Dark matter at small scales with 21-cm

Julian B. Muñoz
Clay Fellow

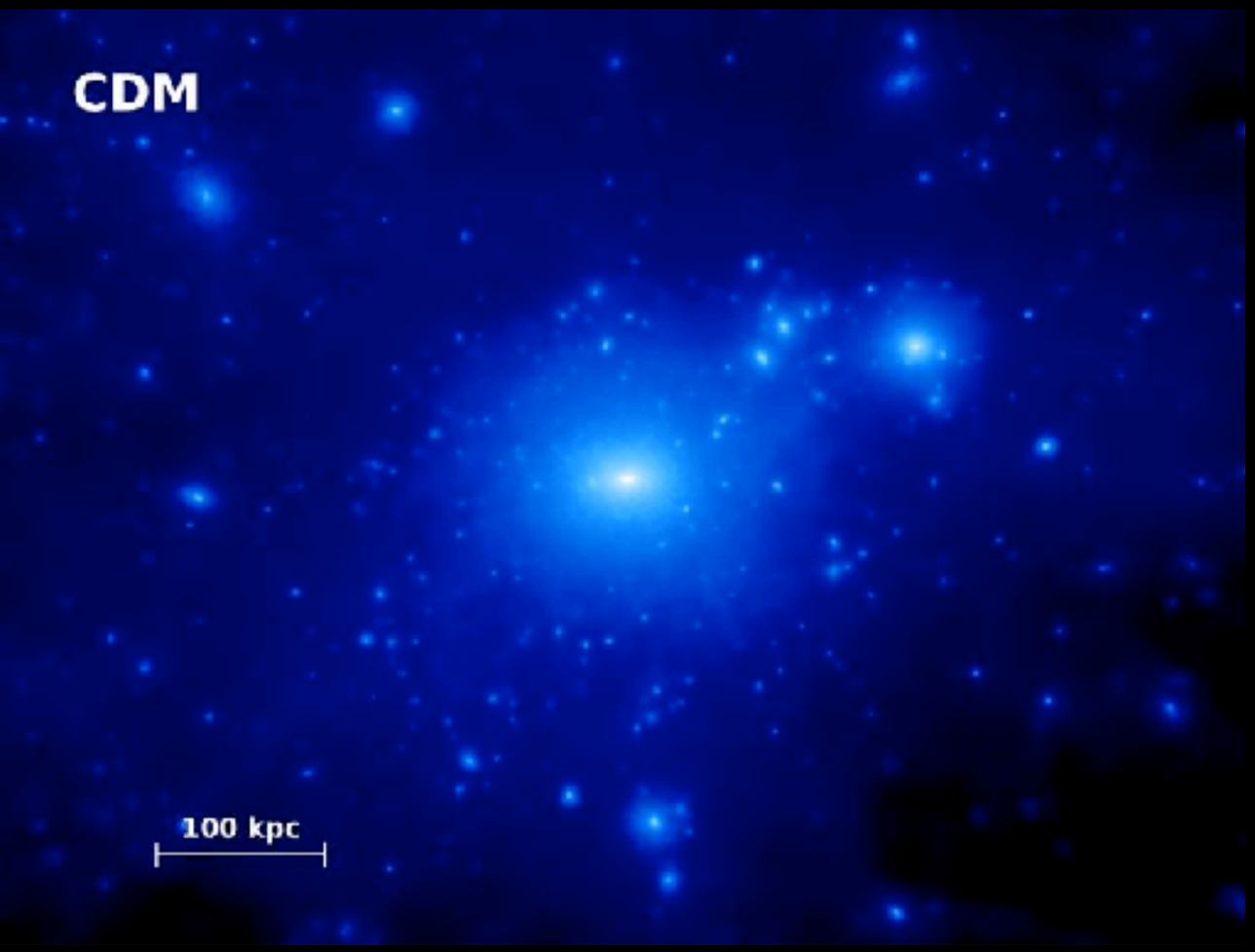
Based on

PRD 101 063526 (2020) w/ Dvorkin and Cyr-Racine
PRD (2021) w/ Bohr, Cyr-Racine, Zavala, and Vogelsberger
In prep. w/ Qin, Murray, Greig, and Mesinger
In prep. w/ Mason, Bohr, Cyr-Racine, Zavala, and Vogelsberger

CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

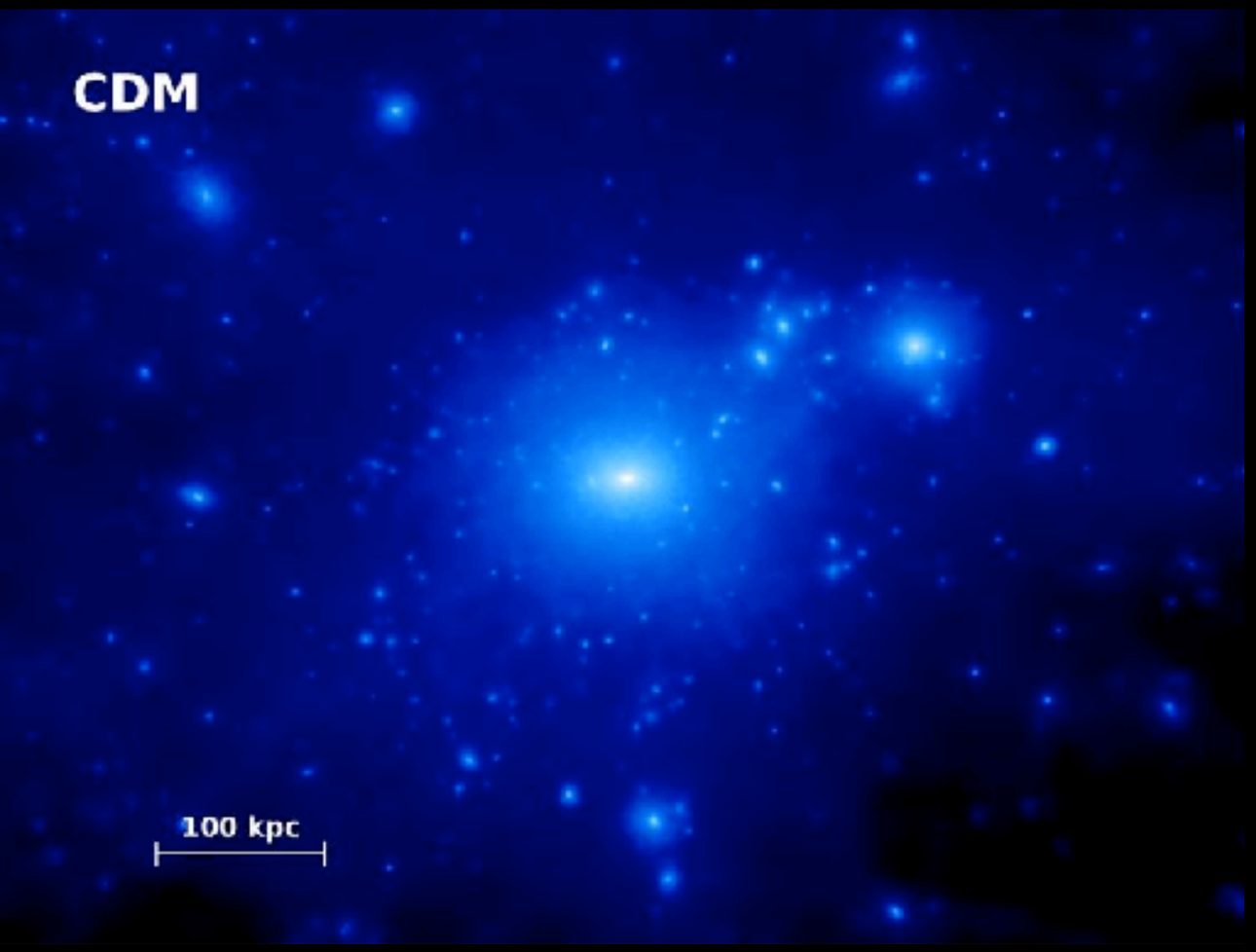
Image: Fuller/NSF

Is DM cold?



Credit: Boehm (IPP Durham)

Is DM cold?



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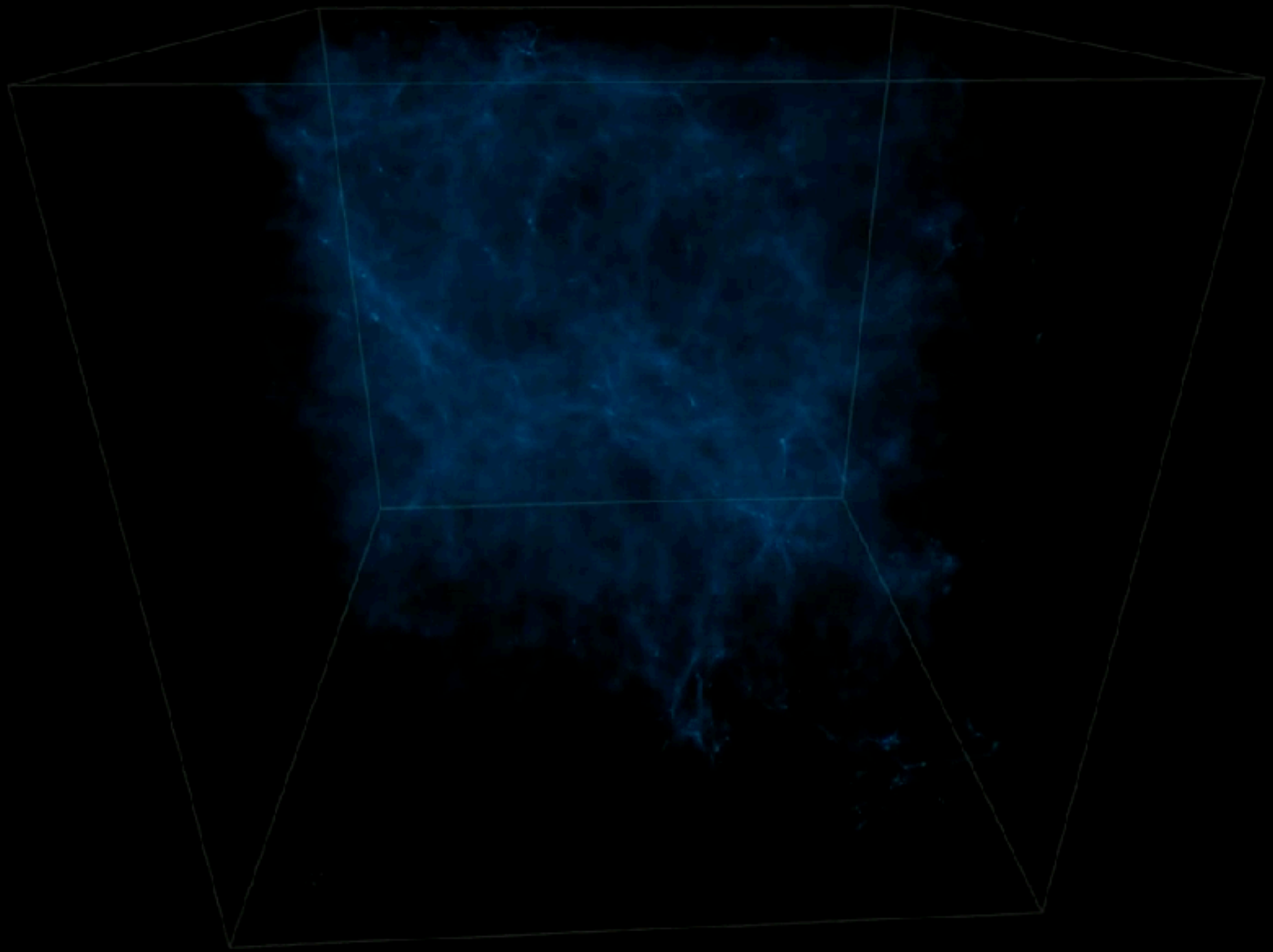
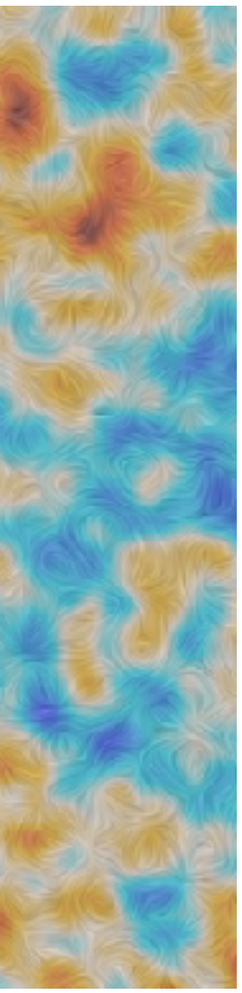
Structure formation is hierarchical



redshift : 11.12

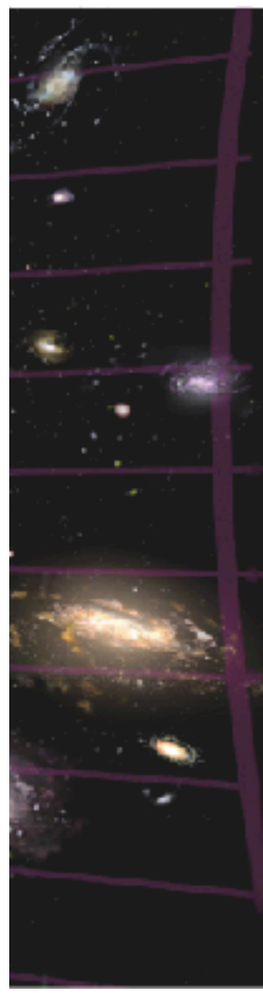
Credit: Illustris team

CMB



$z \approx 10^3$

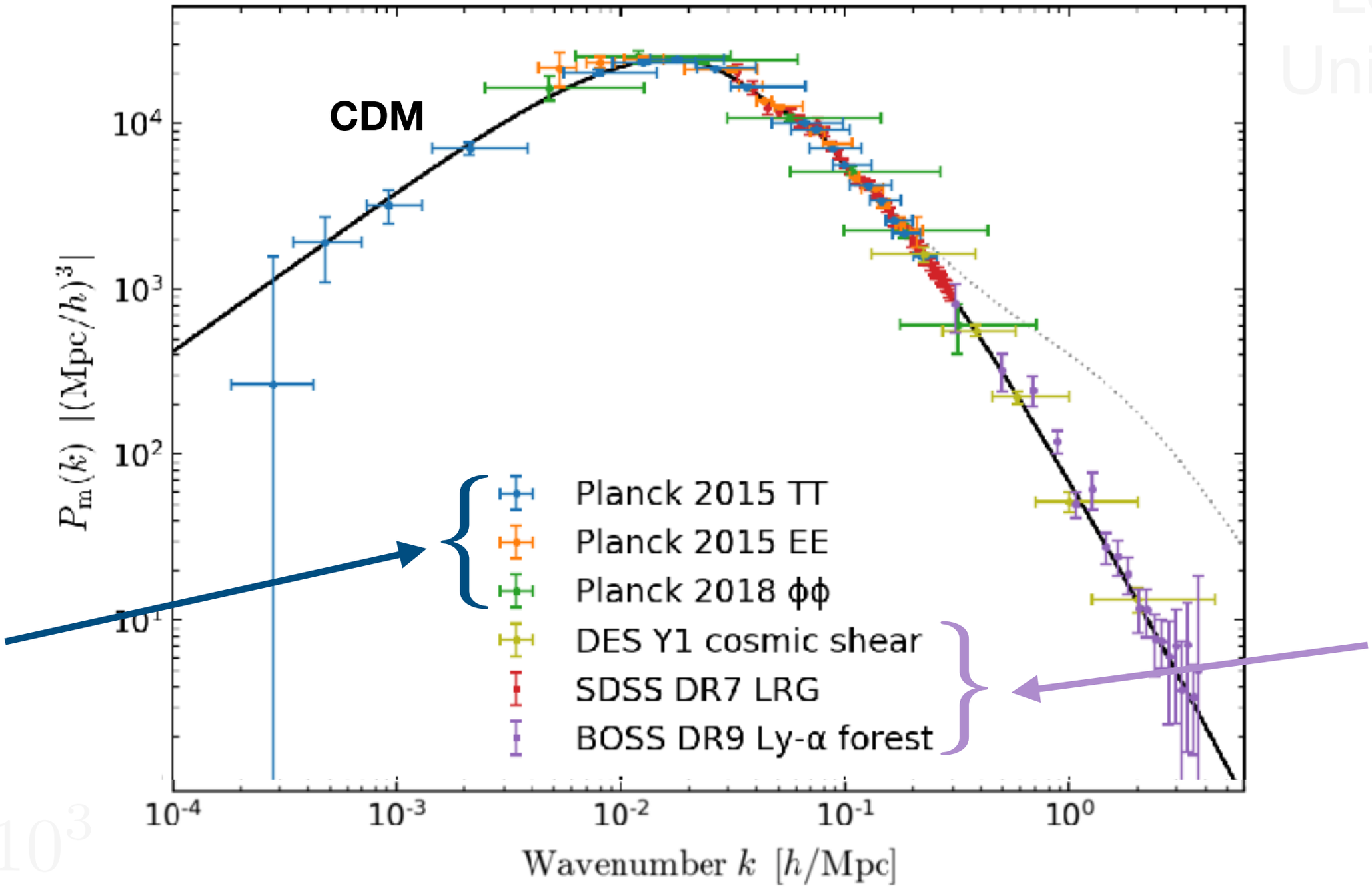
Local Universe

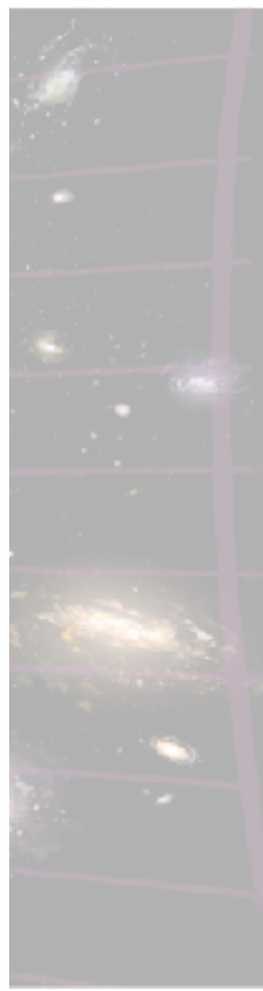


$z = 0$

Chabanier+ arXiv: 1905.08103

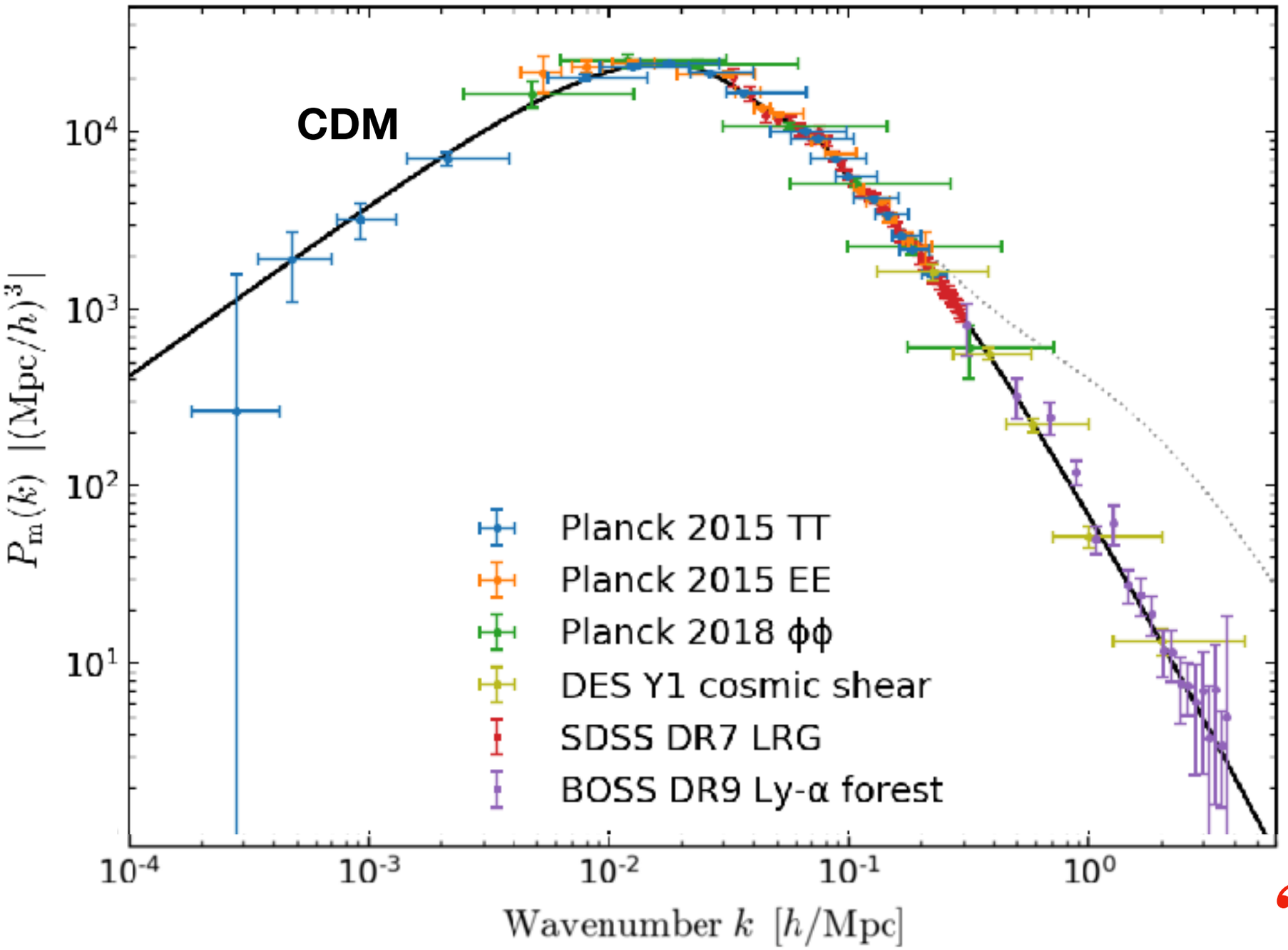
DM is cold ...





Chabanier+ arXiv: 1905.08103

DM is cold **at large scales**



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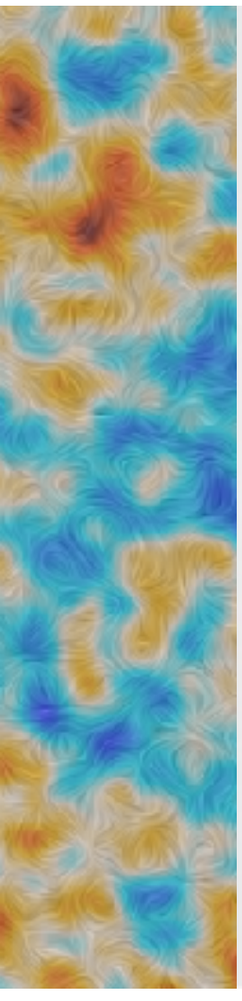
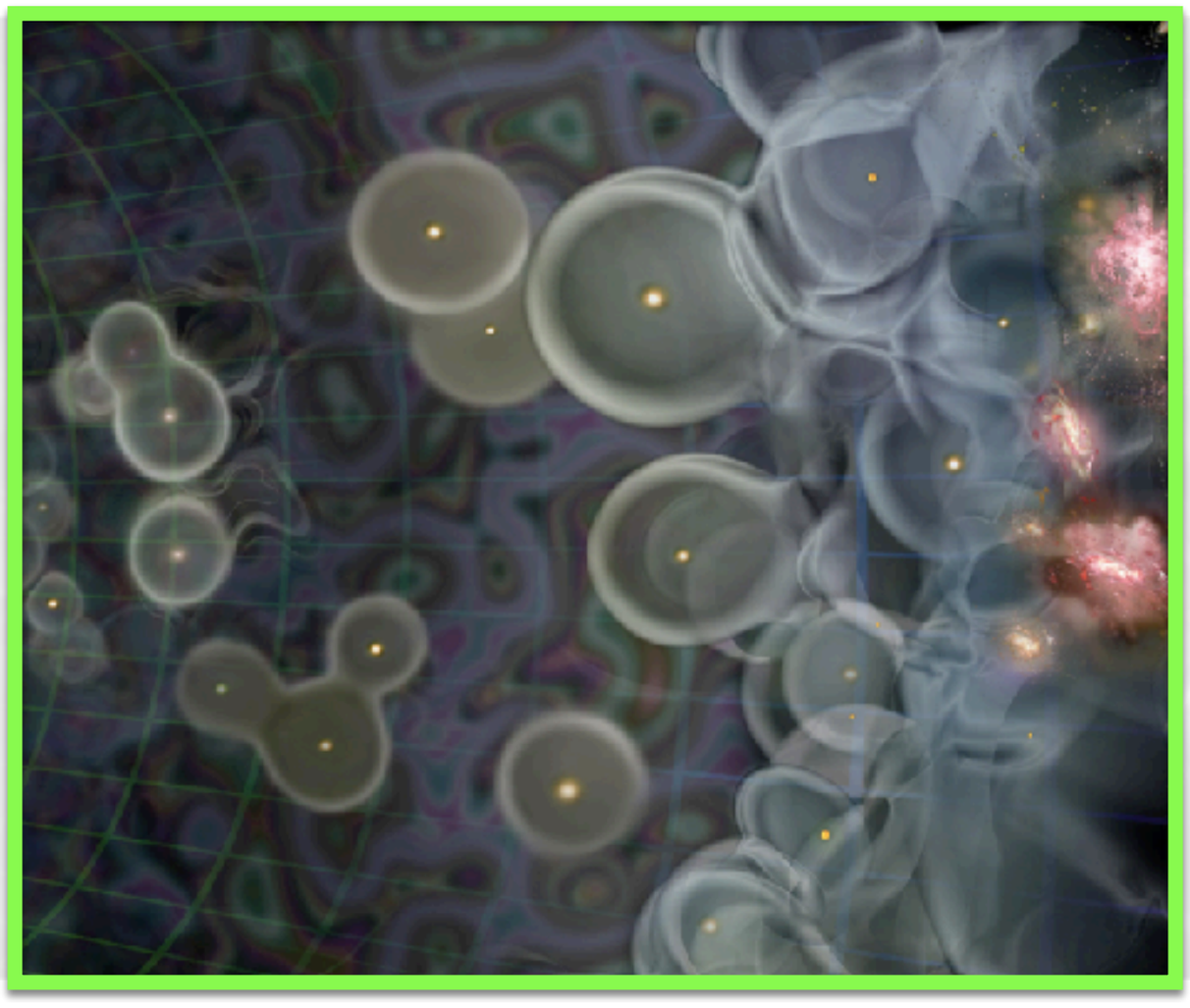
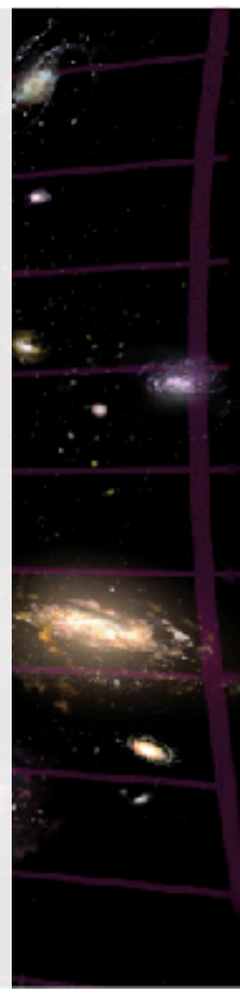
Chabanier+ arXiv: 1905.08103

Targeted by 21-cm experiments:
Eg, EDGES, HERA …

Cosmic Dawn



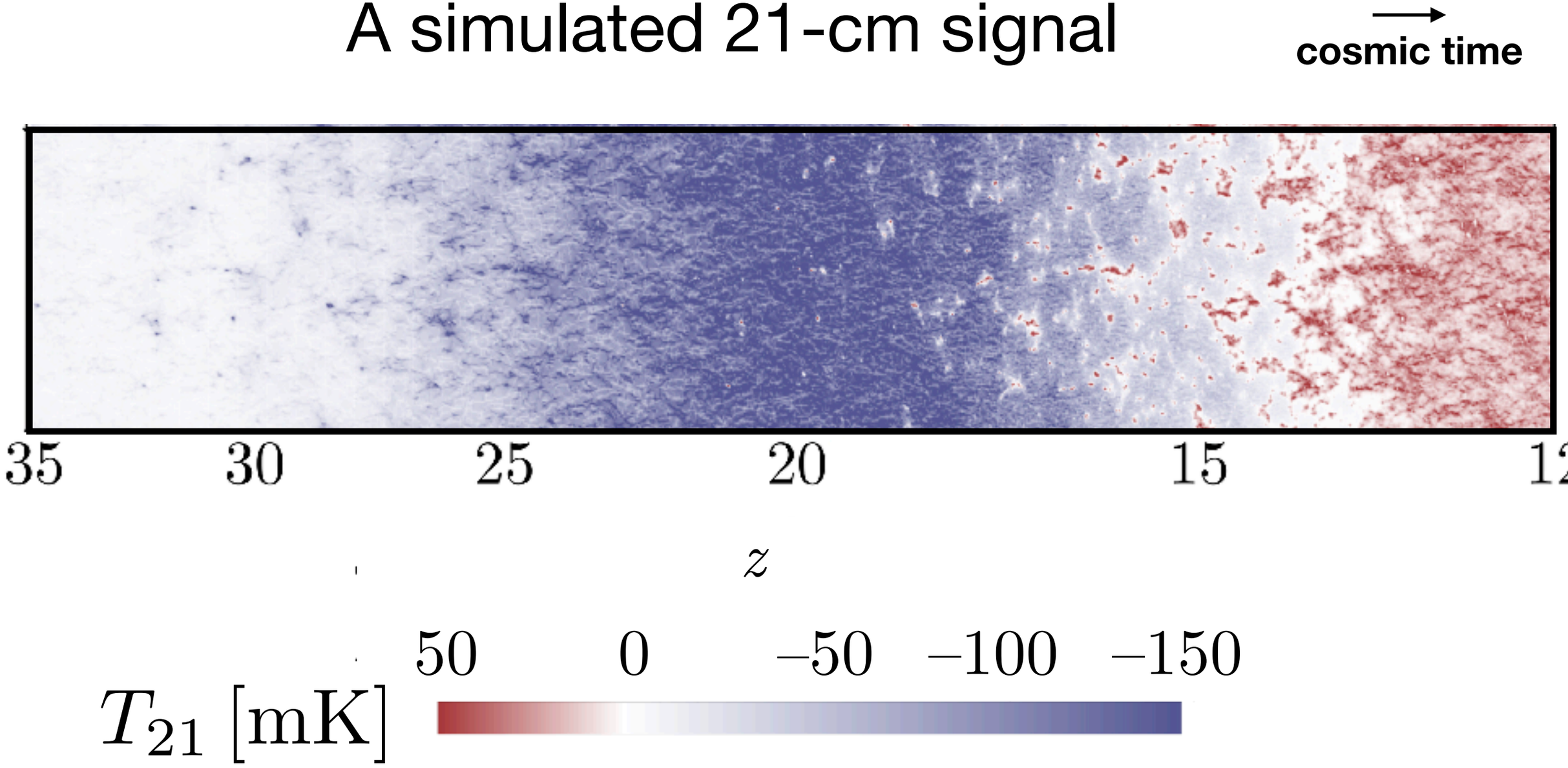




$z \approx 10^3$ $z \approx 20$ $z = 0$

cosmic time →

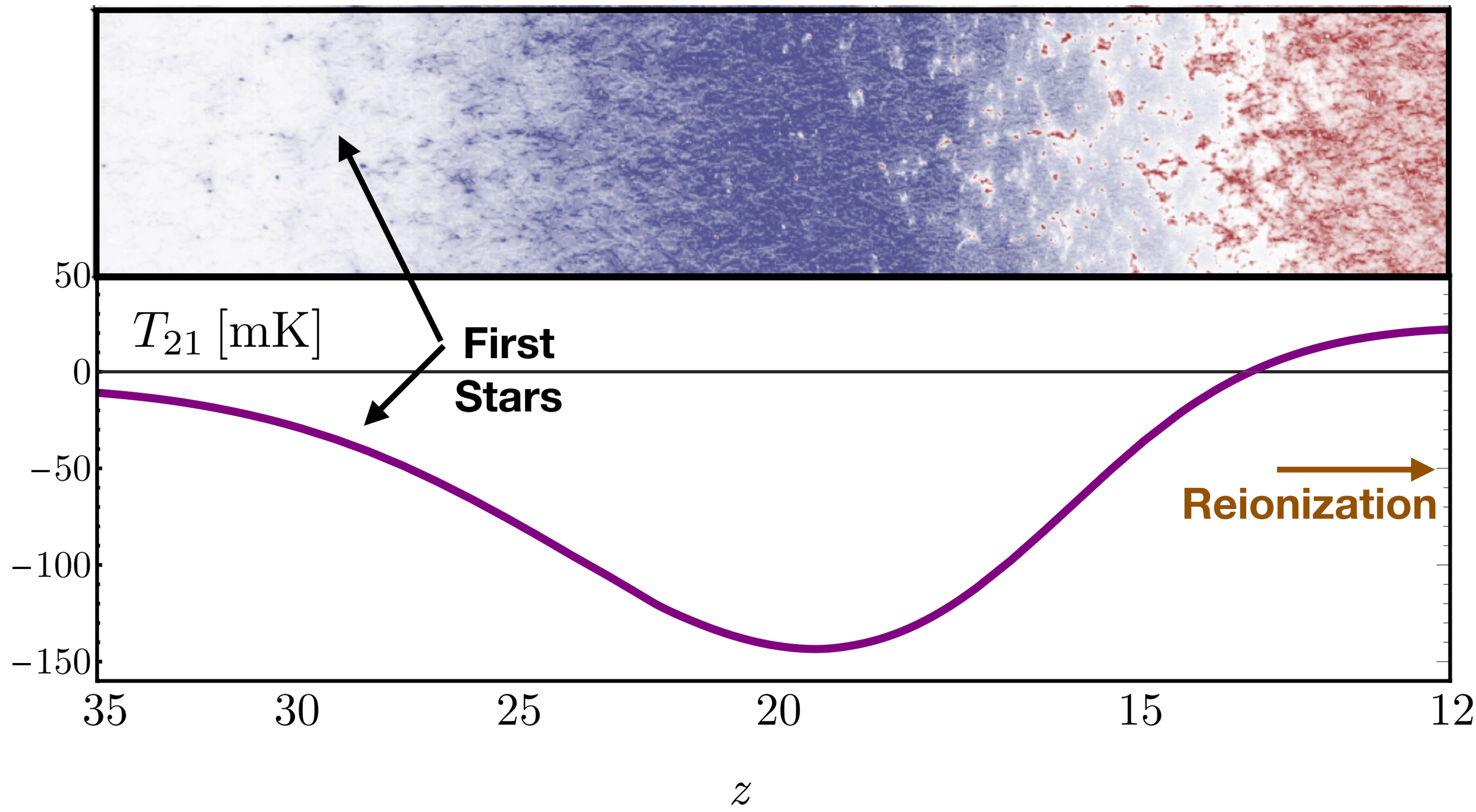
A simulated 21-cm signal



21cmvFAST **JBM** PRD 2019 https://github.com/JulianBMunoz/21cmvFAST

JBM, Qin, Murray, Greig, Mesinger+ (In prep) https://github.com/21cmfast/21cmFAST

A simulated 21-cm global signal



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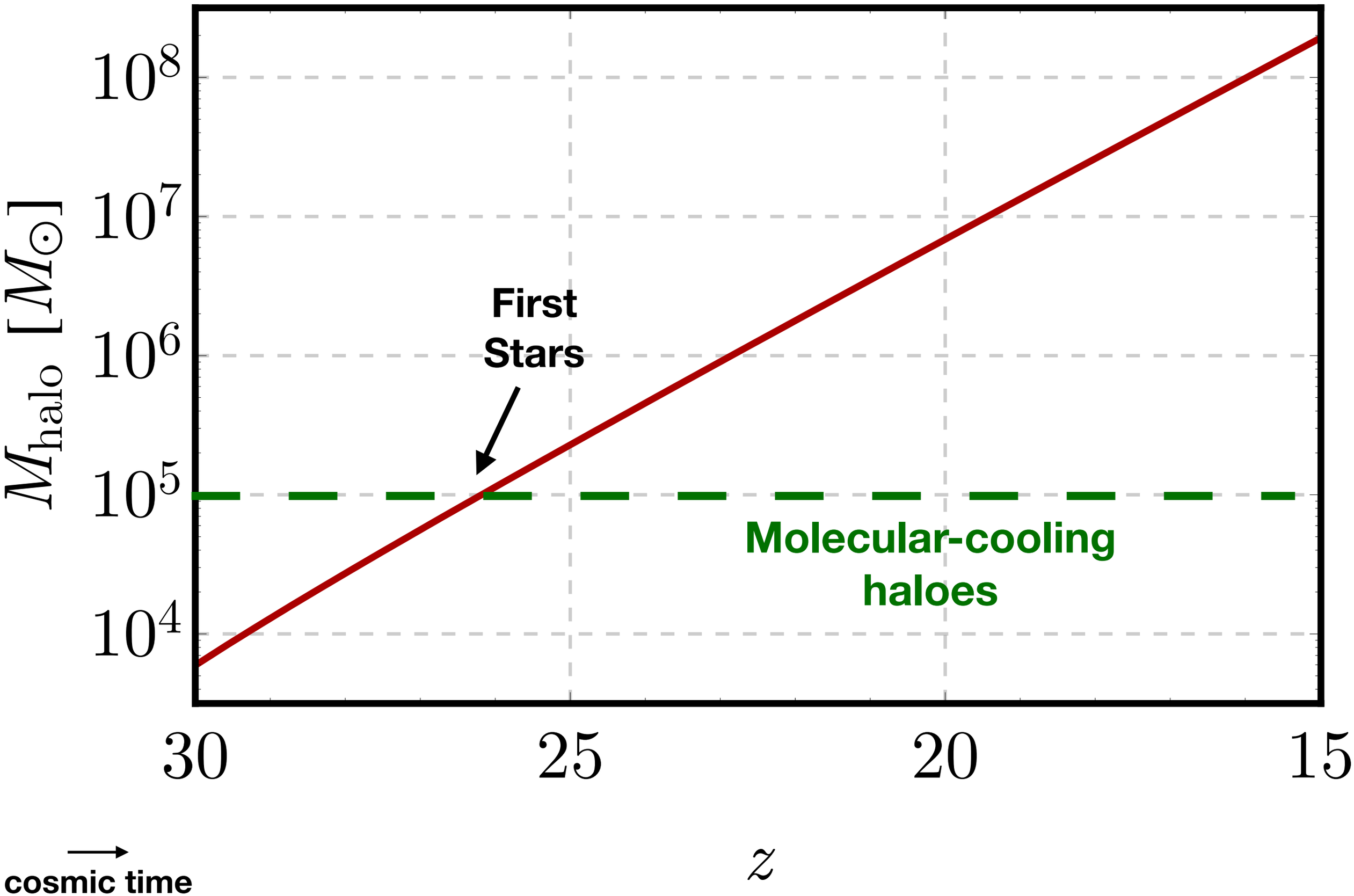

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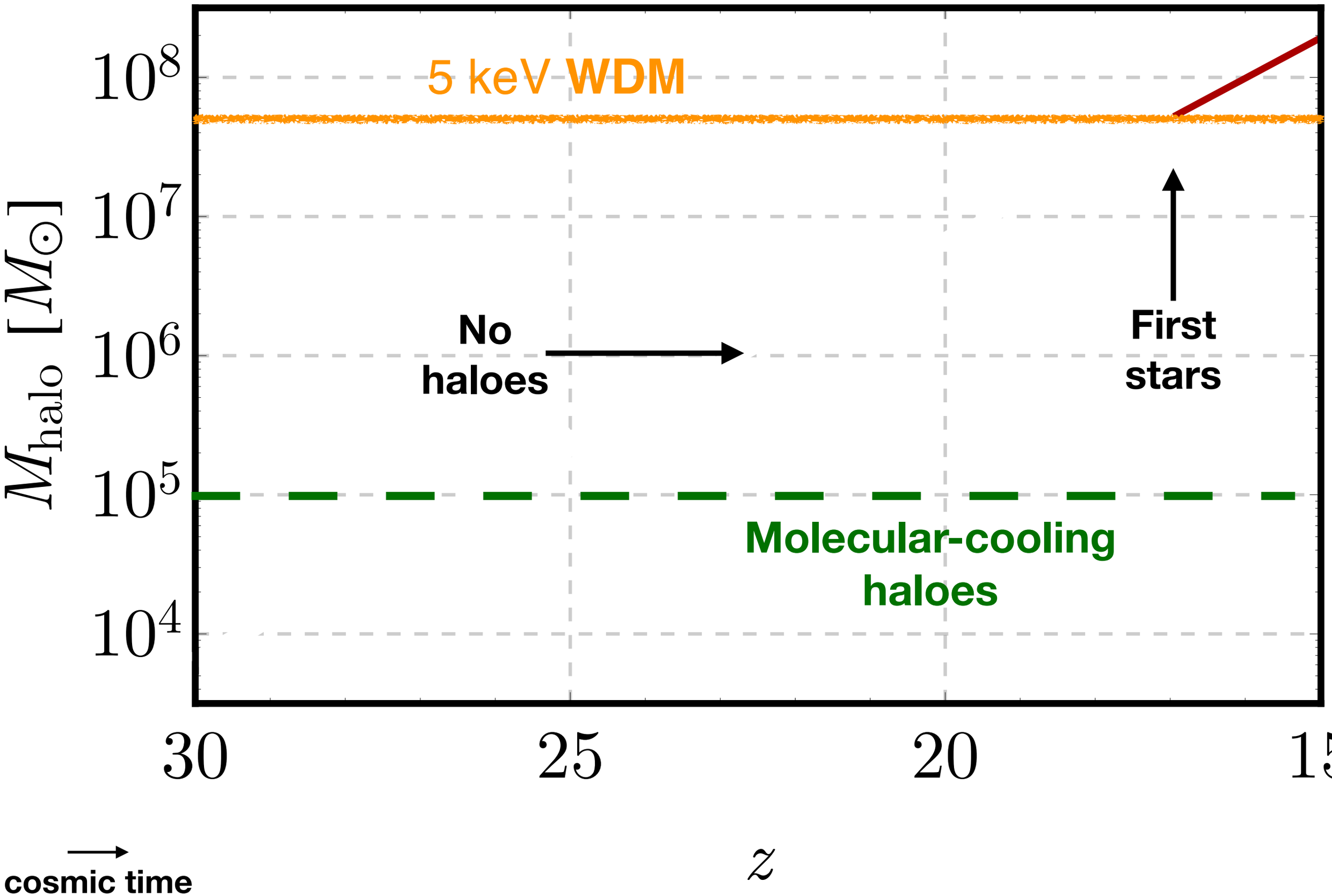
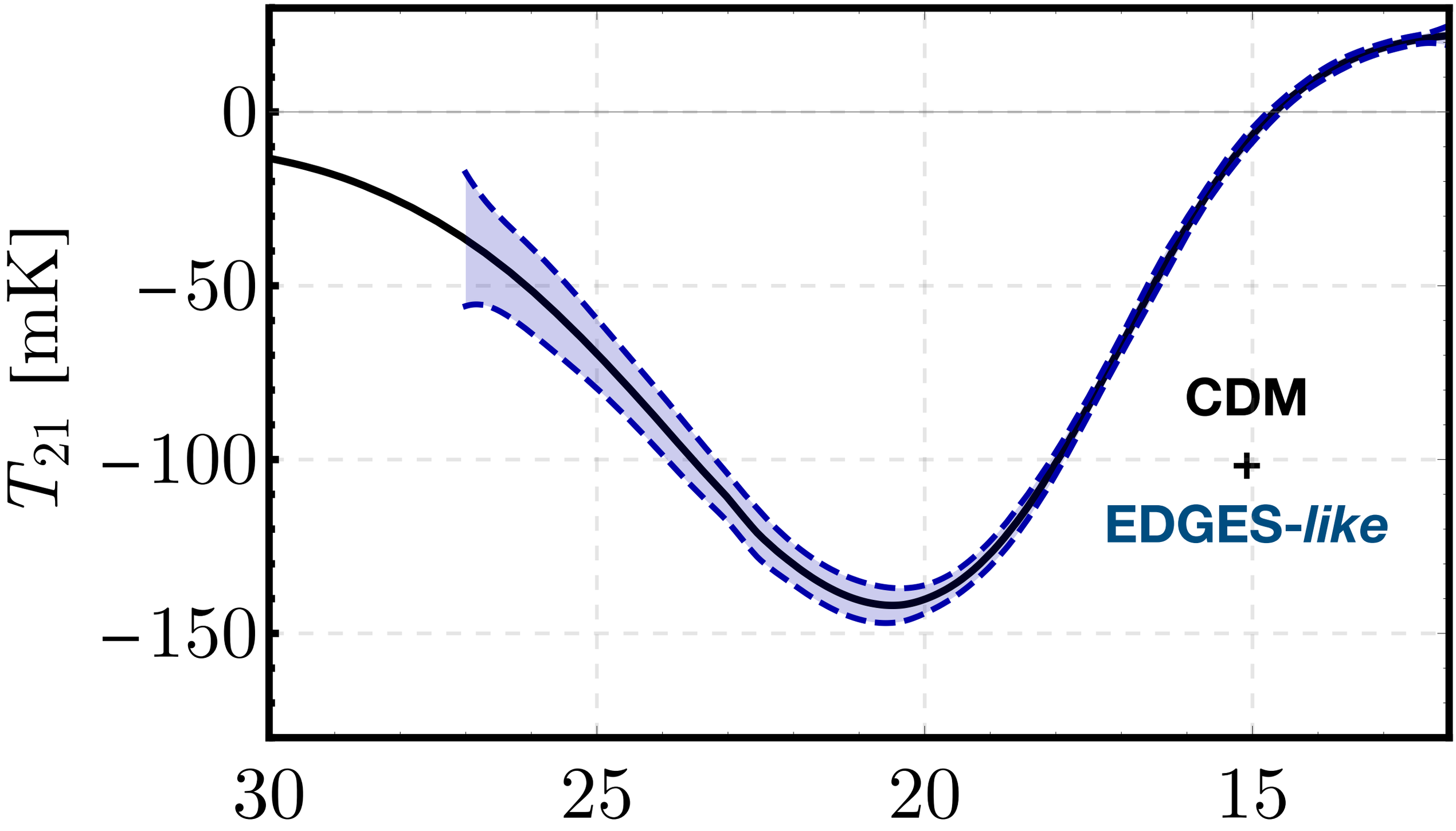


Is DM cold?

cosmic time



JBM, Dvorkin & Cyr-Racine 1911.11144

Is DM cold?

cosmic time

5-keV
WDM

CDM
+
EDGES-*like*

T_{21} [mK]

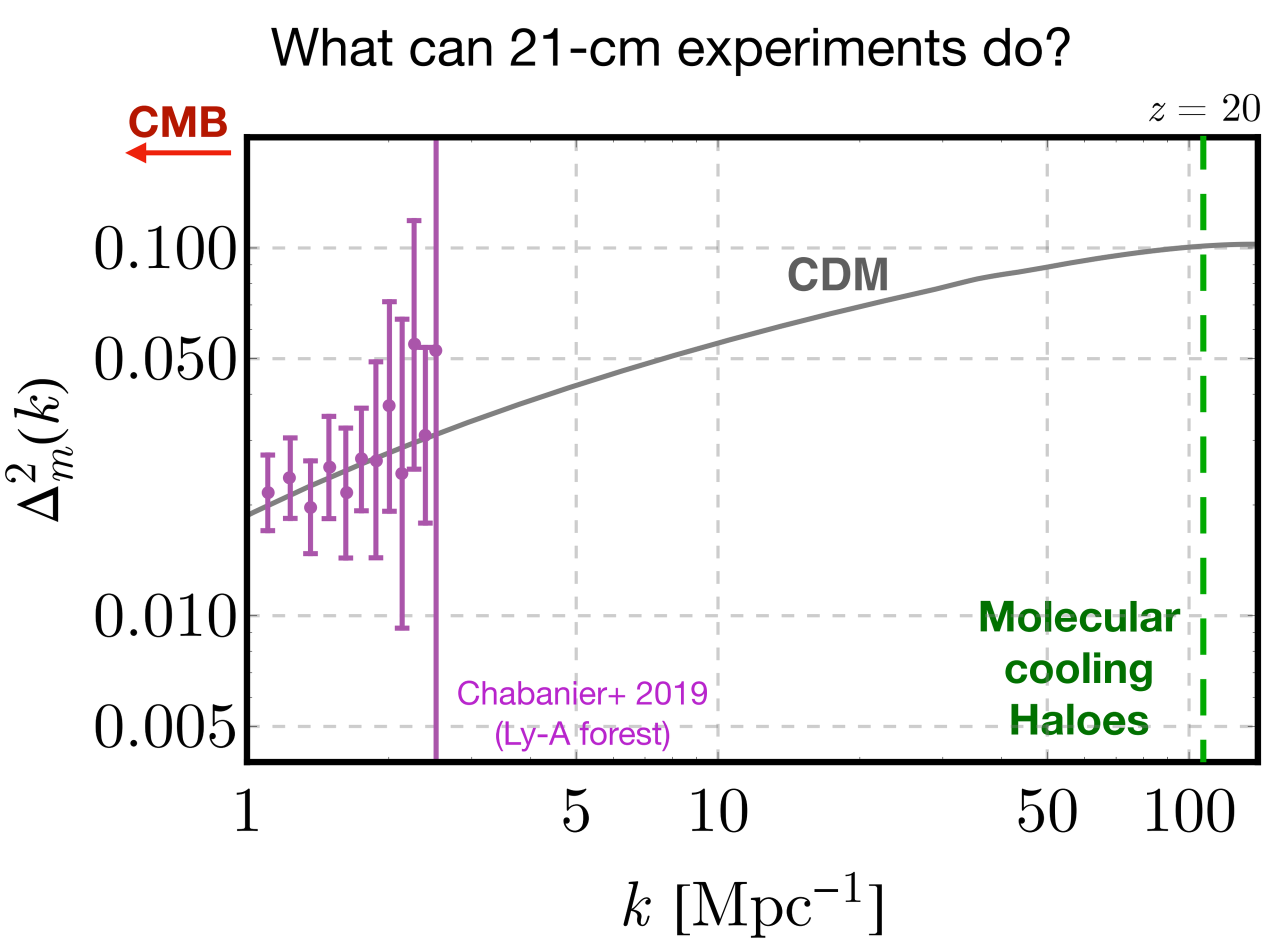
0
−50
−100
−150

30
25
20
15

z

JBM, Dvorkin & Cyr-Racine 1911.11144

What can 21-cm experiments do?



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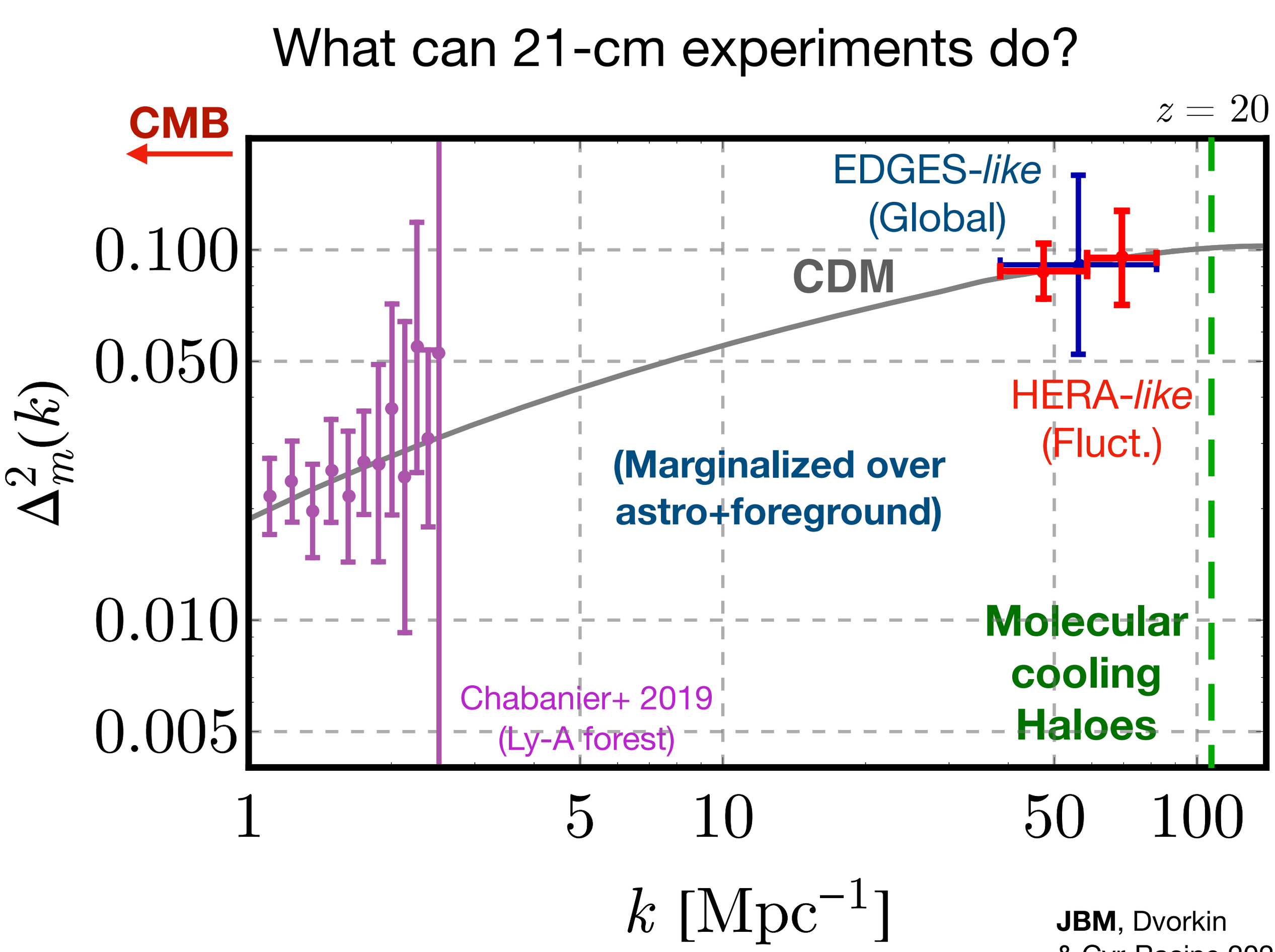
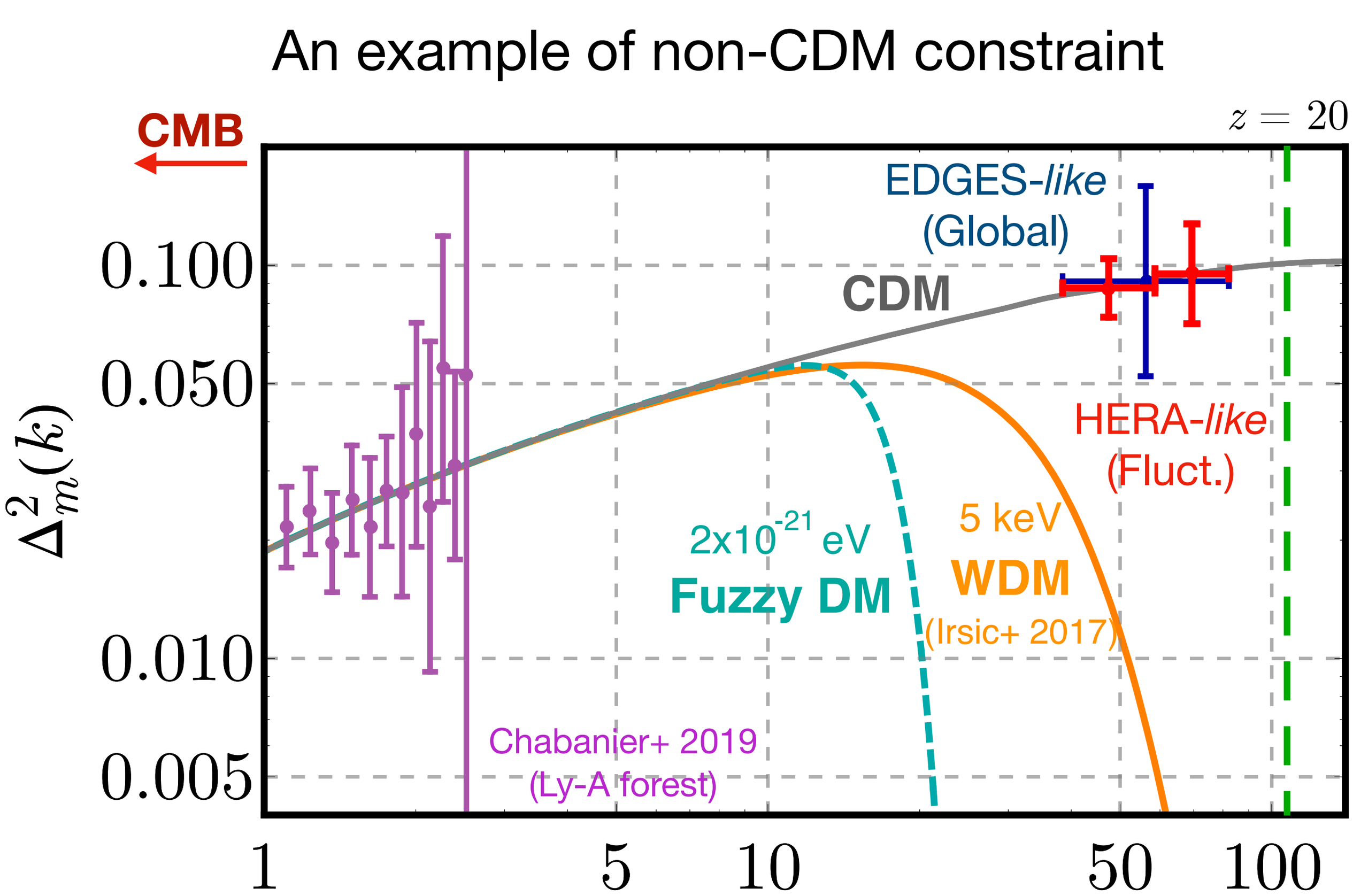


JBM, Dvorkin & Cyr-Racine 2020

An example of non-CDM constraint



Also:
Schneider 2018
Safarzadeh+2018
Lidz & Hui 2018
Boyarsky+ 2018
Yoshiura+ 2018

JBM, Dvorkin & Cyr-Racine 2020

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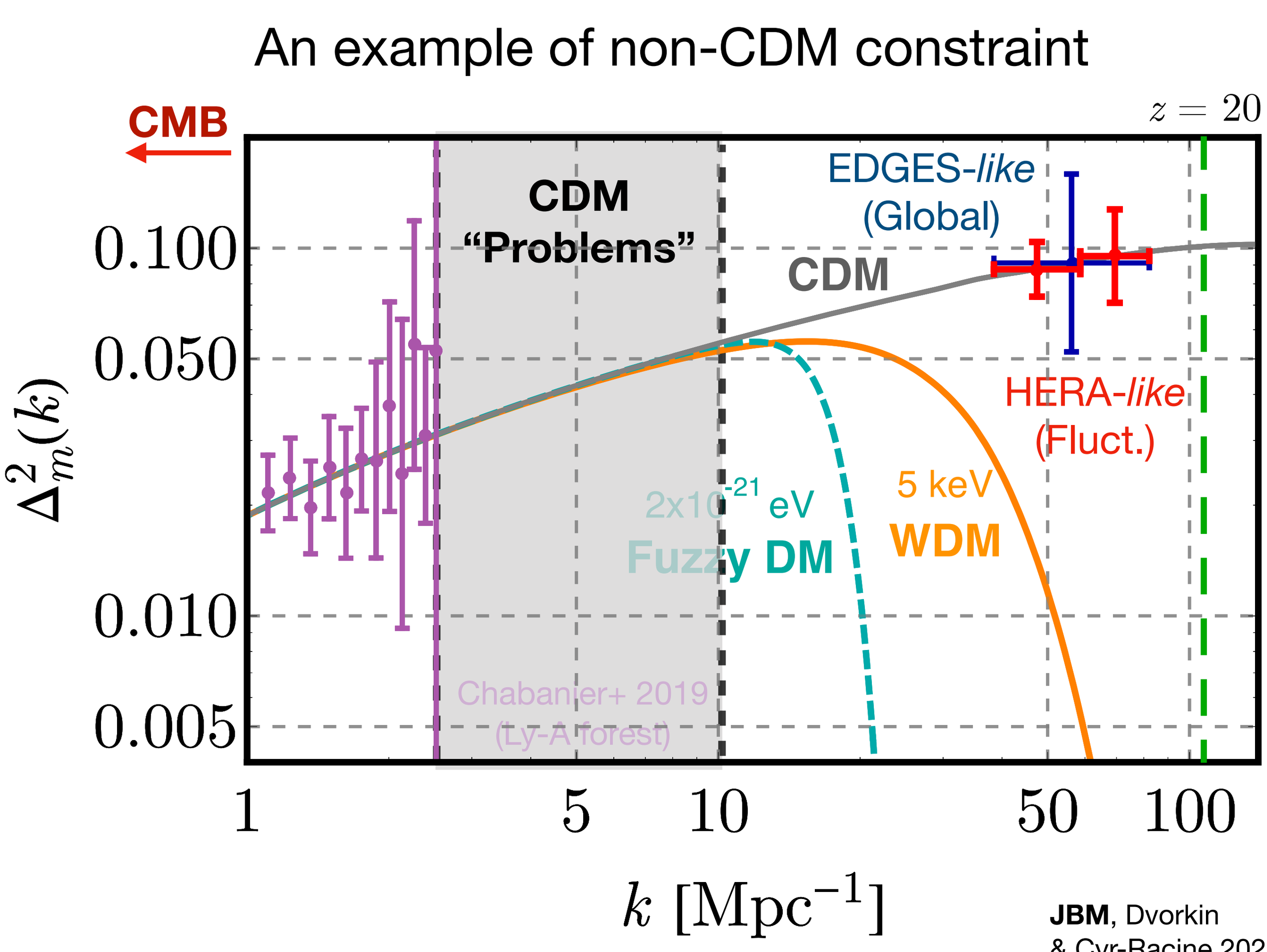
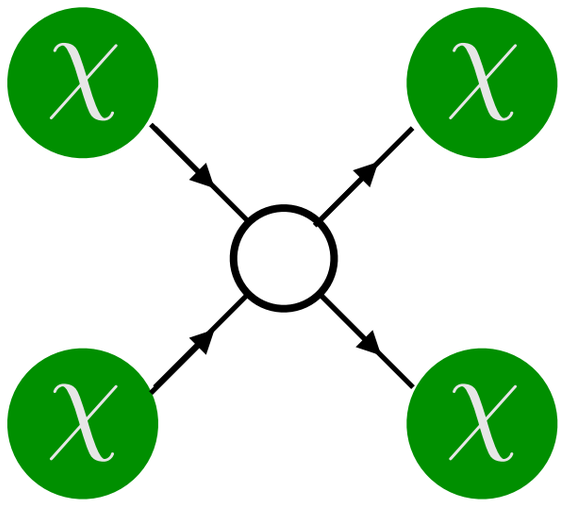
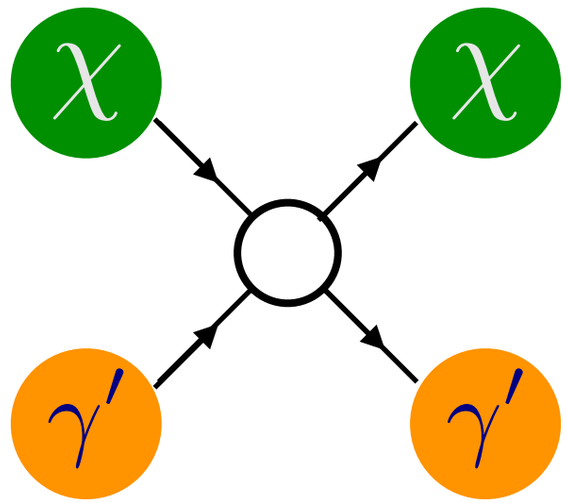


JBM, Dvorkin & Cyr-Racine 2020

Beyond a cutoff: Self Interactions

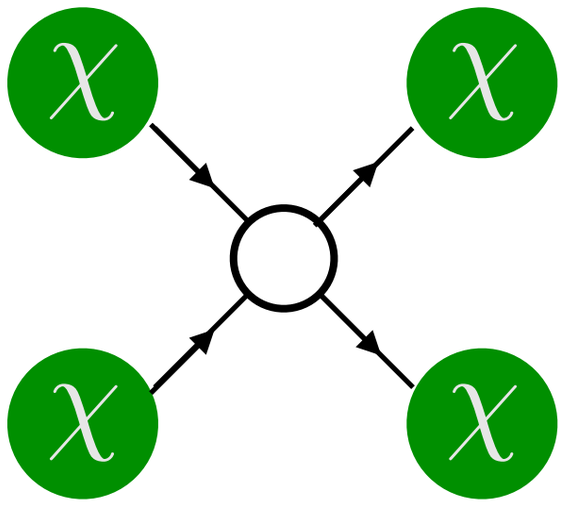


DM-DM:
Halo profiles, etc.



DM-DR:
Power Spectrum

Beyond a cutoff: Self Interactions



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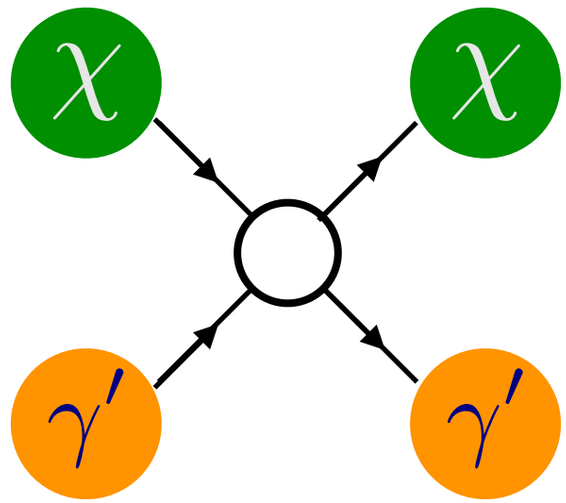


DM-DR:
Power Spectrum

Effective Theory of Structure Formation: **ETHOS**

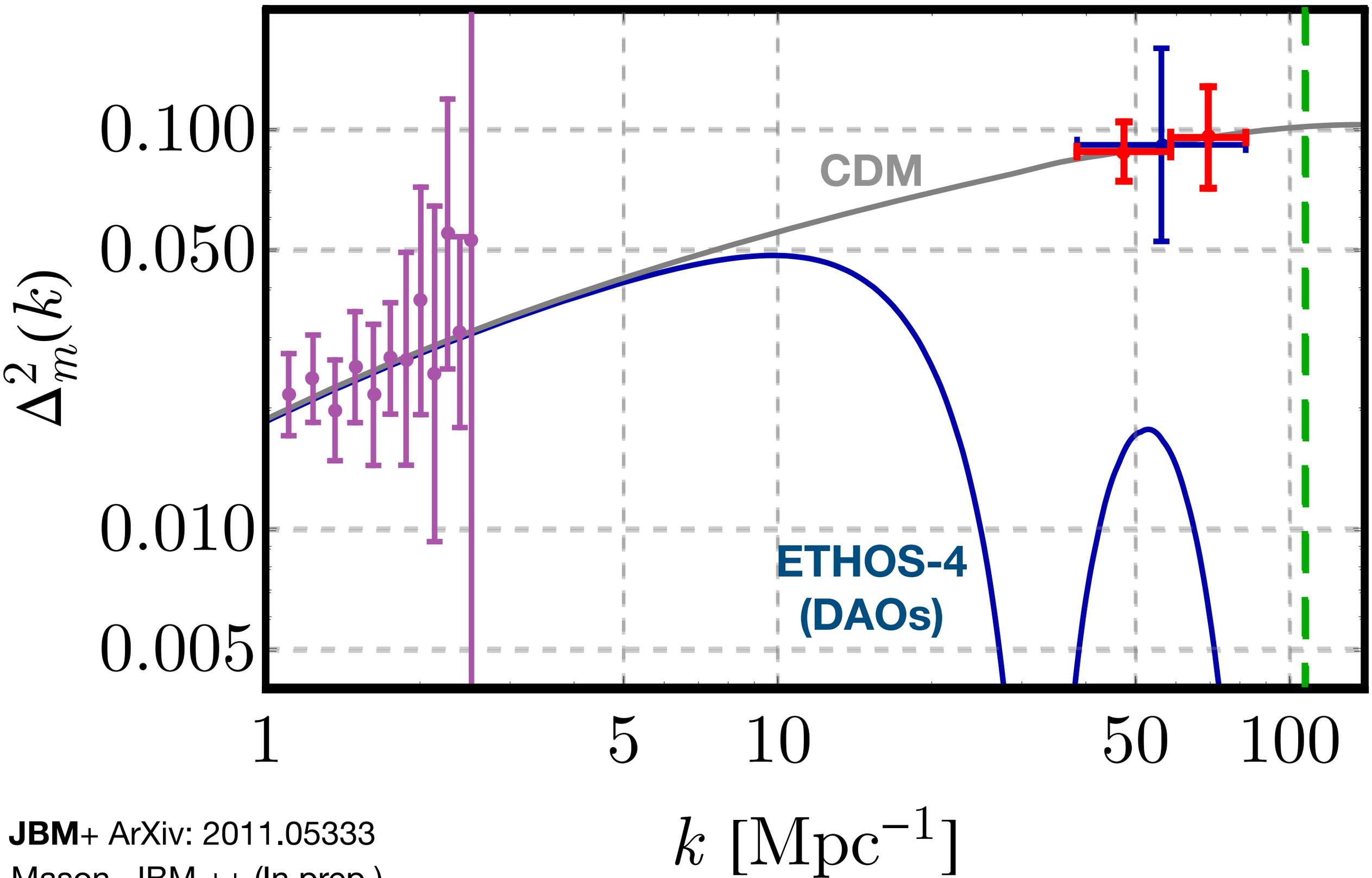
Vogelsberger+ 2016
Cyr-Racine+2016

ETHOS at $z = 0$

Vogelsberger+ 2016
Cyr-Racine+2016

Credit: Volgesberger/MIT

ETHOS at $z = 20$



JBM+ ArXiv: 2011.05333

Mason, JBM ++ (In prep.)

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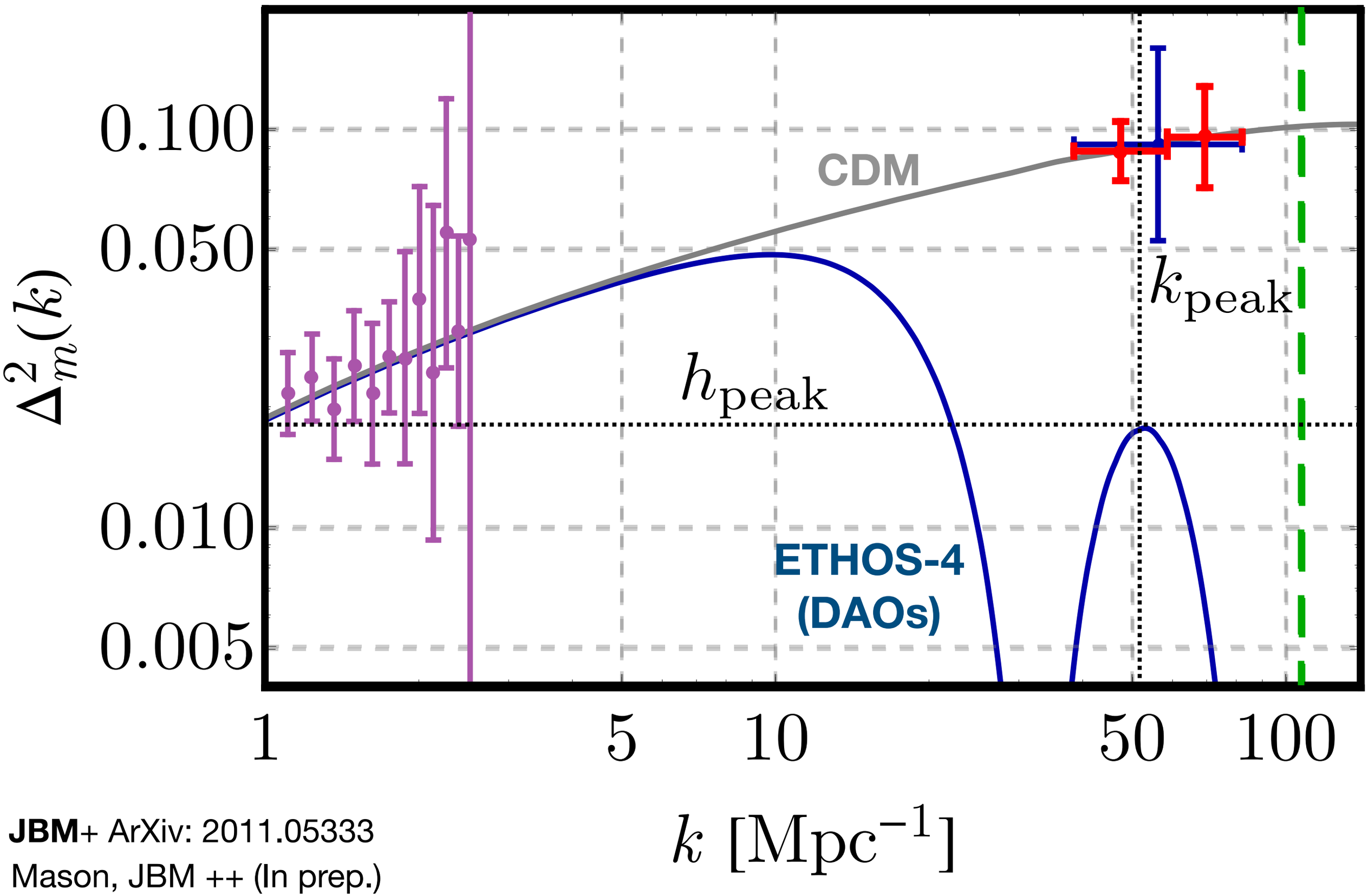

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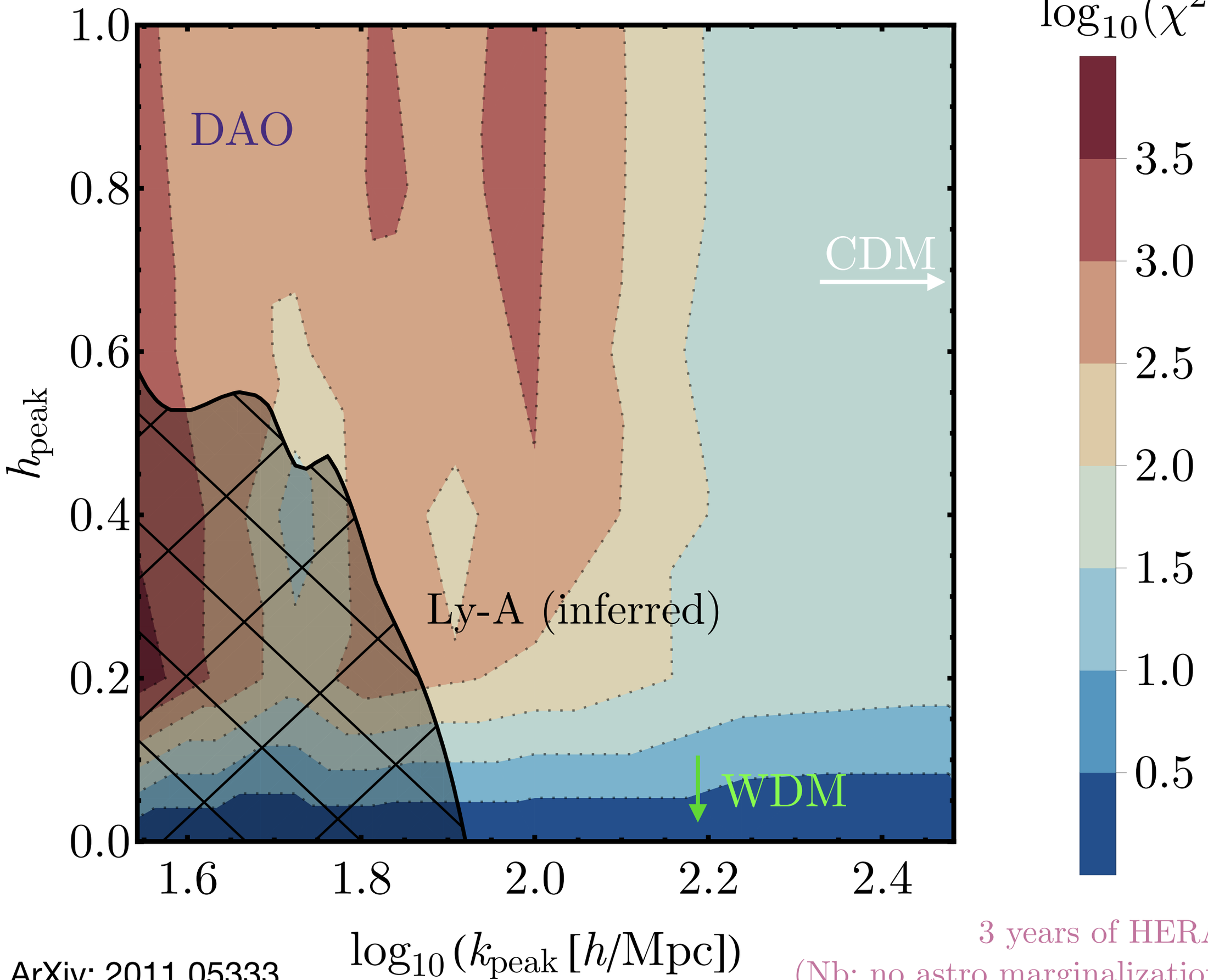
21-cm as a model discriminator



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3 years of HERA data
(Nb: no astro marginalization here)

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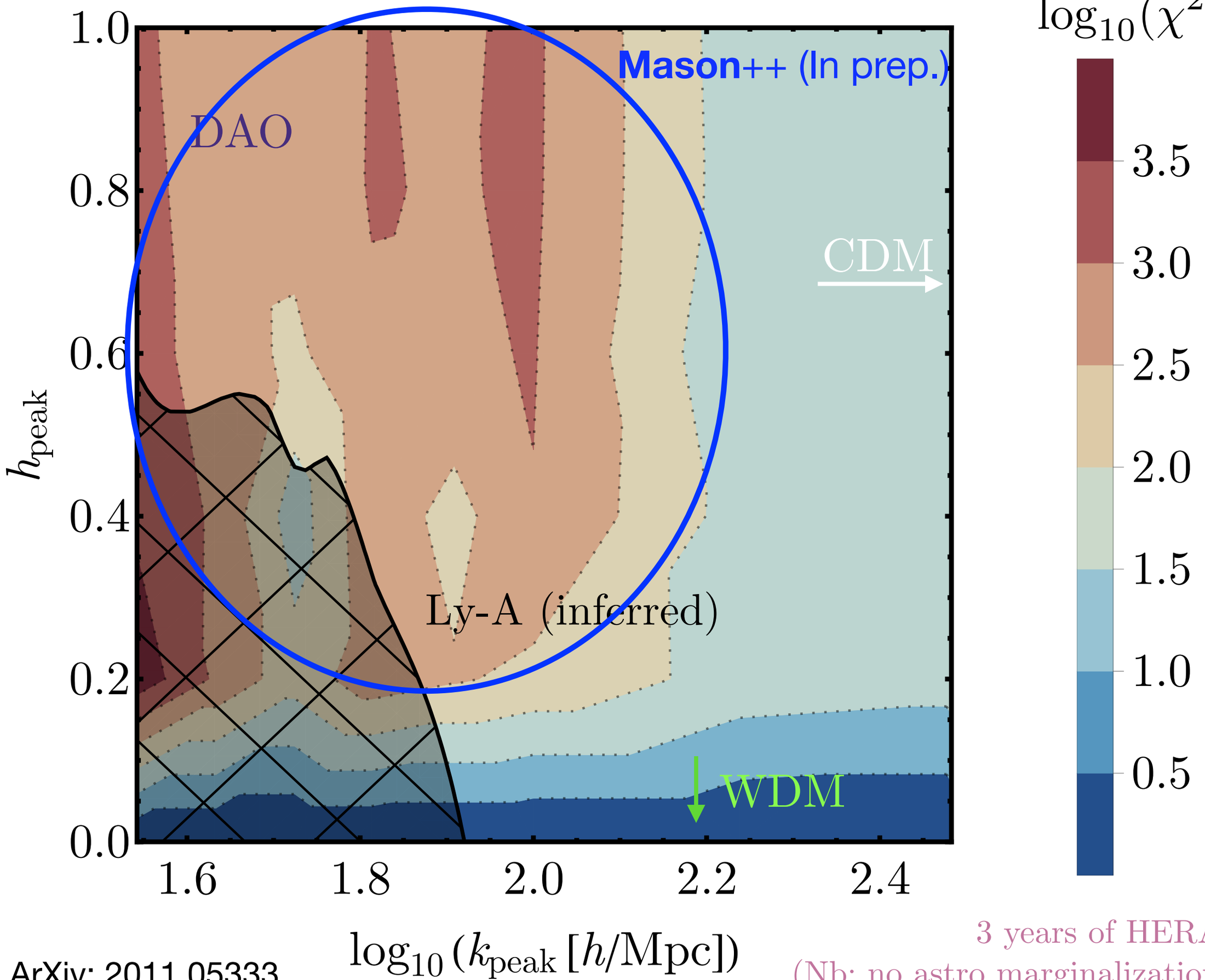

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