Constraining Sterile Neutrinos with the Lyman α forest

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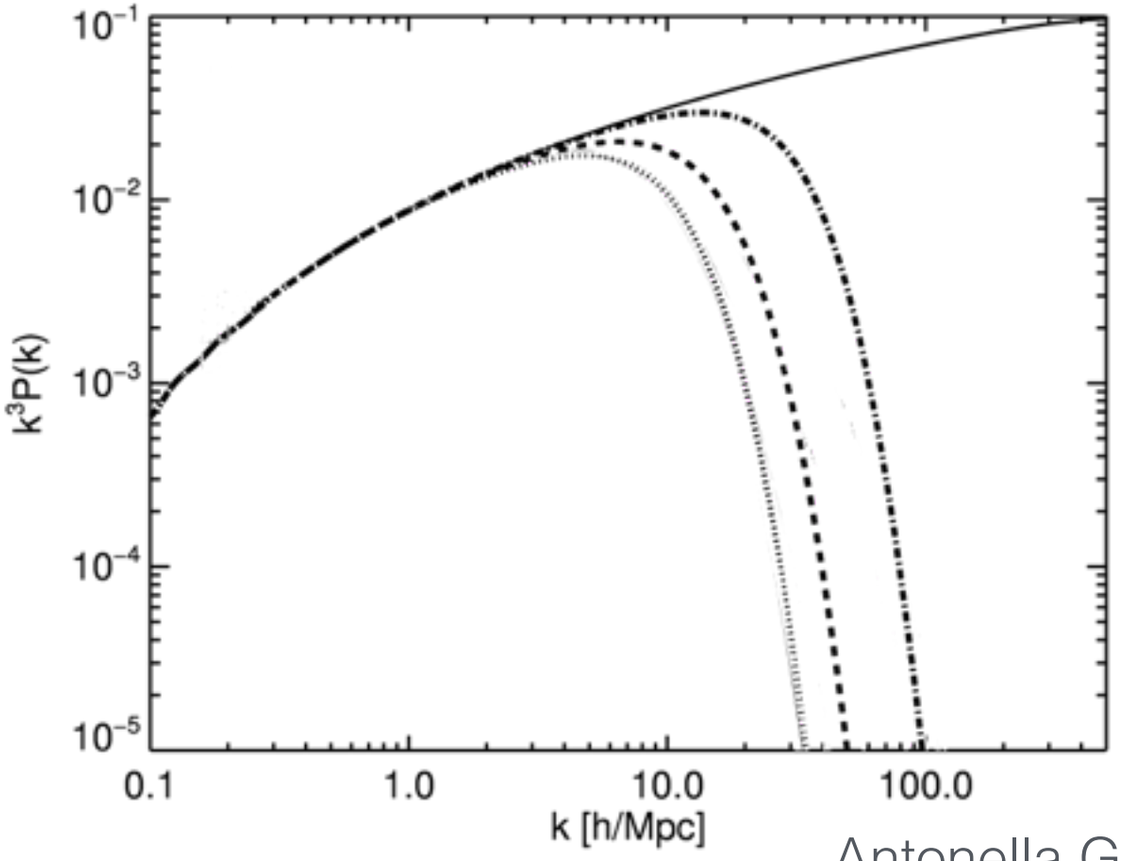
Thanks to: Matteo Viel

HDM WDM CDM

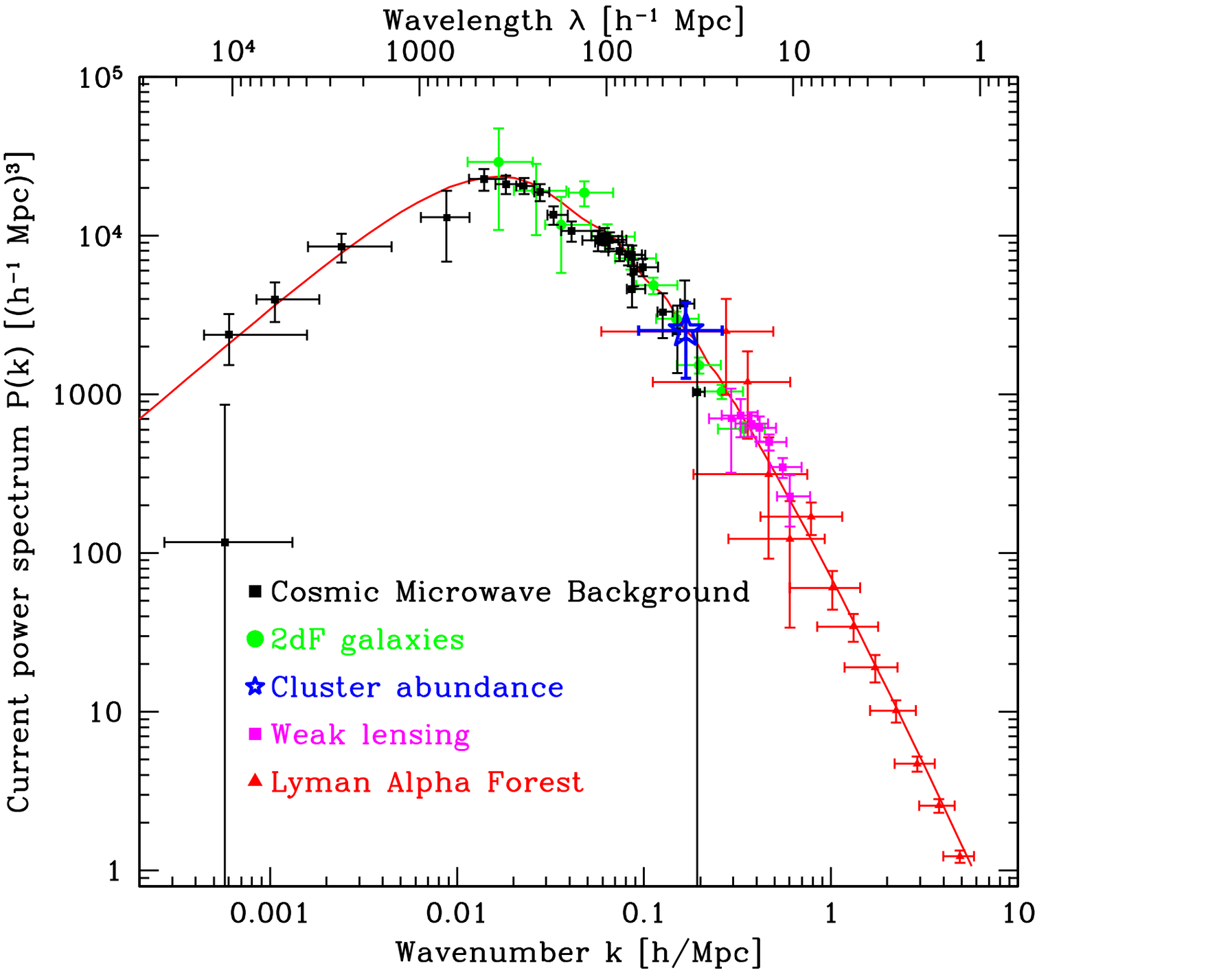
(Moore, Maccio' et al)



CDM: the particles were created/ decoupled non-relativistic

WDM: particles were created/decoupled relativistic, but became non-relativistic in the radiation-dominated epoch

HDM: particles were created relativistic, became non-relativistic around the matter-dominated epoch



(Tegmark & Zaldarriaga 2002)

Intergalactic medium

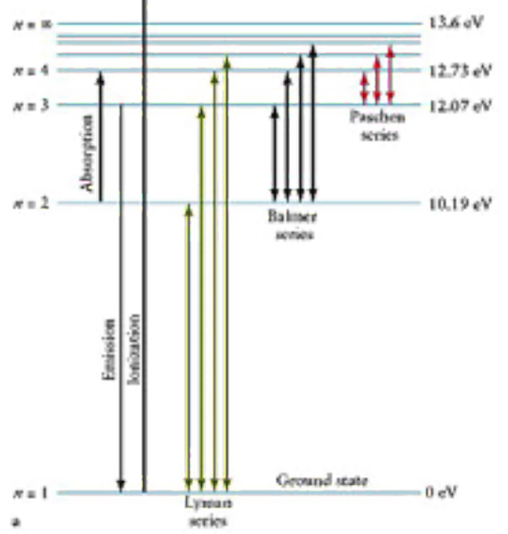
(Schaye et al 2015)

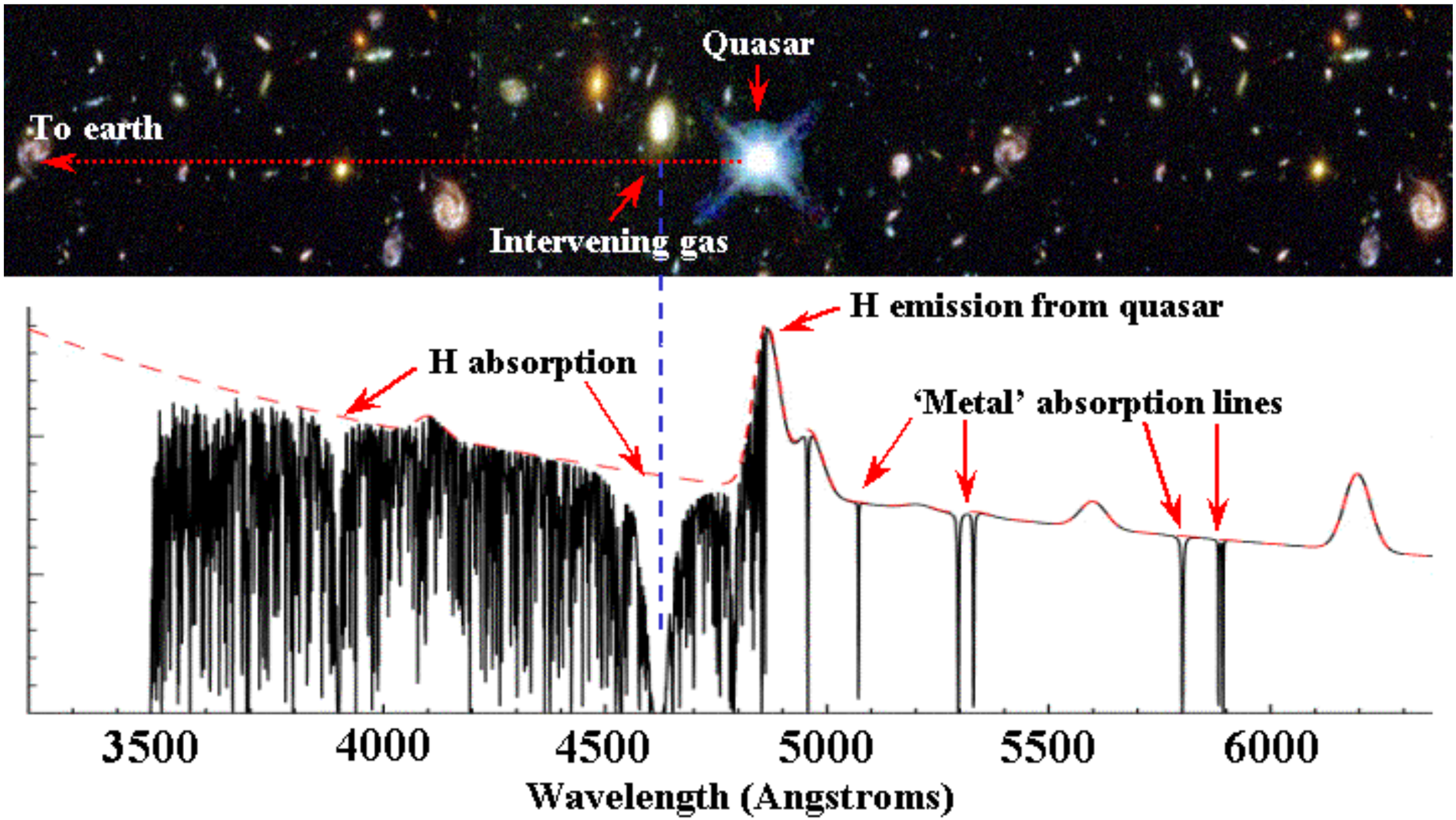
Intergalactic medium

(Schaye et al 2015)

Lyman-α forest

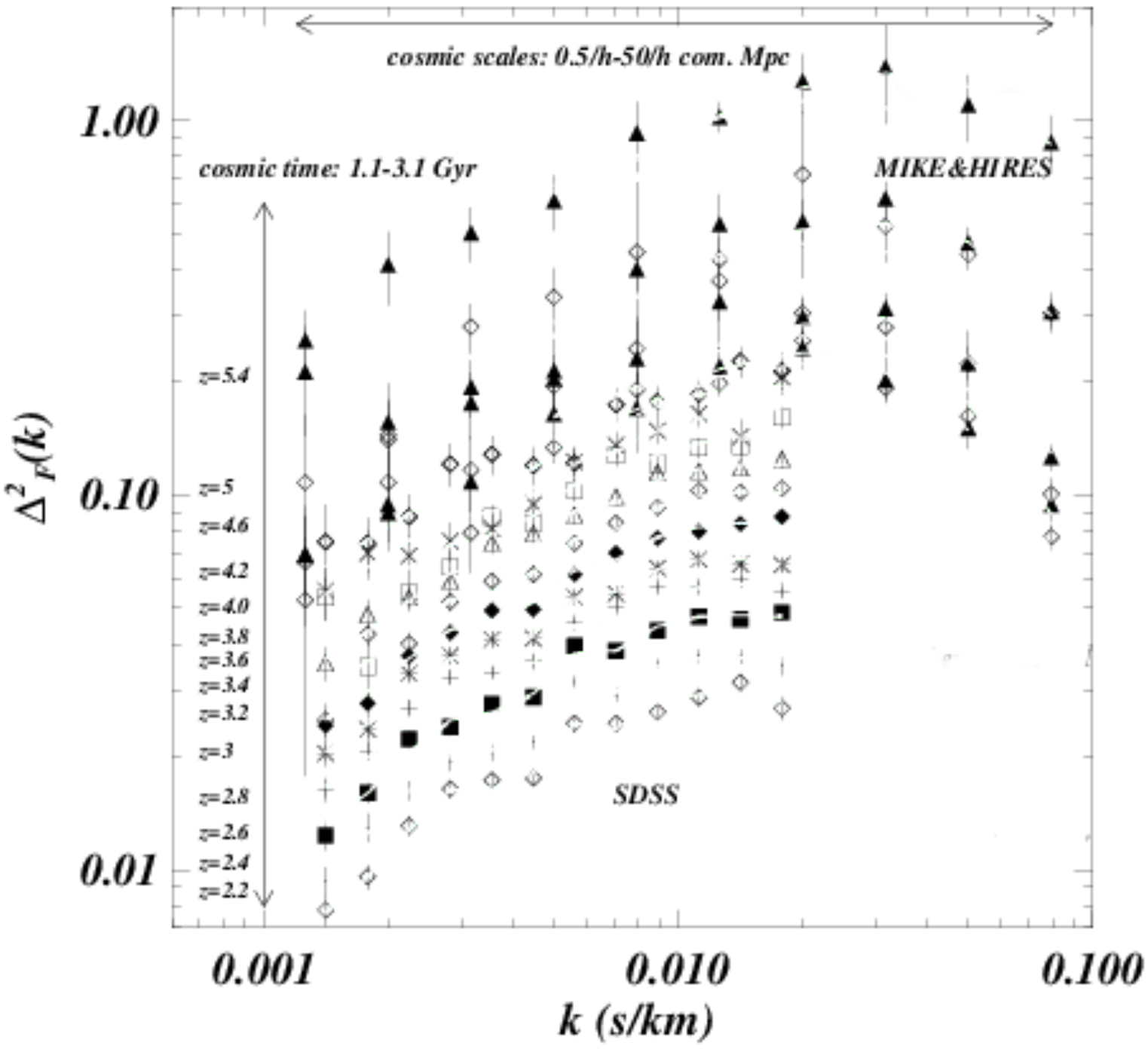
$$\lambda_\alpha = 1216\text{Å}$$





Previous constraints on WDM from the Lyman-α forest

(Viel et al, 2013)



SDSS
(Seljak et al 2006)
(Viel et al 2005)
(Viel et al 2006)
(Boyarsky et al 2009)

$$m_{\rm WDM} \gtrsim 2\,{\rm keV}$$

MIKE & HIRES
(Viel et al, 2013)

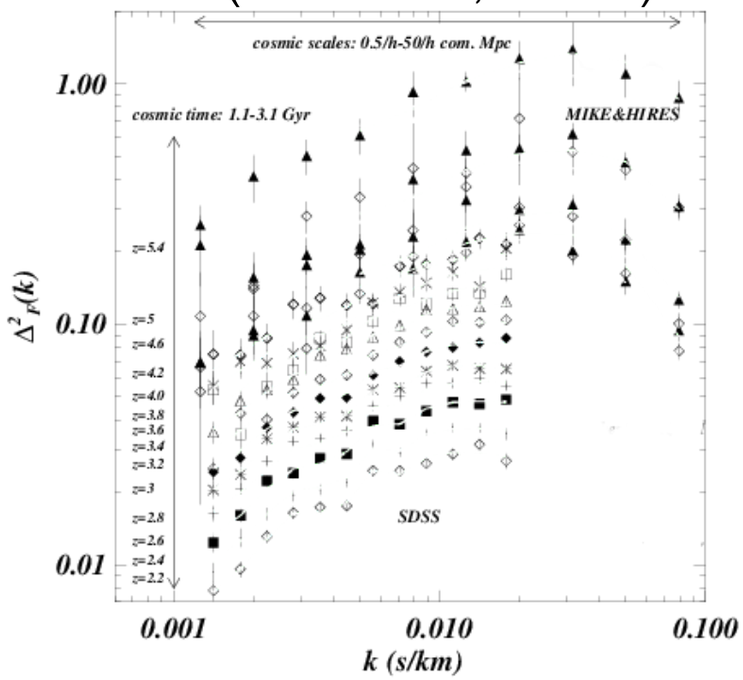
$$m_{\rm WDM} \gtrsim 3.3\,{\rm keV}$$

SDSS-III/BOSS
(Baur et al 2015)

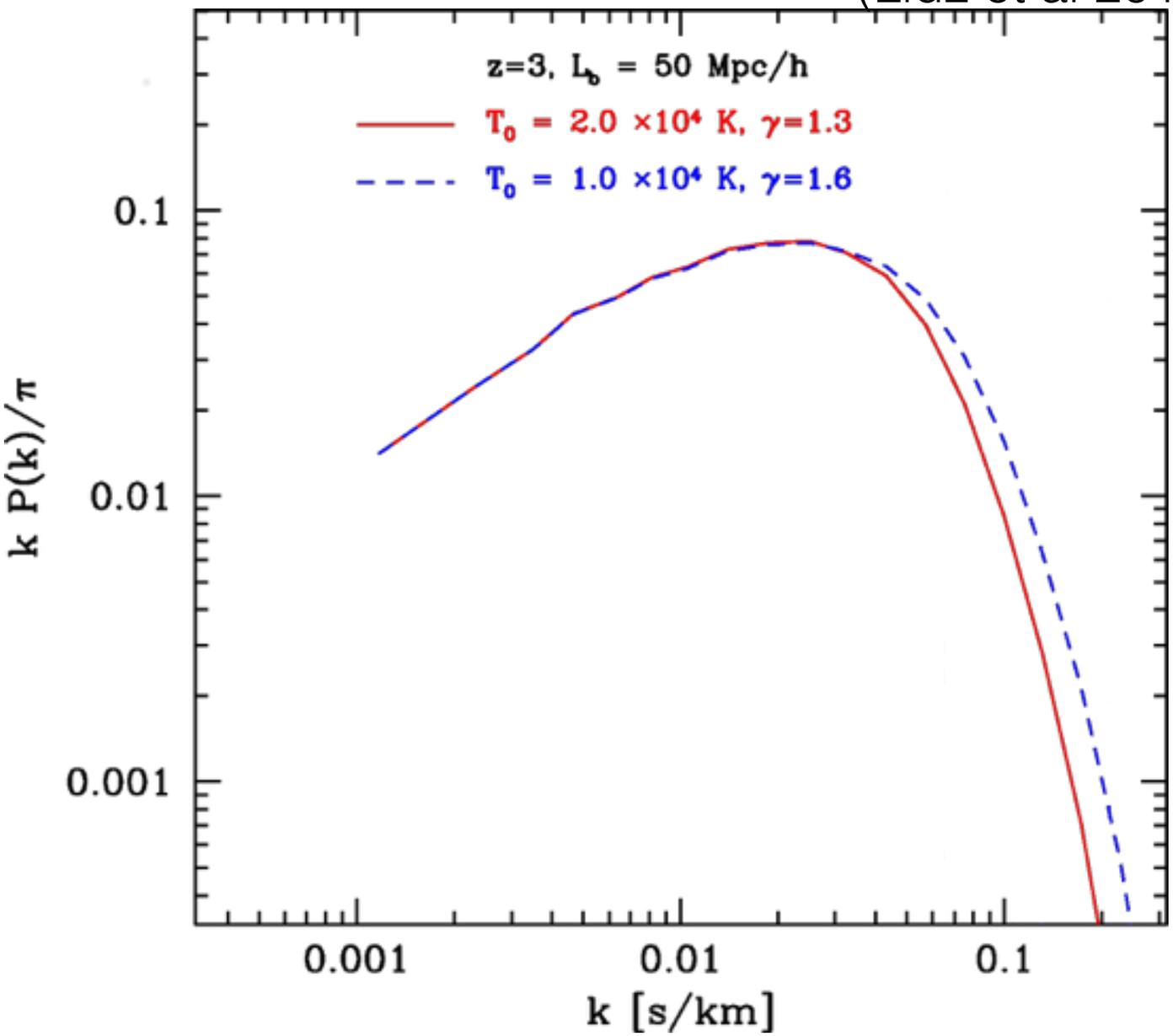
$$m_{\rm WDM} \gtrsim 4.35\,{\rm keV}$$

WDM or IGM temperature?

(Viel et al, 2013)



(Lidz et al 2010)

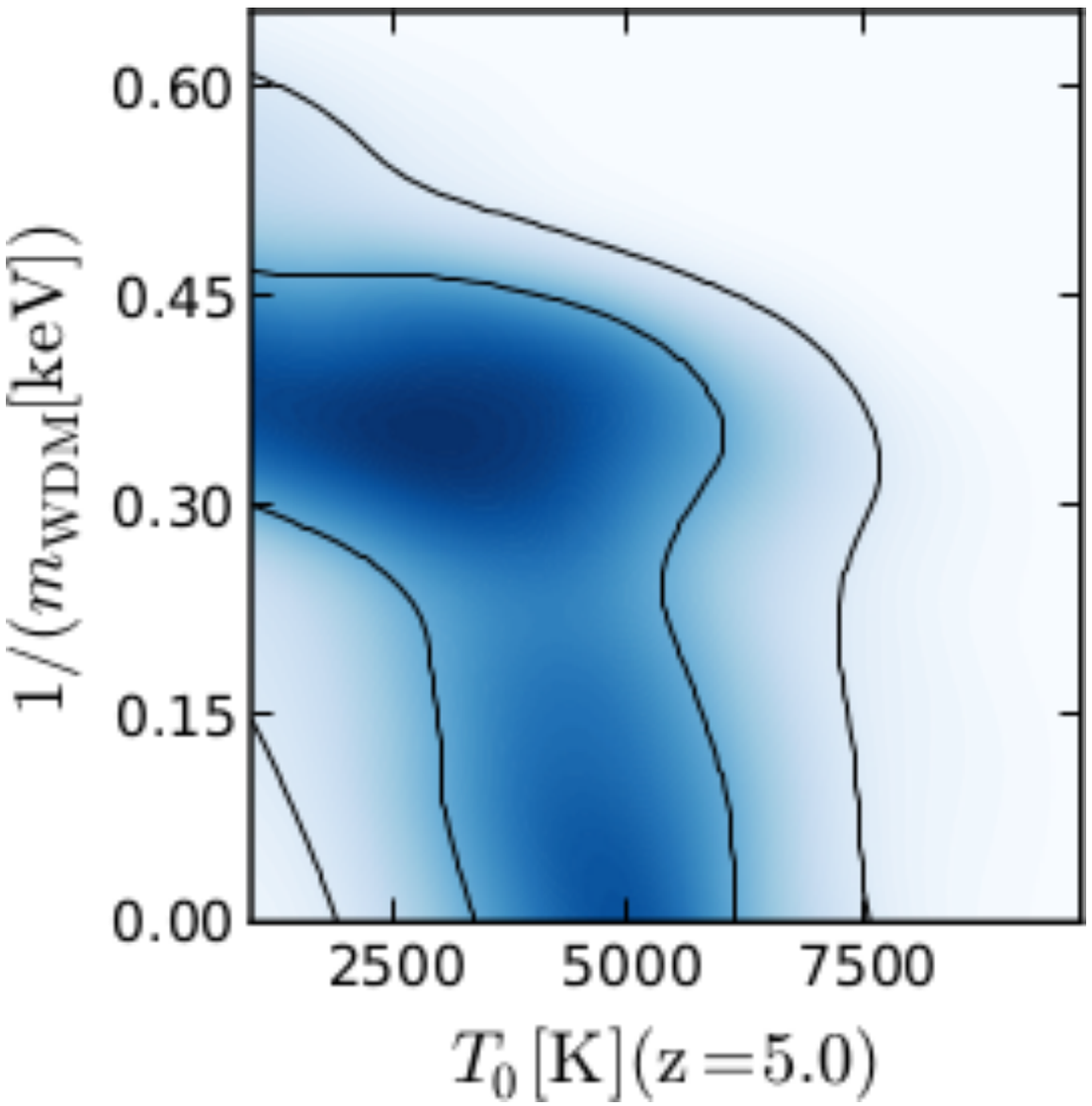


The flux power spectrum at small scales is affected by:

- temperature of the IGM (1D effect)
- pressure (3D)

(Gnedin & Hui 1998)
(Theuns, Schaye & Haehnelt 2000)

Our reanalysis of (Viel et al 2013)

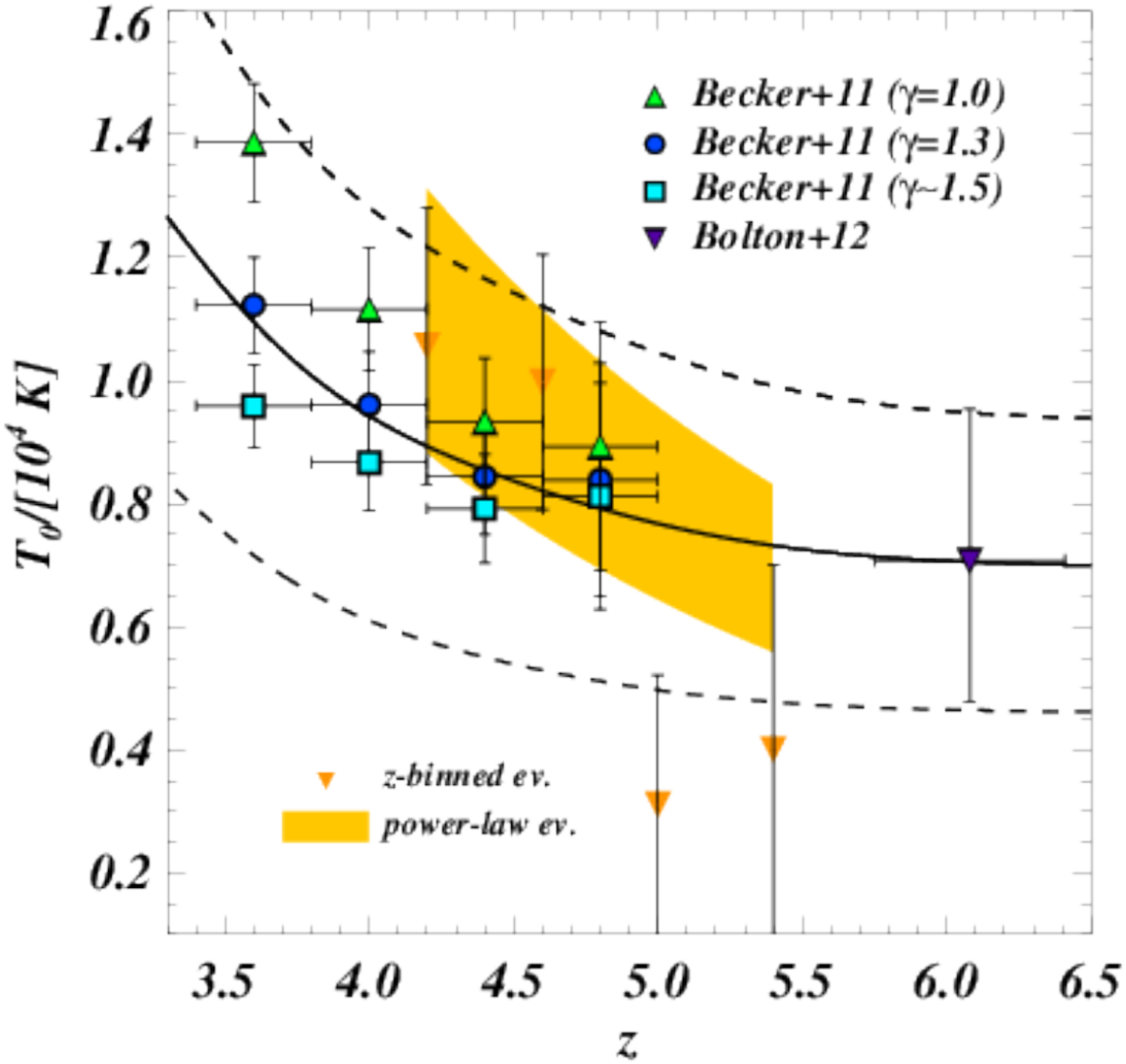


- Exactly same Likelihood function
- Different priors range

$$m_{\rm WDM} \gtrsim 2\,{\rm keV}$$

same limit as from SDSS

IGM thermal history



- Missing satellite problem -> high redshift temperature $\sim 10^4\,\mathrm{K}$

  WDM suppresses small structures
- Hardness of primordial stars

  We do not actually know how long they last
- Agreement with other measurements of IGM temperature

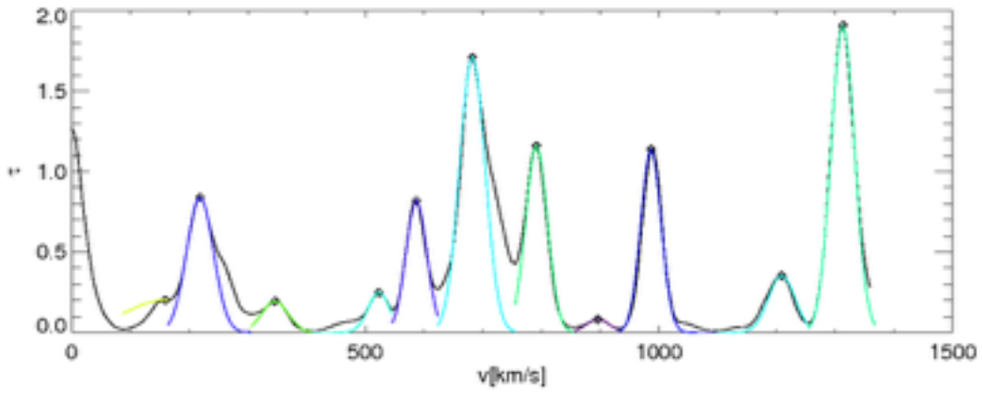
  We agree with a early HeII reionization

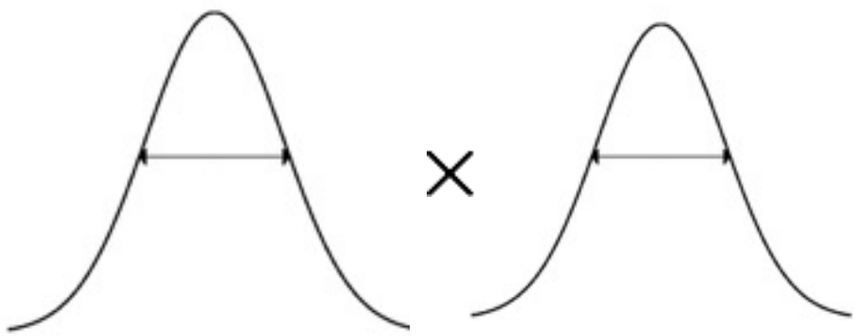
About Methodology

- Bayesian analysis depends on assumption on priors
- It is not clear that a power law in temperature is a good assumption
- The high redshift data could be affected by systematics,

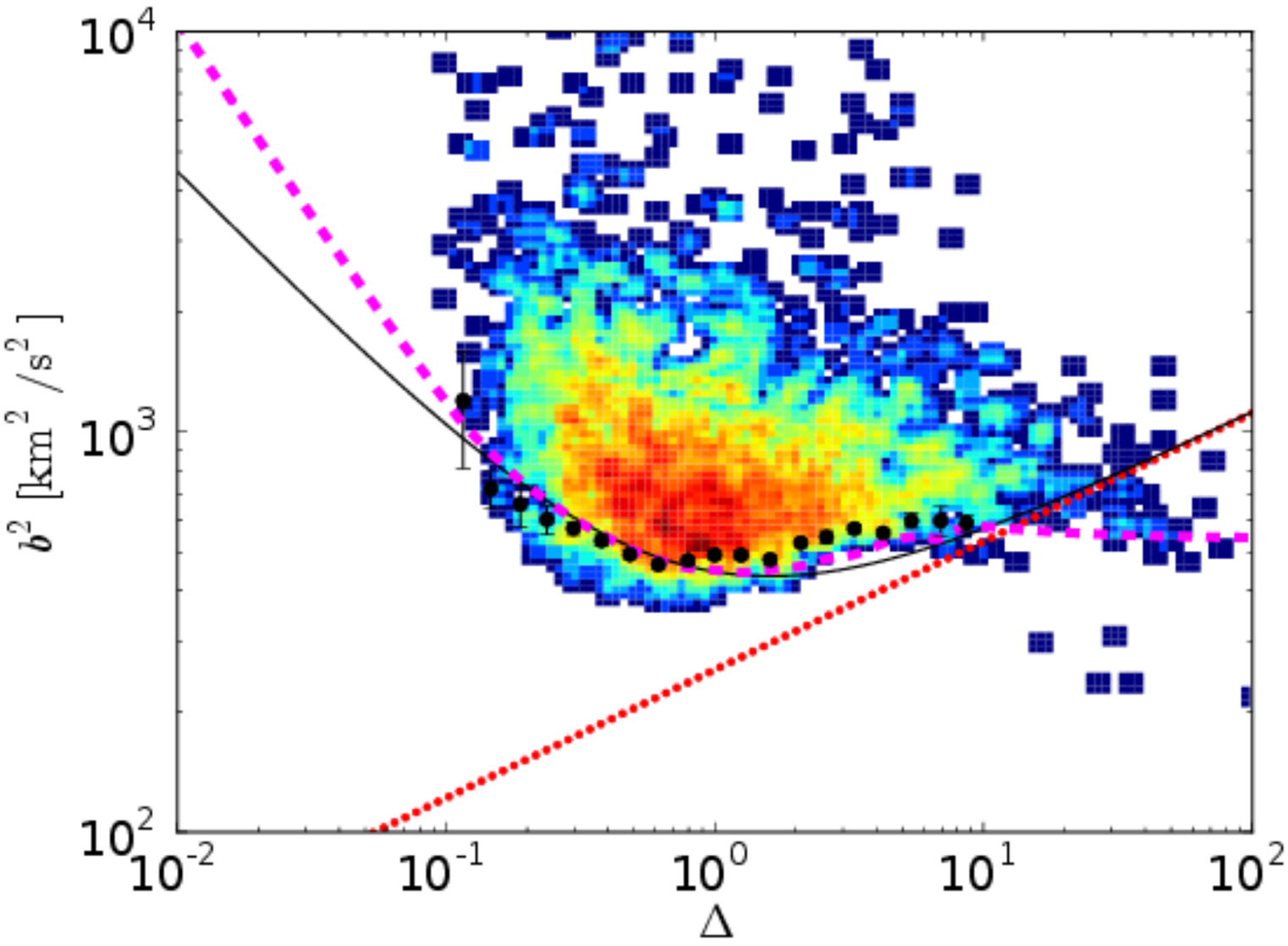
  as pointed out by (Becker et al 2015)

IGM temperature from line broadening



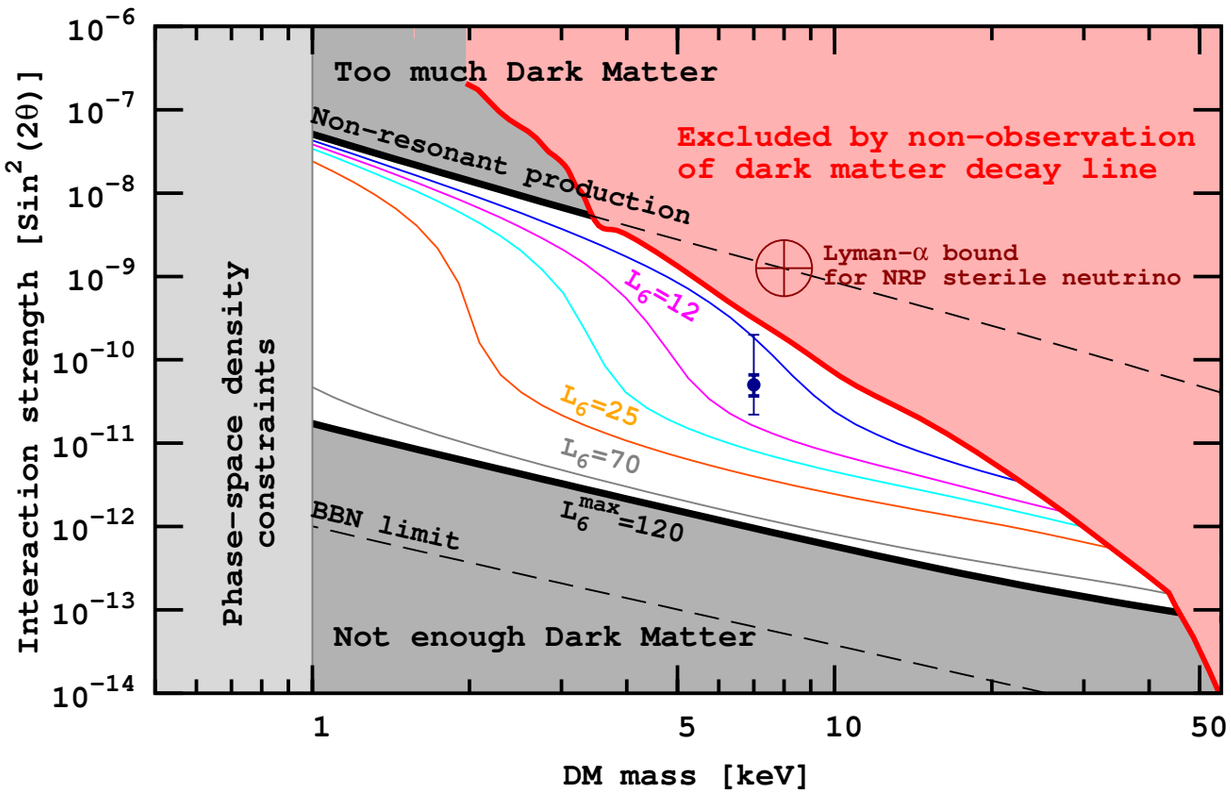


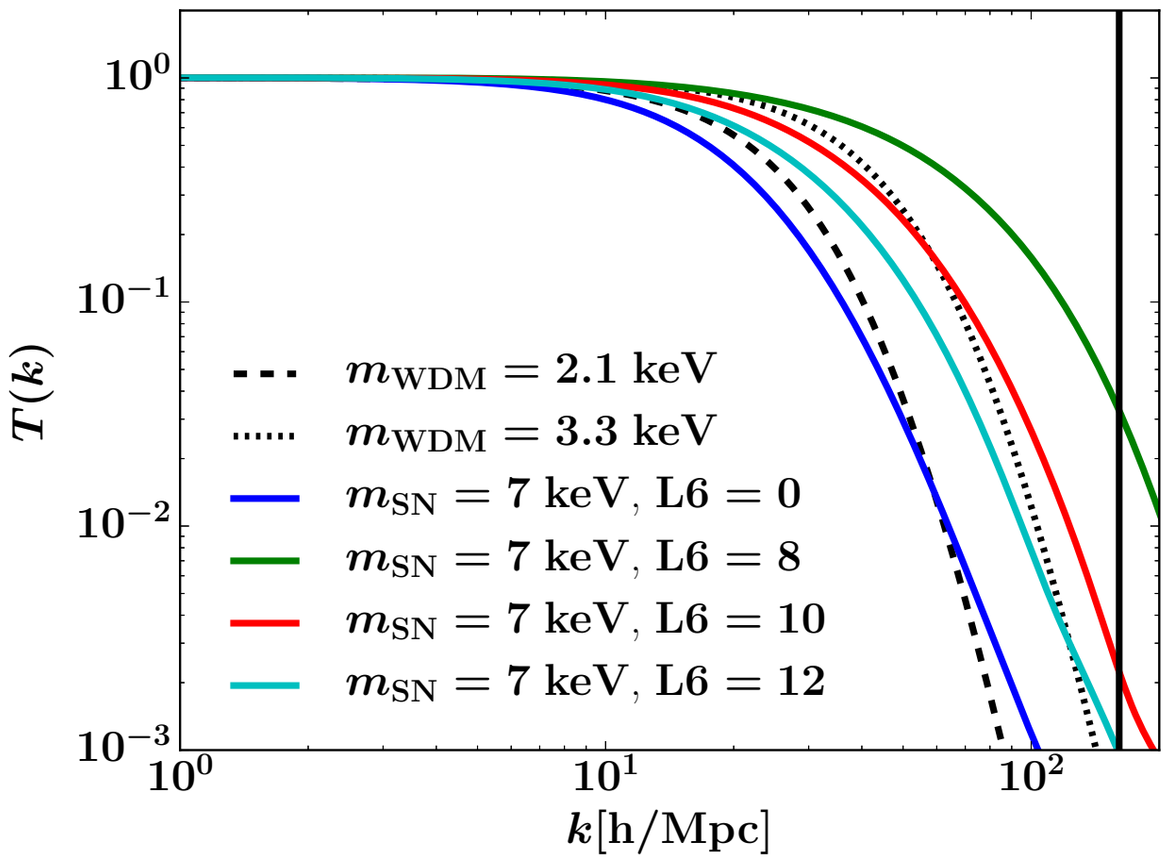
$$\sqrt{\frac{2k_BT}{m_{\rm H}}} \qquad H(z)\lambda_F$$



Garzilli, Theuns, Schaye MNRAS 450, 2 (2015)

Conclusions





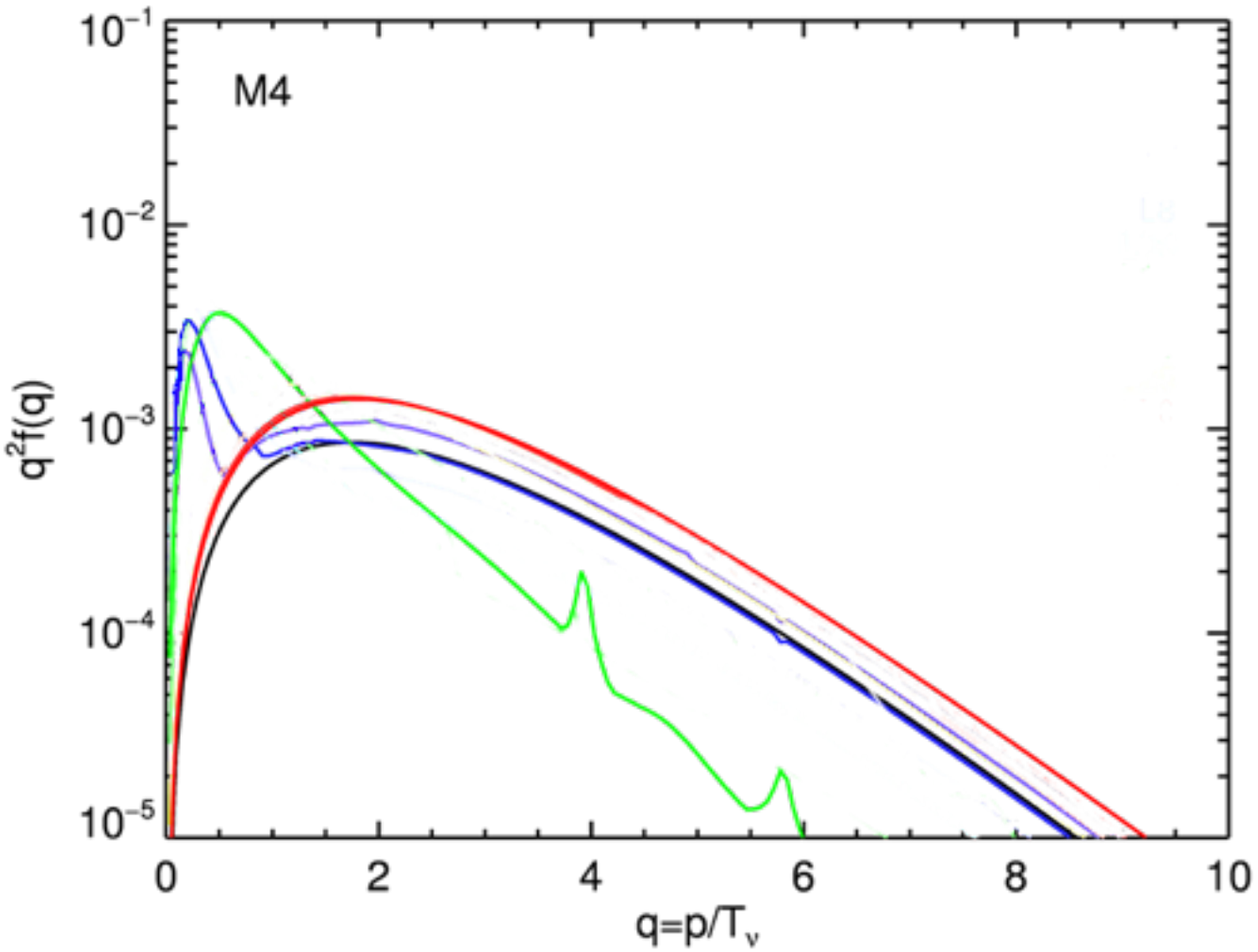
$m_{\rm SN} = 7\,{\rm keV}$ is motivated by the recent report of X-ray line at energy $E = 3.5\,{\rm keV}$

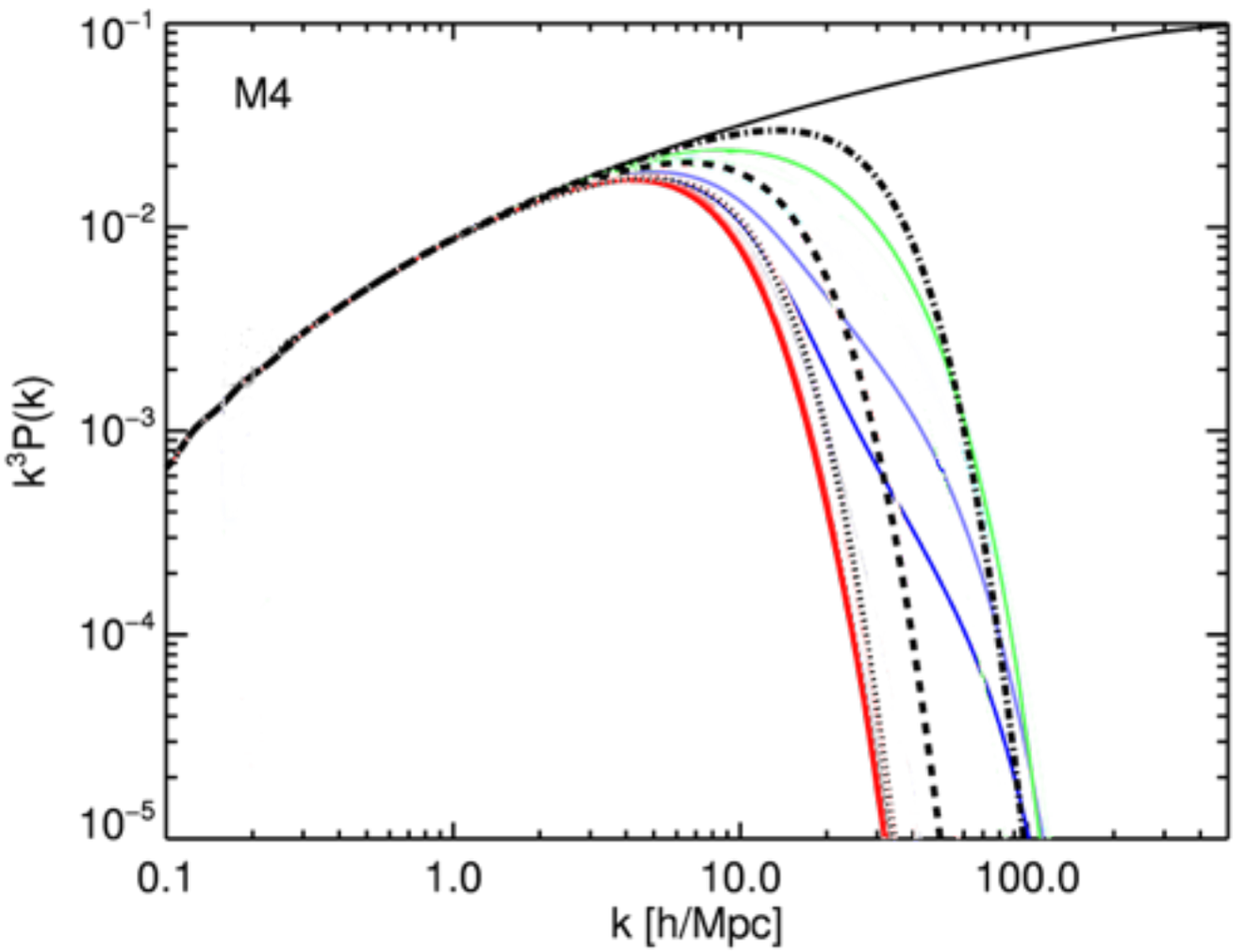
(Bulbul et al 2014)
(Boyarsky et al 2014)

Other slides

Warm Dark Matter and Sterile Neutrinos

(Laine & Shaposhnikov 2008)
(Mark Lovell)

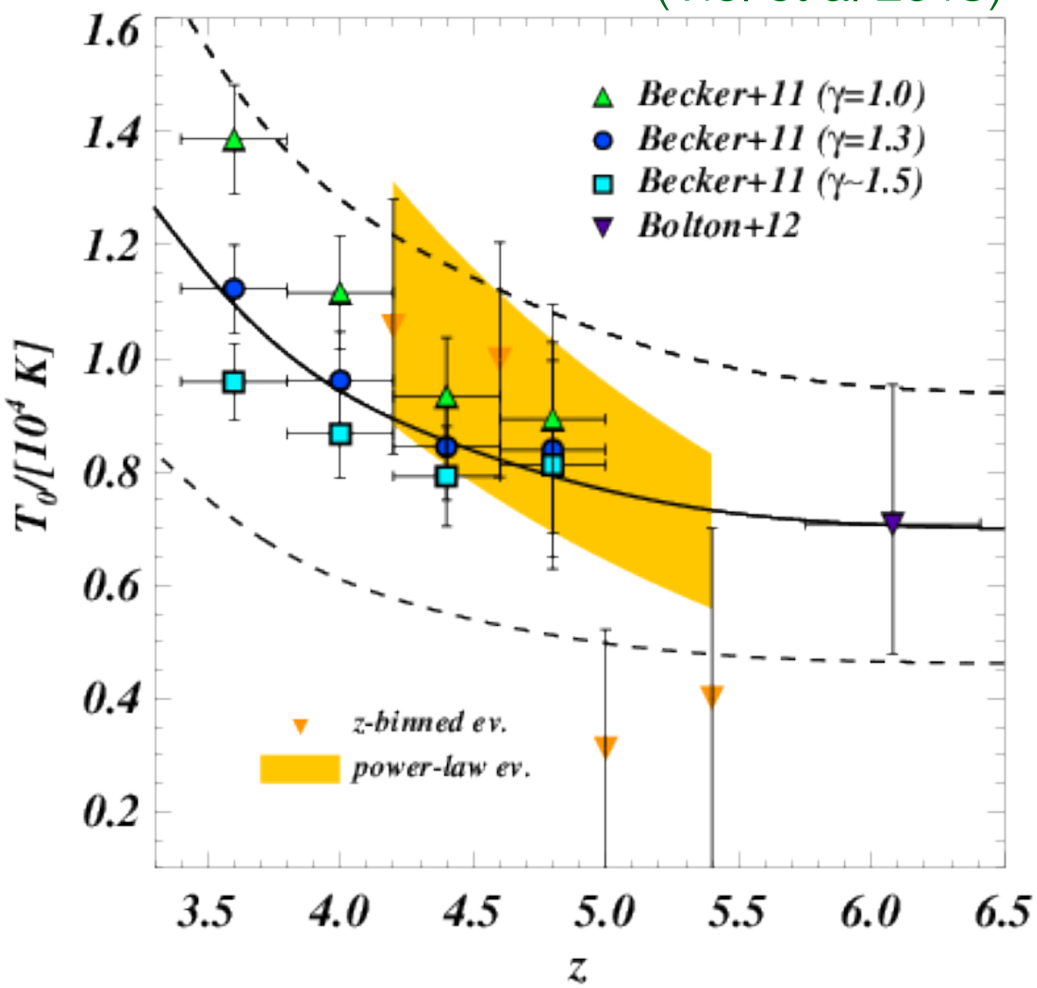




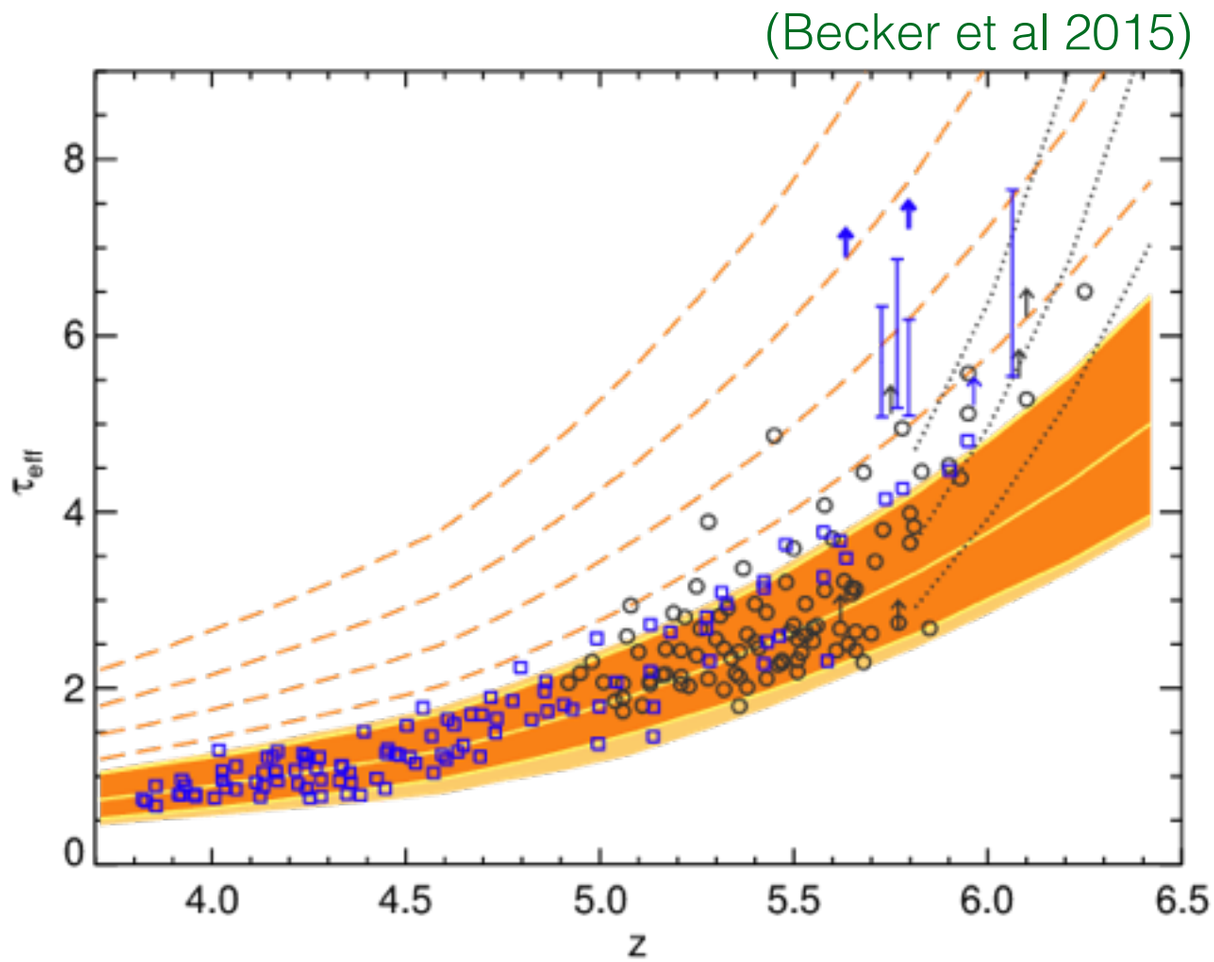
(Viel et al, 2005) $m^{NRP}_{\mathrm{sterile}\nu} = 4.43\,\mathrm{keV}\left(\frac{m_{\mathrm{thermal}}}{1\,\mathrm{keV}}\right)^{4/3}\left(\frac{0.12}{\Omega_\nu h^2}\right)^{1/3}$

Low temperature or *large optical depth*

(Viel et al 2013)

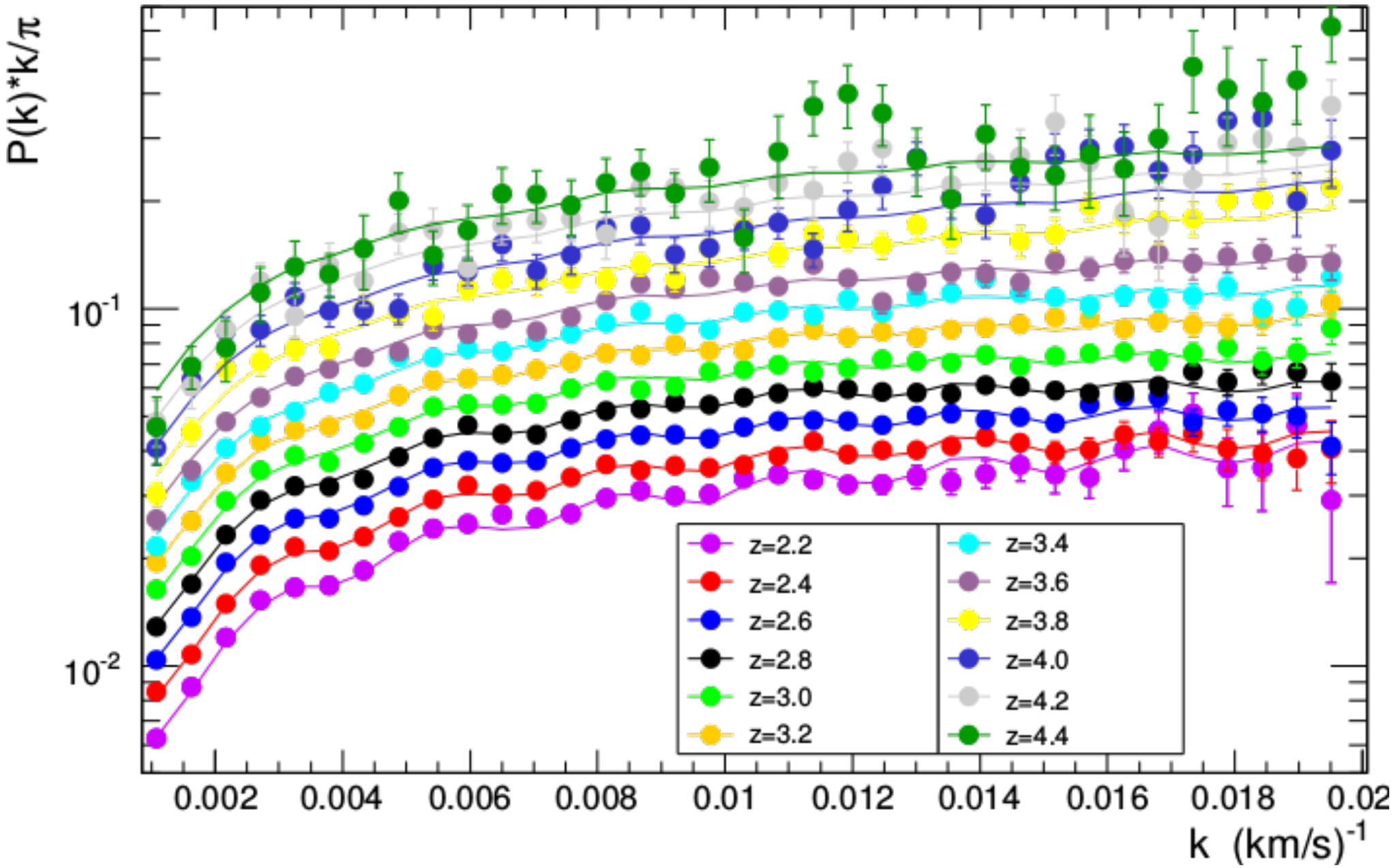


(Becker et al 2015)



- *Jump in temperature at z=5.0 agrees with HeII reionization*
- *possible systematic in high redshift data*

Constraints from SDSS-III/BOSS



(Baur et al 2015)
(Palanque-Delabrouille et at 2015)