

Dark Matter and the 21-cm Global Signal



Julian B. Muñoz

Based on

arXiv:1509.00029

arXiv:1802.10094

arXiv:1804.01092

arXiv:1904.07868

arXiv:1904.07881

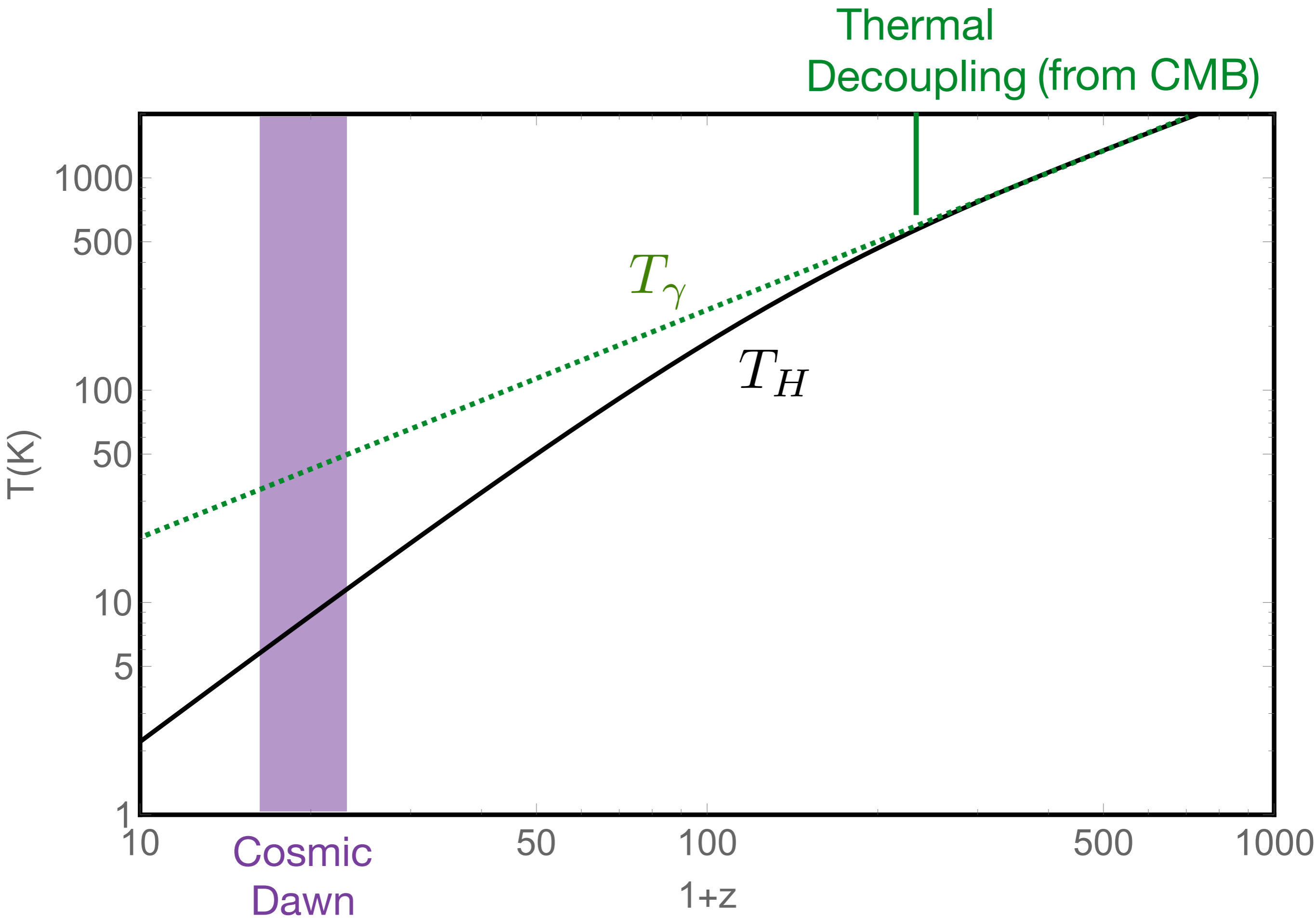
with

Yacine Ali-Haimoud

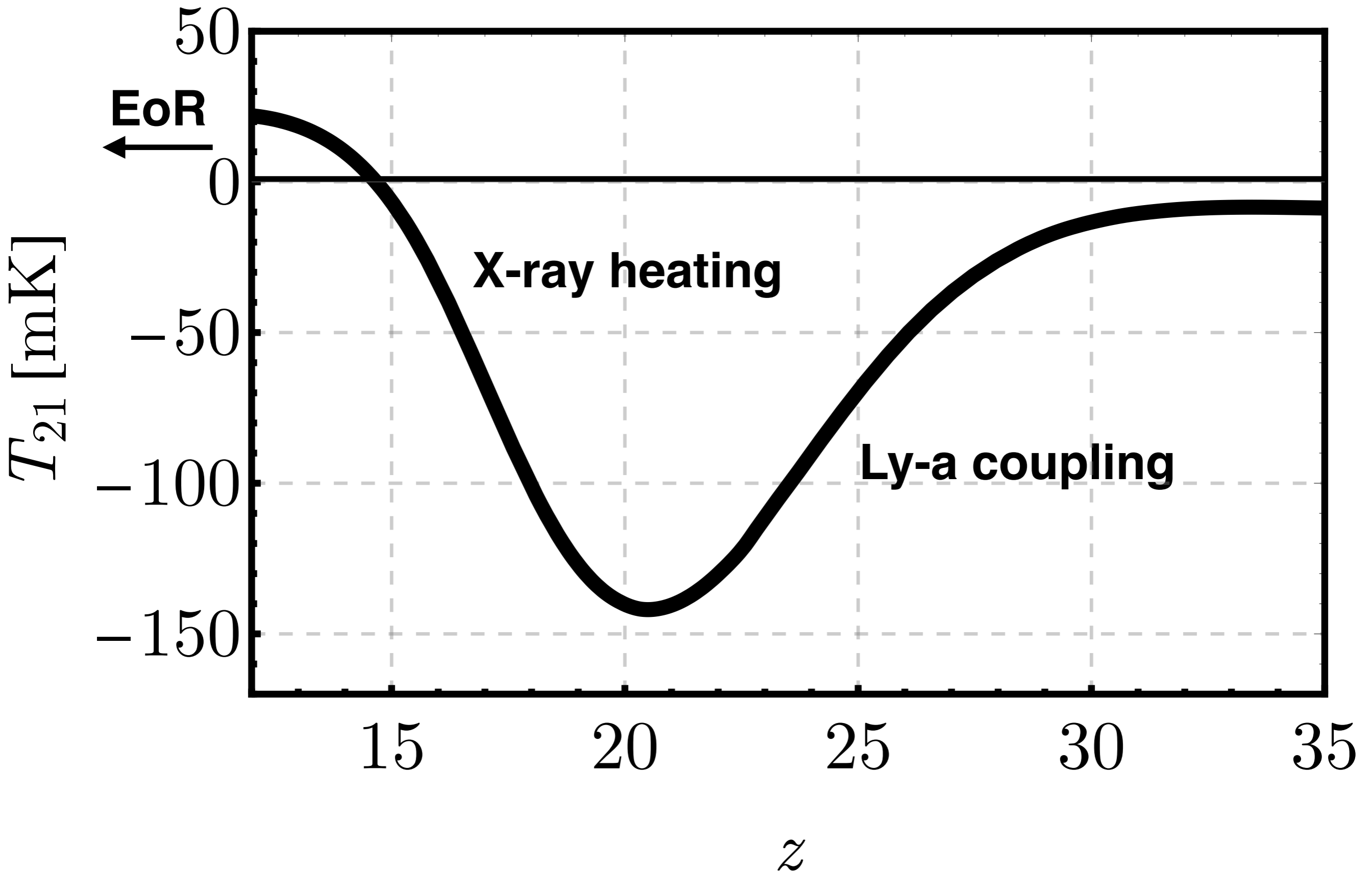
Cora Dvorkin

Avi Loeb

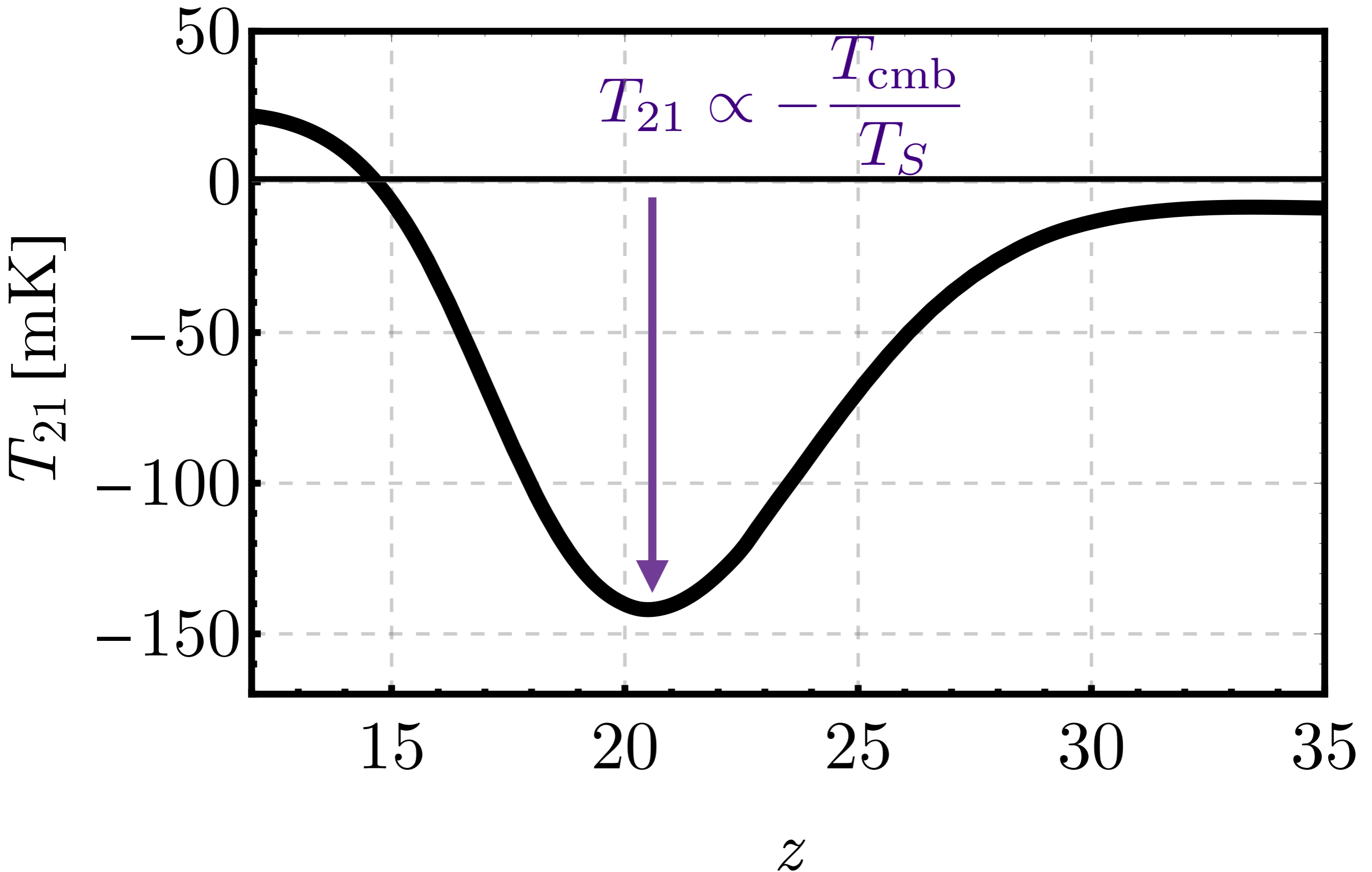
Ely Kovetz



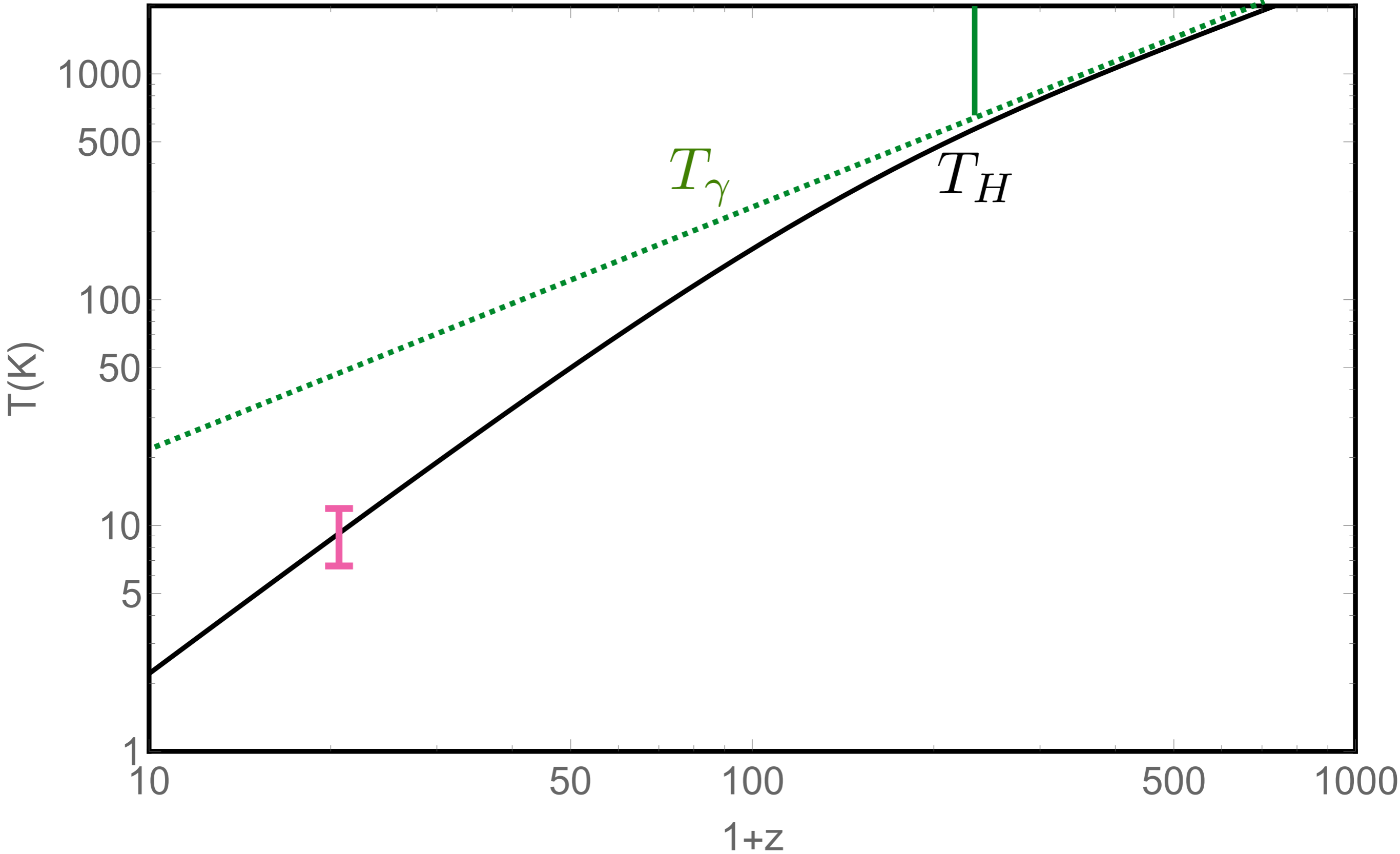
A typical 21-cm profile

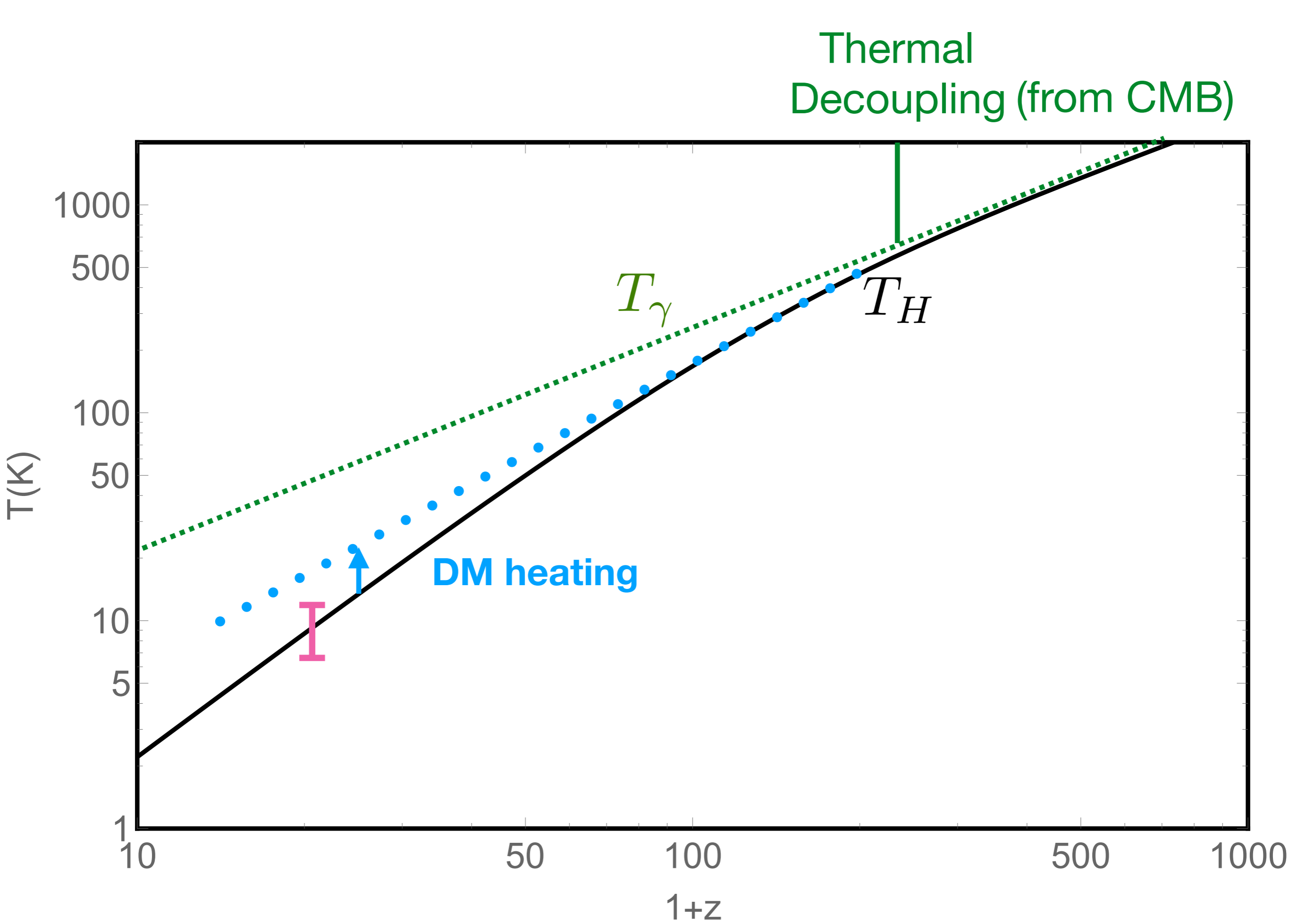


A thermostat at cosmic dawn



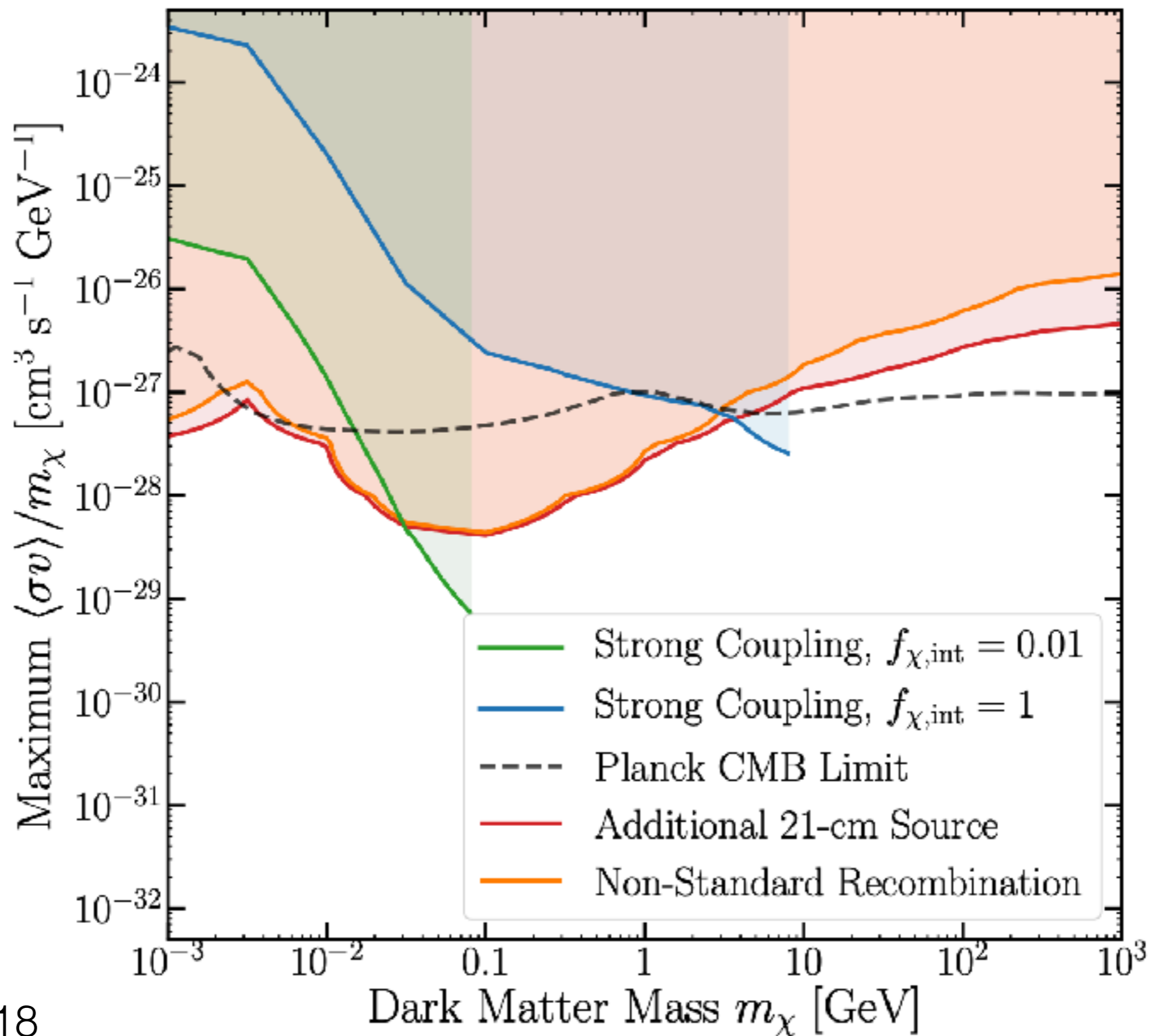
Thermal
Decoupling (from CMB)





Liu & Slatyer, 2018

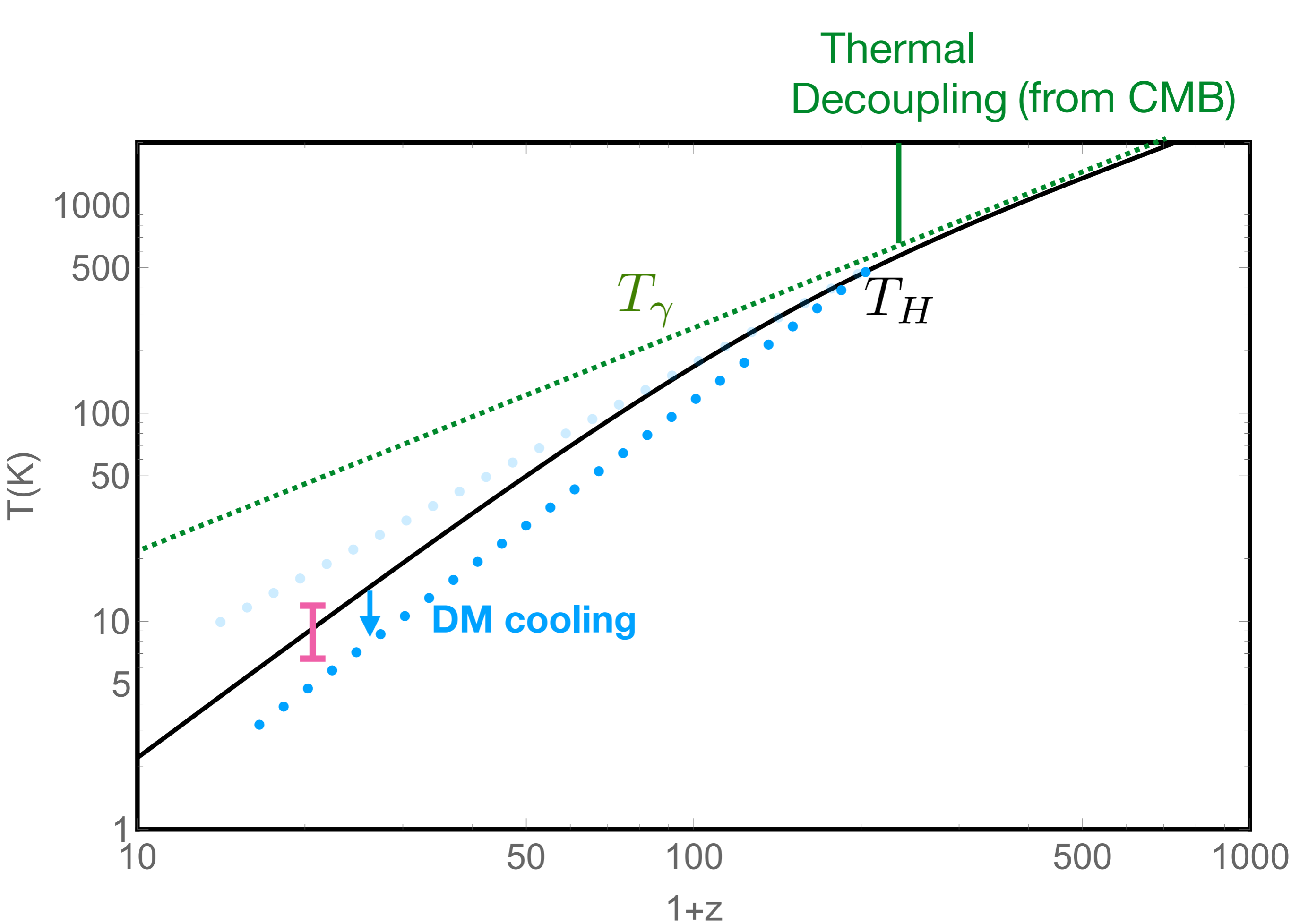
Combined Limits, $\chi\chi \rightarrow e^+e^-$



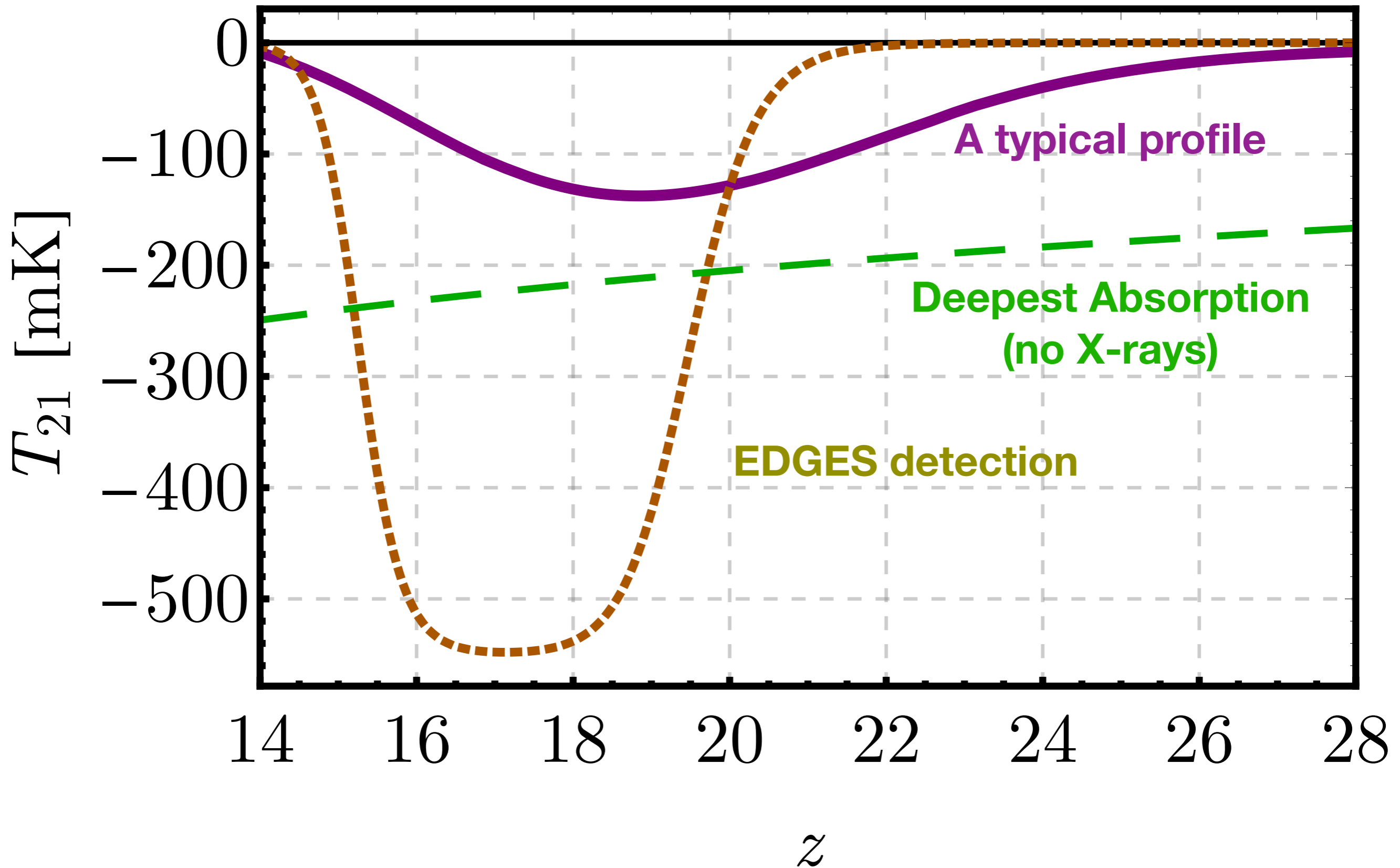
also:

D'Amico+ 2018

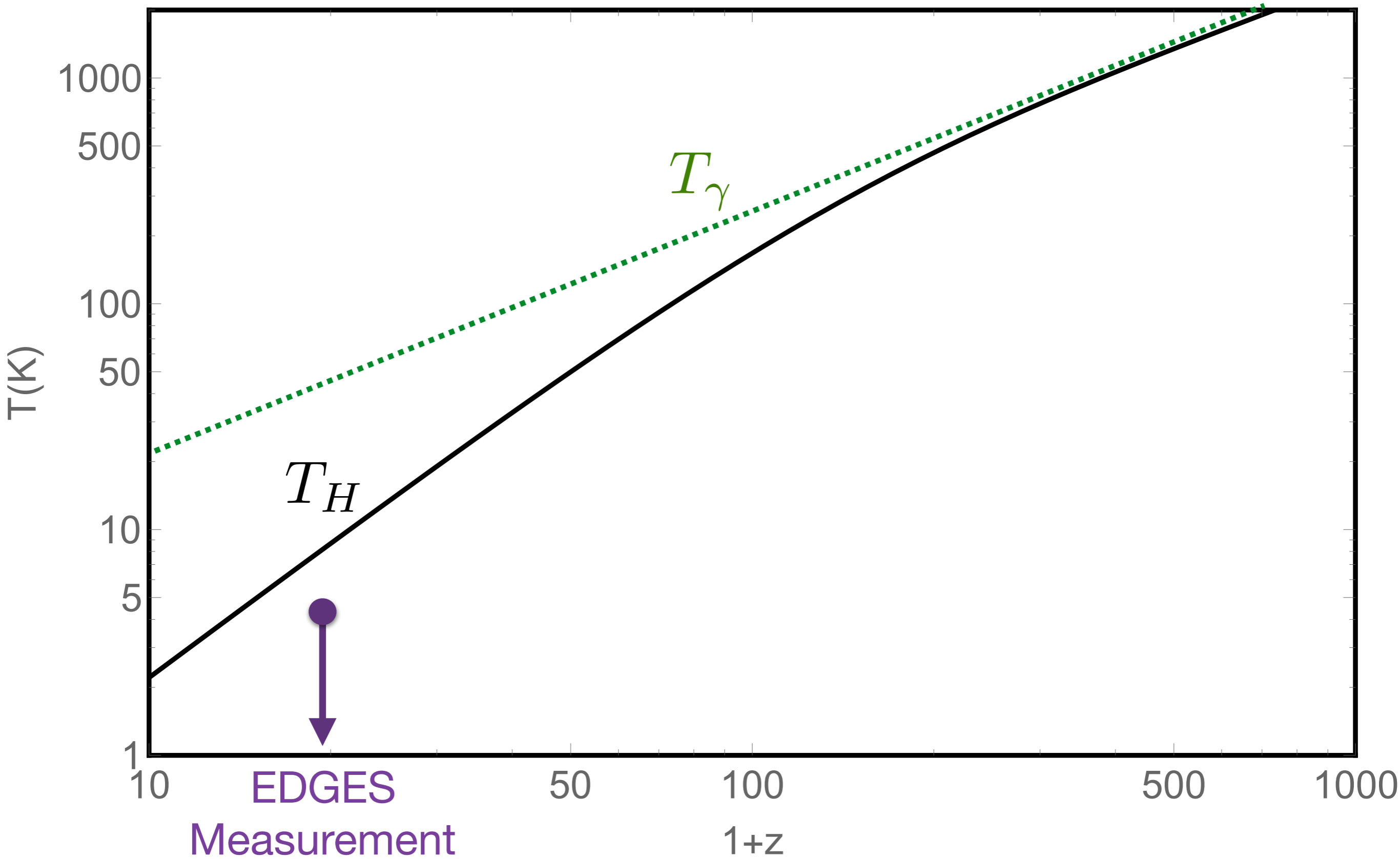
Lopez-Honorez+ 2016 ...

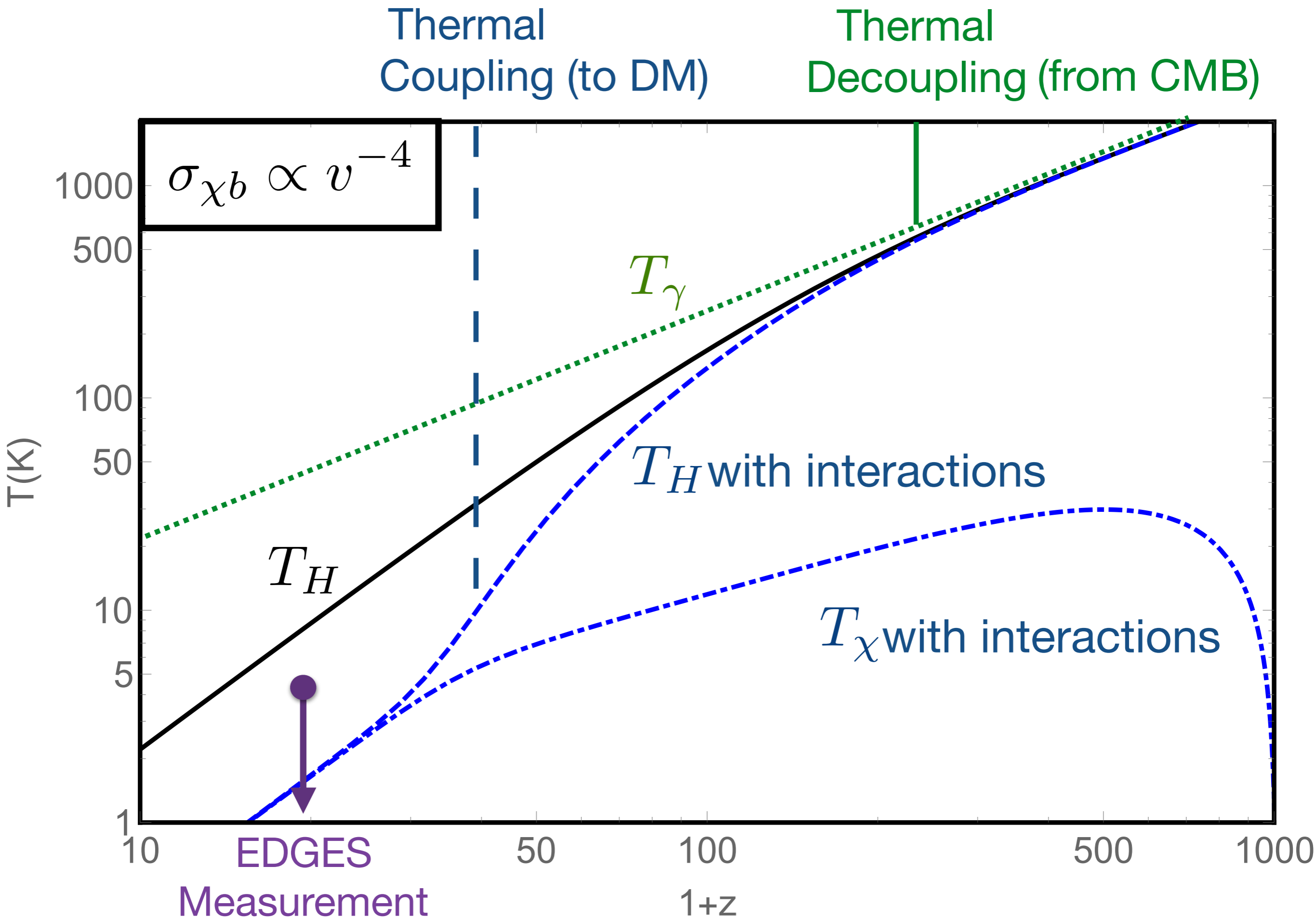


What does the thermostat say?



What does the thermostat say?

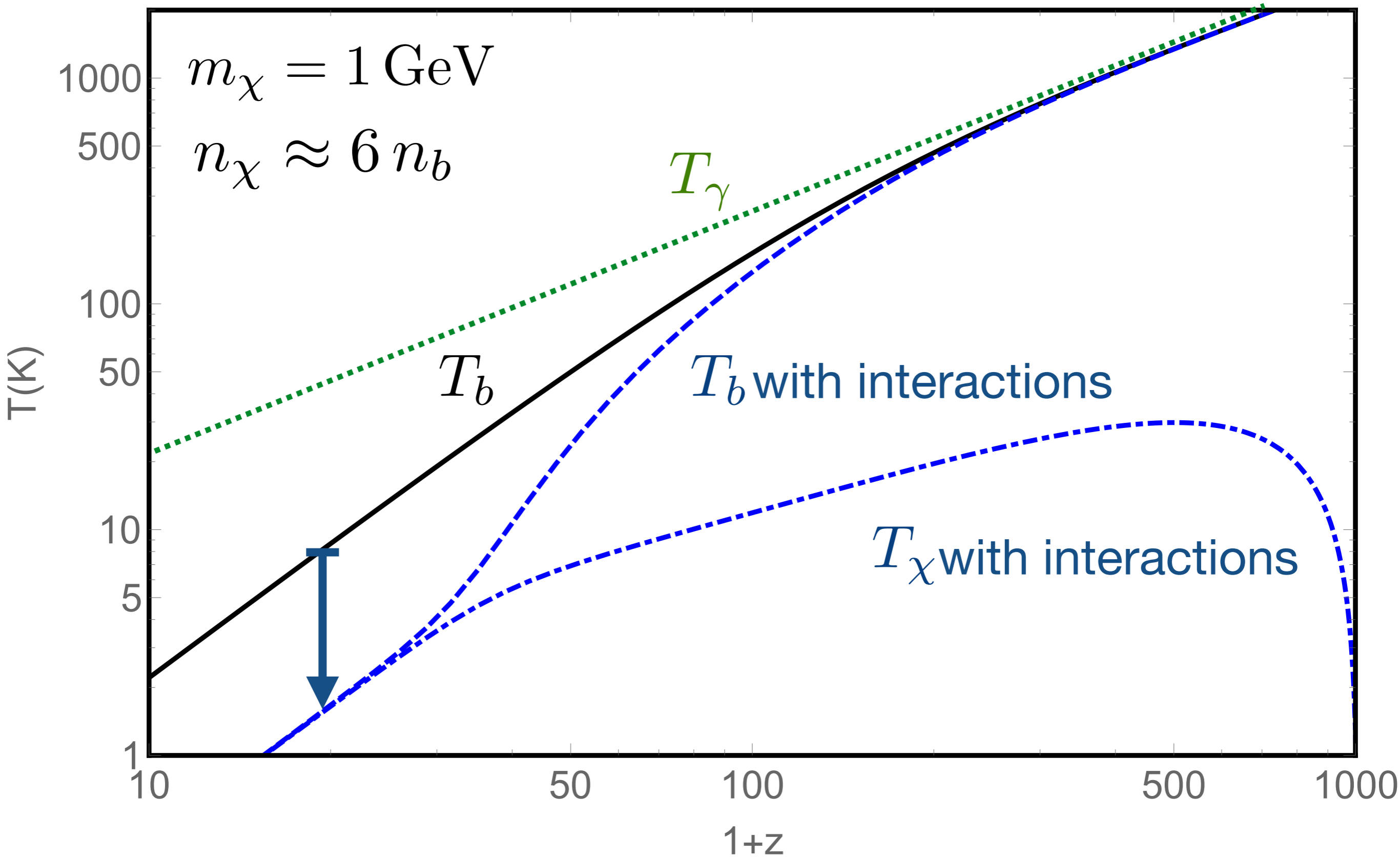




Can DM explain EDGES?

Requirements

$$n_{\chi} \geq n_b \quad \rightarrow \quad m_{\chi} \leq 6 \text{ GeV} \quad (6 \text{ proton masses})$$



Can DM explain EDGES?

Requirements

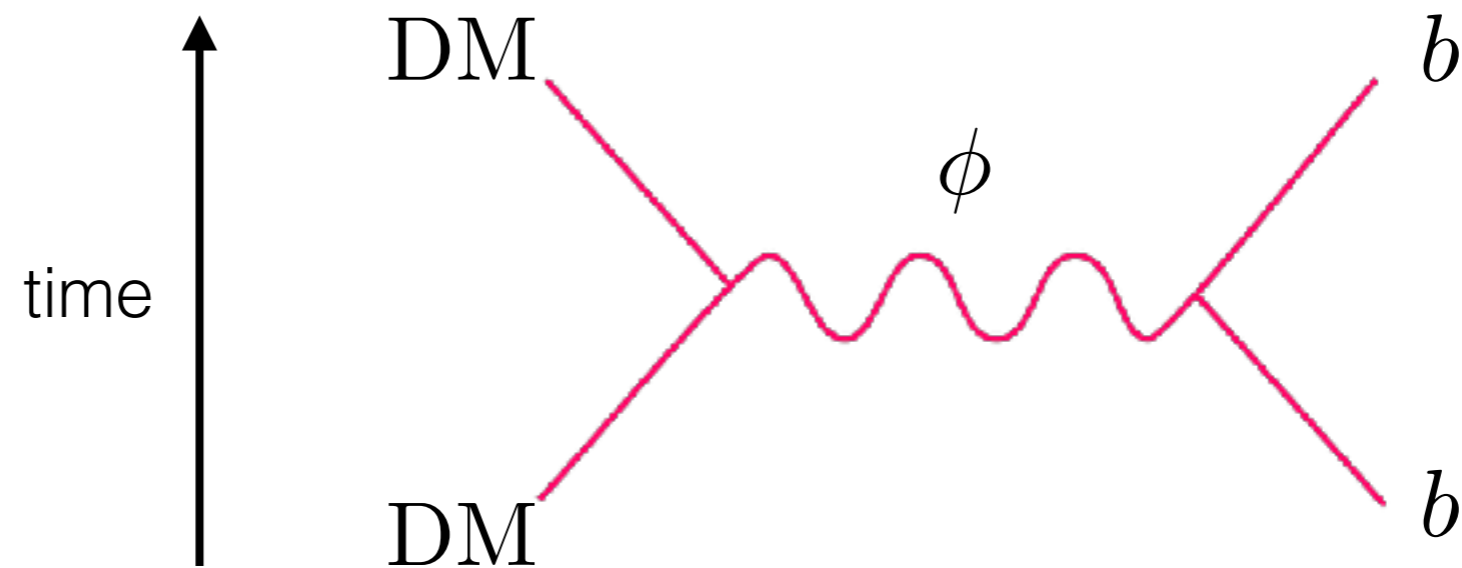
$$n_{\chi} \geq n_b \quad \rightarrow \quad m_{\chi} \leq 6 \text{ GeV}$$

$$\sigma_{\chi b} \propto v^{-4}$$

A fifth-force?

Barkana 2018

$$\sigma(v) = \sigma_c \left(\frac{v}{c} \right)^{-4} = \sigma_1 \left(\frac{v}{1 \text{ km/s}} \right)^{-4}$$

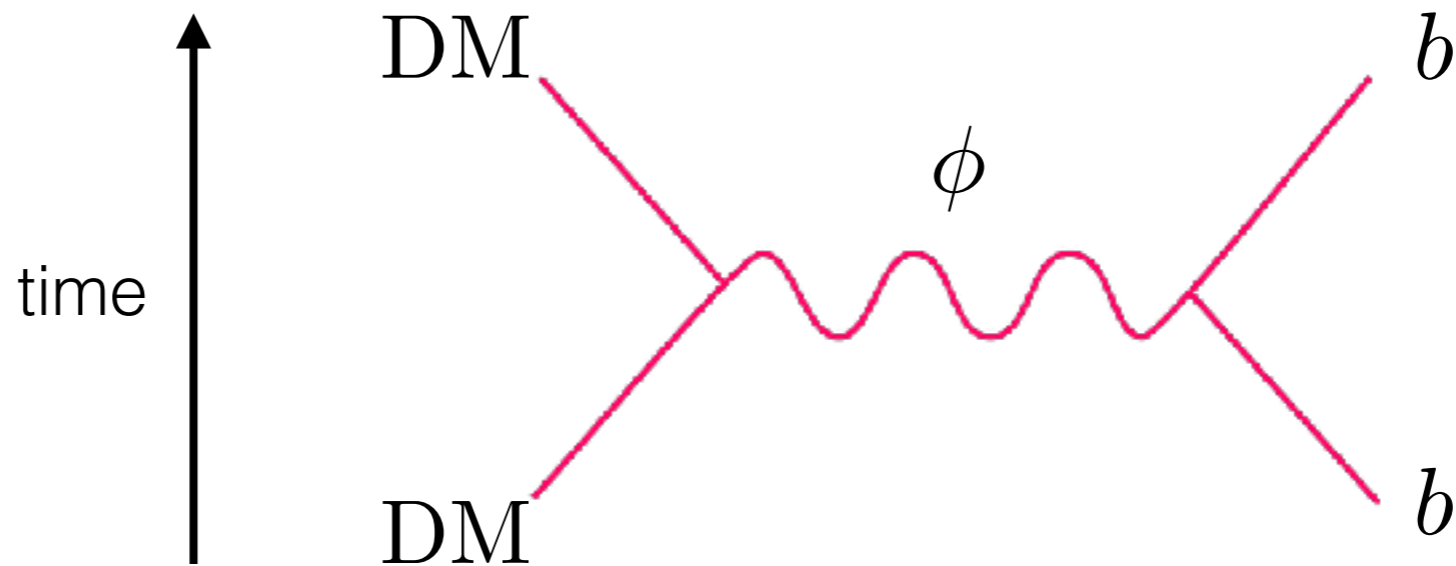


A fifth-force?

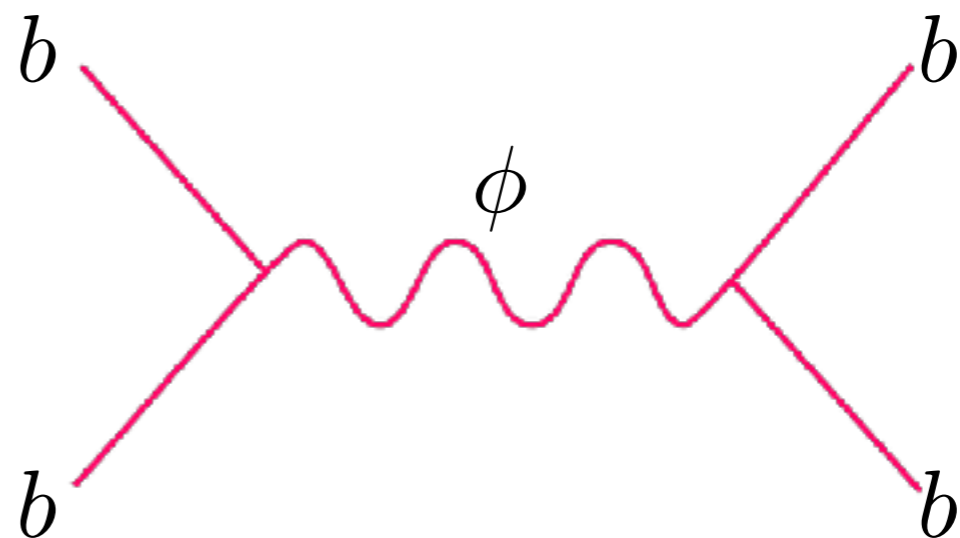
Barkana 2018

$$\sigma(v) = \sigma_c \left(\frac{v}{c} \right)^{-4} = \sigma_1 \left(\frac{v}{1 \text{ km/s}} \right)^{-4}$$

However, this:



Also implies this:



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Fifth Force

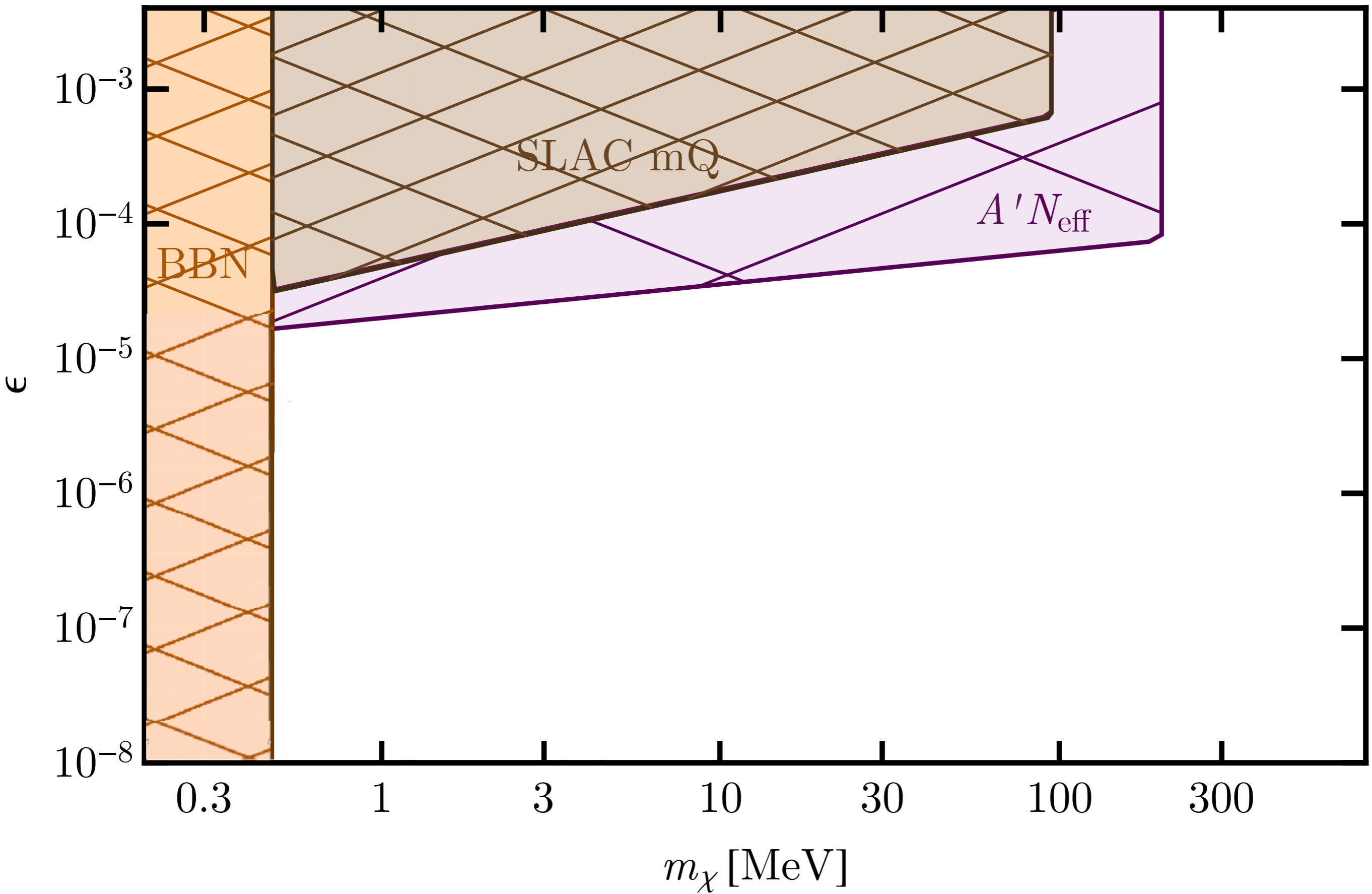
Kadota+ 2014

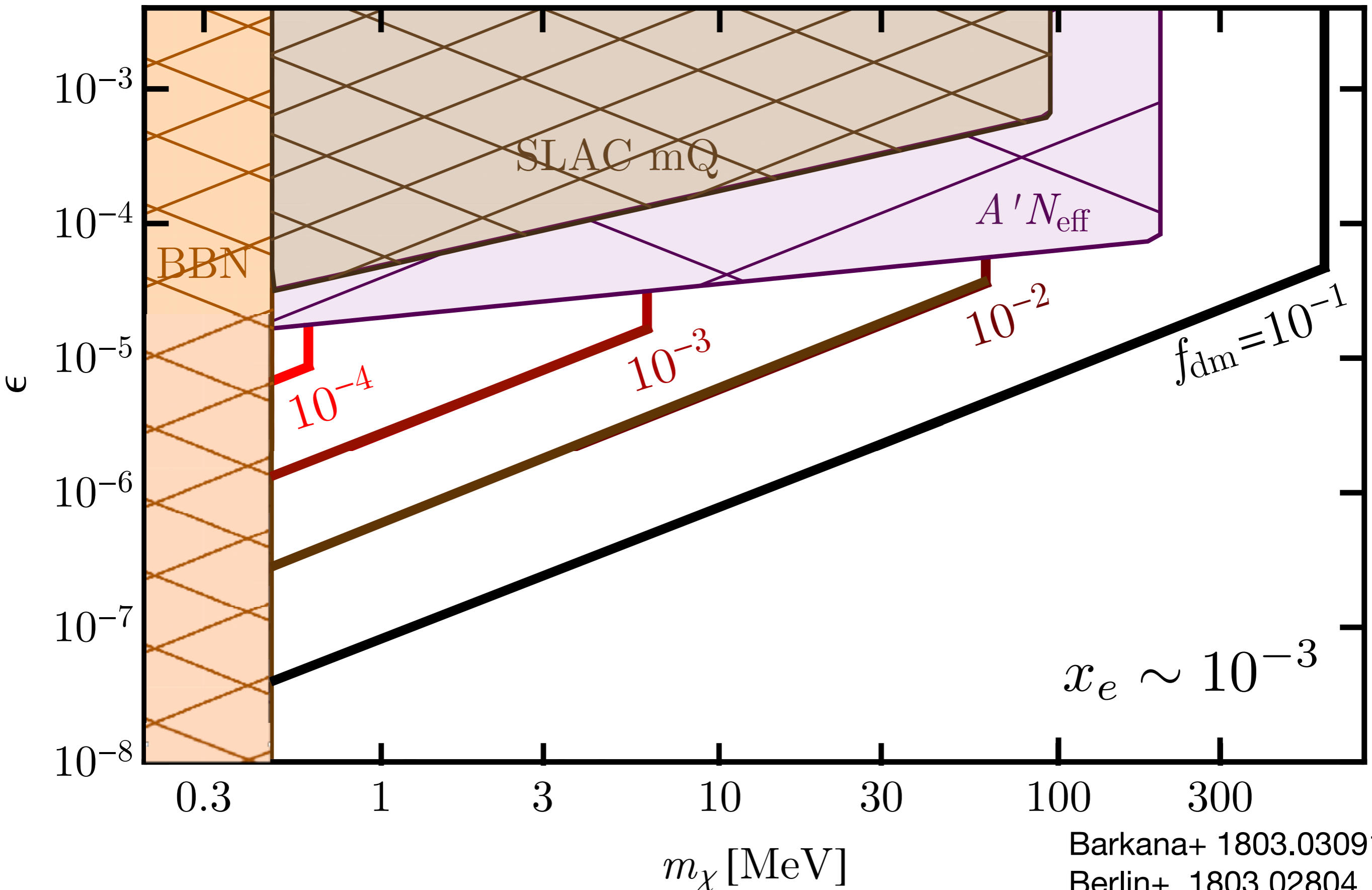
JBM+ 2015

Barkana 2018

Millicharged DM

JBM and Loeb 2018



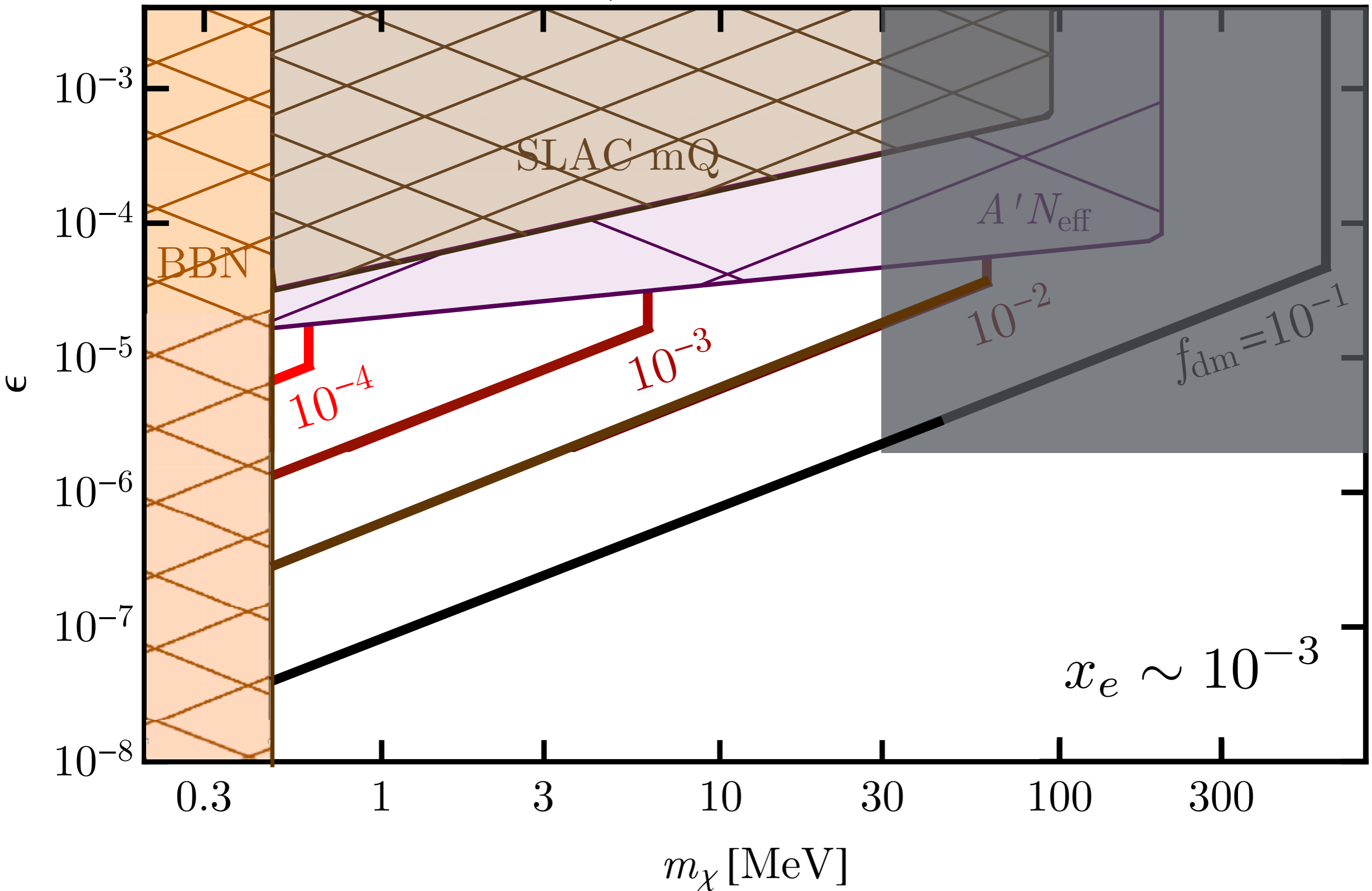


JBM and Loeb 1802.10094

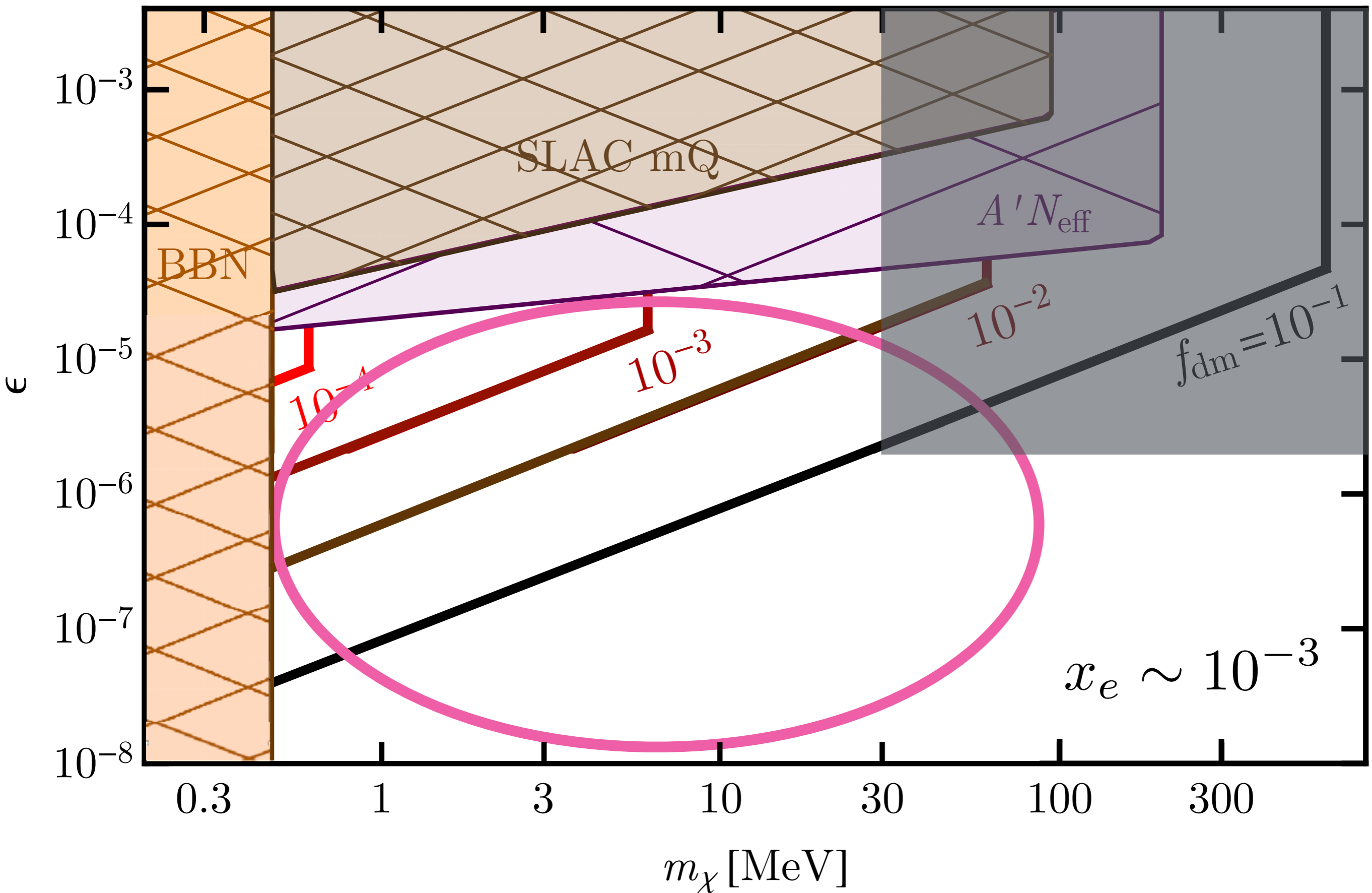
Barkana+ 1803.0309
 Berlin+ 1803.02804
 Liu+ 1908.06986

Dolgov et al. 2013
de Putter et al.; Kovetz et al. 2018

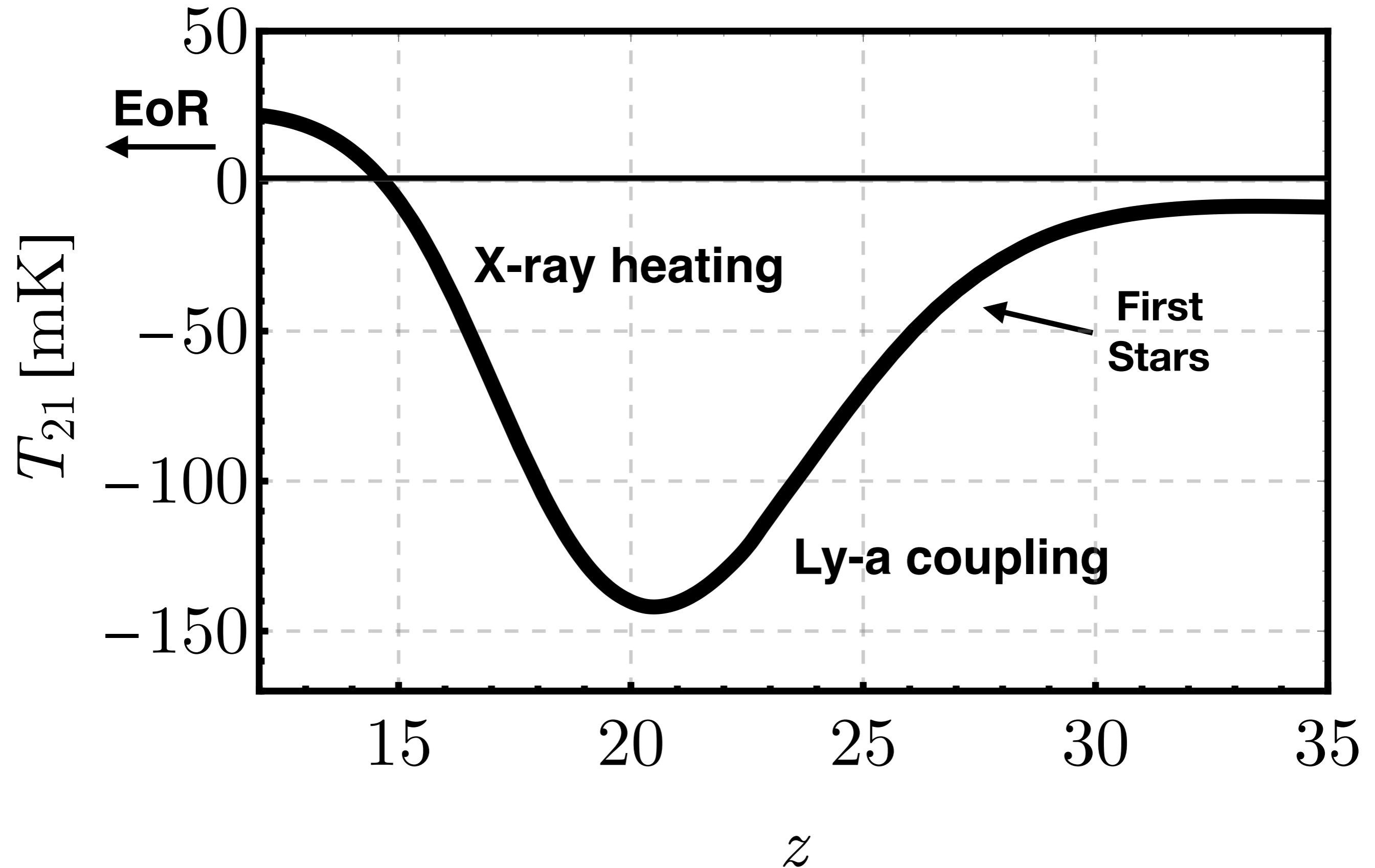
$f_{\text{coupled}} < 0.4\%$



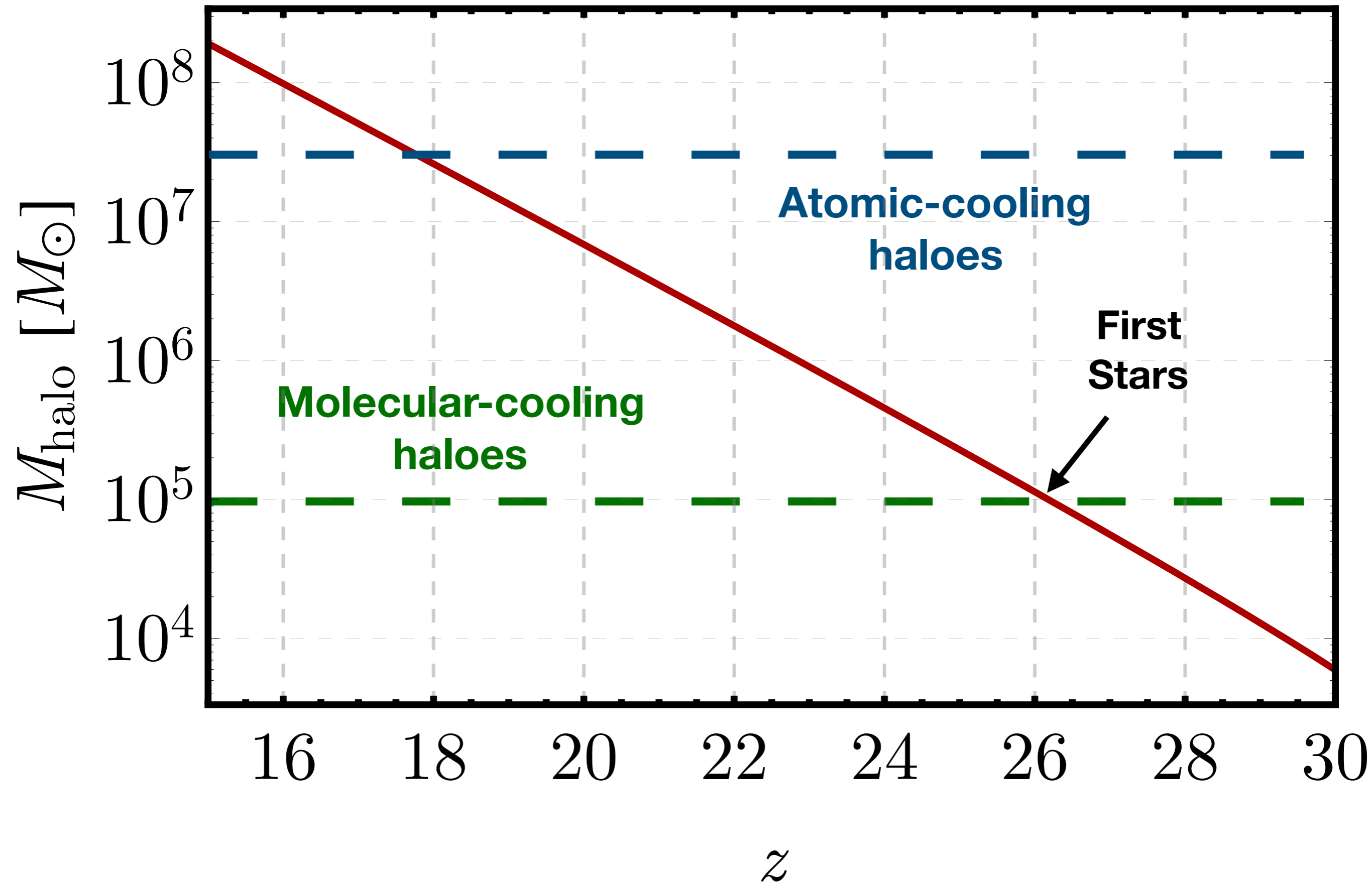
The take-home message:



How DM affects the timing

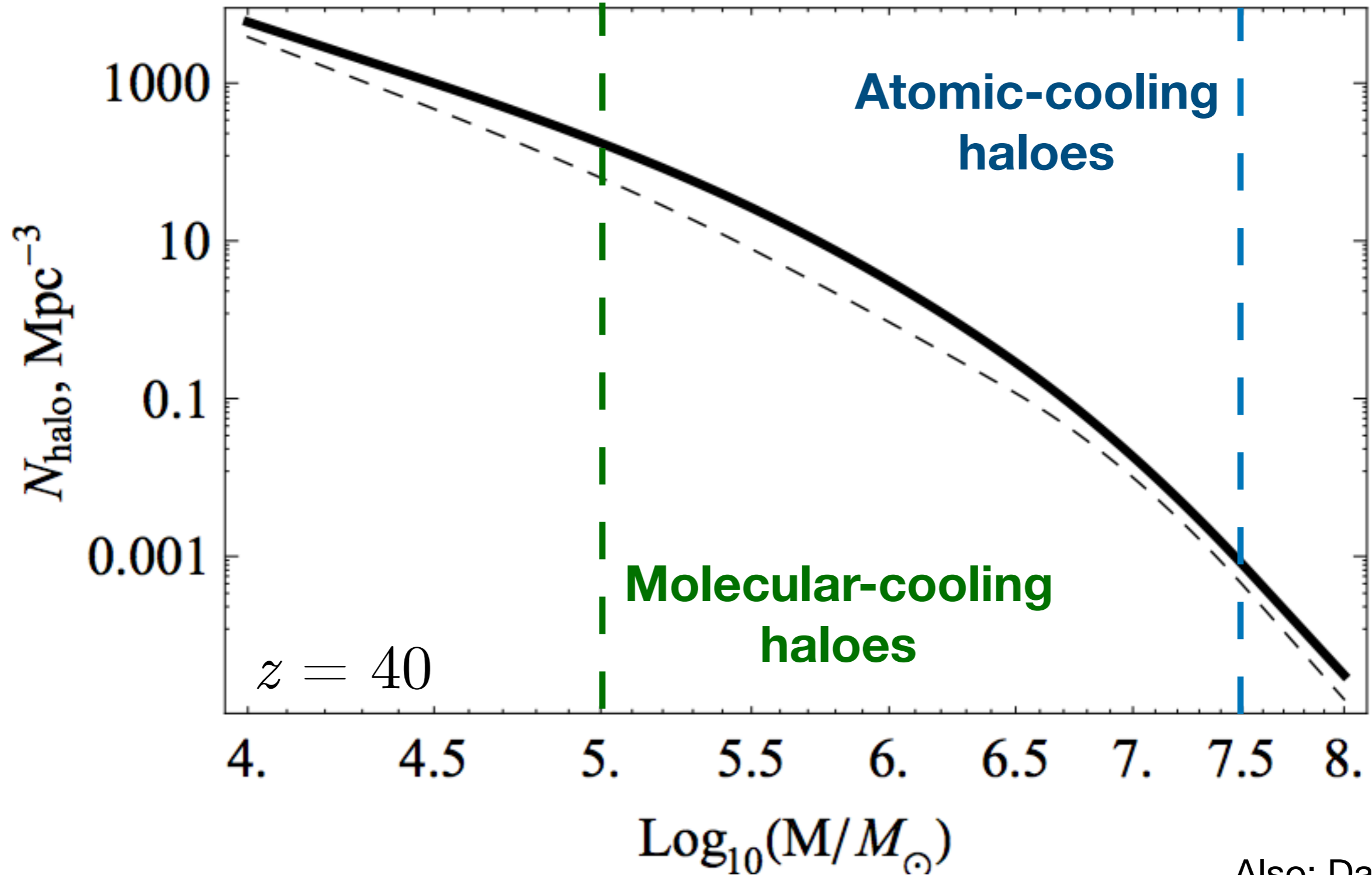


How DM affects the timing



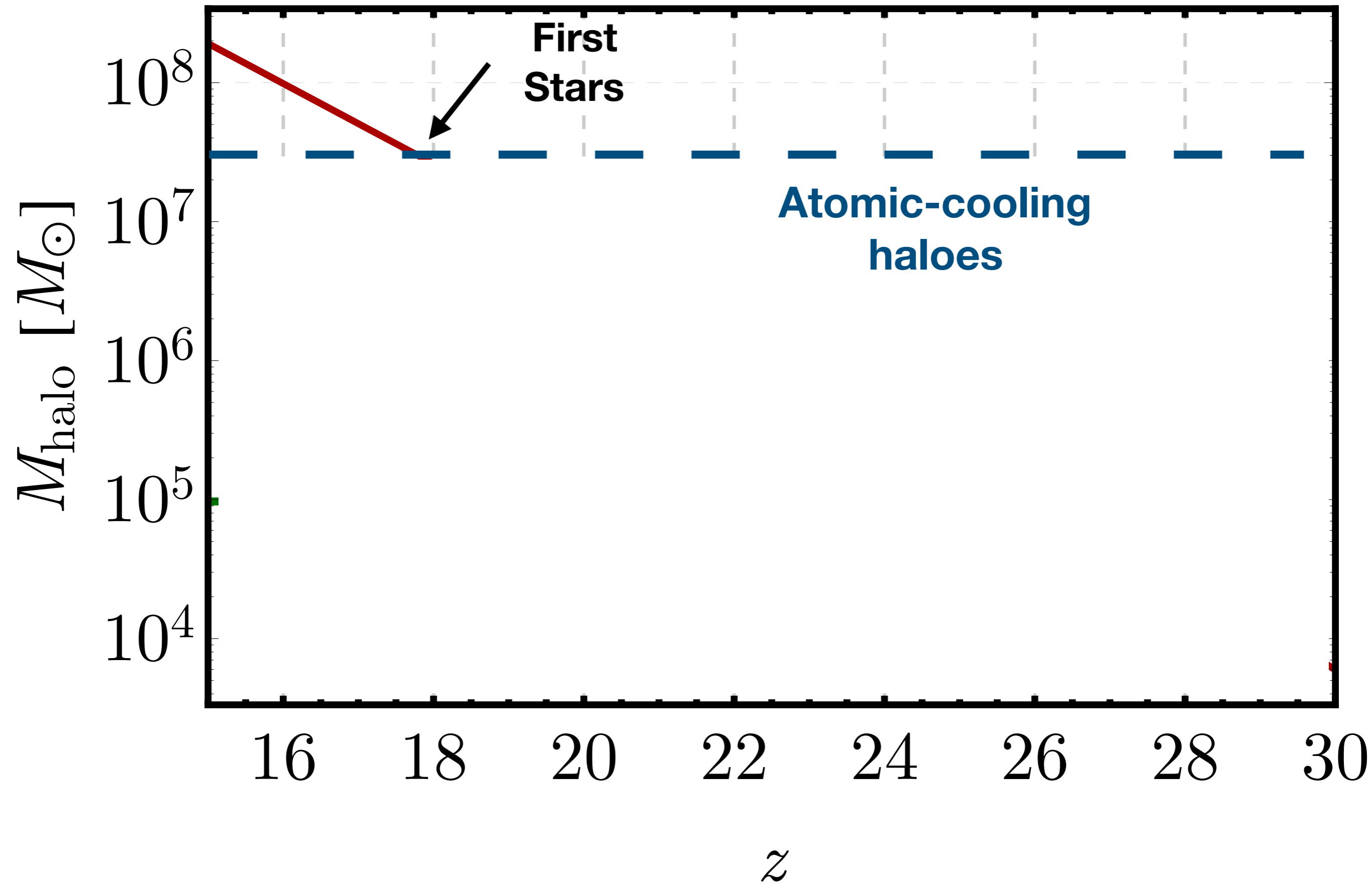
DM-baryon relative velocities

Tseliakhovich and Hirata 2010

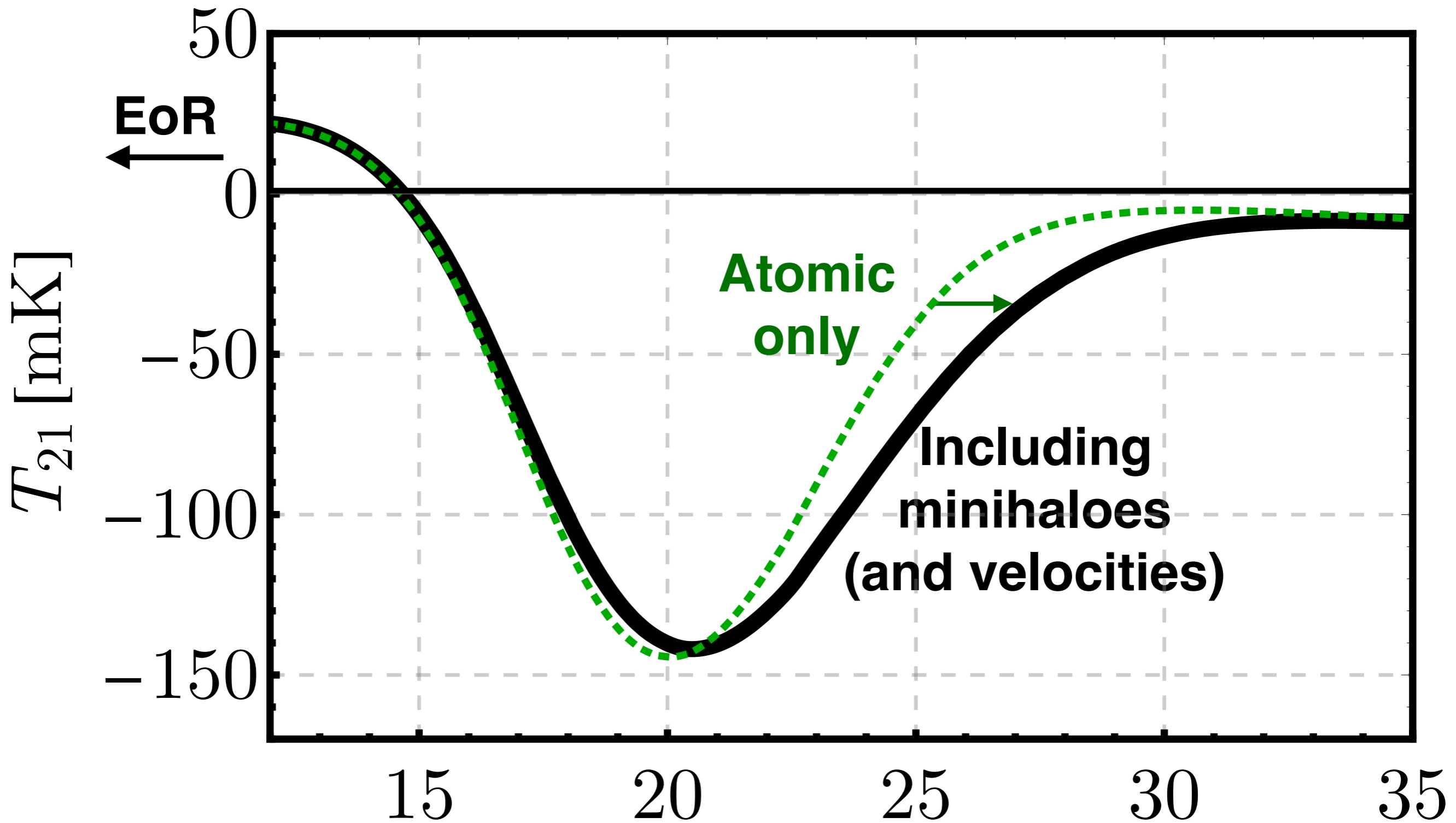


Also: Dalal+ 2010
Fialkov+ 2014 ...

What is commonly done:

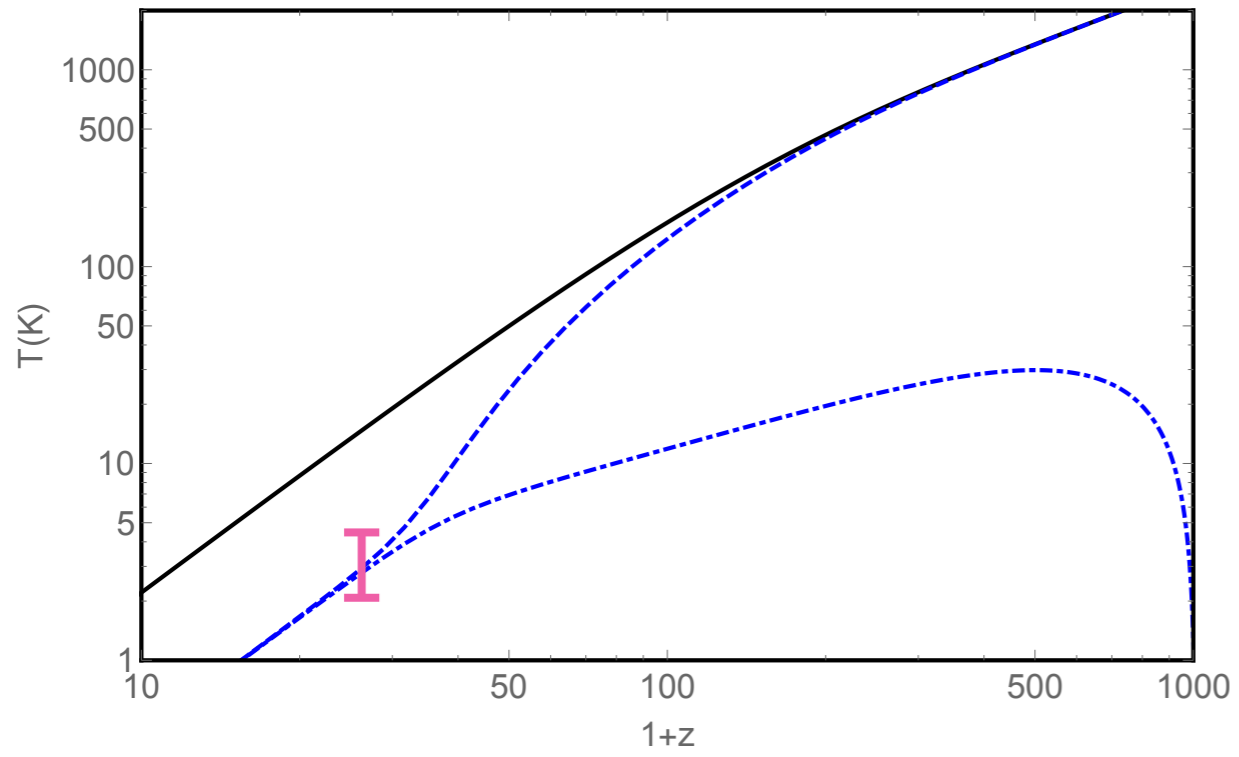


How DM affects the timing

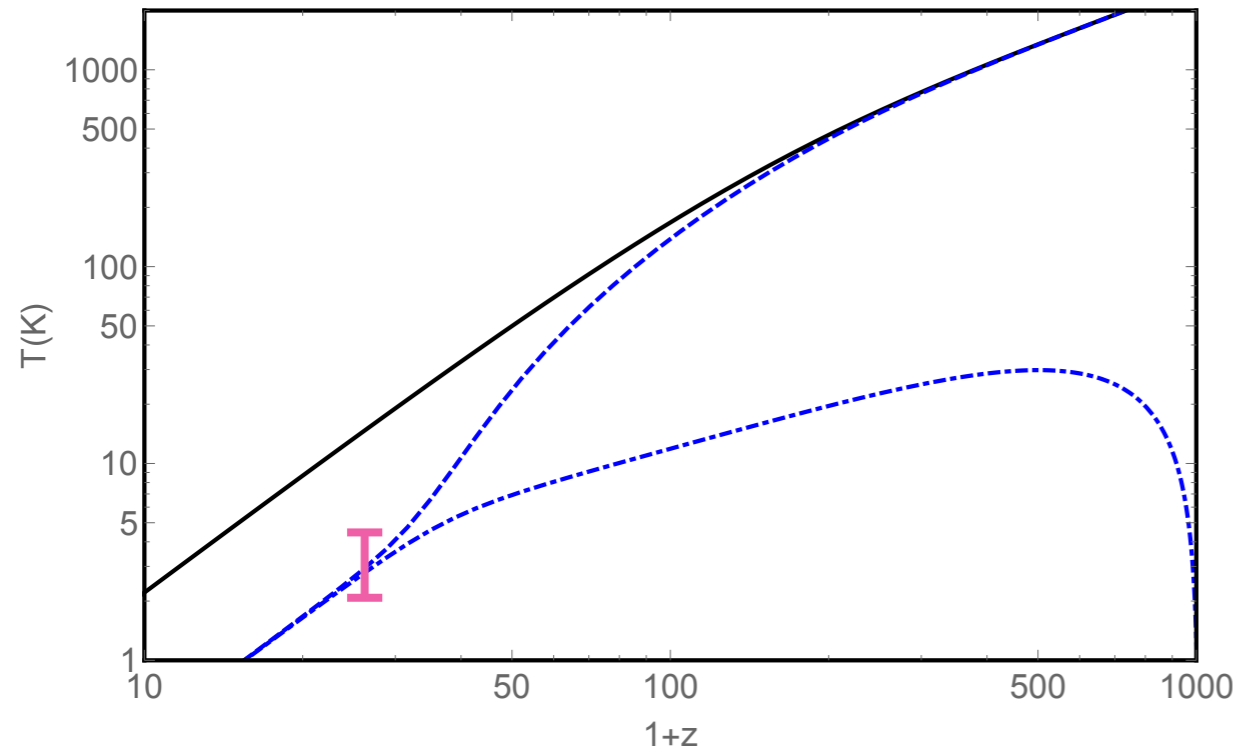


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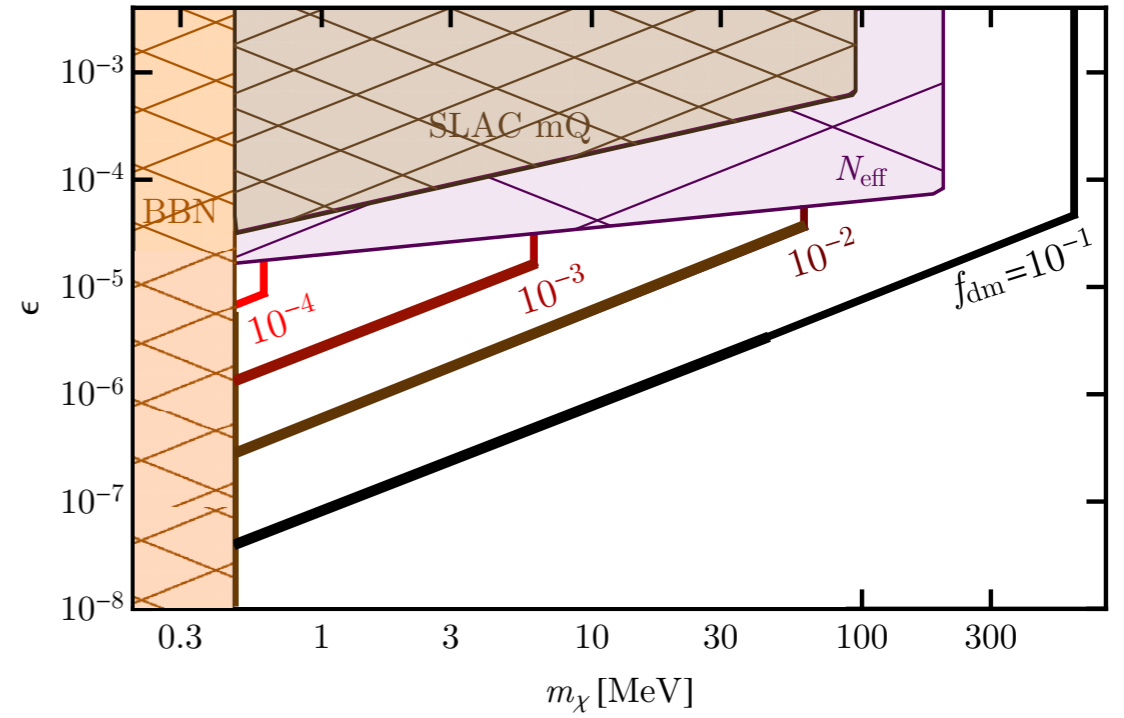
Summary



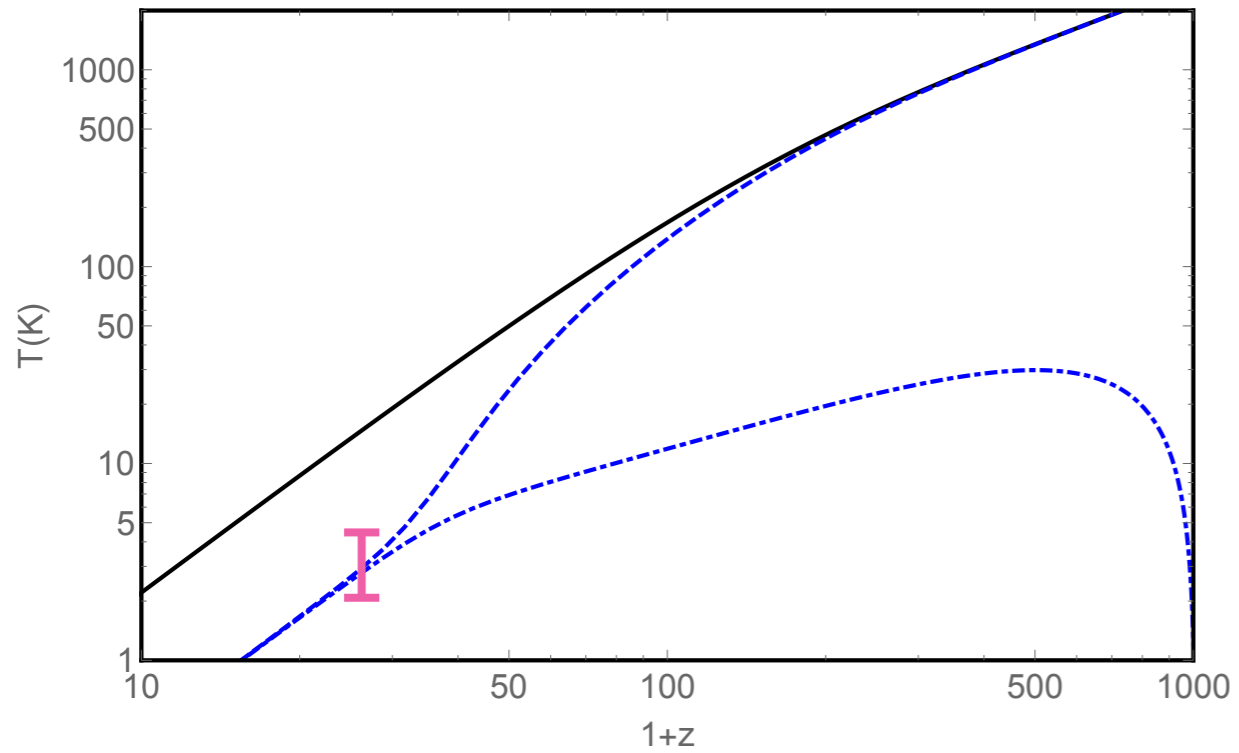
Summary



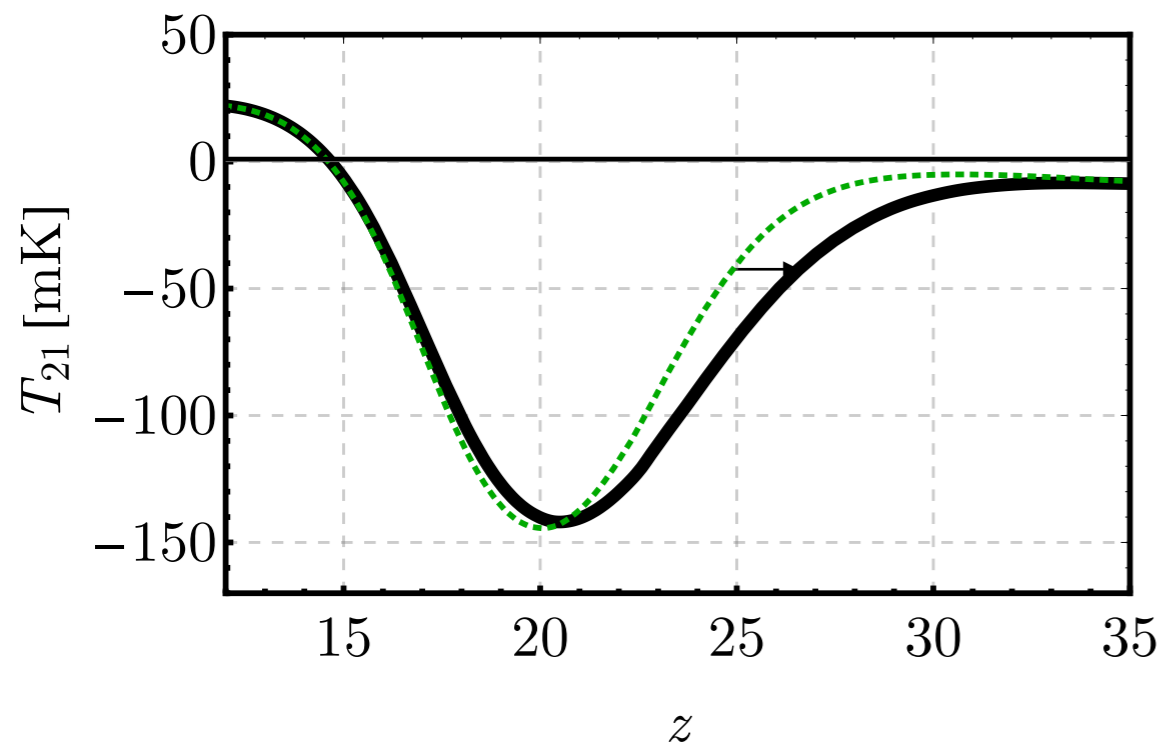
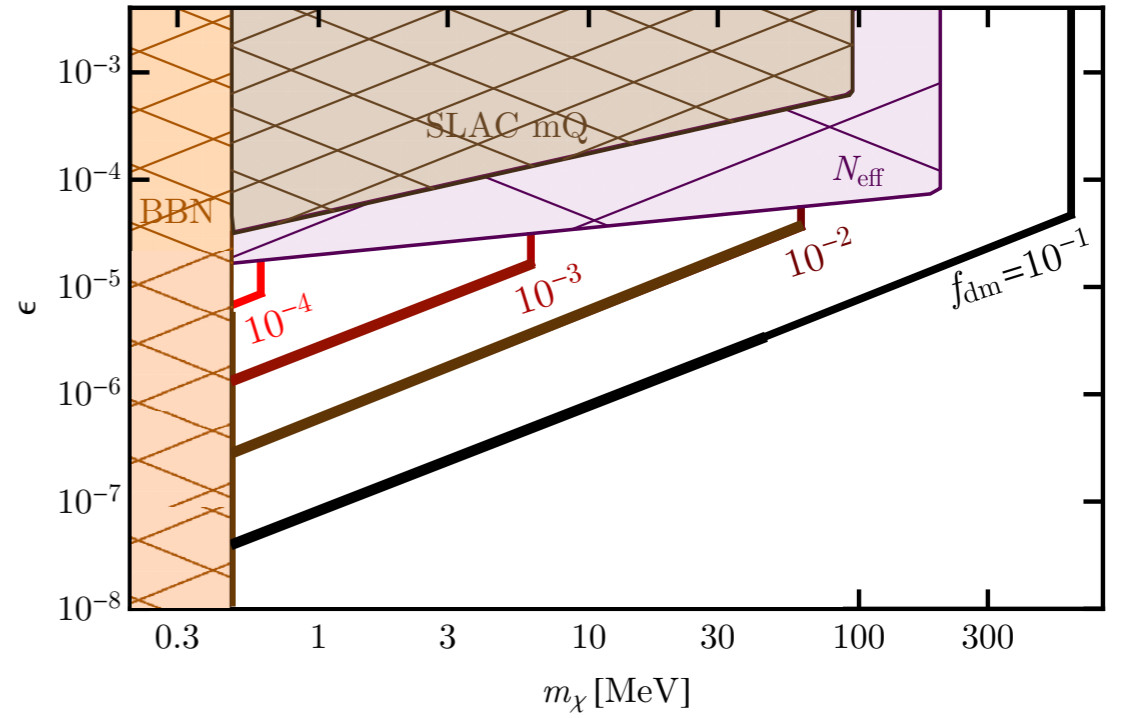
EDGES



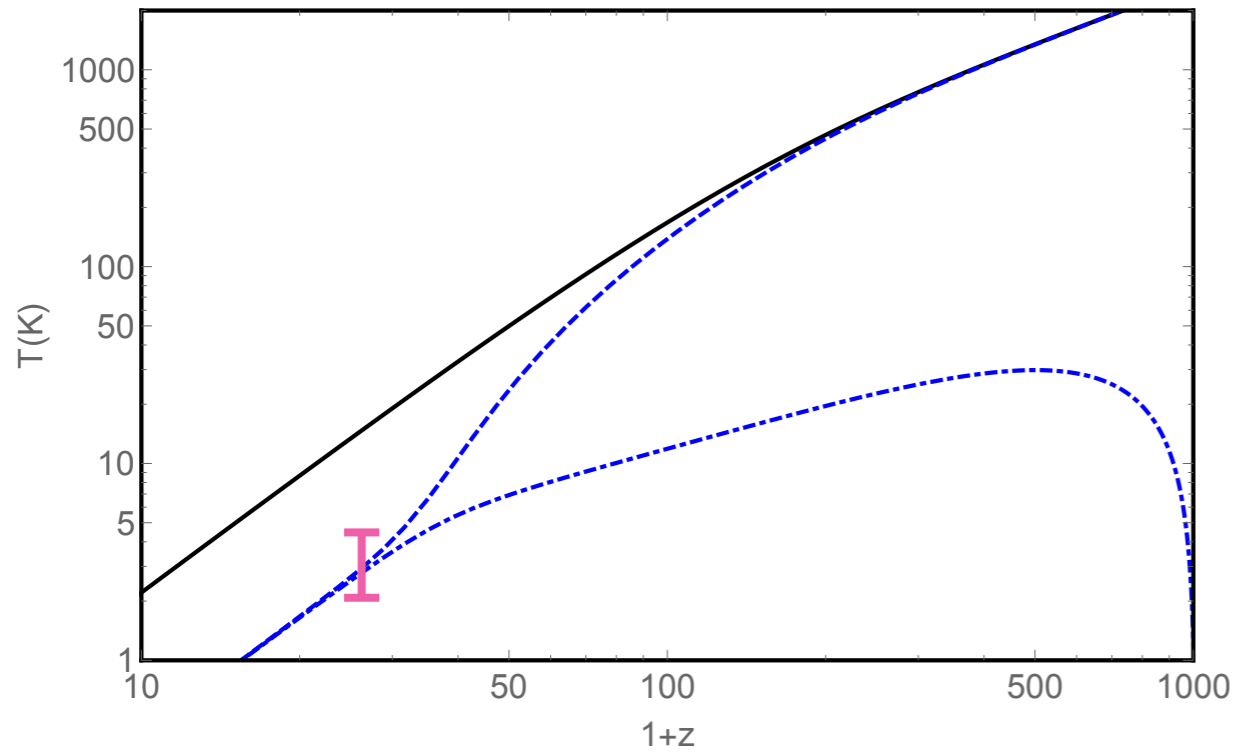
Summary



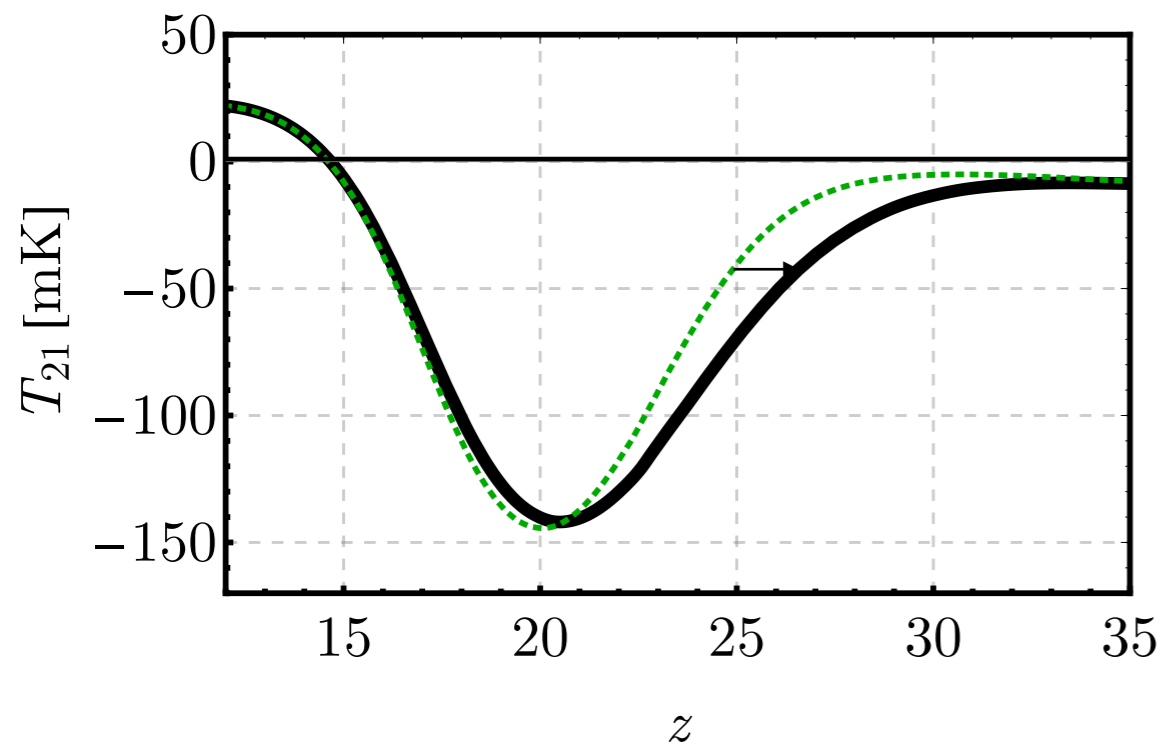
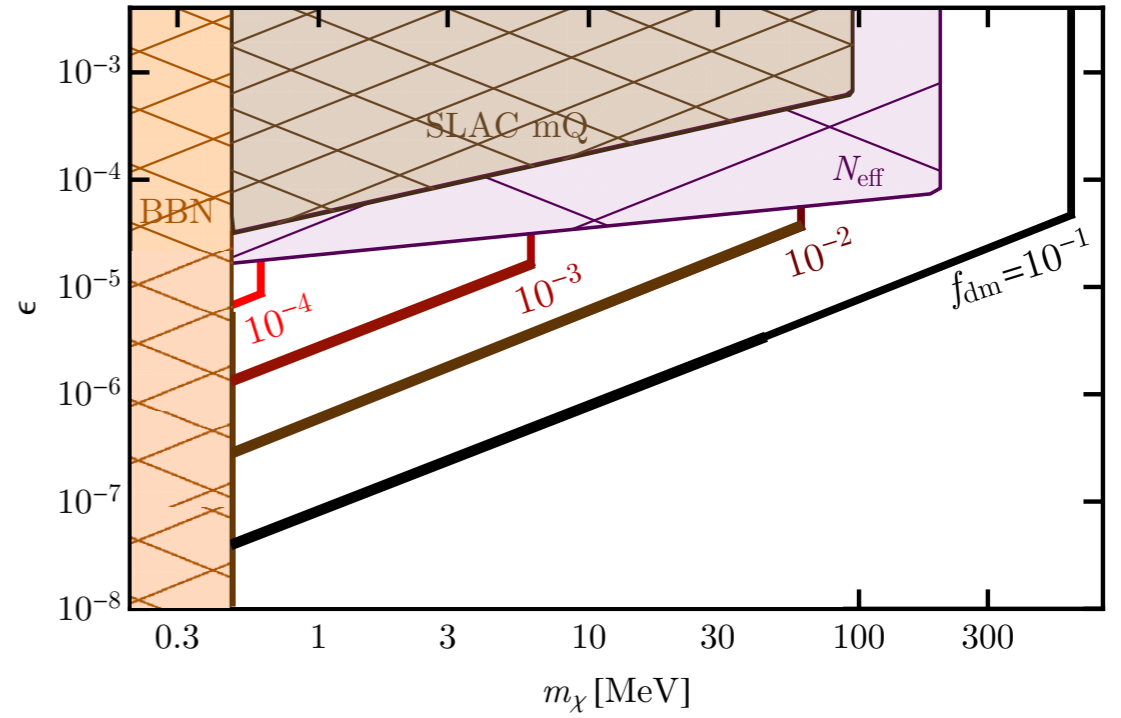
EDGES



Summary



EDGES



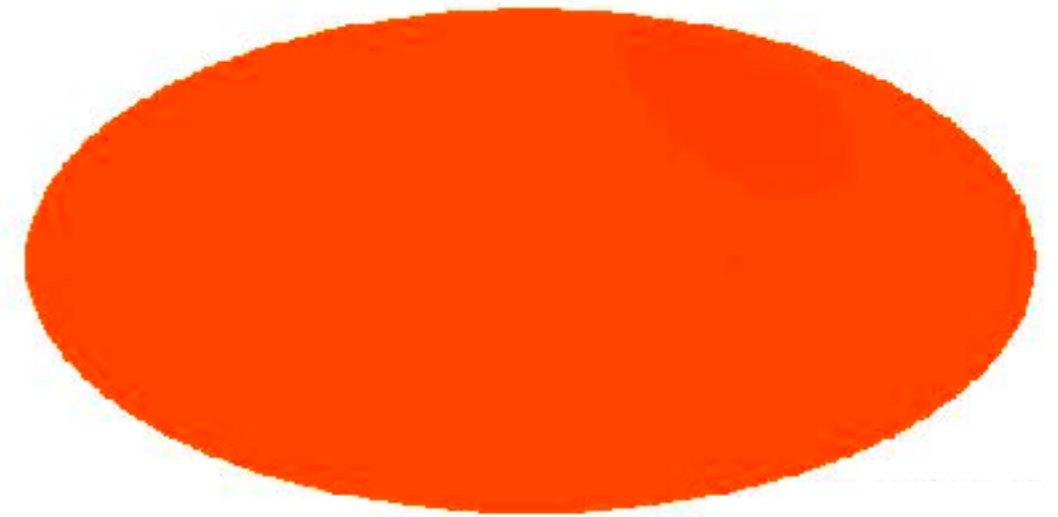
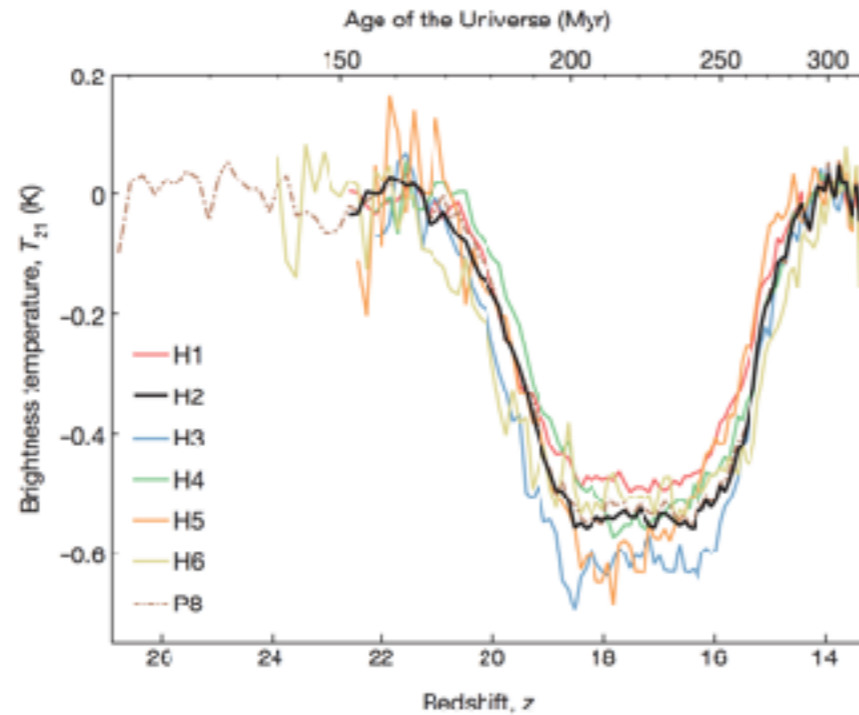
Thanks!

The 21-cm fluctuations

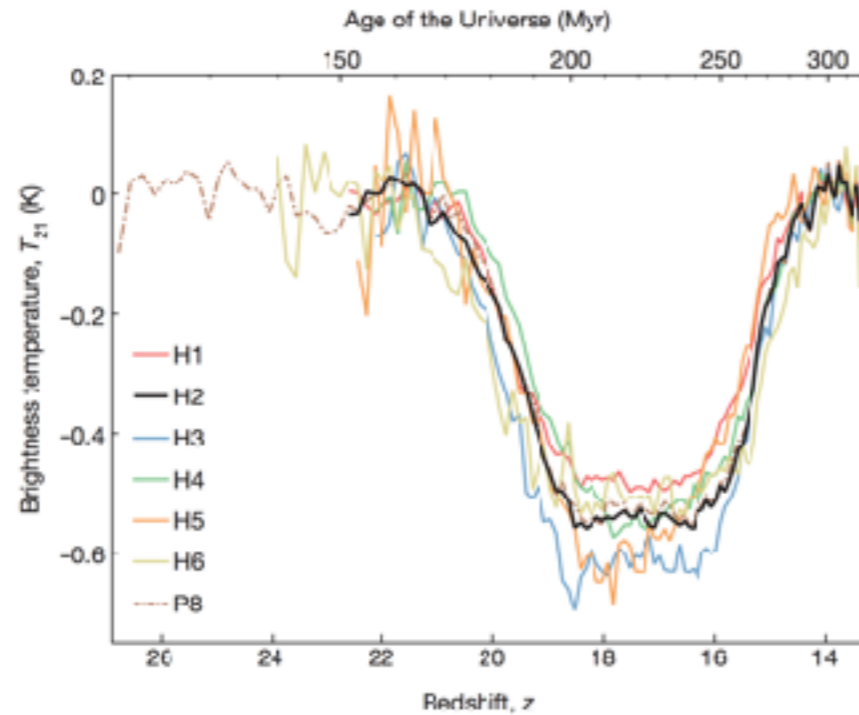
21-cm Global Signal

=

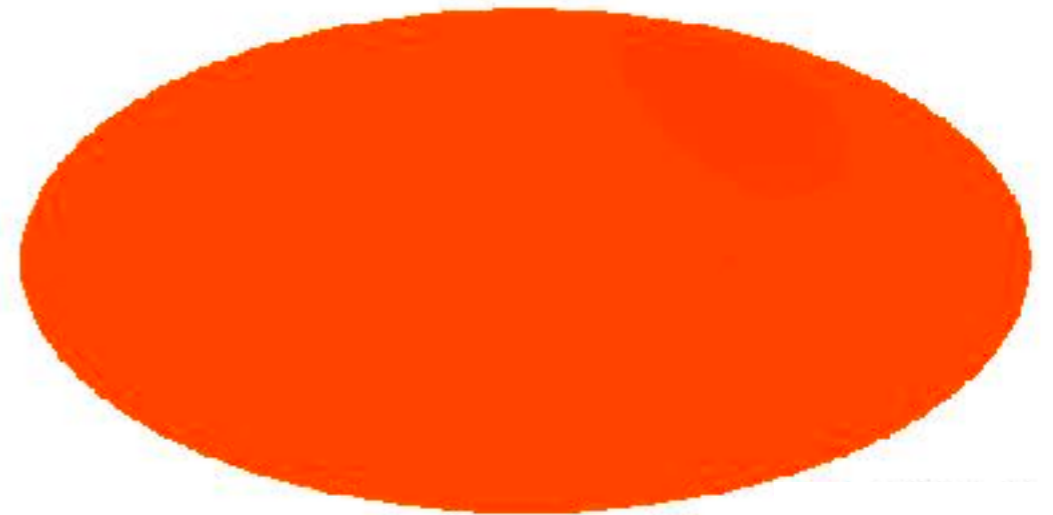
CMB Monopole



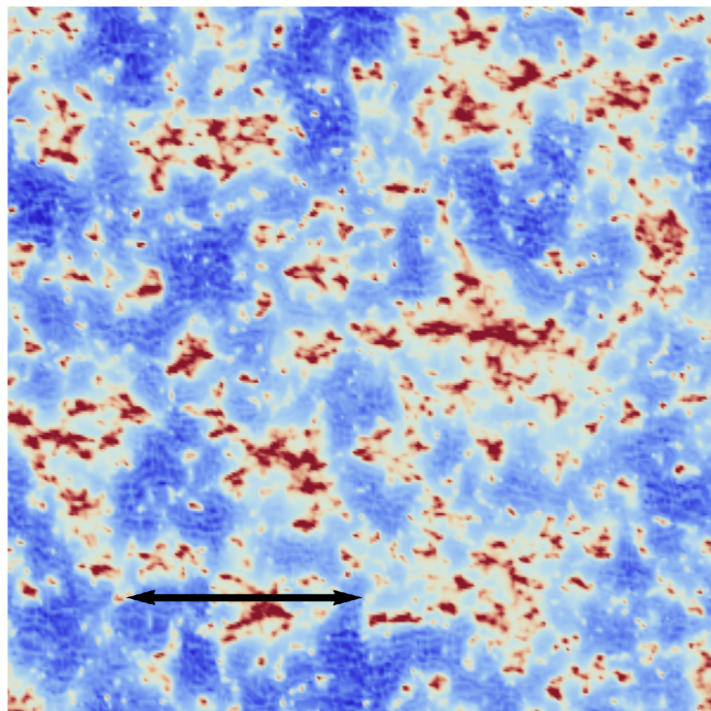
21-cm Global Signal



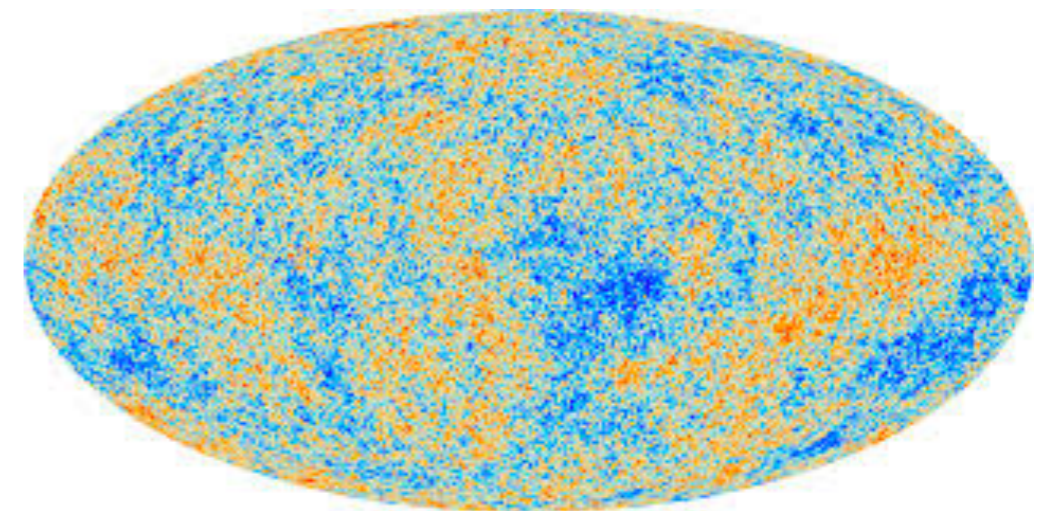
= CMB Monopole



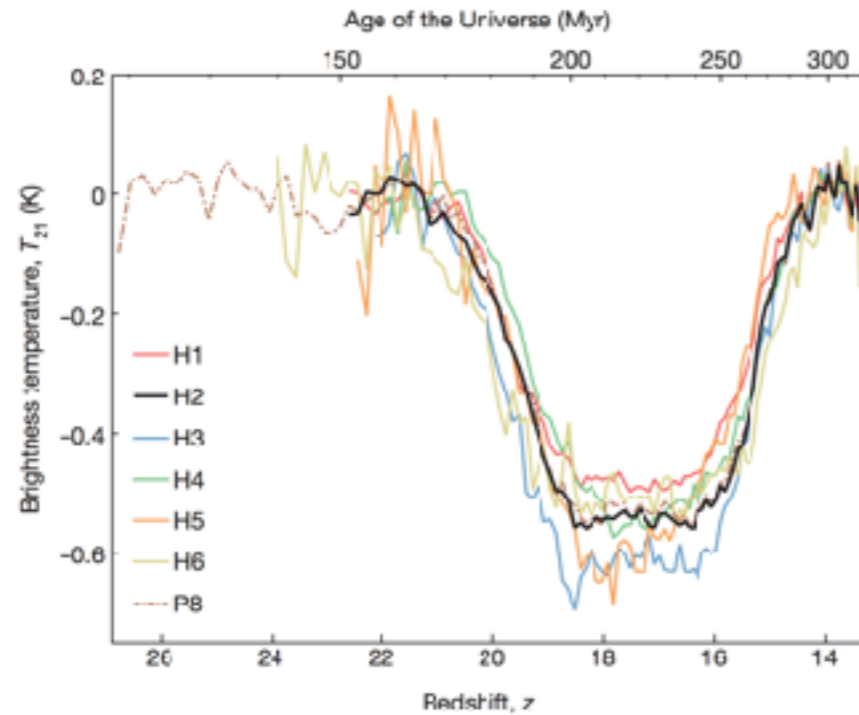
21-cm Fluctuations



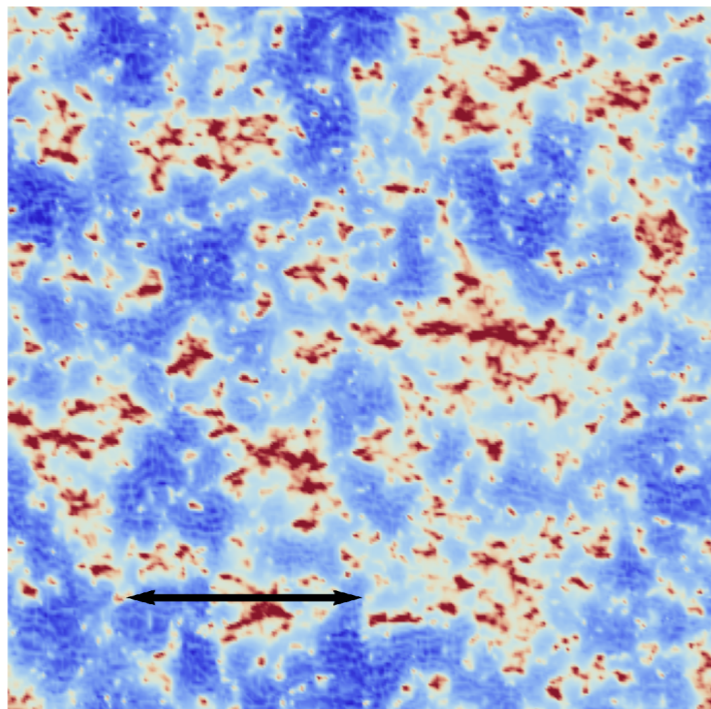
= CMB Anisotropies



Is this observable?



**1 antenna
~100 hours**



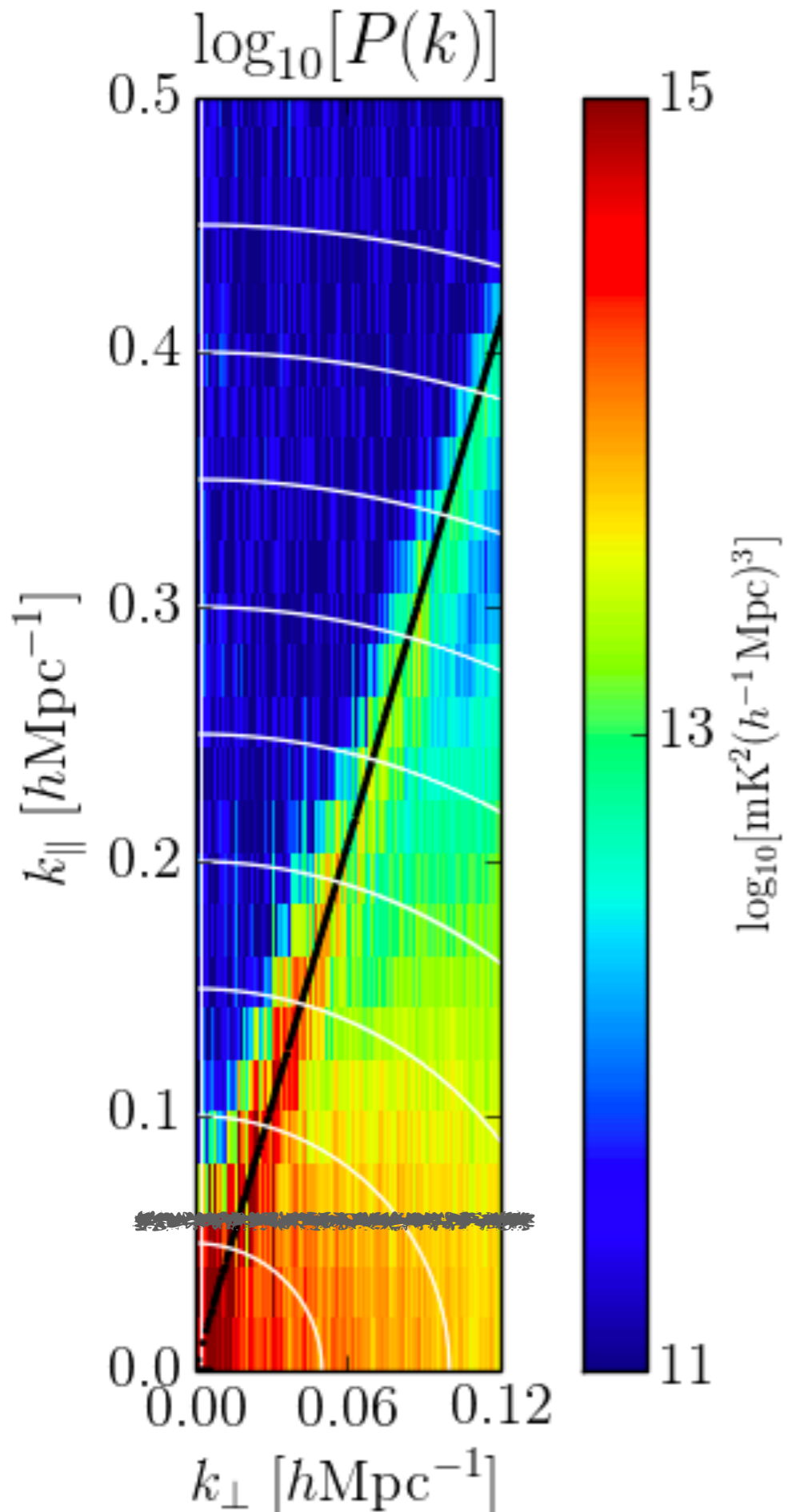
**~100 antennae
~1000 hours**

Is this observable?

HERA (Hydrogen Epoch of Reionization Array):
350 antennas, 14-m in diameter



Foreground “wedge”



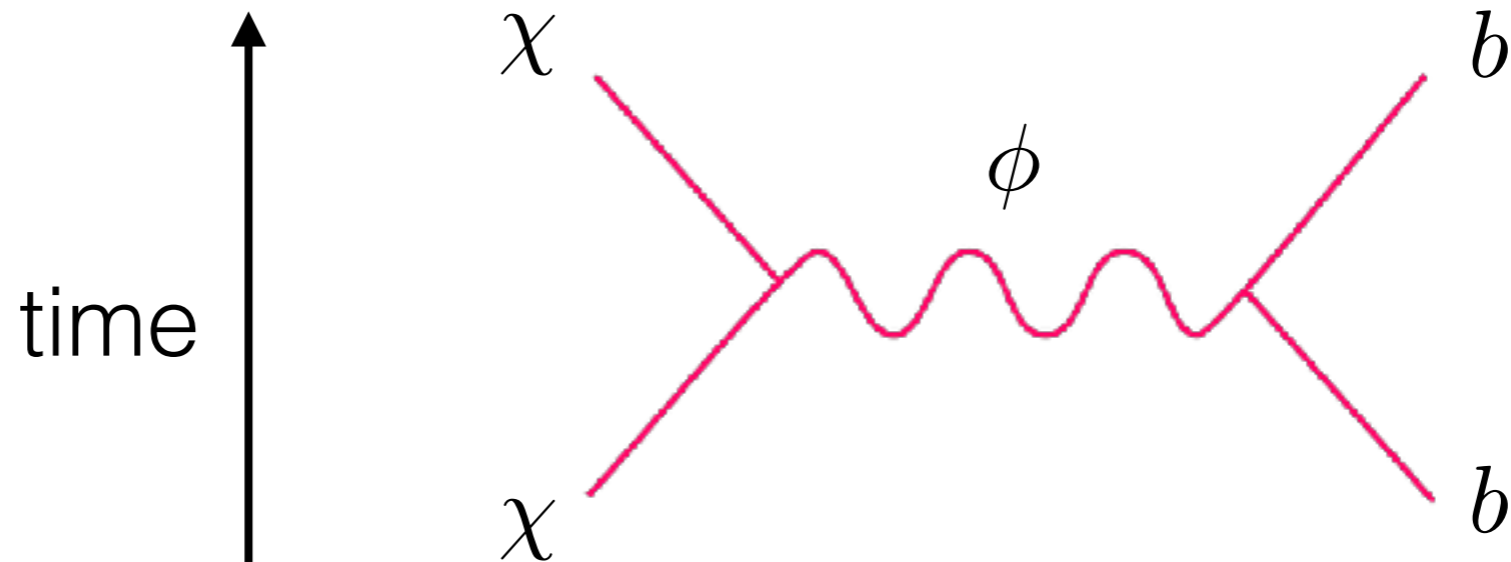
Foregrounds swamp the signal.
Avoid the “wedge”

Fifth-force

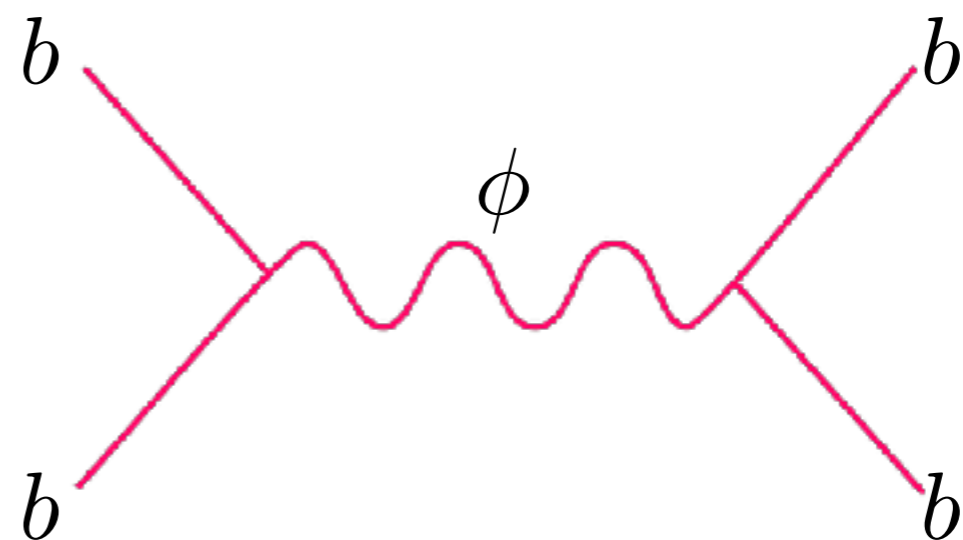
Barkana Nature 2018

$$\sigma(v) = \sigma_c \left(\frac{v}{c} \right)^{-4} = \sigma_1 \left(\frac{v}{1 \text{ km/s}} \right)^{-4}$$

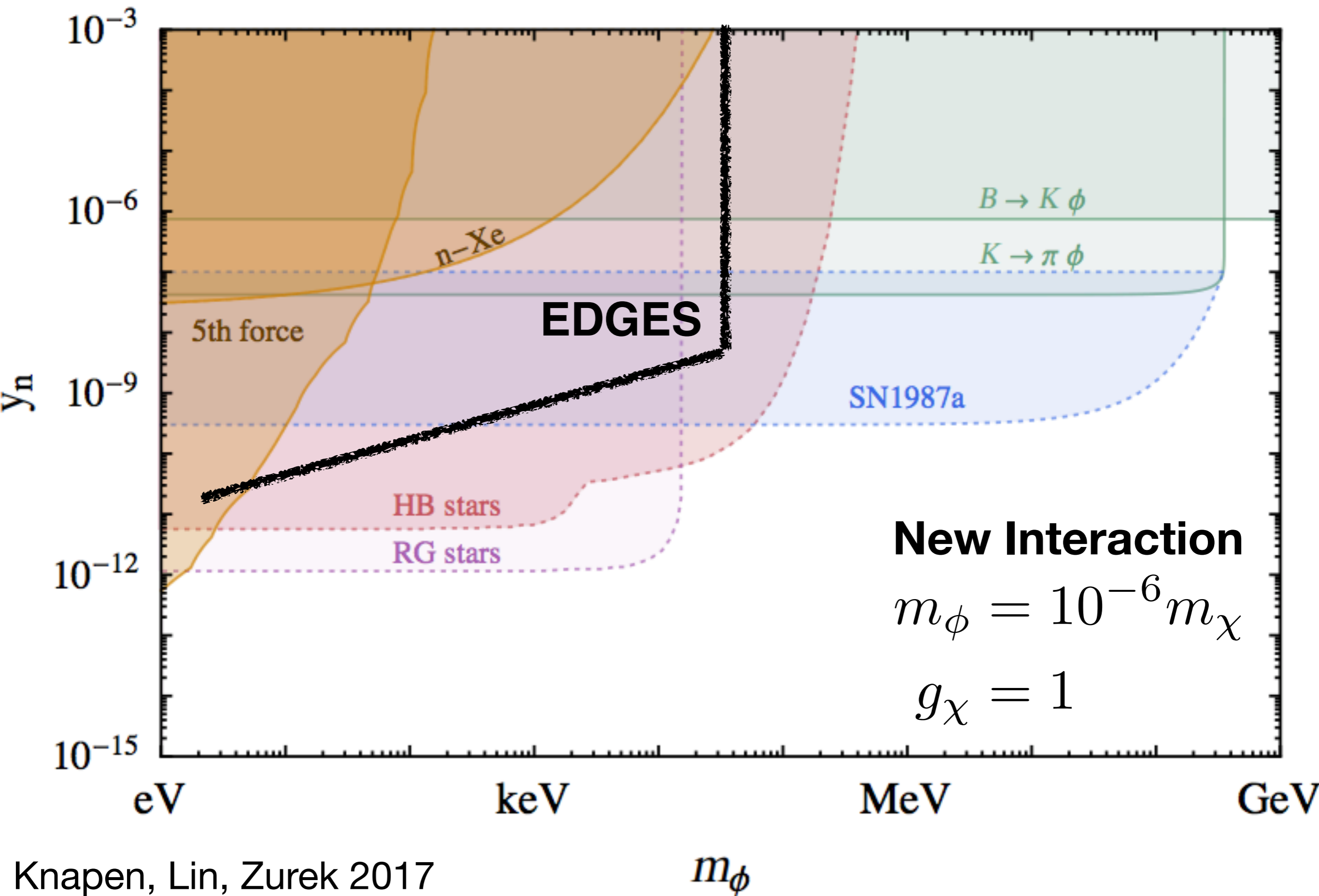
However, this:



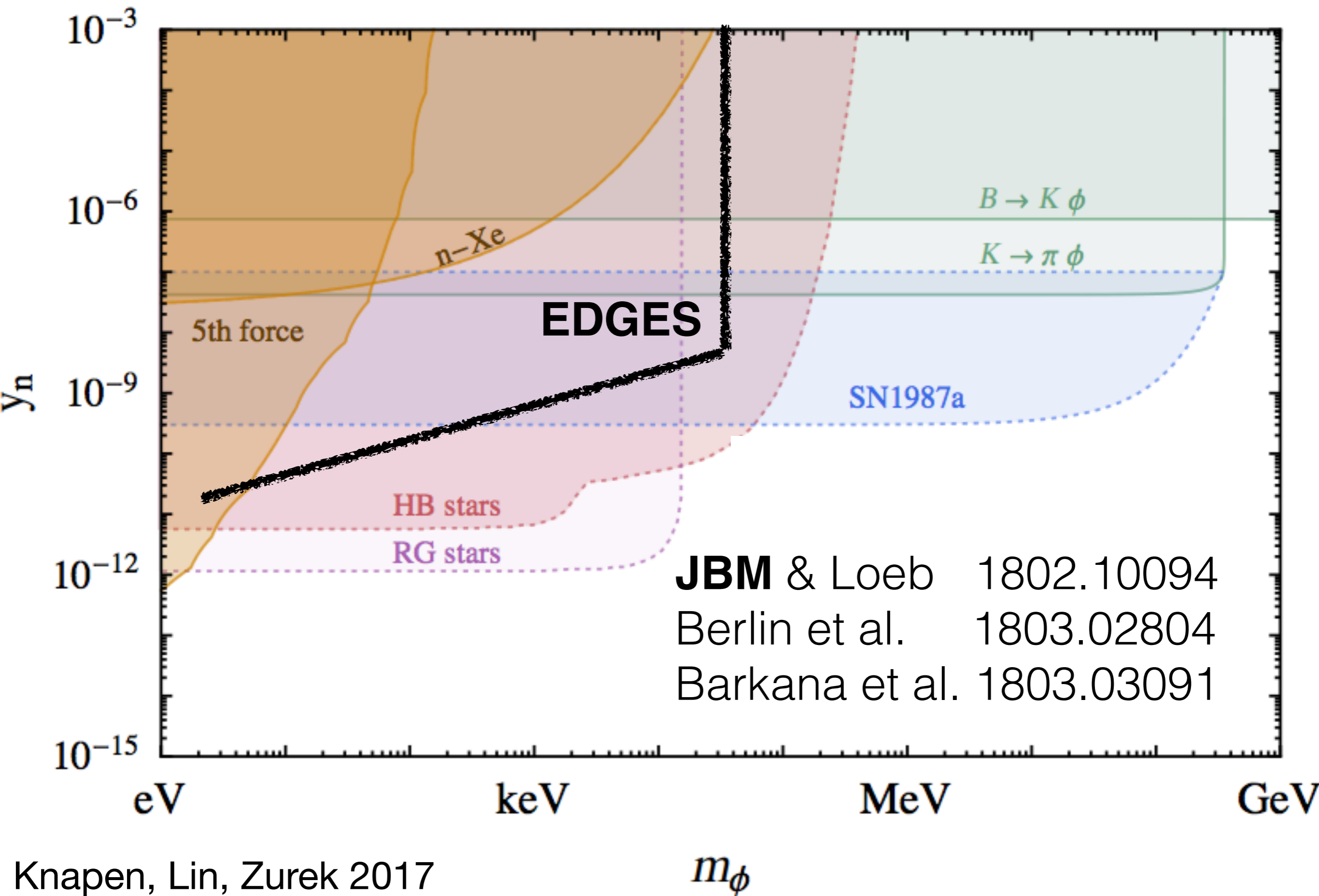
Also implies this:



Fifth-force constraints



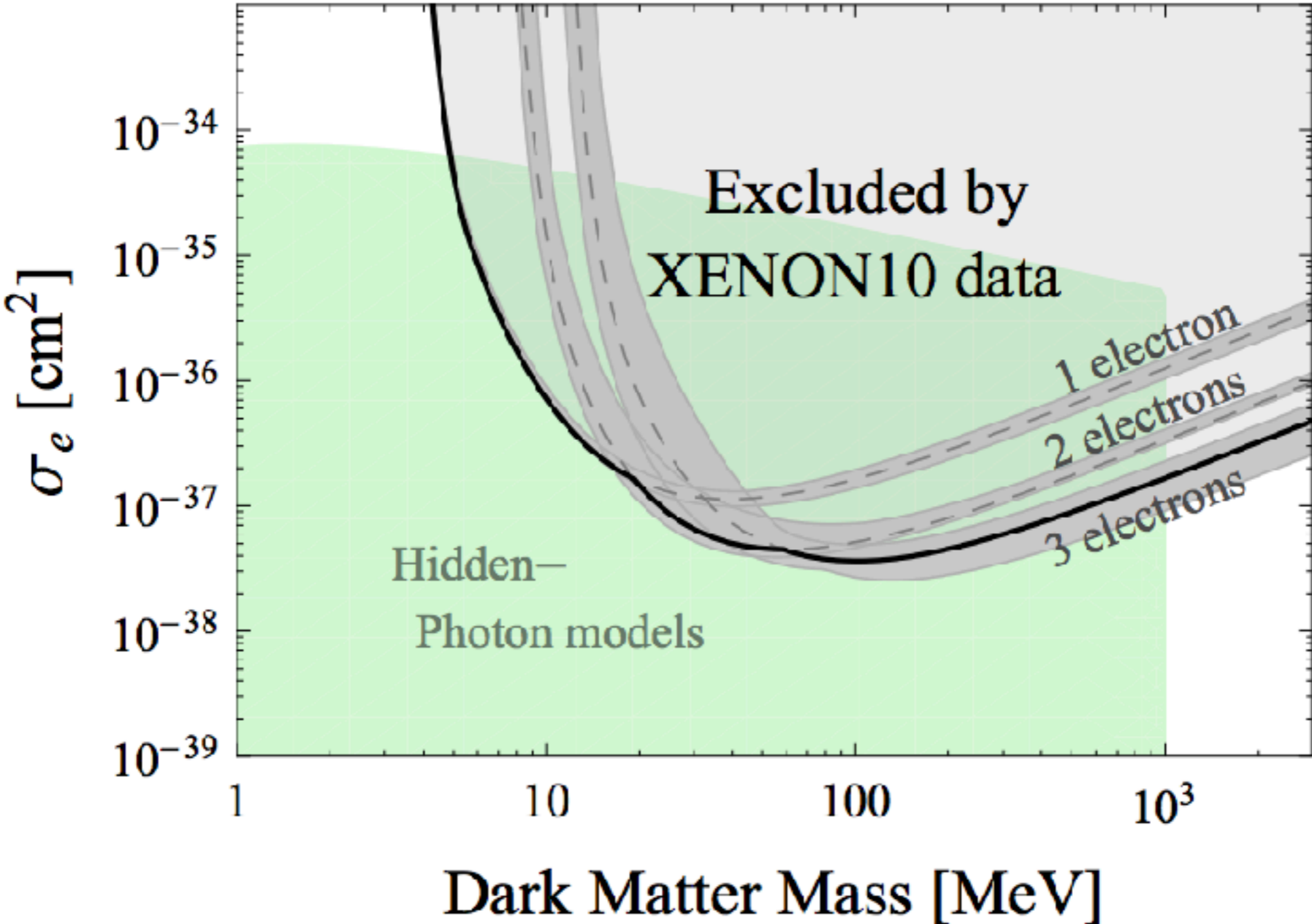
Fifth-force constraints



Can you test this?

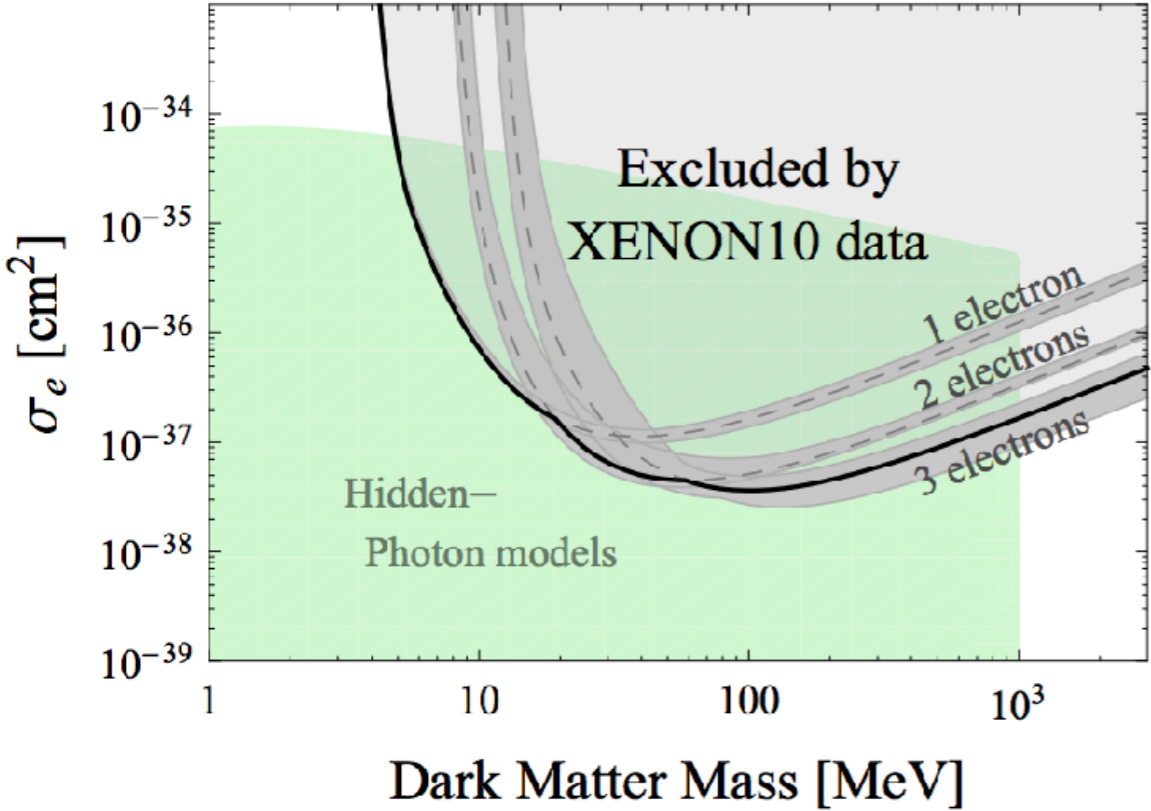
Essig et al. 2012

$$\sigma_{DD} \sim 10^{-27} \text{ cm}^2$$



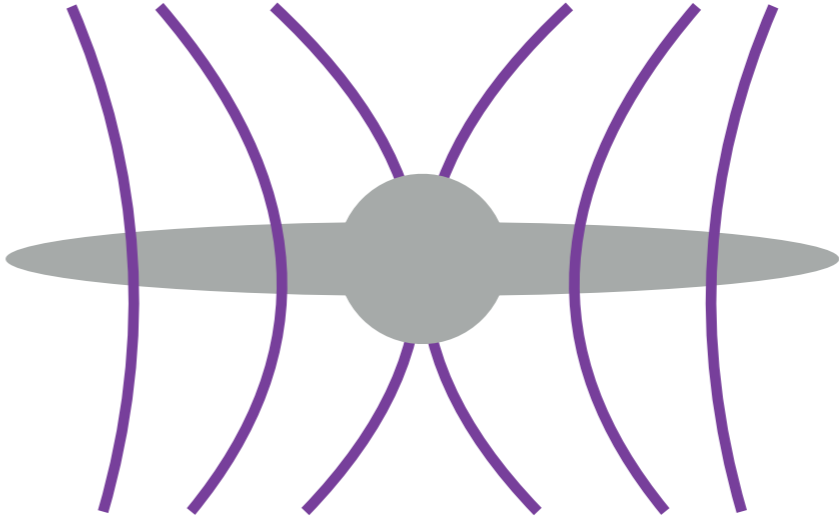
Can you test this?

Essig et al. 2012



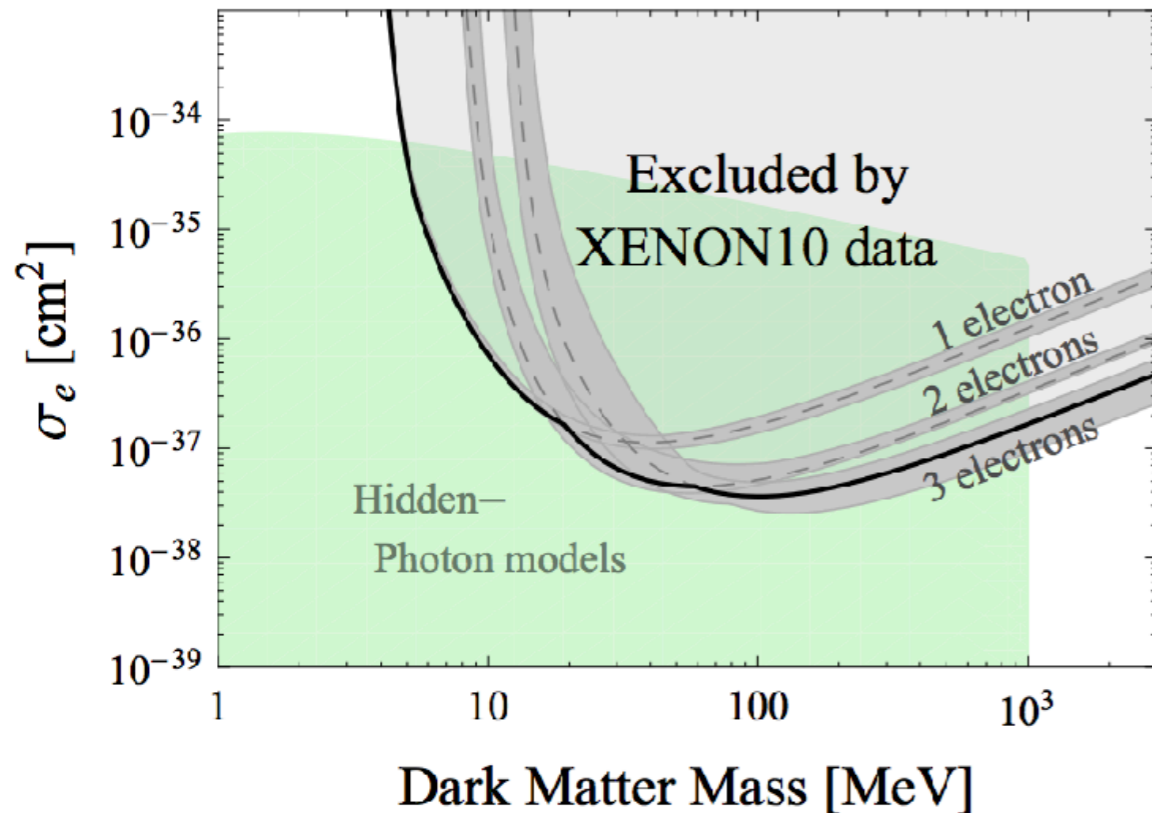
Although:

$$\sigma_{DD} \sim 10^{-27} \text{ cm}^2 > \sigma_{\text{m.f.p.}}$$



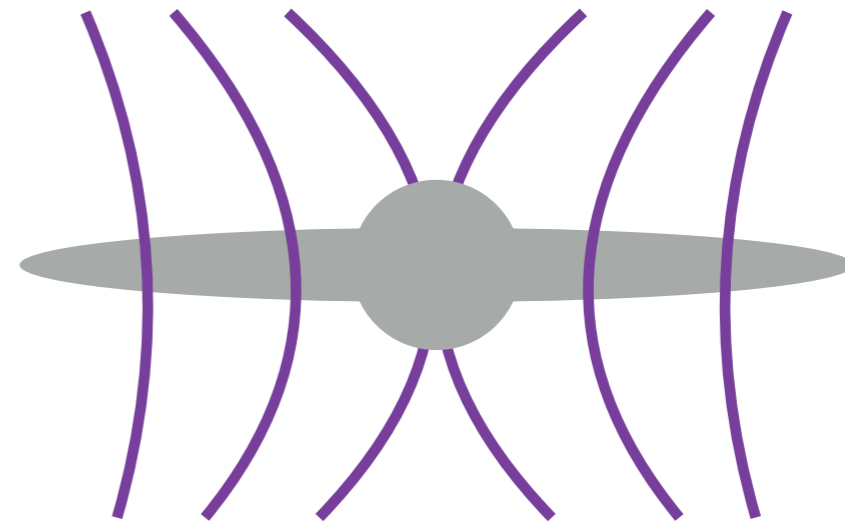
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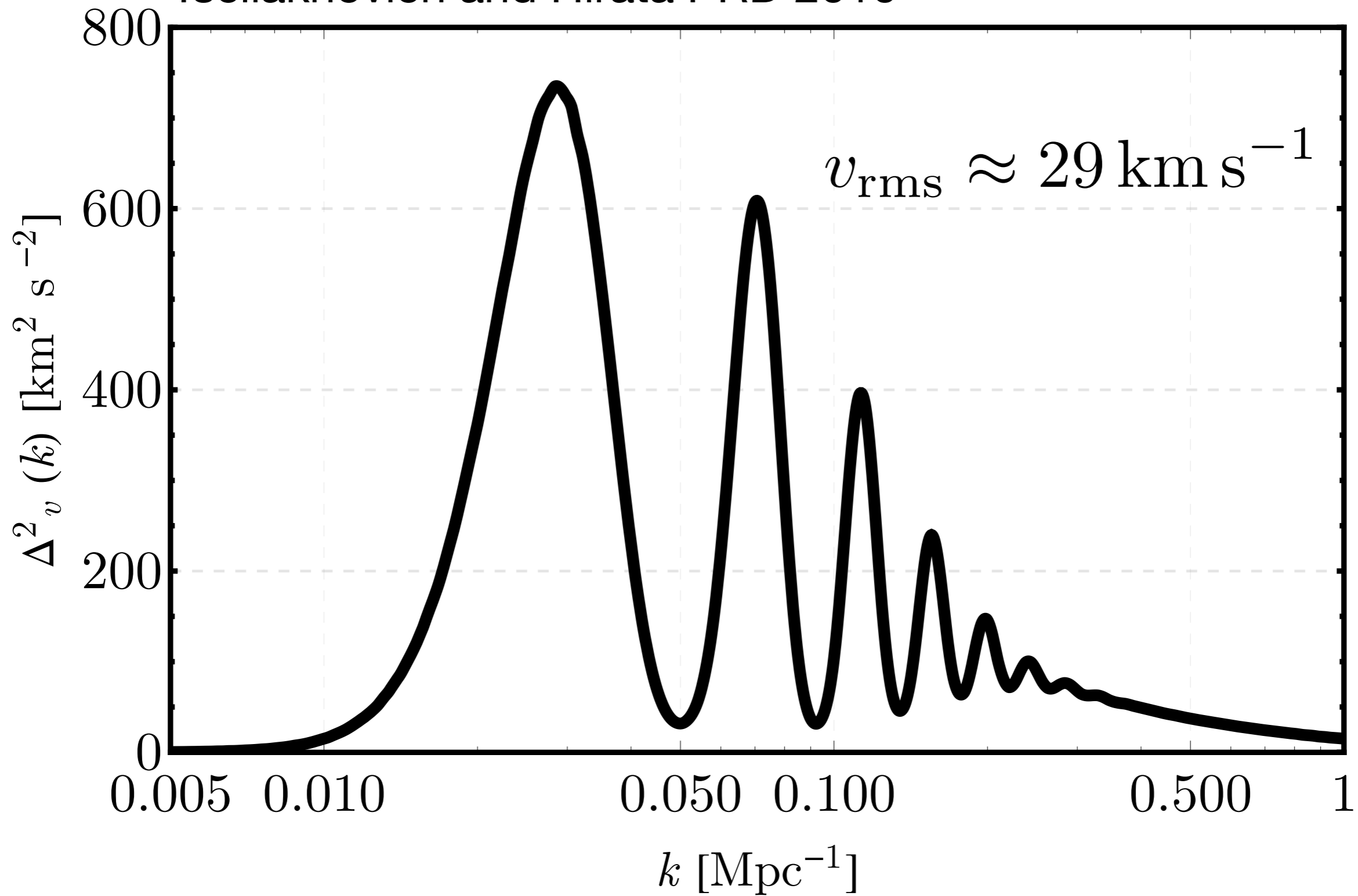


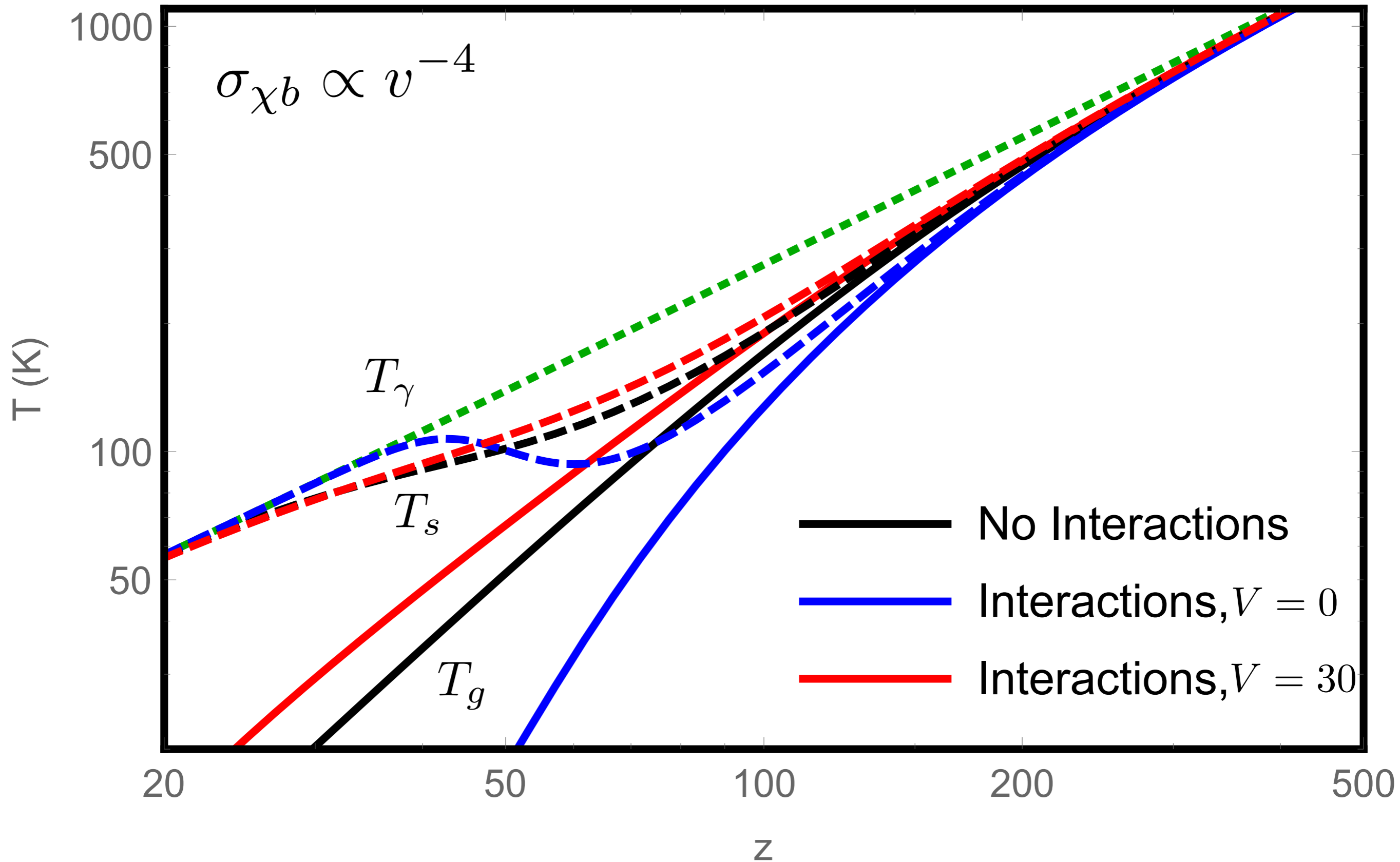
SHiP @ CERN + others

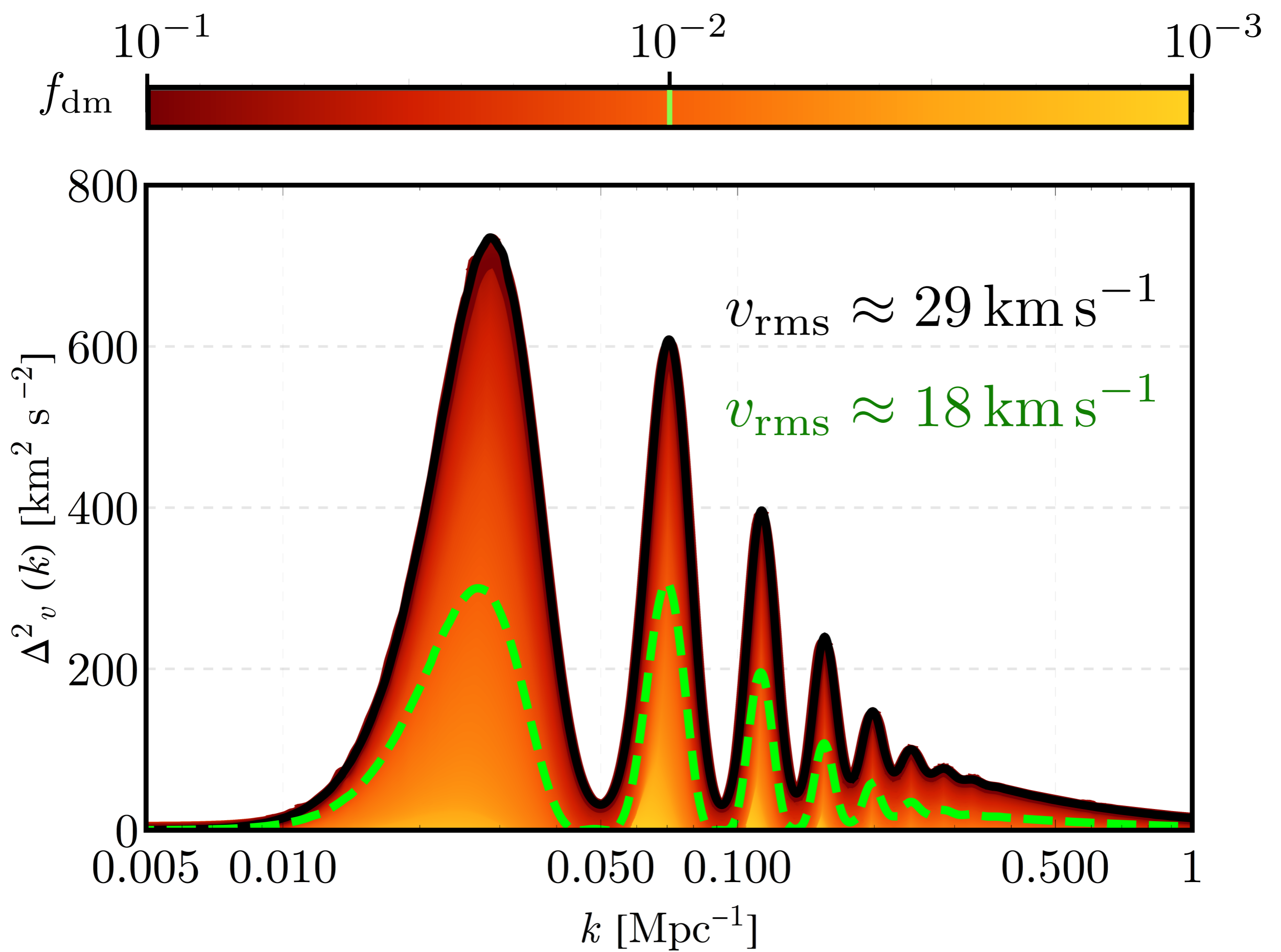
LDMX ~ SLAC mQ/10

$$\epsilon > 10^{-3}$$

Tseliakhovich and Hirata PRD 2010

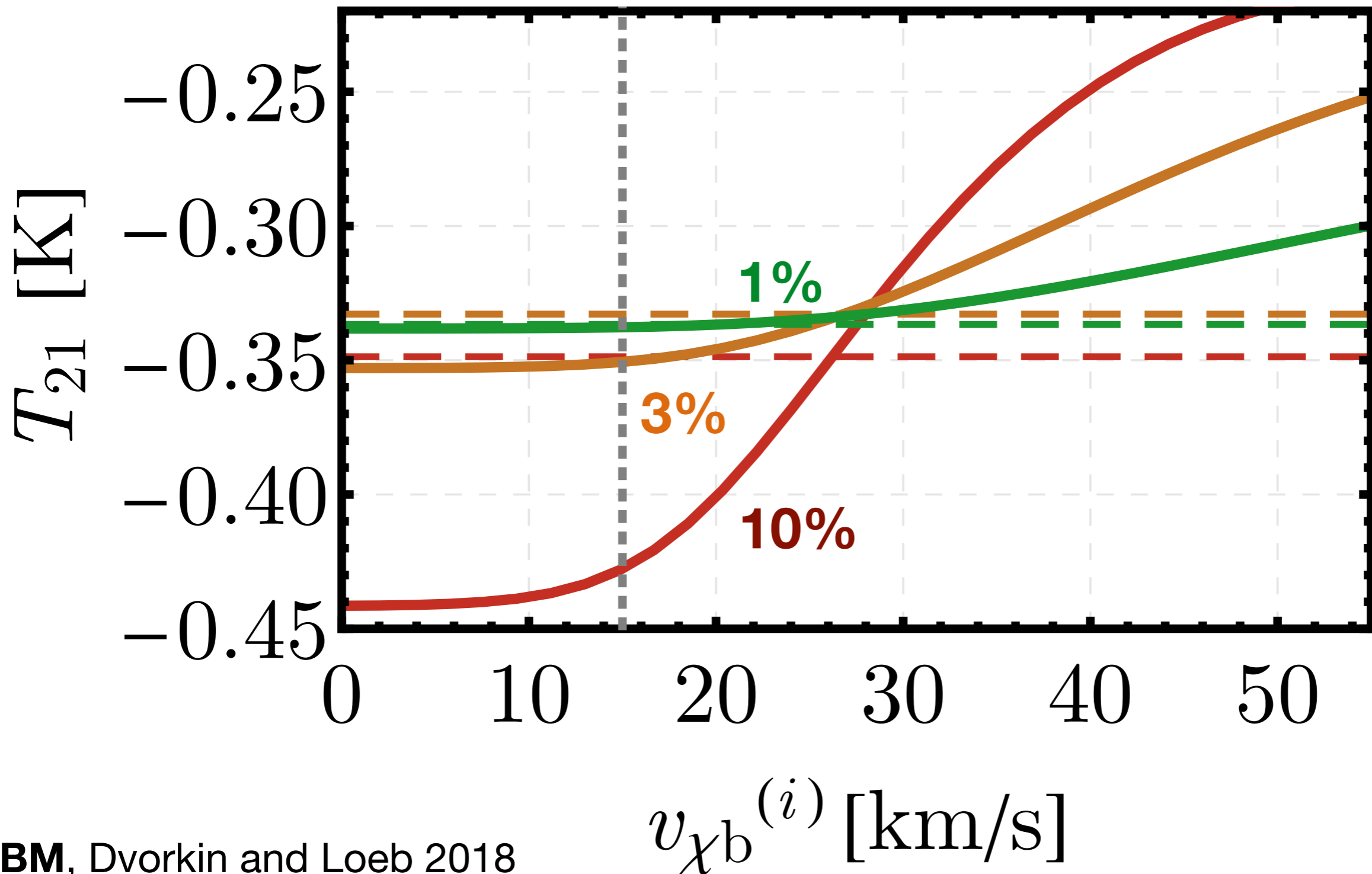


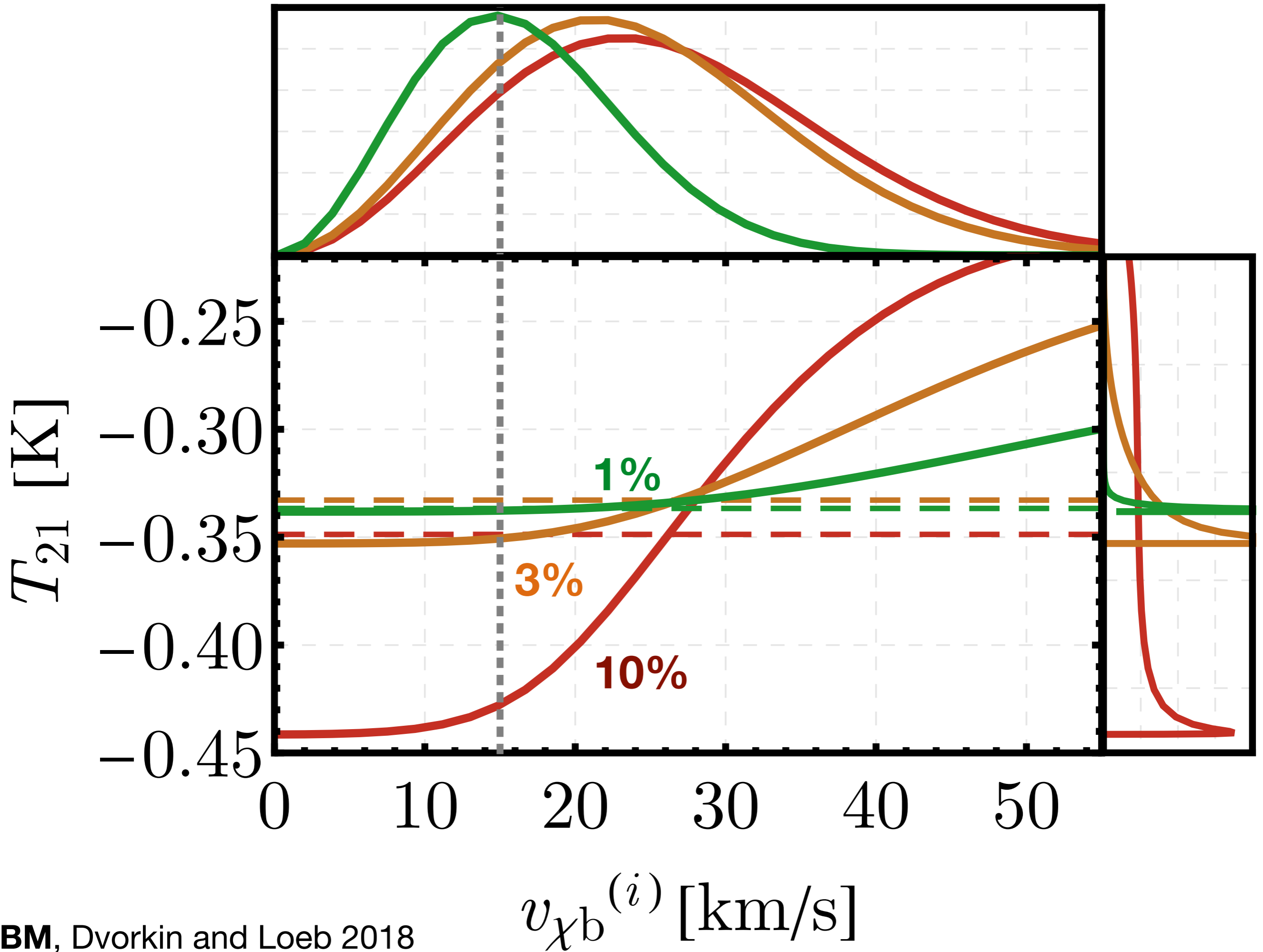




$$T^{(21)} = \tau \frac{T_s - T_{\text{cmb}}}{1 + z} (v_{\chi,b}^{(i)}) \leftarrow \text{Relative velocity at decoupling}$$

$$\sigma_{\chi b} \propto v^{-4}$$





21-cm fluctuations

