Exploiting the 21cm power spectrum: forecasts for SKA on warm dark matter

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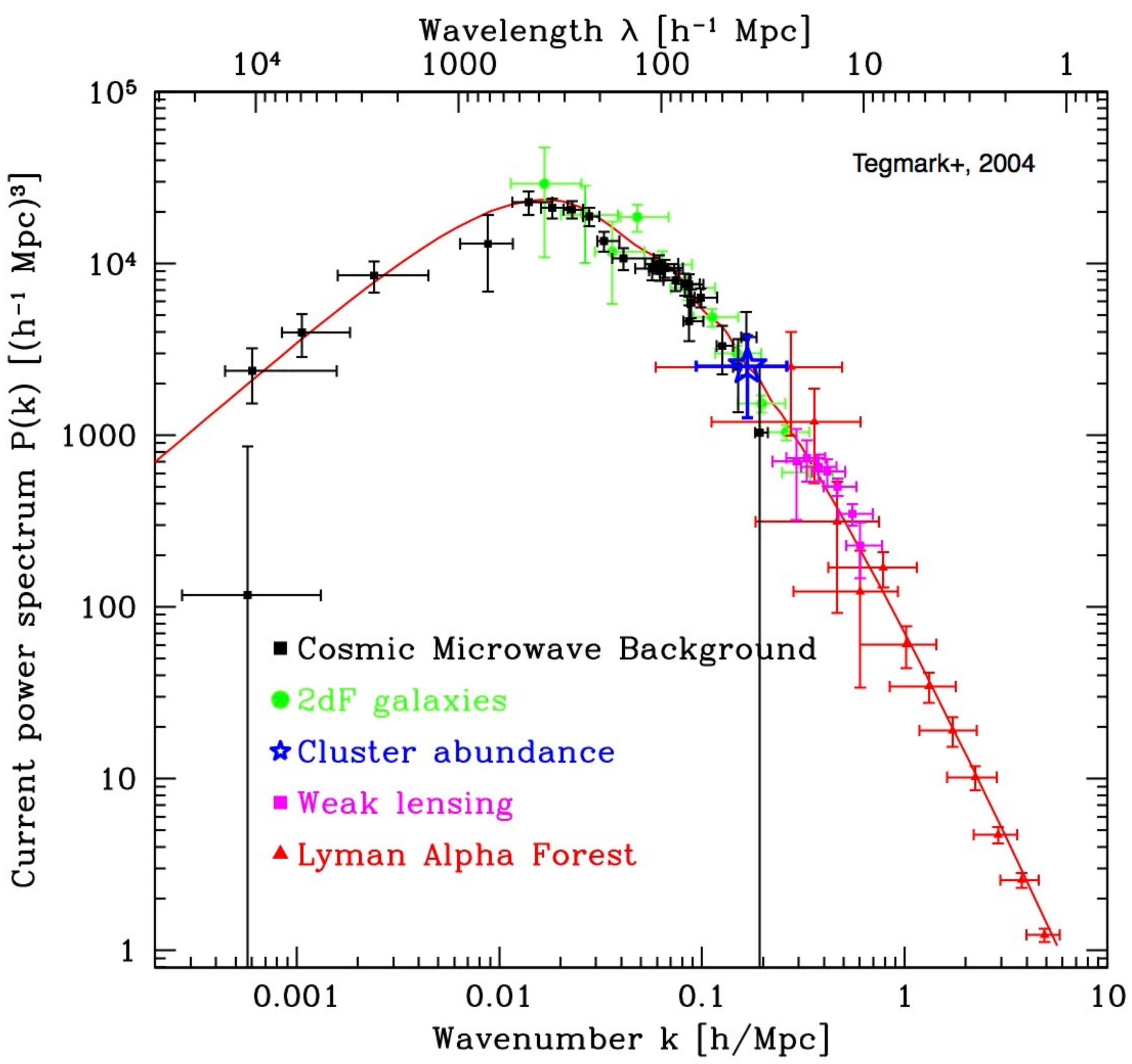
Meudon, June 16th 2016

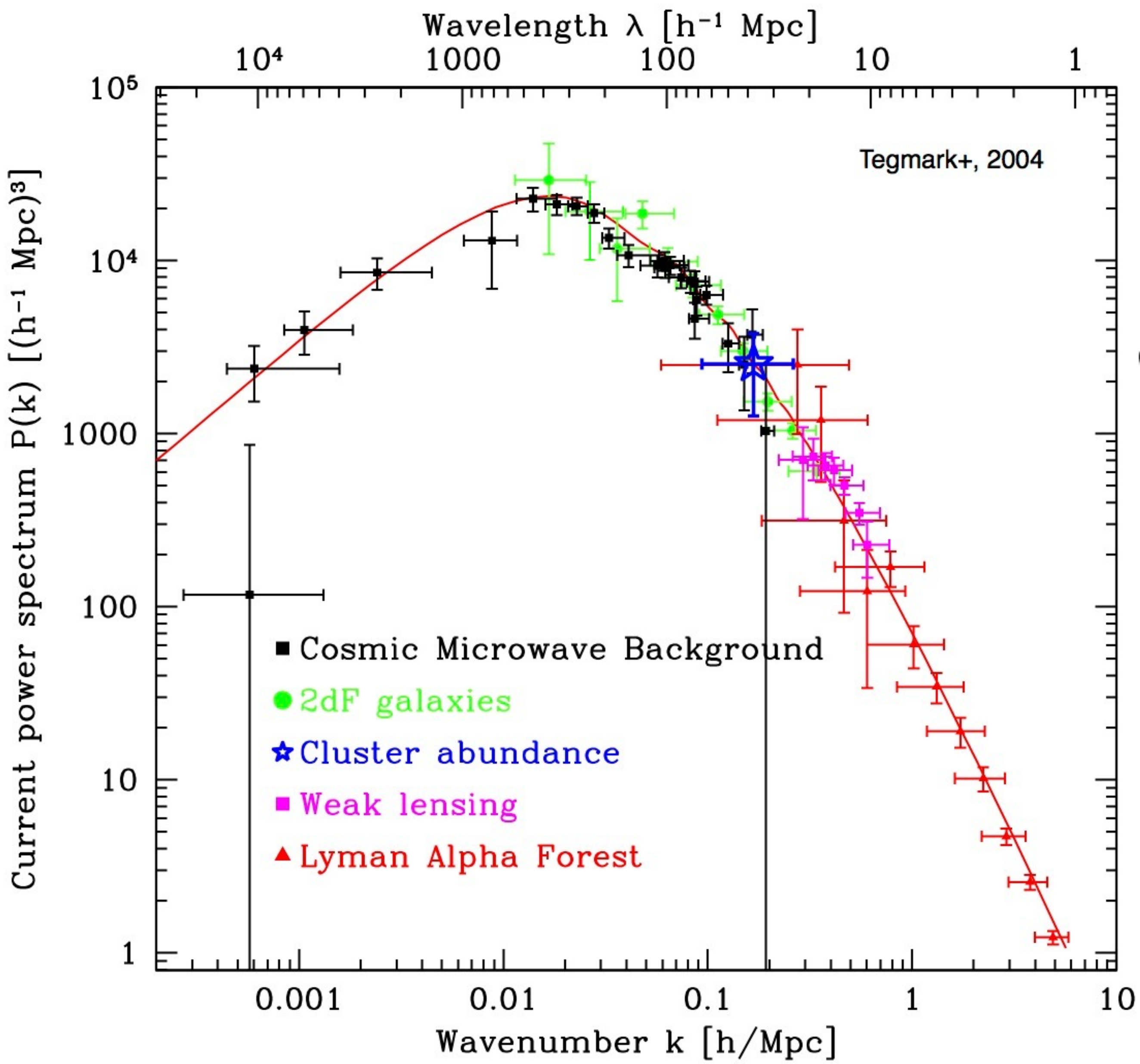
based on JCAP07(2015)047

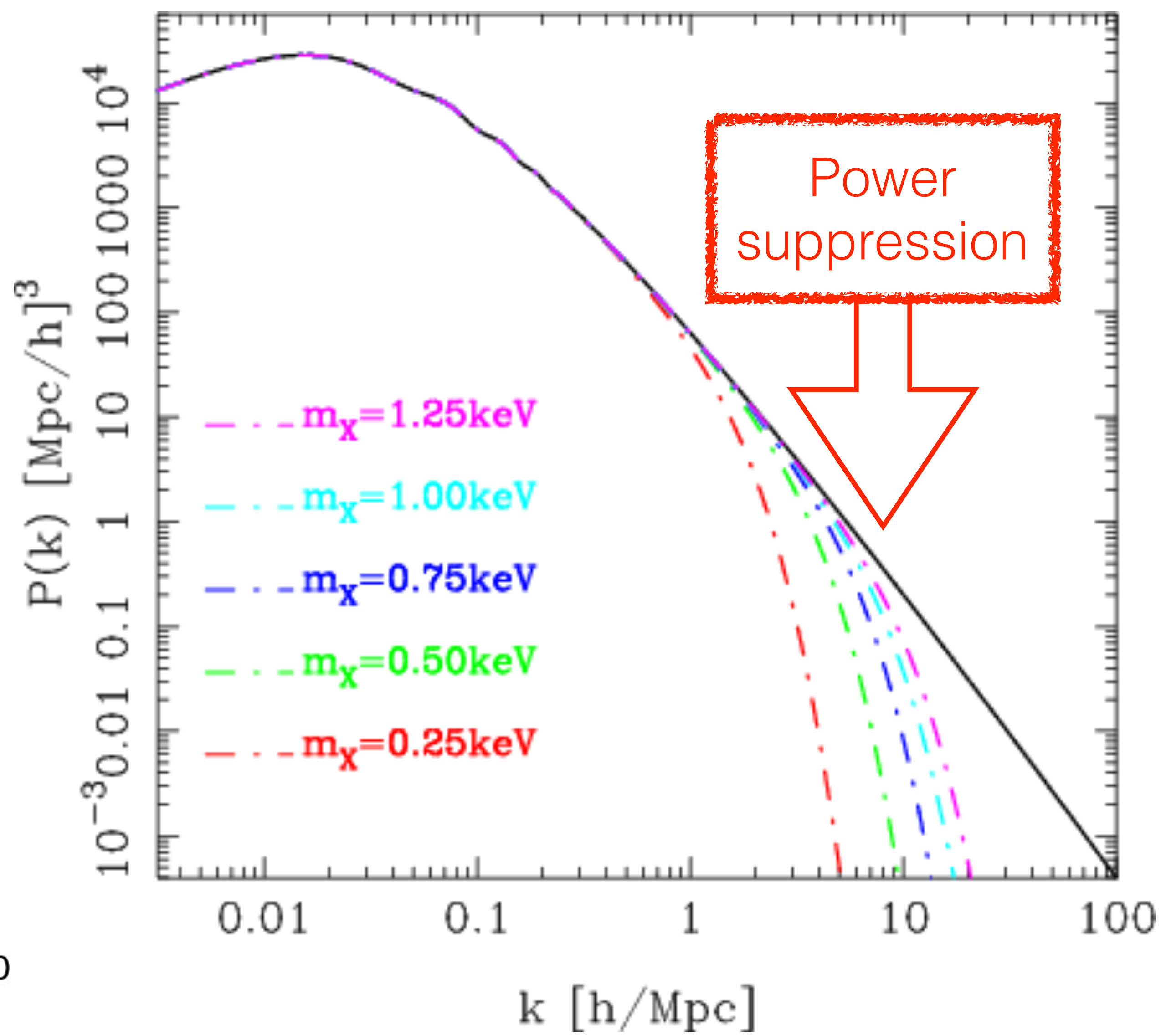
work done with Francisco Villaescusa-Navarro, Matteo Viel, Andrea Lapi

what does LLS tell us about the warmness of DM ?



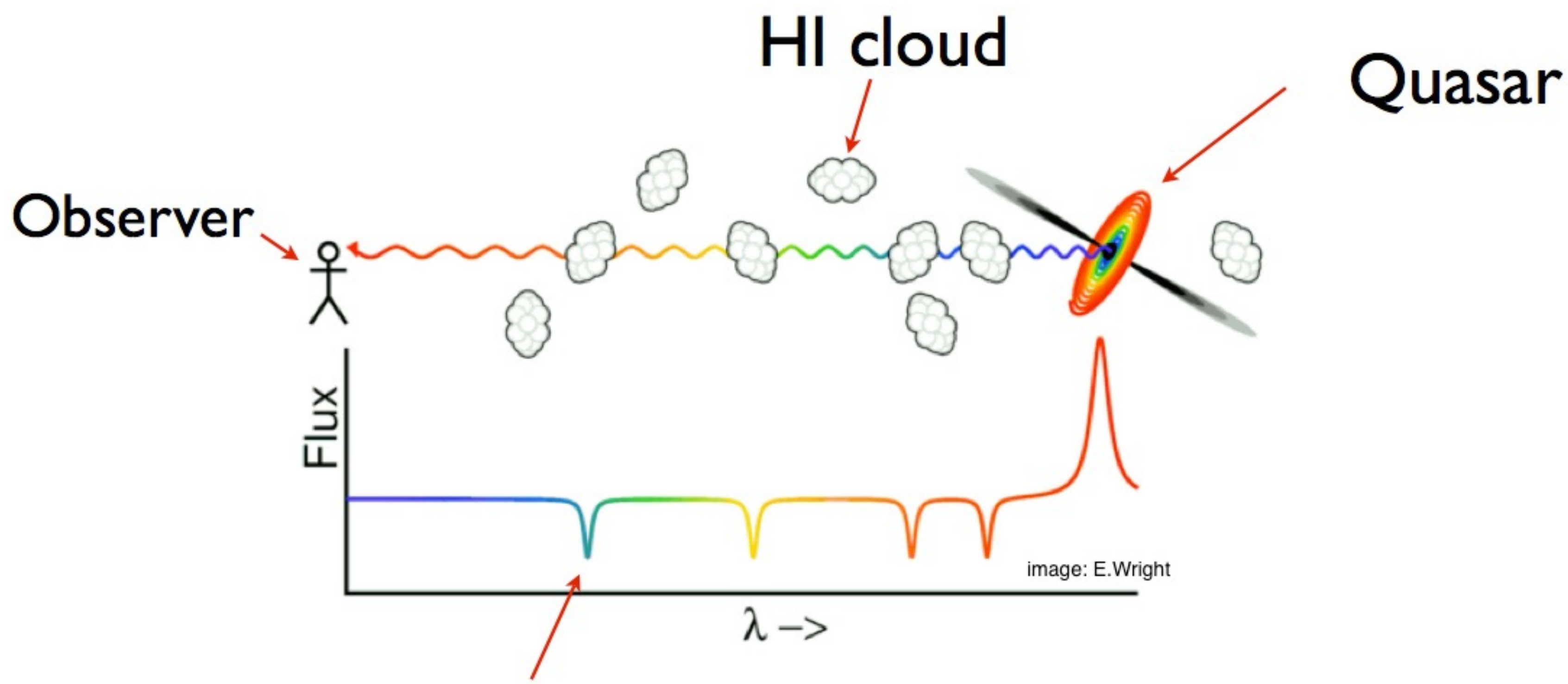
what does LLS tell us about the warmness of DM ?

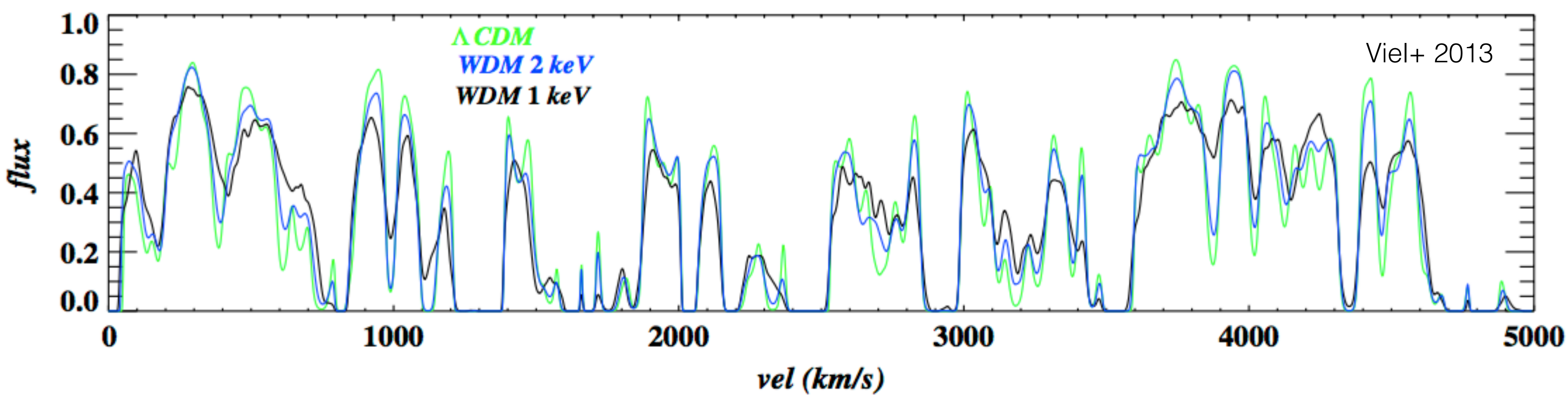




constrained up to k ~ 3 Mpc^{-1} (Ly-α)

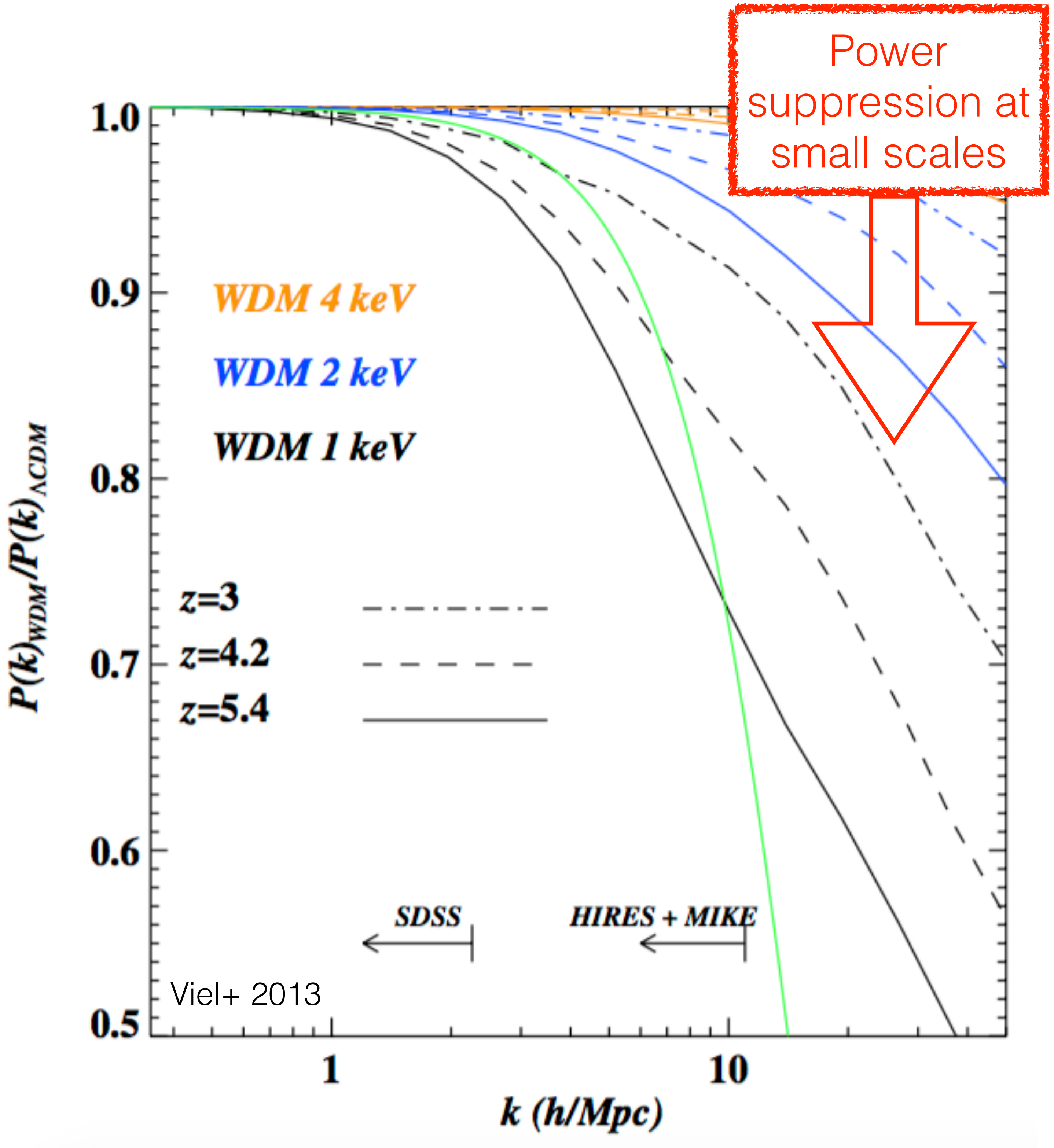
Lyman-α forest flux power spectrum





current constrain: m_{WDM} >3.3 keV (2σ) [Viel+2013]

looking after the cut-off



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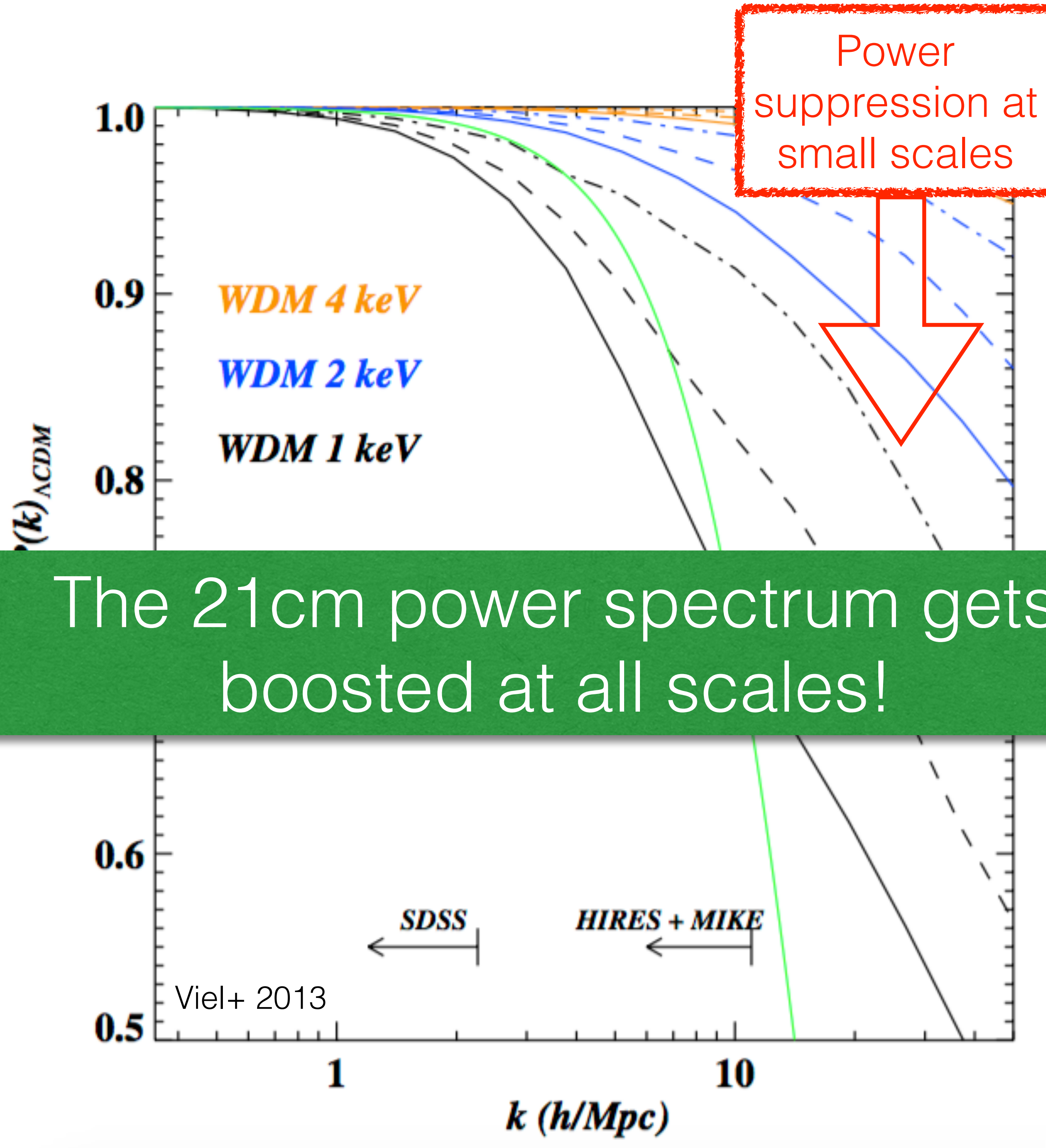
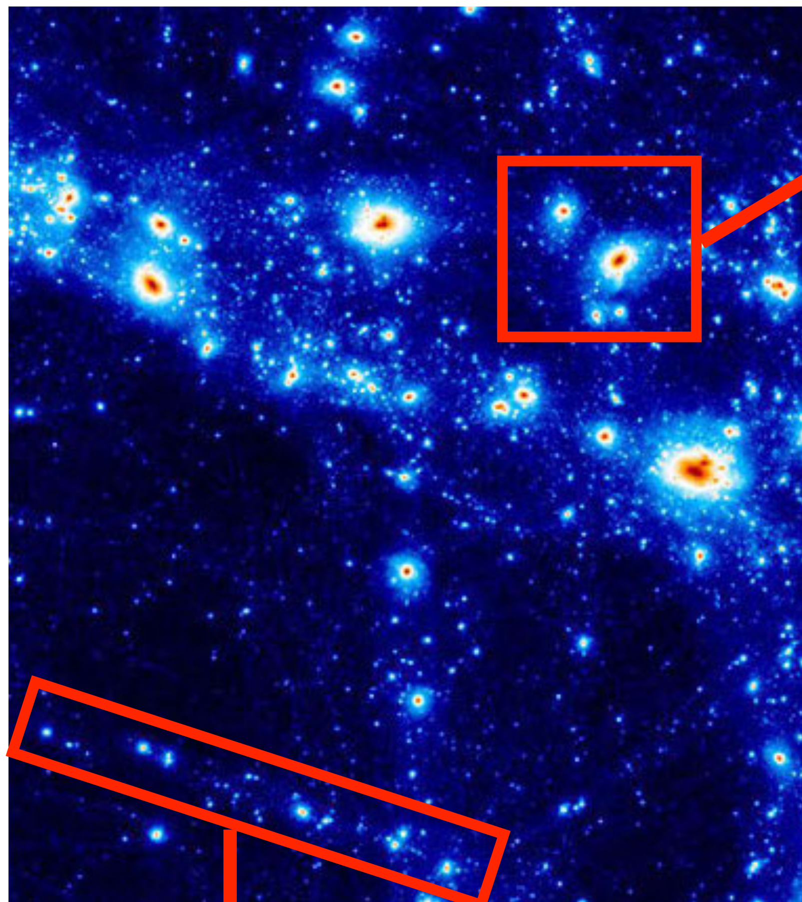


The 21cm power spectrum gets boosted at all scales!

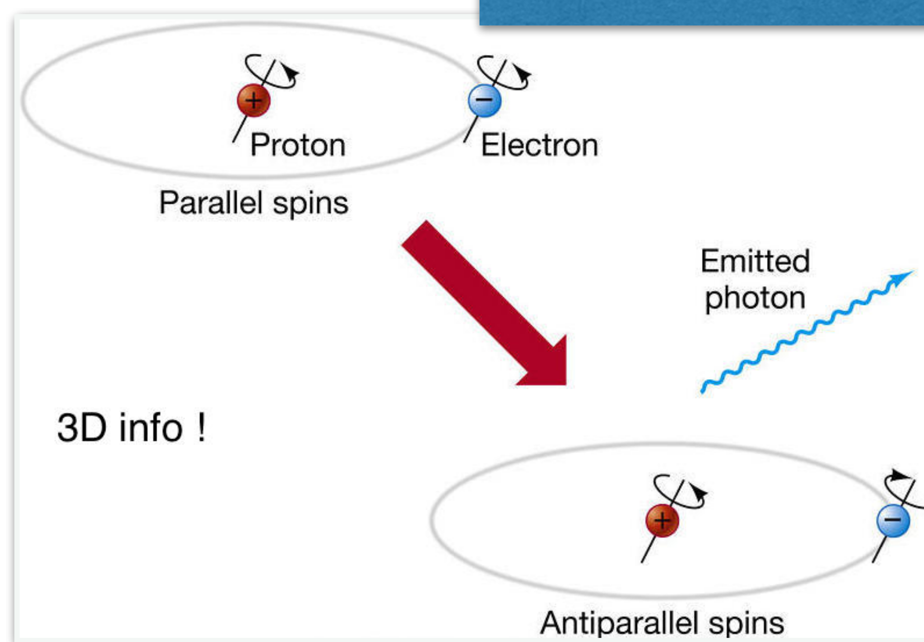
neutral hydrogen in the universe



Galaxies (DLAs)

Dense, self-shielded HI

21cm radiation signal !

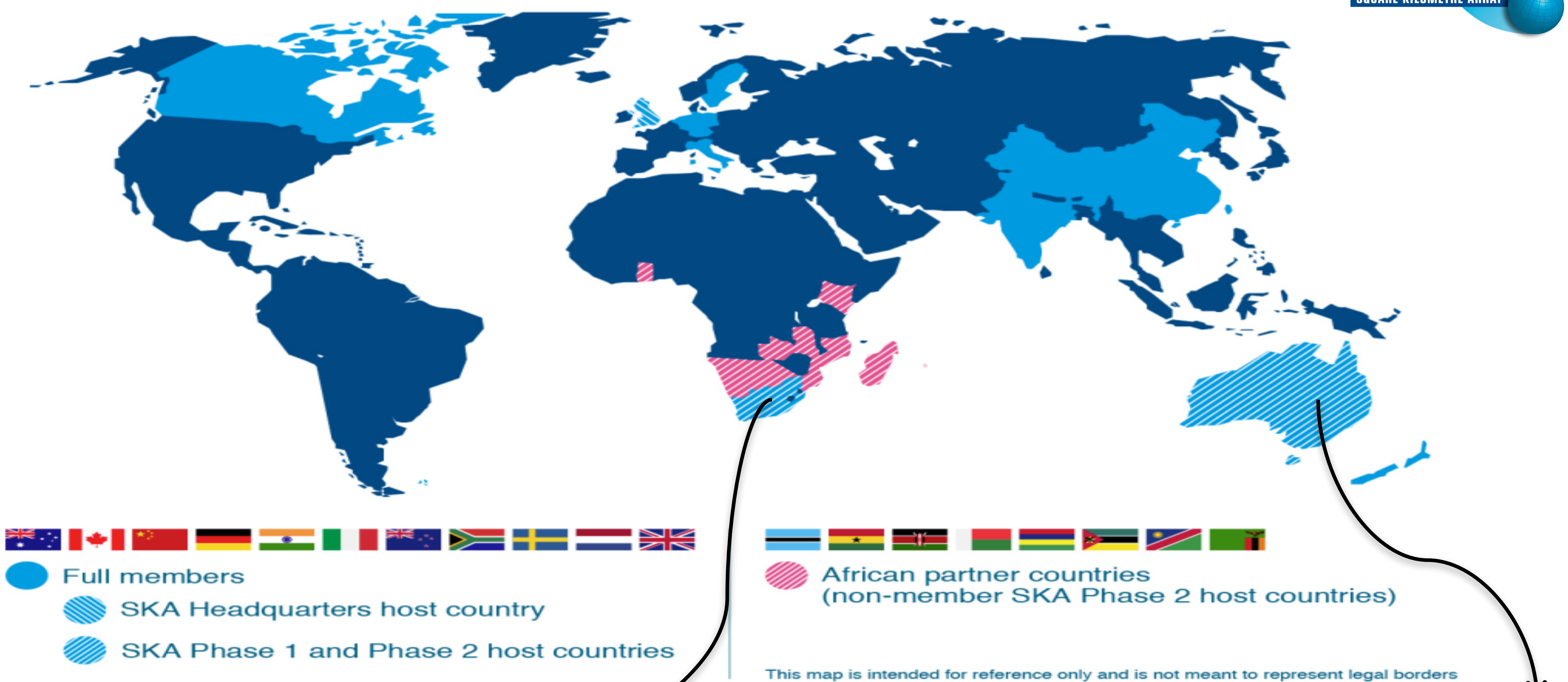


Lyman-α forest flux

mostly ionised H

- observation perspective (SKA)
- intensity mapping: mapping the collective HI 21cm radiation background without resolving the individual sources

SKA
SQUARE KILOMETRE ARRAY

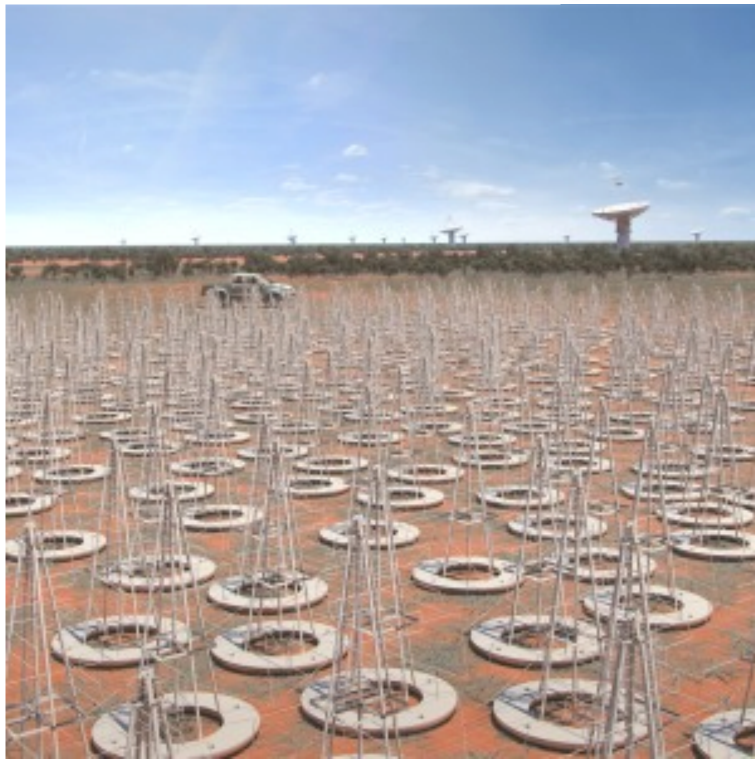


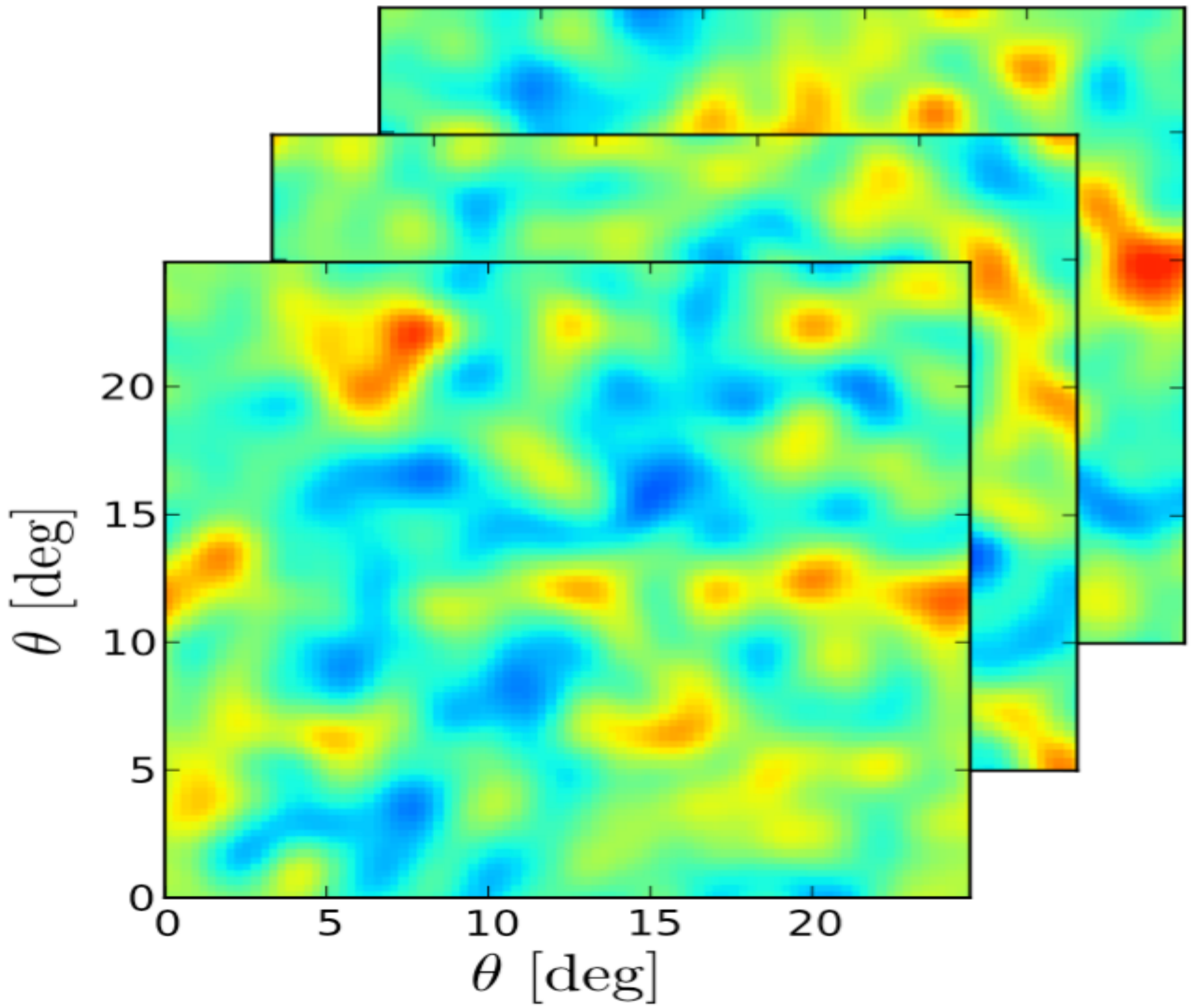
Phase I

SKA1-MID
- 0<z<3
- 200 dishes; 15m
- South Africa

SKA1-LOW
- 3<z<27
- 911 antennae
- Australia

Very isolated places to avoid RIF





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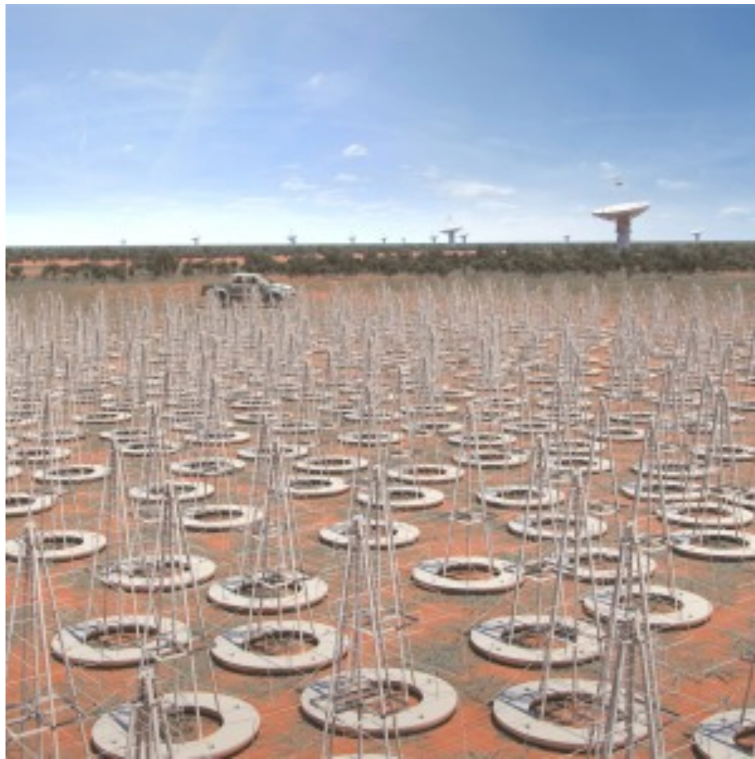
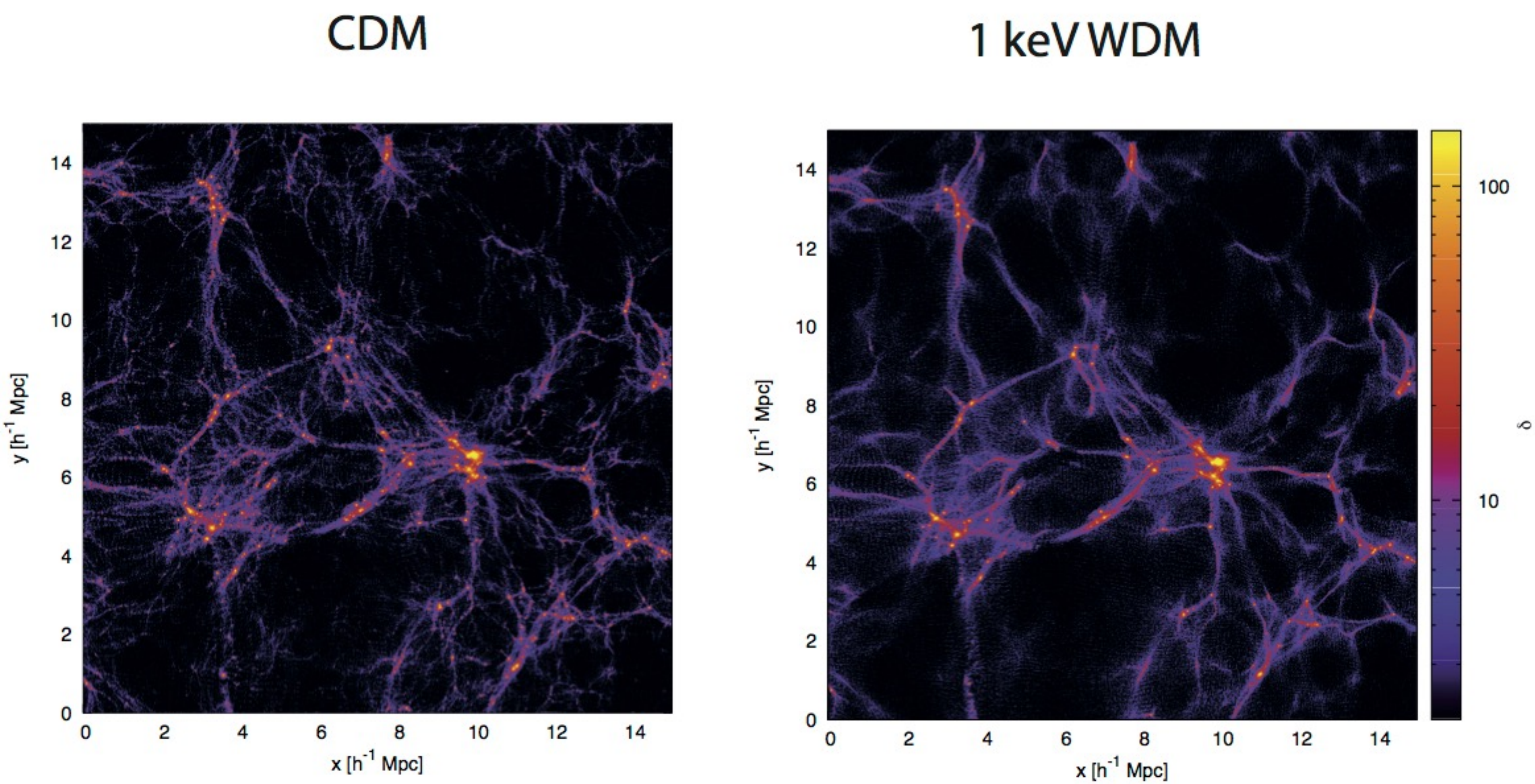


simulation suite

- Gadget3, w/ radiative cooling+ SF
- box size = 30 Mpc/h
- 512^3 DM + 512^3 baryons particles
- 5 cosmologies: CDM and
  1, 2, 3 and 4 keV WDM
- from z=99 to z=3
  (snapshot at 3, 4 and 5)

impact of WDM on the matter distribution



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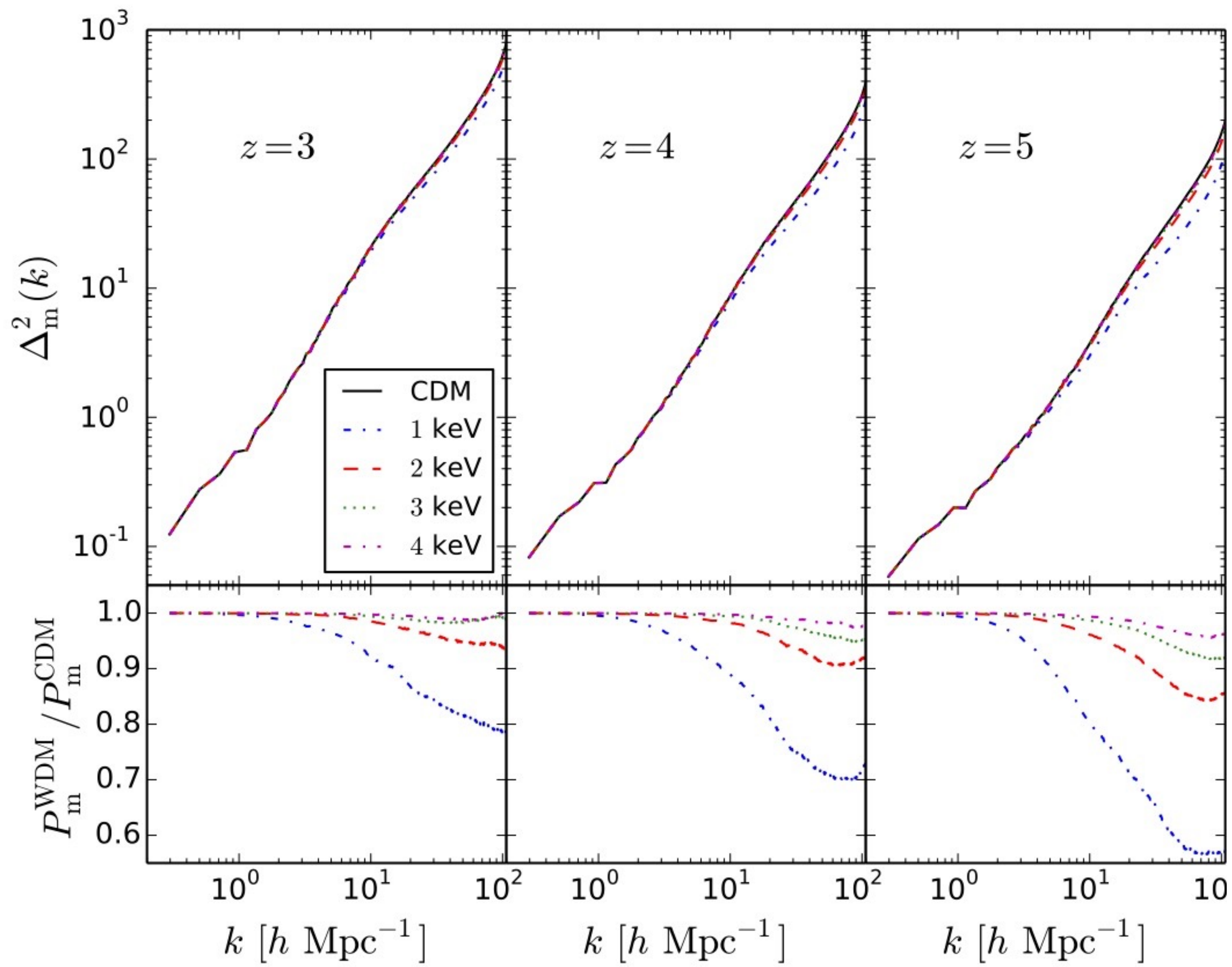
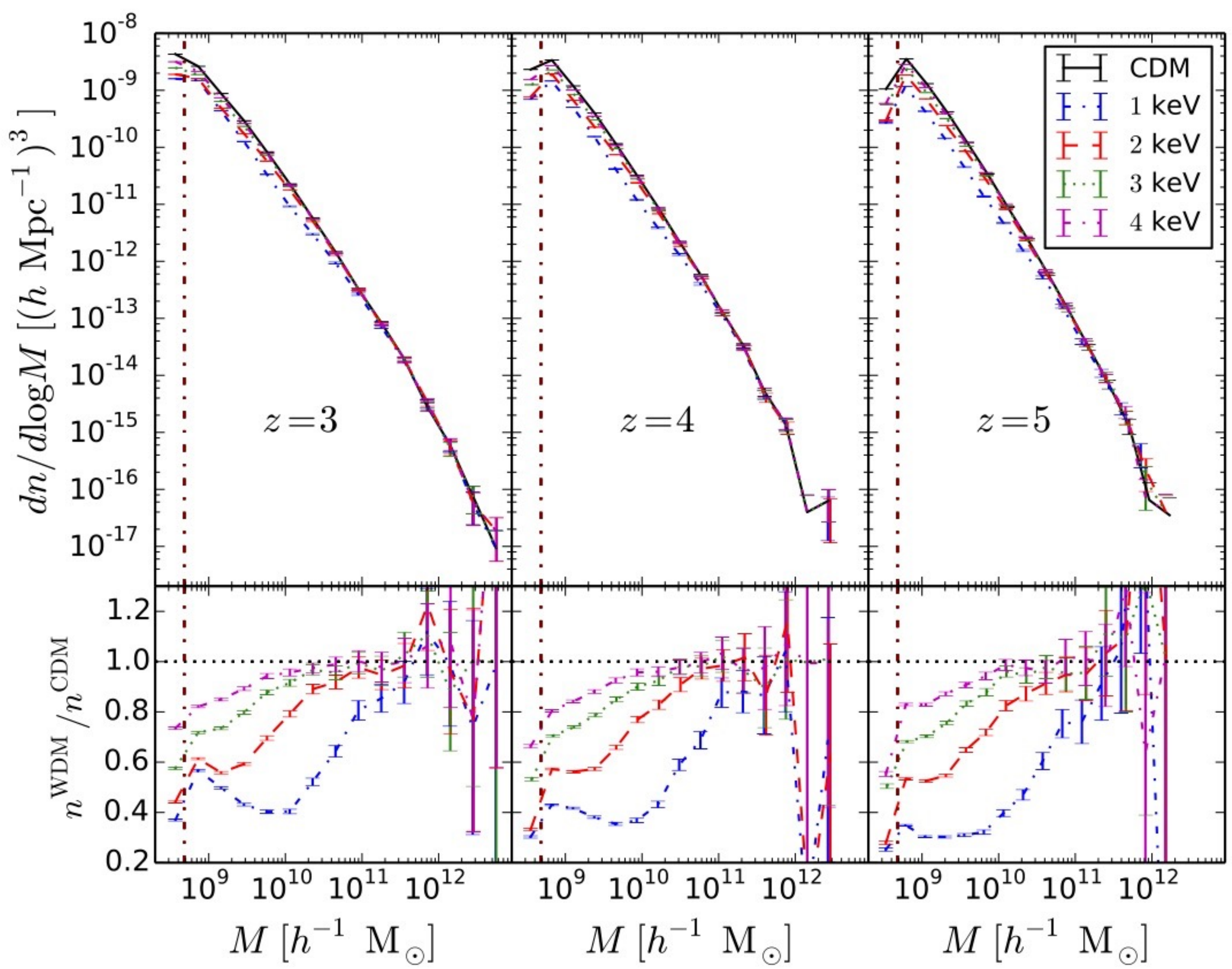




Overall, for WDM masses between 3 and 4 keV we observe a suppression in power up to ~10% on small scales ...

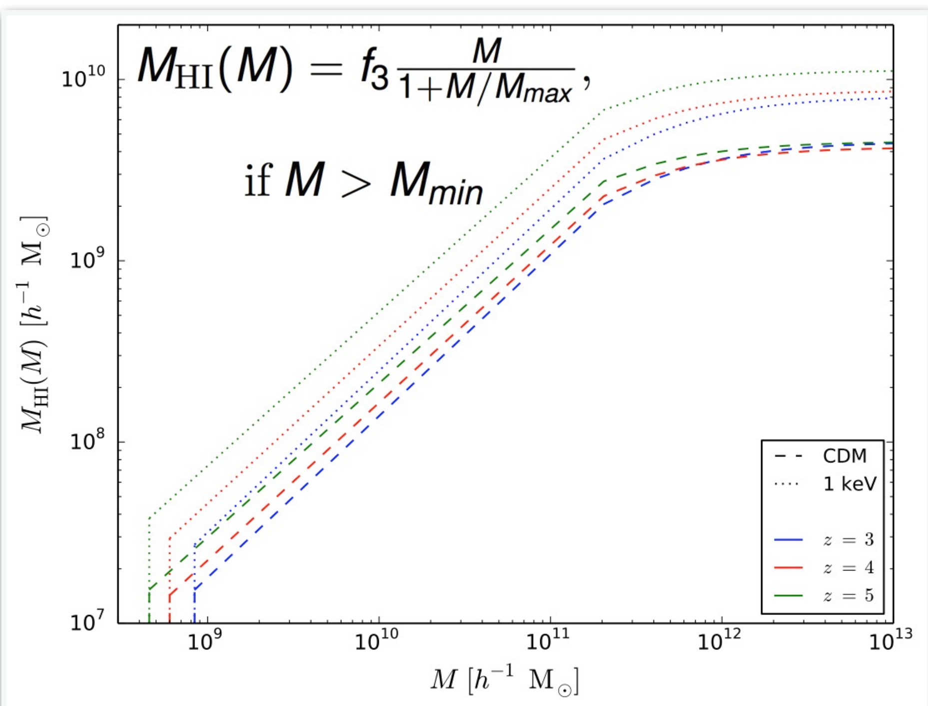
... and a reduction in the number of $10^9\ h^{-1} M_\odot$ halos of the order of ~ 20 – 40% compared to the CDM case.

modelling the HI distribution

halo based method

(Bagla 2010)

HI resides only in DM halos



- f_3 such that $\Omega_{HI} = 10^{-3}$
- M_{min} and M_{max} corresponding to halo circular velocities of 30 and 200 km/s

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

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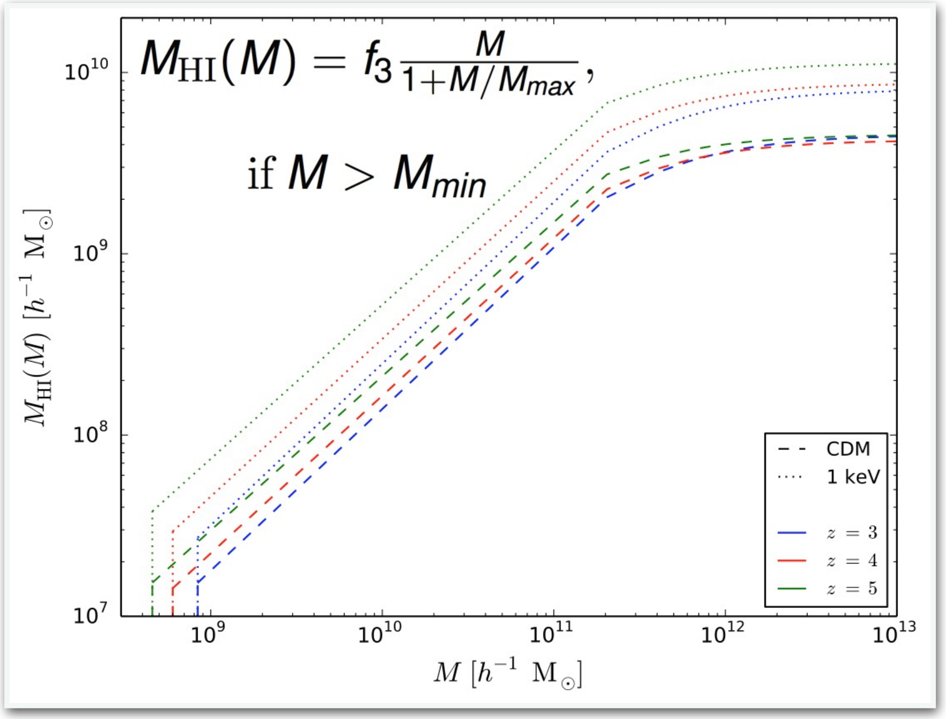

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Both methods were tested with LLS and DLAs HI column density distribution function !

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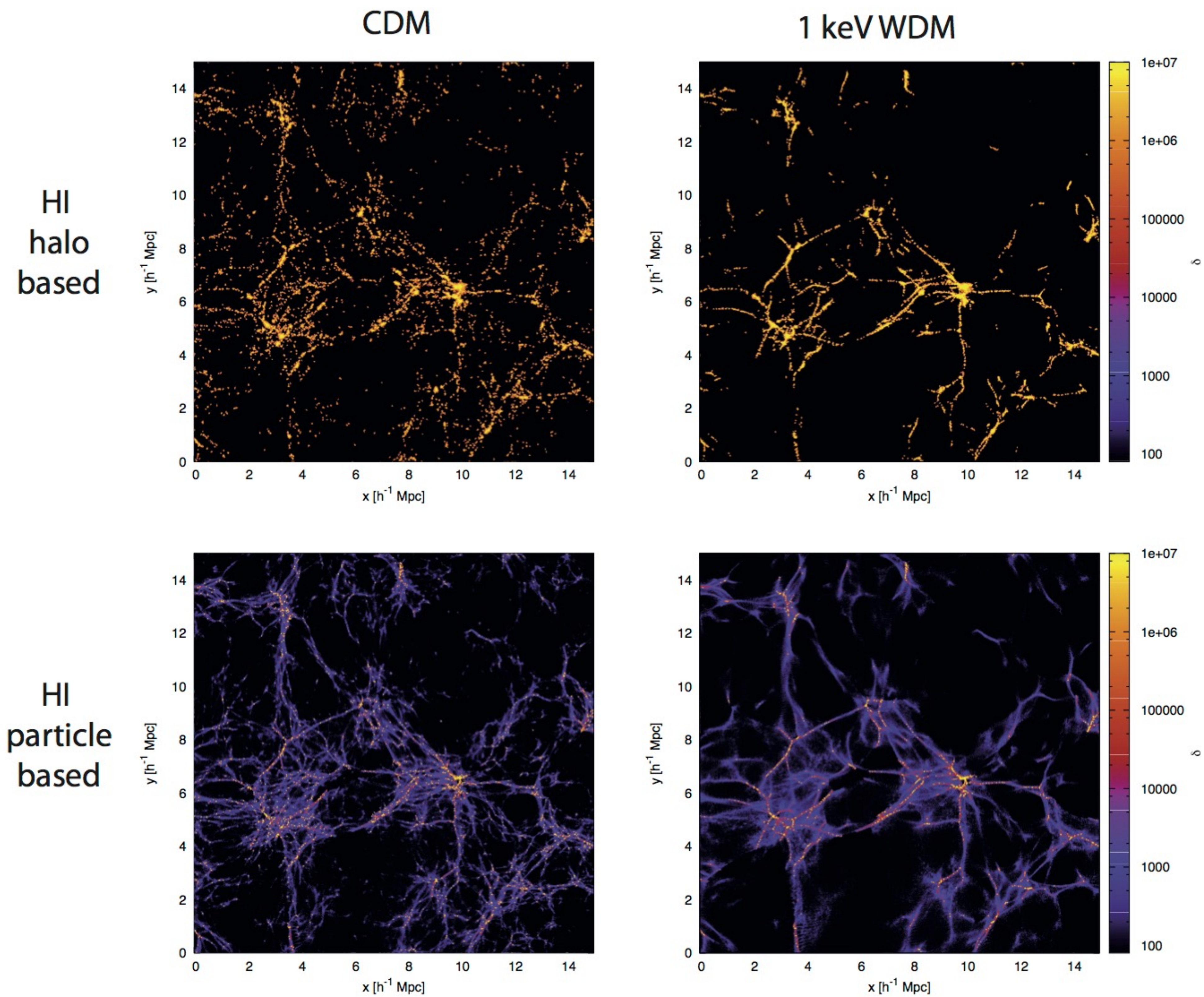
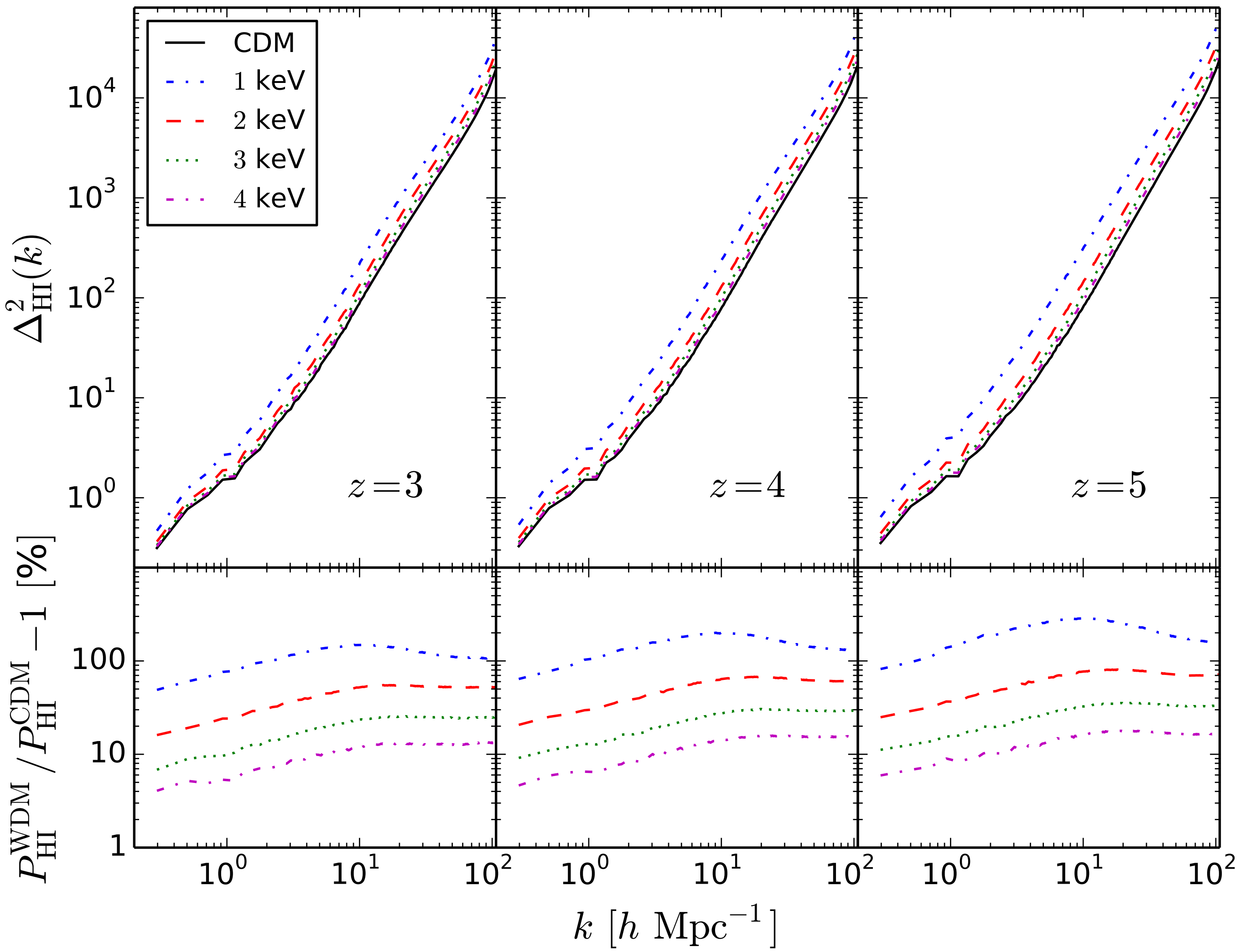


modelling the HI distribution

halo based method



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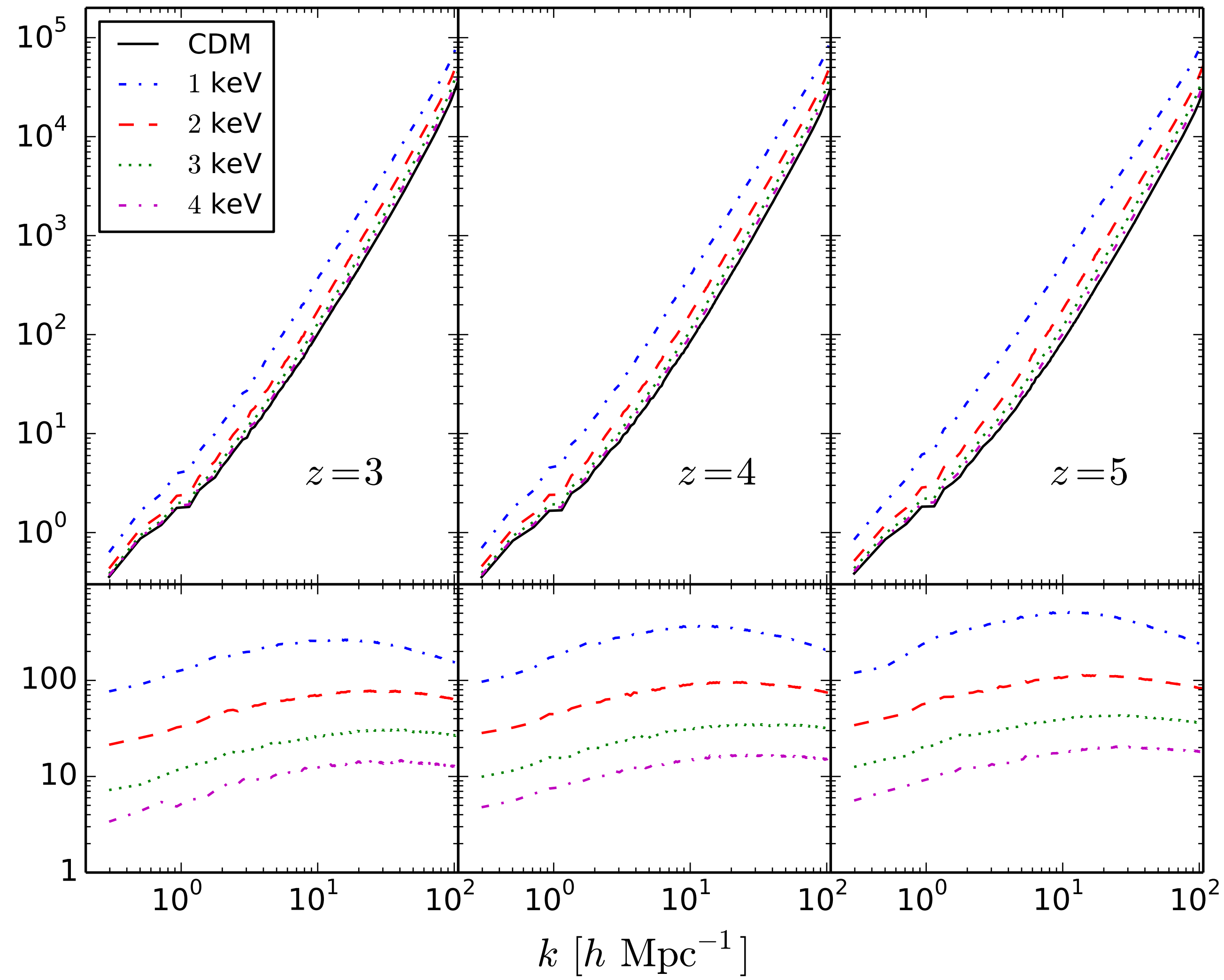
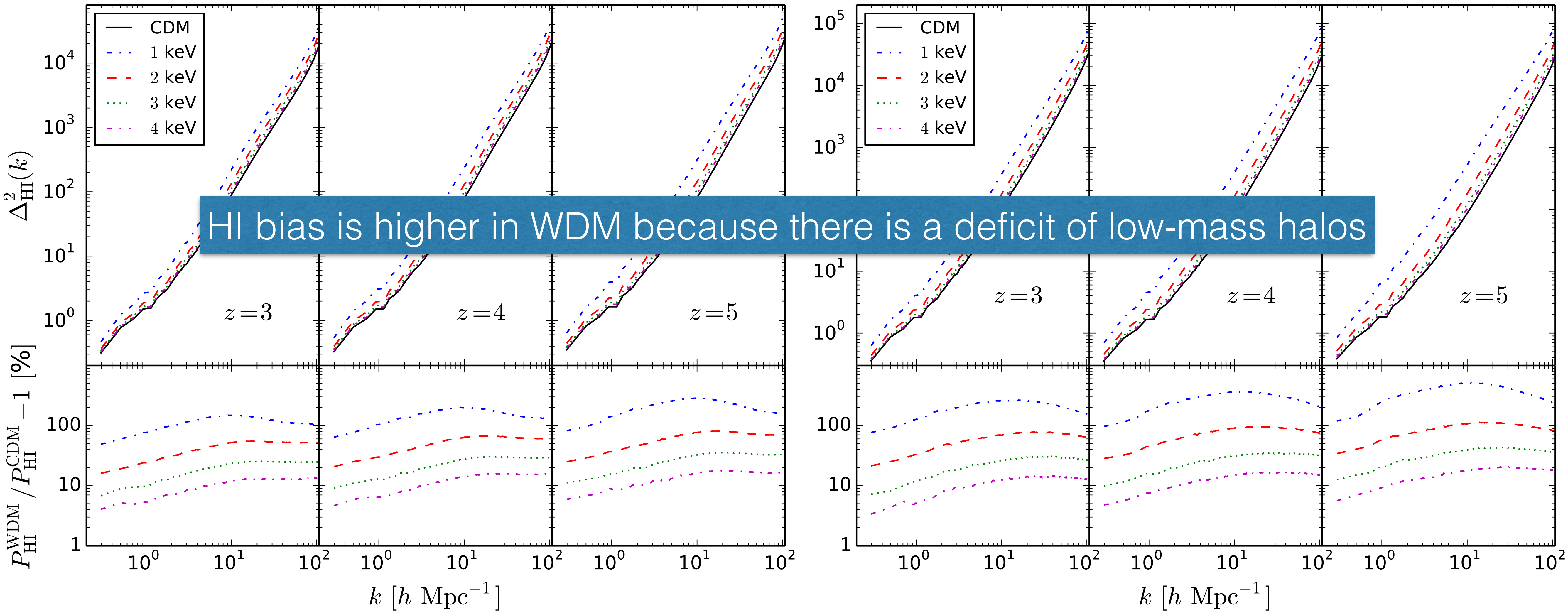


modelling the HI distribution

halo based method

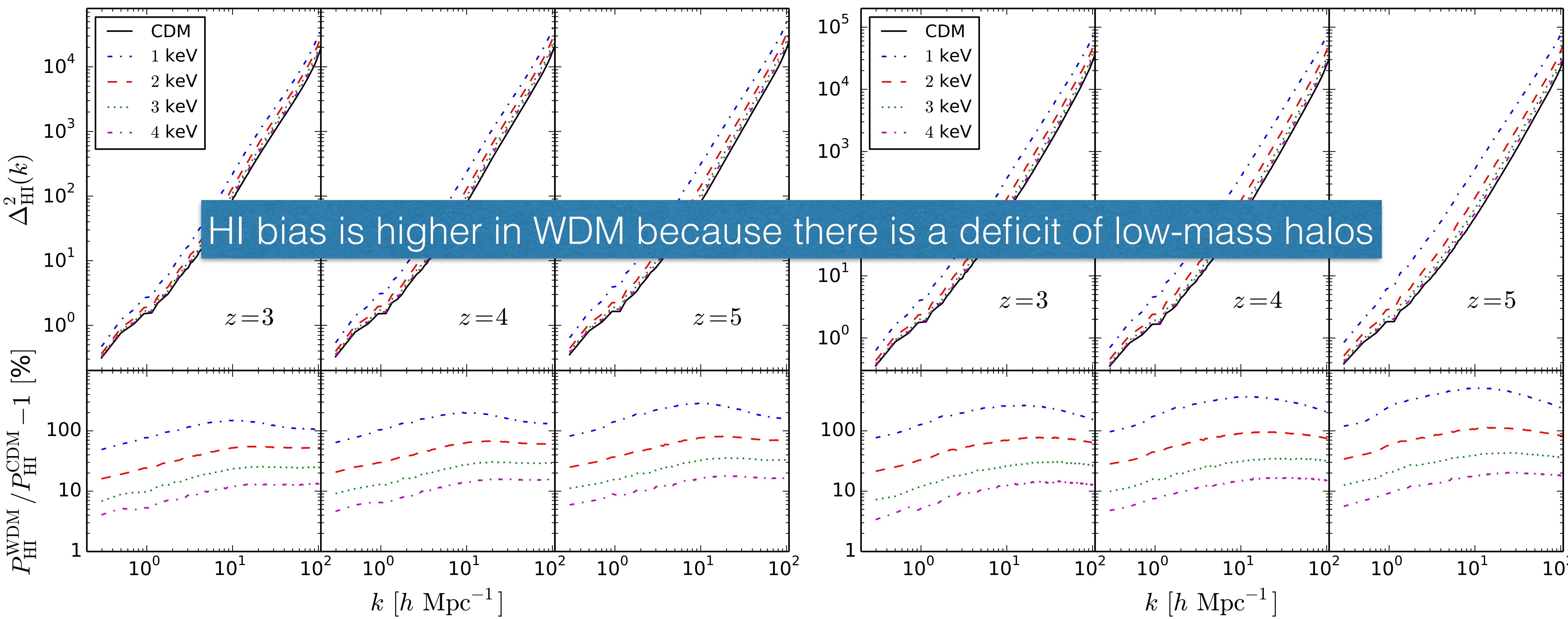
particle based method



HI bias is higher in WDM because there is a deficit of low-mass halos

modelling the HI distribution

halo based method | **particle based method**



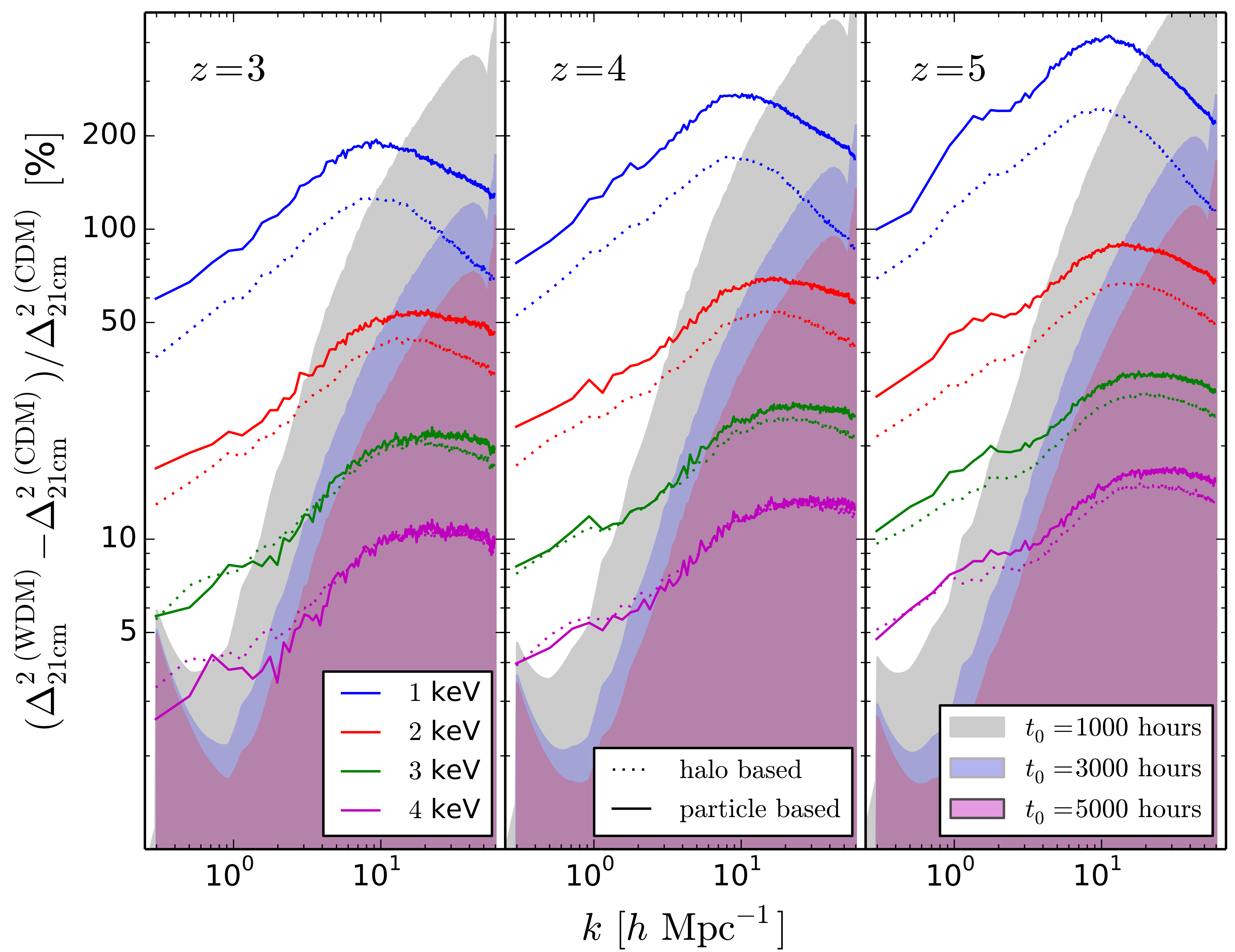
HI bias is higher in WDM because there is a deficit of low-mass halos

brightness temperature δT_b → 21cm signal

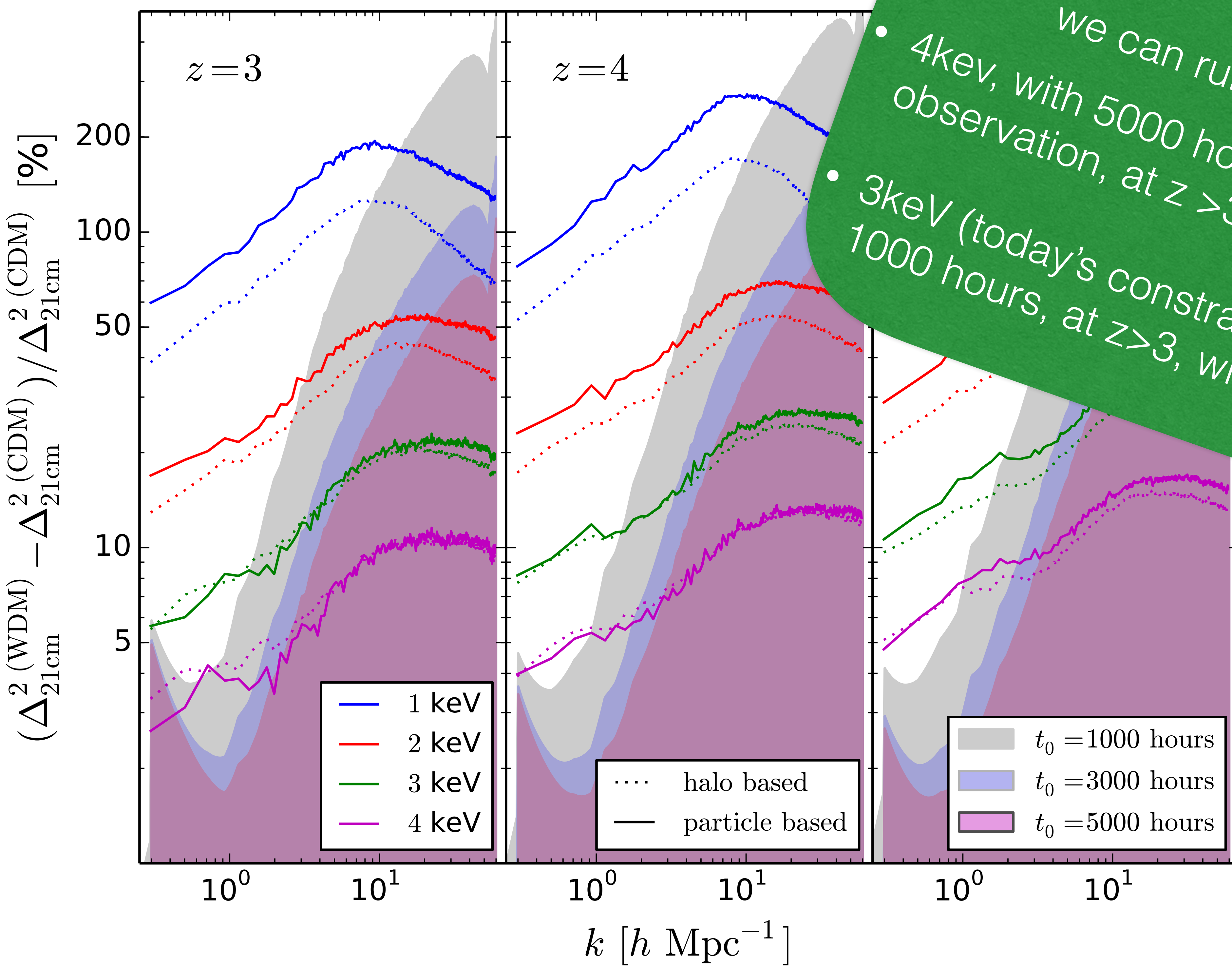
(Furlanetto+ 2006)

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

21cm P(k) and SKA1-low forecasts



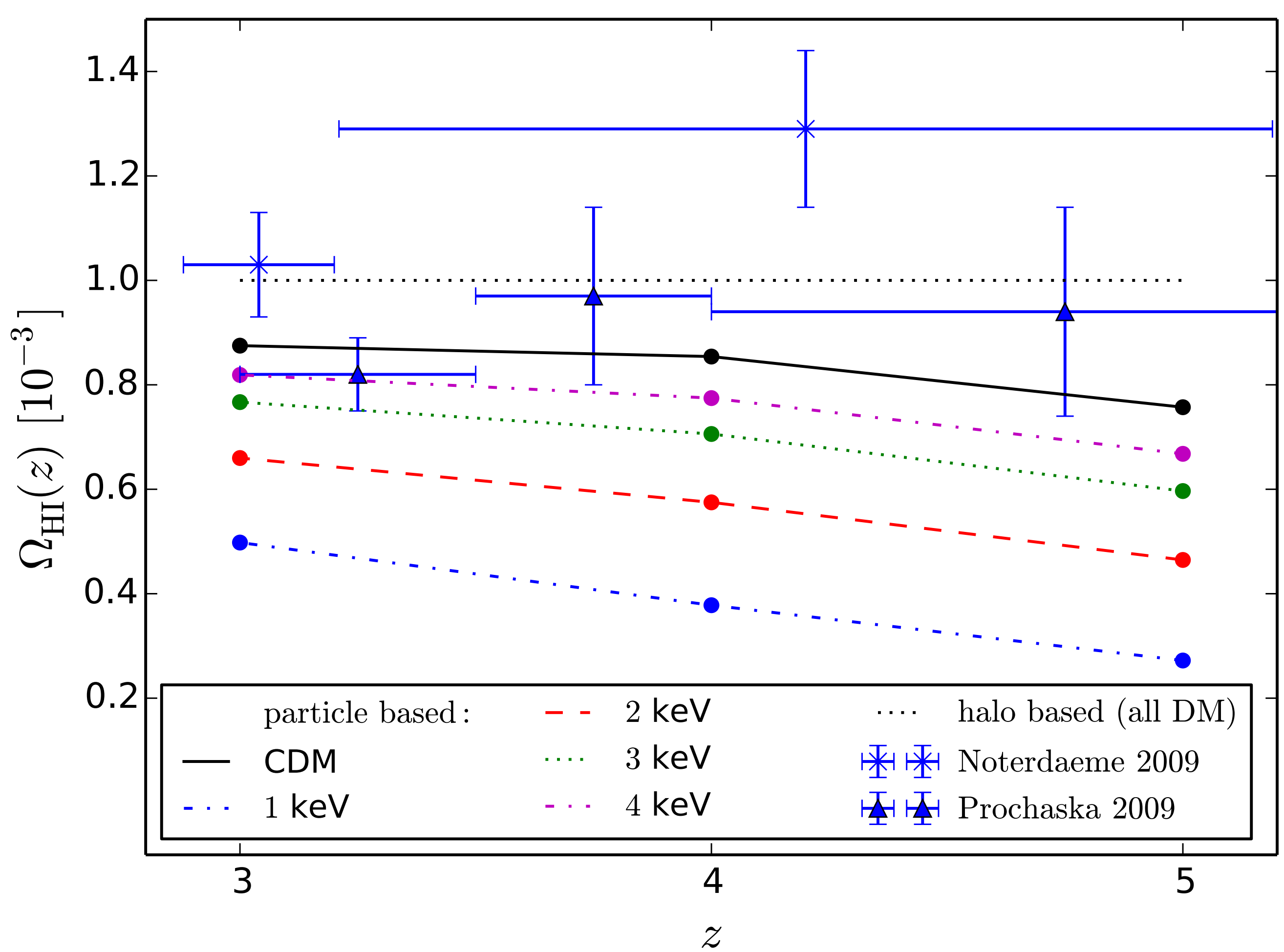
21cm P(k) and SKA1-low forecasts



we can rule out:

- 4kev, with 5000 hour observation, at z >3, with 3σ
- 3keV (today's constraint) with 1000 hours, at z>3, with > 2σ

the Ω_{HI} - m_{WDM} degeneracy



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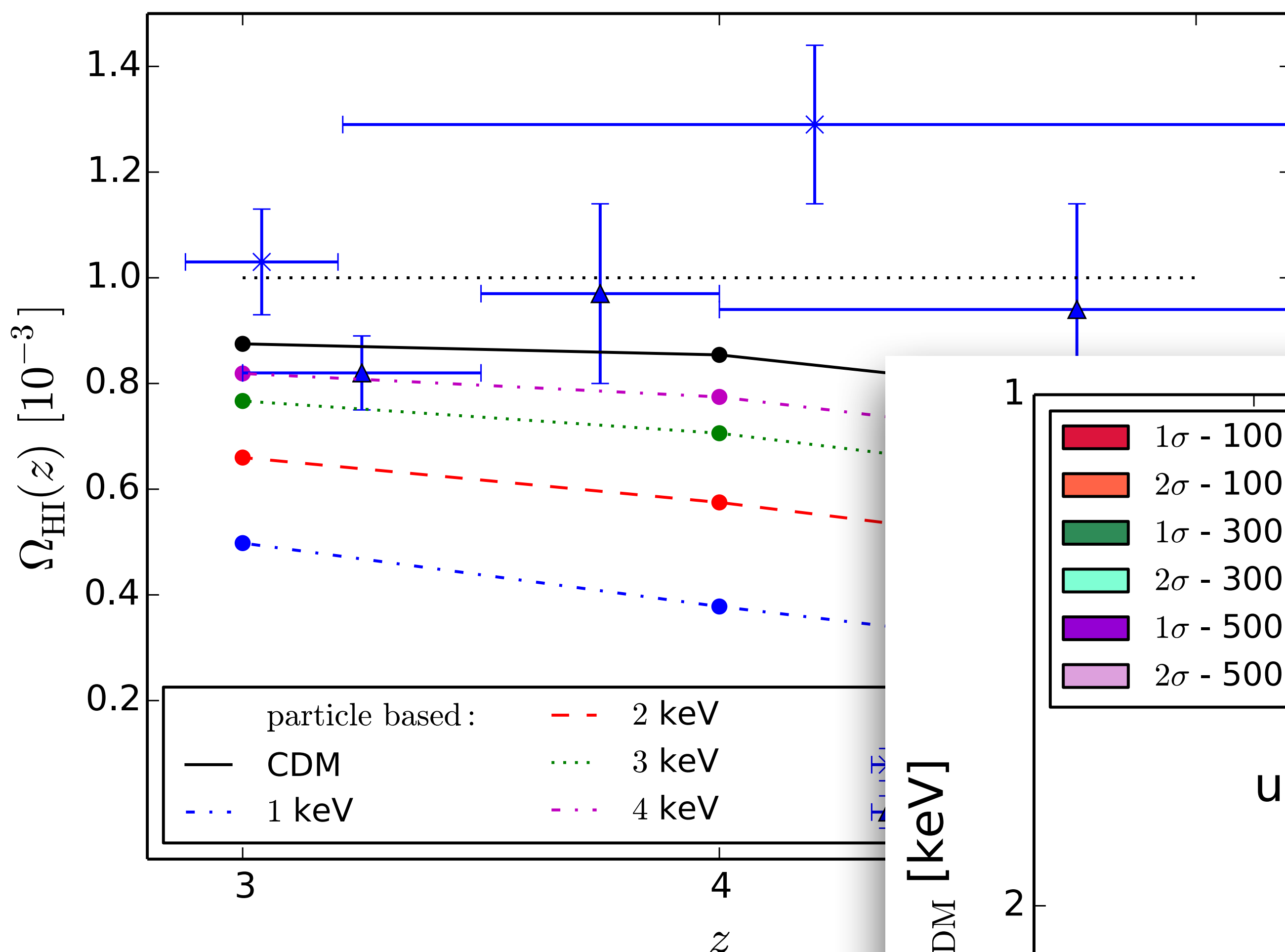
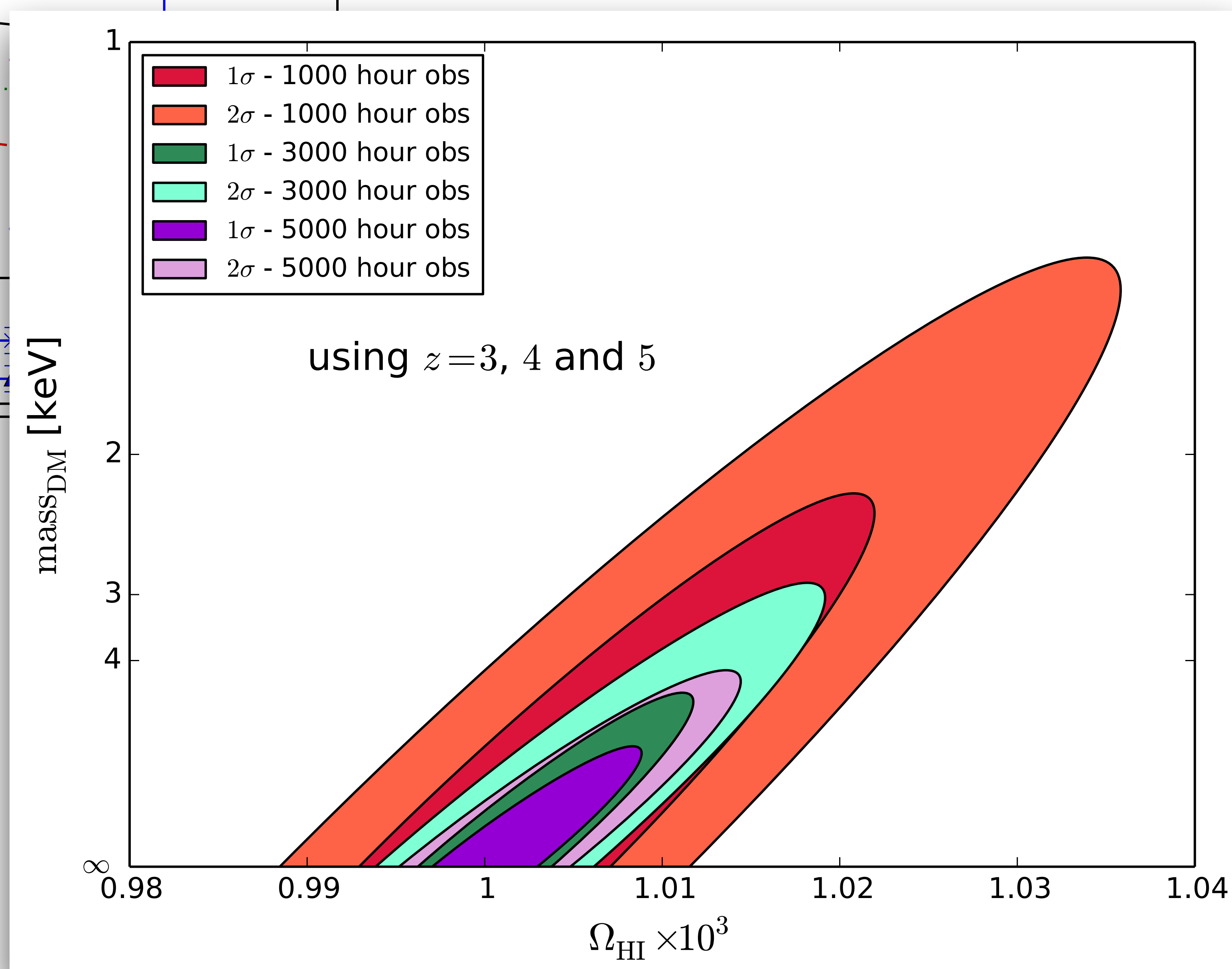


fisher matrix analysis



reference model

- $\Omega_{HI} = 10^{-3}$
- $m_{DM} = \infty$ (CDM)

summary

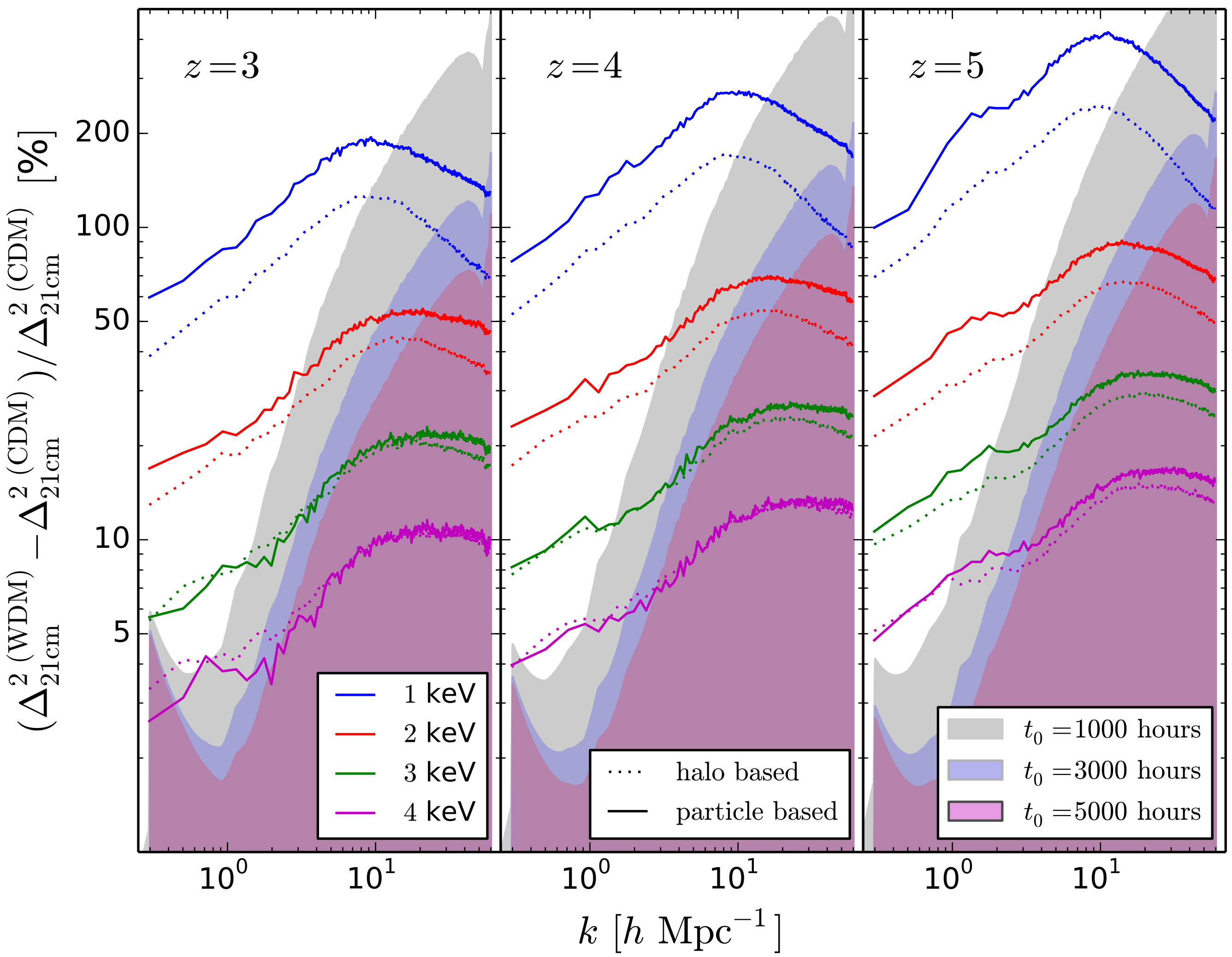
we investigated the impact of WDM on the 21cm intensity mapping in the post-reionization era (z = 3 - 5)

- hydro sims for 5 different models,

  CDM + WDM (1, 2, 3, 4keV)

- assignment of HI a-posteriori

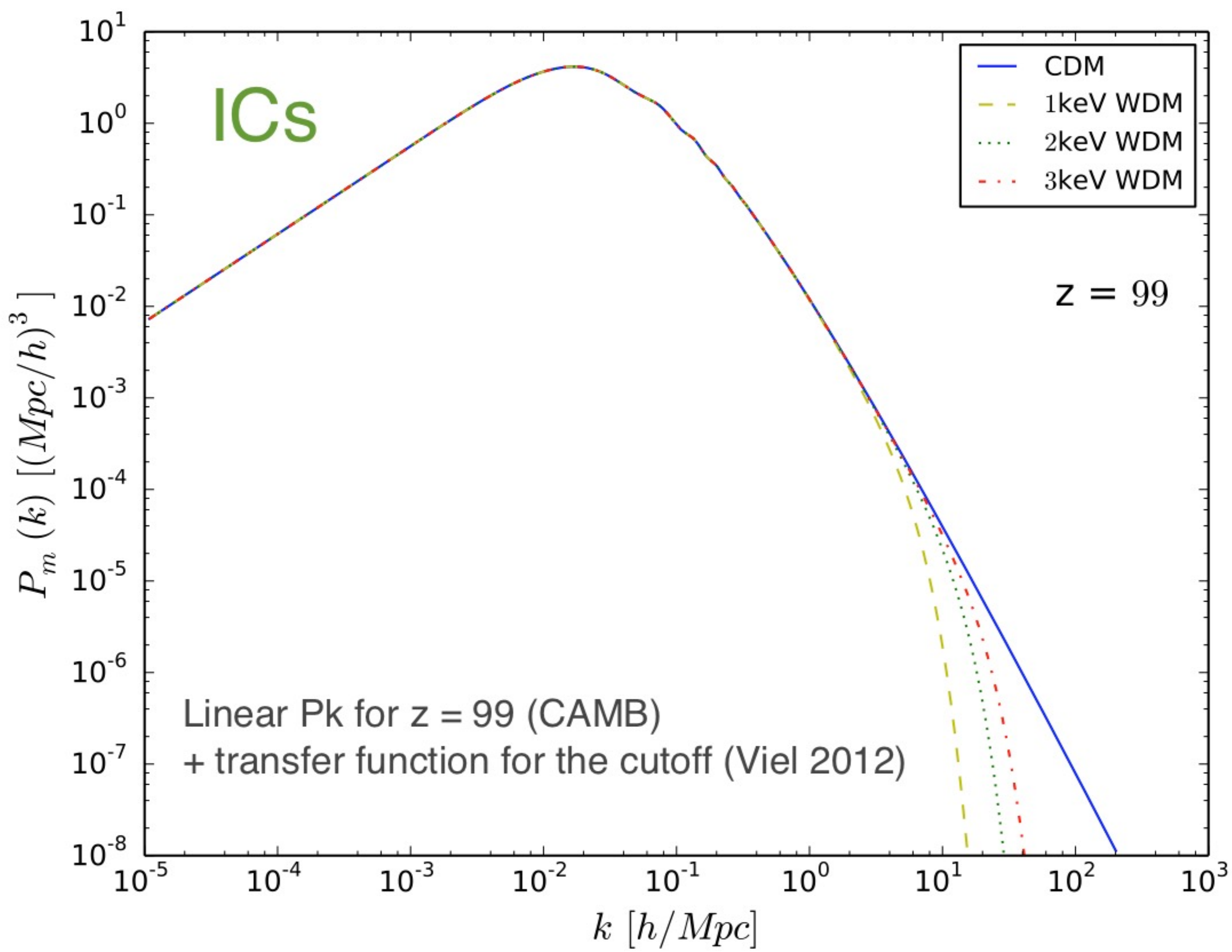
  (halo + particle based methods)



The suppression on power in the matter power spectra results in an increase of power in the terms of the HI and hence the 21cm power spectra (SKA forecasts).

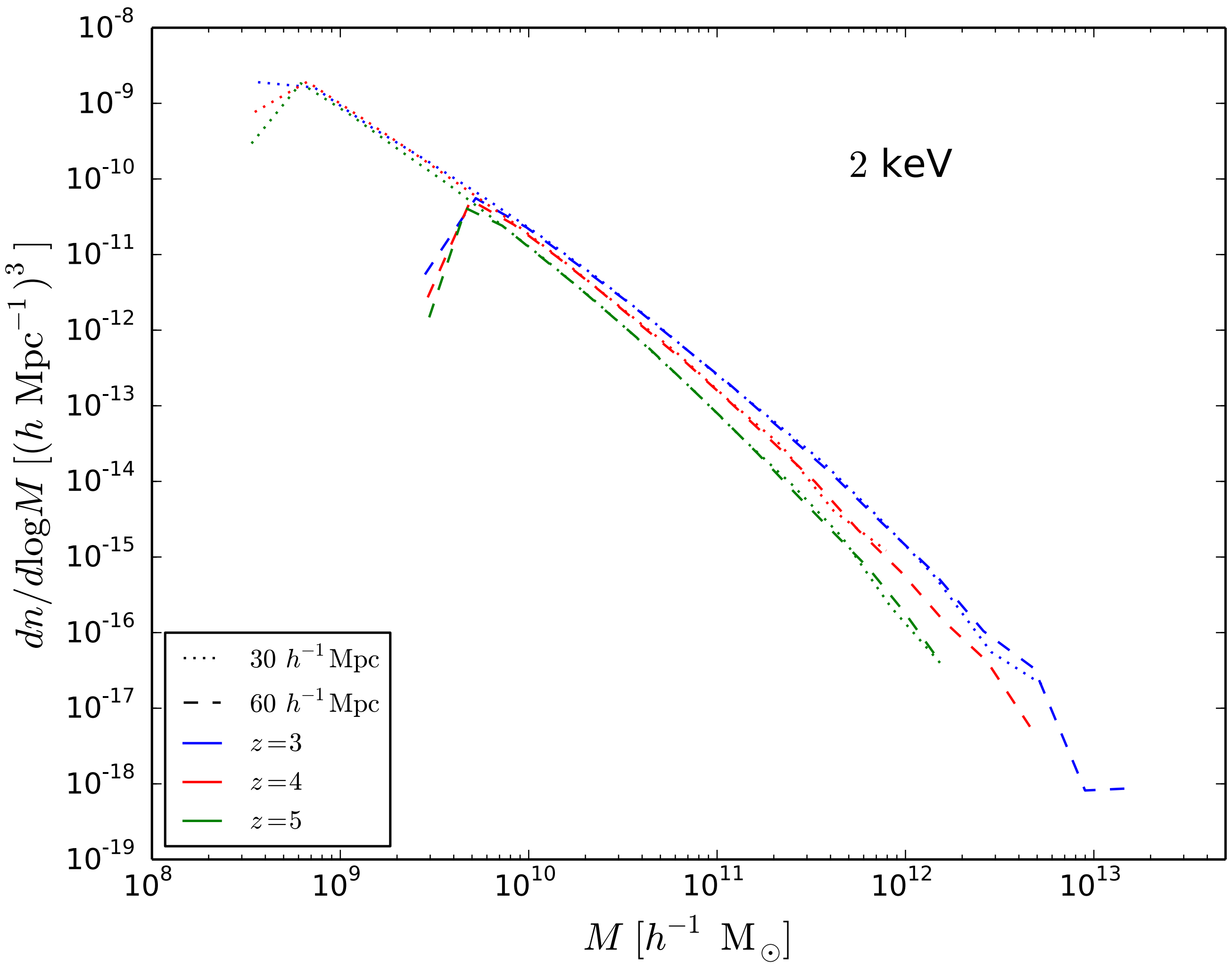
thanks!

simulation ICs



Halo mass function

Number of massive halos



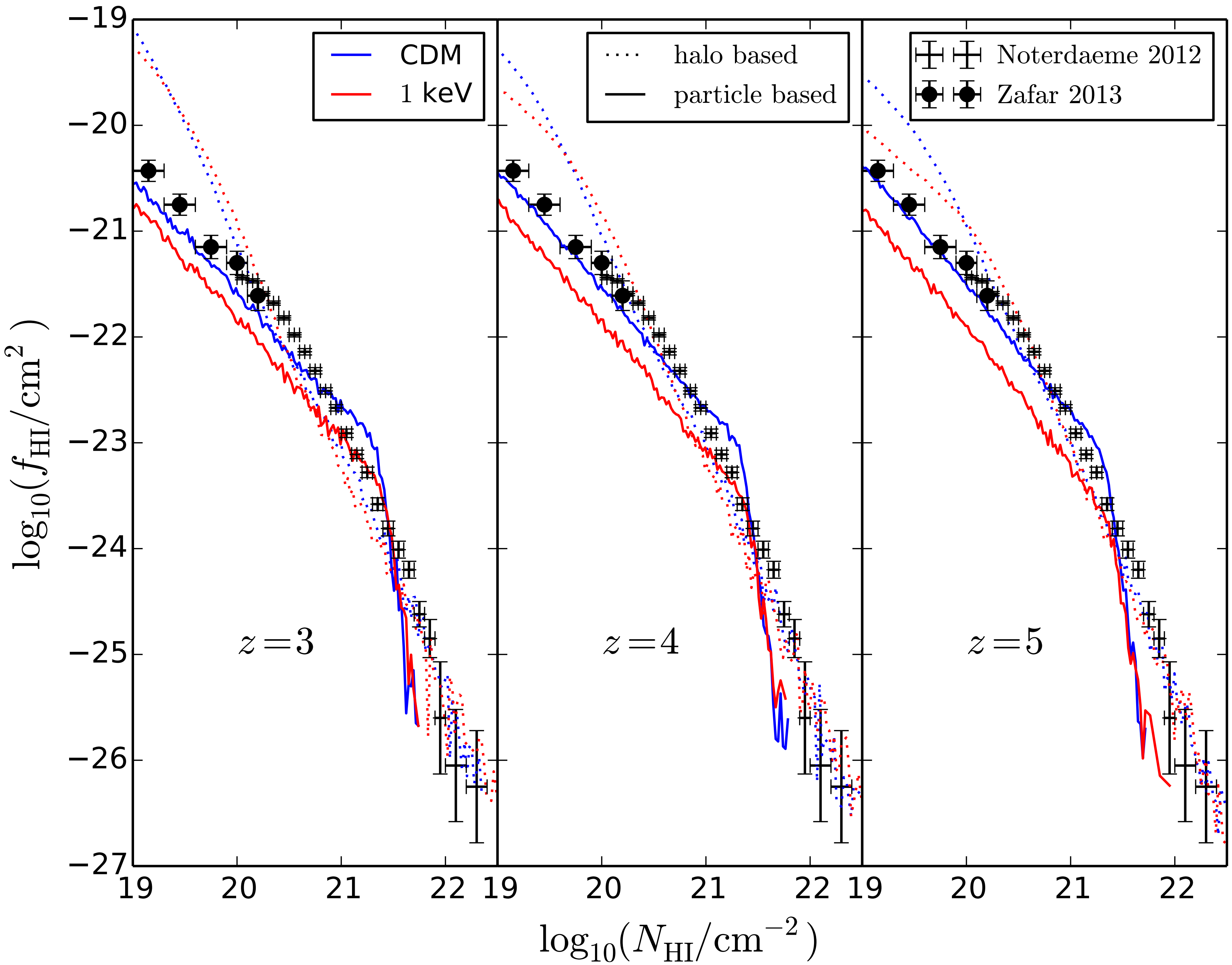
Do we have spurious fragmentation?

$$\frac{dn^{\mathrm{sim}}_{\mathrm{WDM}}}{d\log M}(M) = \frac{dn^{\mathrm{ST}}_{\mathrm{WDM}}}{d\log M}(M)\left[1 - \alpha e^{-M/M_0}\right] ,$$

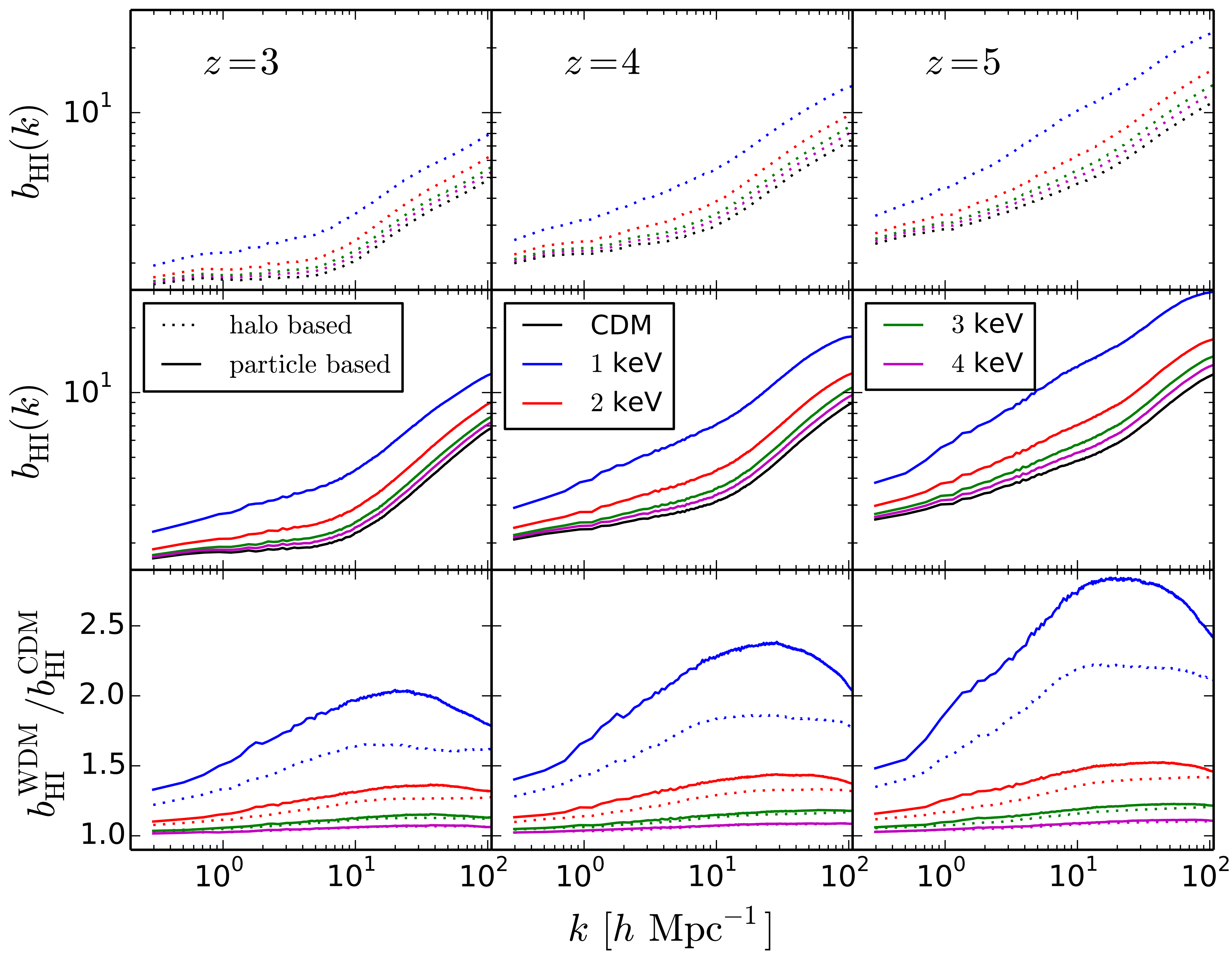
m_{WDM} [keV]	z	α	$M_0\ [10^9\ h^{-1}\mathrm{M}_\odot]$
1	3	-1.72	0.887
	4	-1.92	0.960
	5	-2.06	0.737
2	3	0.571	3.98
	4	0.389	3.80
	5	0.286	4.81
3	3	0.830	1.86
	4	0.726	1.28
	5	0.427	1.74
4	3	0.958	1.44
	4	1.04	0.890
	5	0.522	1.05
∞	3	1.26	1.04
	4	2.77	0.491
	5	1.69	0.455

testing the HI modelling

HI column density distribution function



the HI bias: $b^2_{HI}(k) = P_{HI}(k)/P_m(k)$



matter clustering properties reflected by HI?