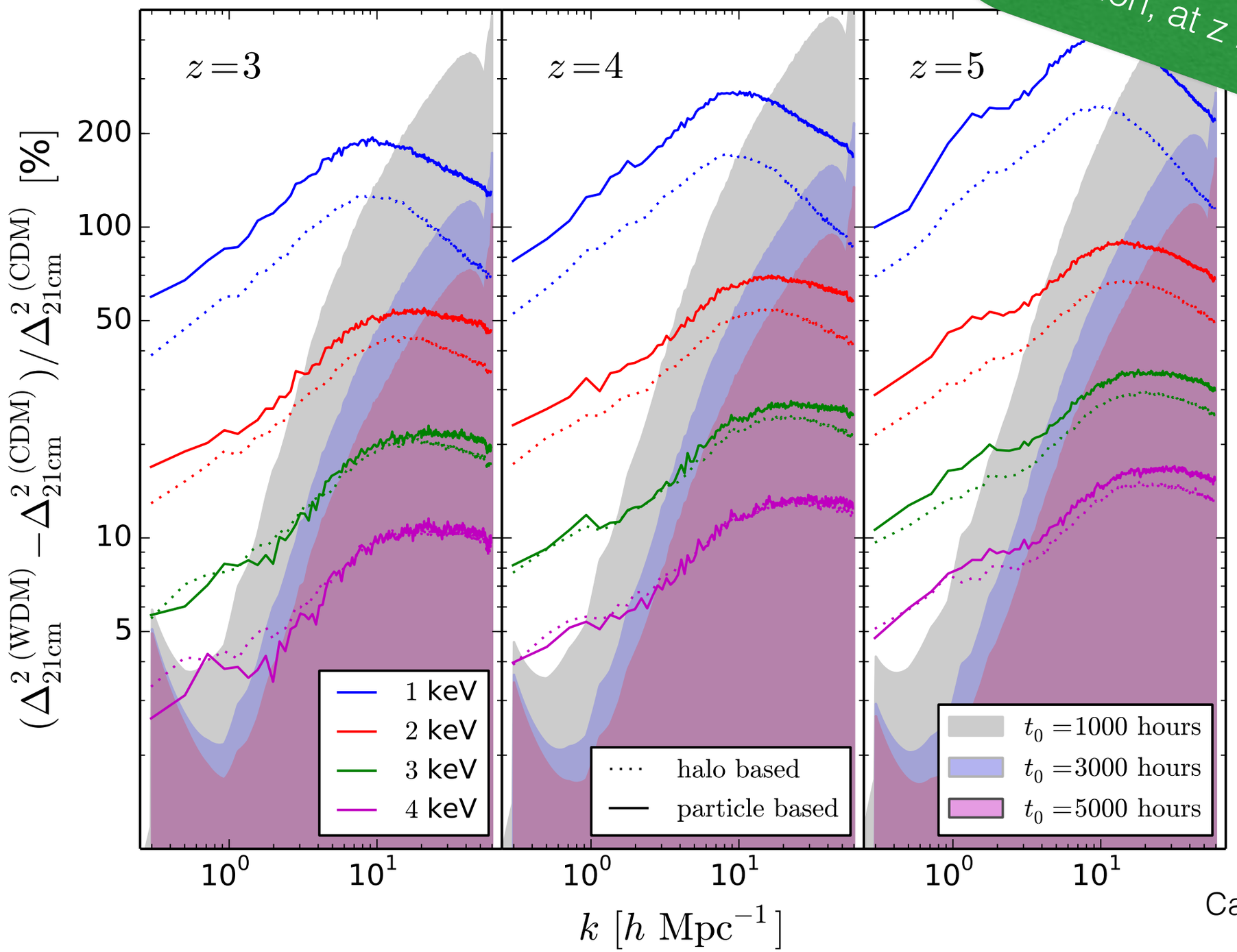
21cm P(k) and SKA1-low forecasts

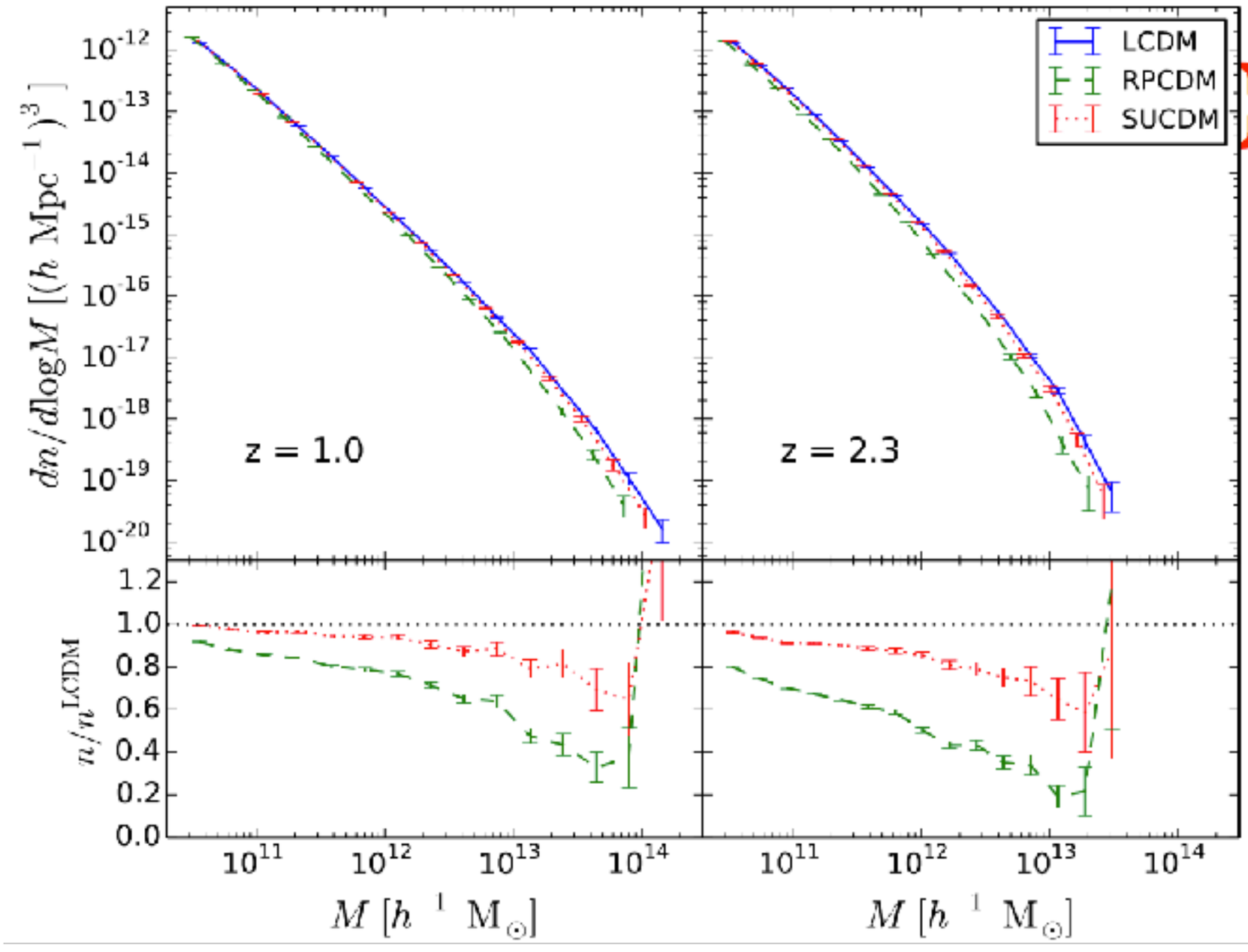
we can rule out:
- 4kev, with 5000 hour observation, at z >3, with 3σ



Carucci+ 2015

What about dark energy?

Halo mass function



non- Λ DE

Ramses, DM only. Box size = 162 Mpc/h, 1024^3 DM particles,
see http://www.deus-consortium.org and therein references

What about dark energy?

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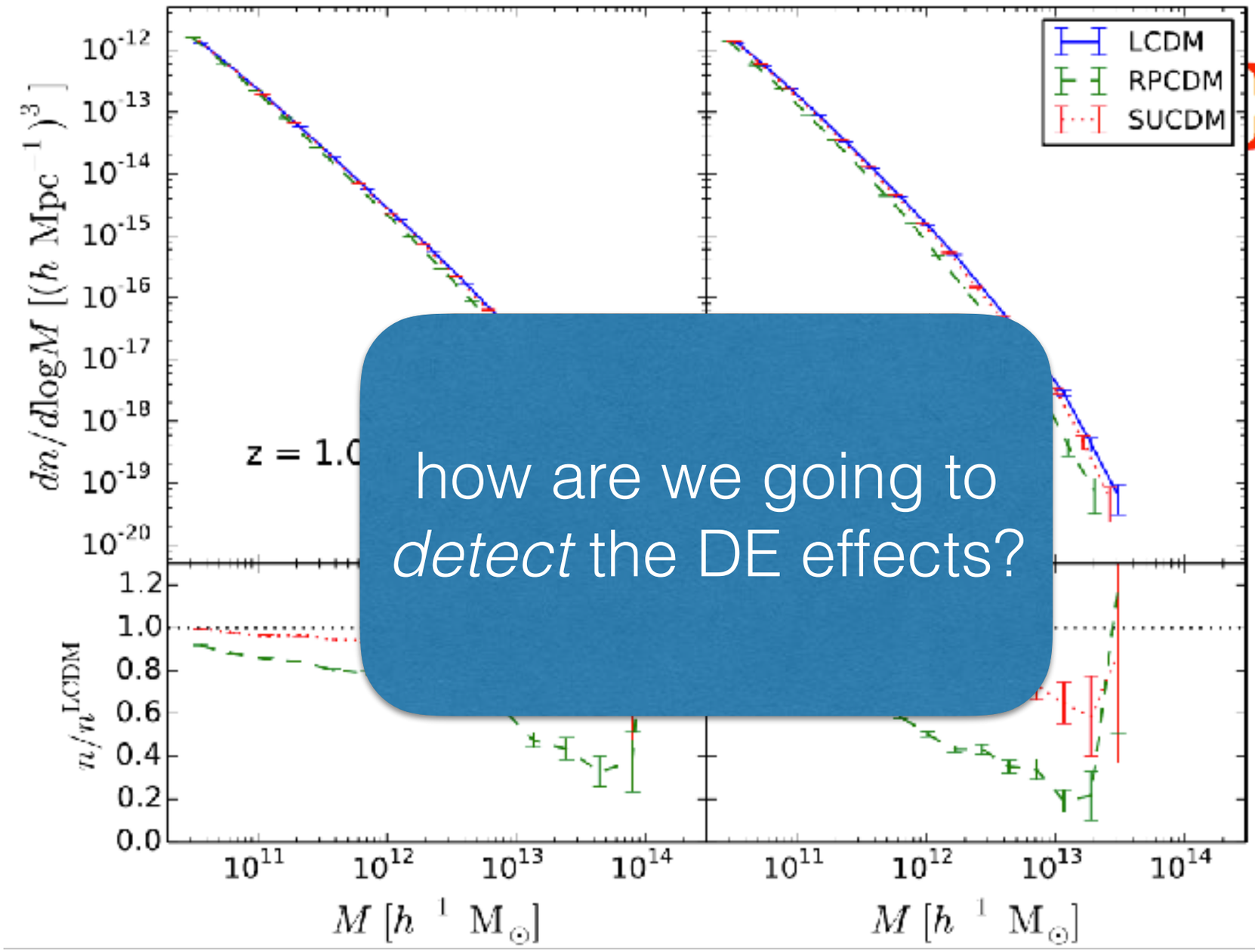

how are we going to *detect* the DE effects?

non- Λ DE

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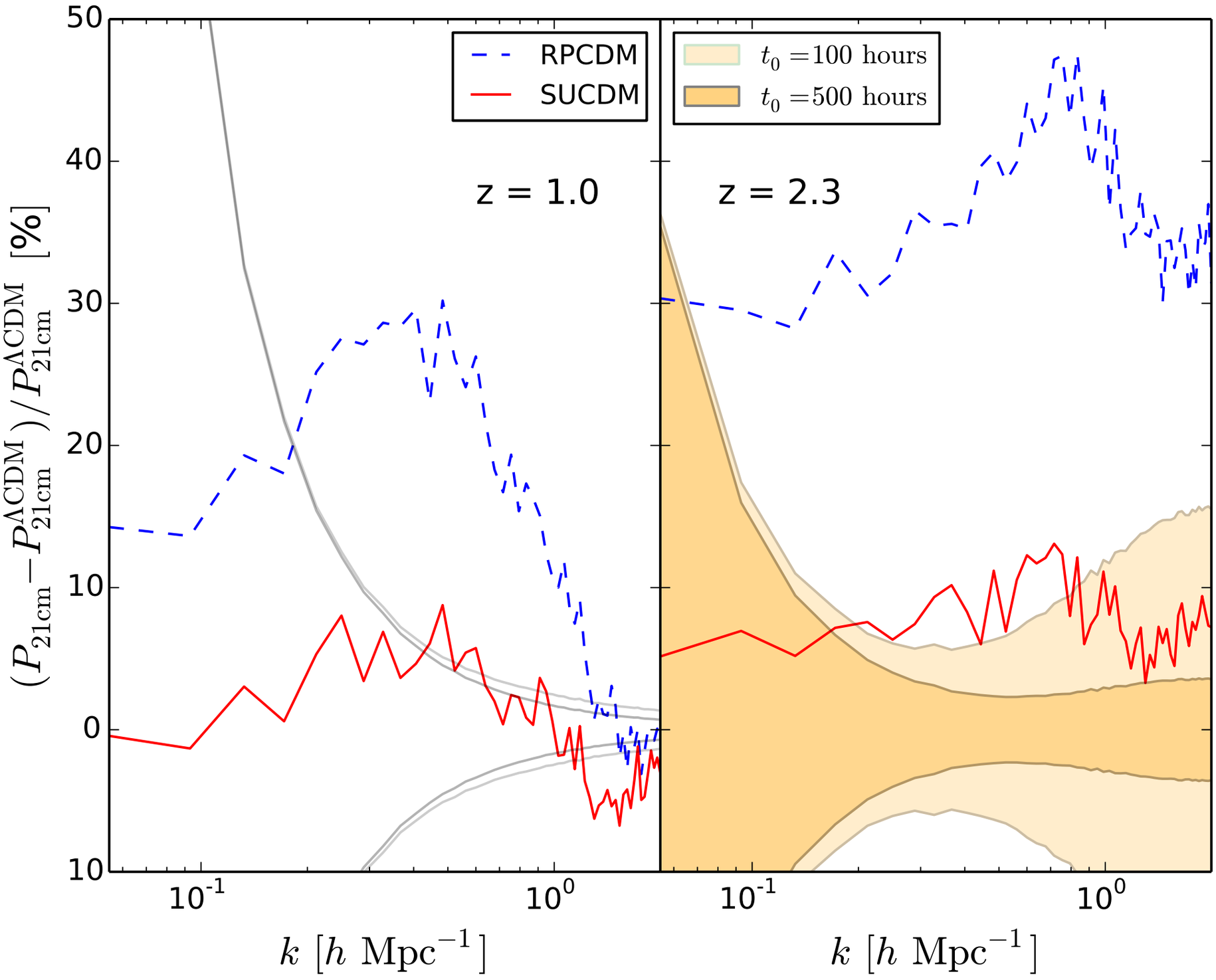
21cm IM: to distinguish indistinguishable cosmologies

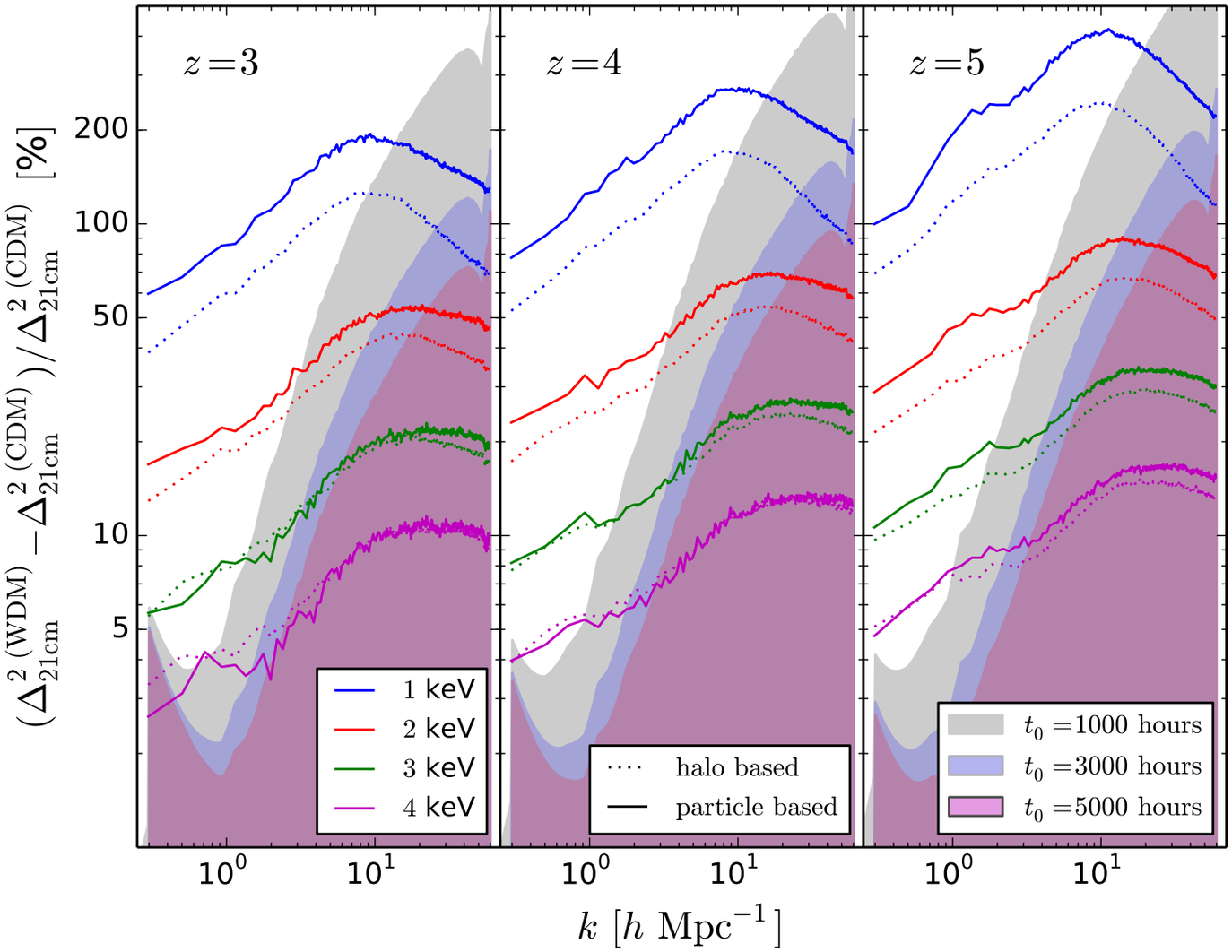


Carucci, Corasaniti, Viel 2017

21cm intensity mapping will be a great cosmological probe

investigated the impact of **WDM** on the **21cm IM** in the post-reionization era (z = 3 - 5)

Increase of power in the terms of the 21cm power spectra (SKA forecasts).



potential discriminating power for alternative-to-LCDM cosmologies

thanks!