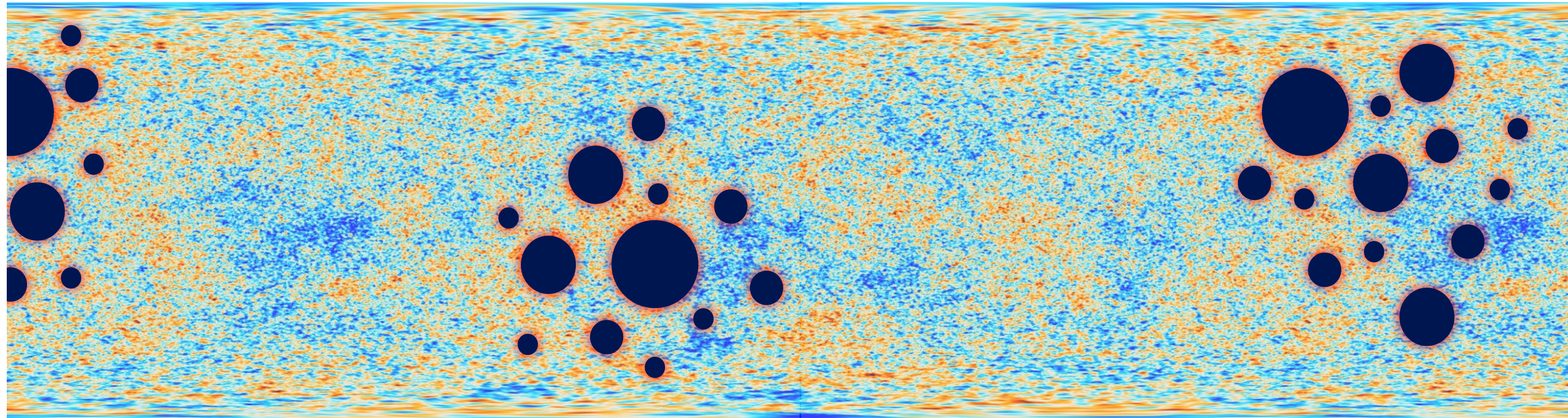


Probing the **primordial** power spectrum with dark matter **minihalos** and the **CMB**



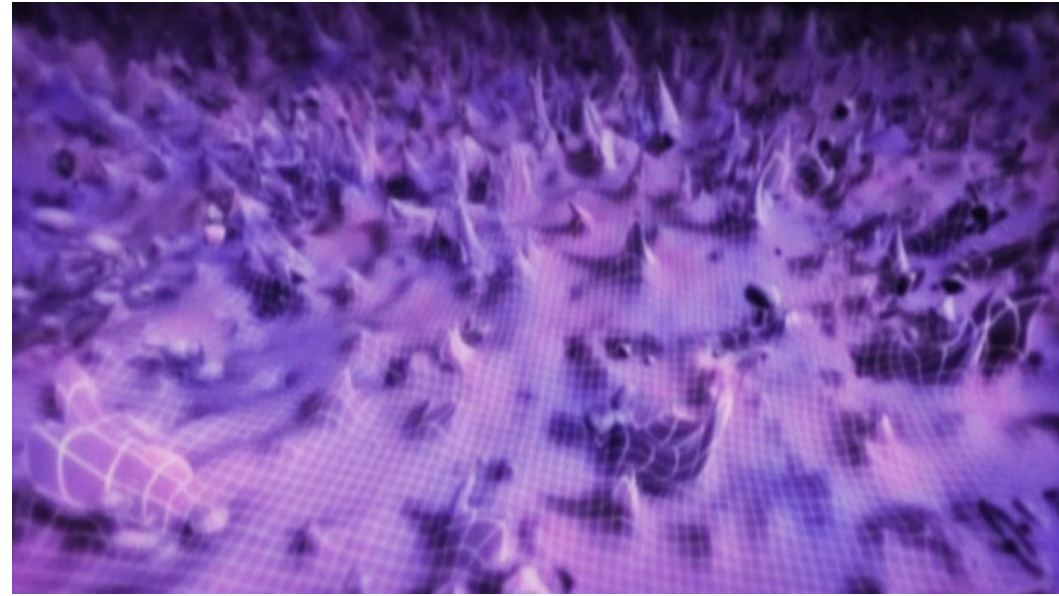
Guillermo Franco Abellán



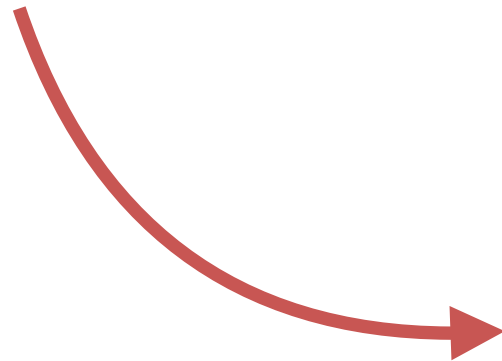
Based on: [arXiv:2304.02996](https://arxiv.org/abs/2304.02996)
with [Gaétan Facchinetti \(ULB\)](#)

PONT - 03/05/2023

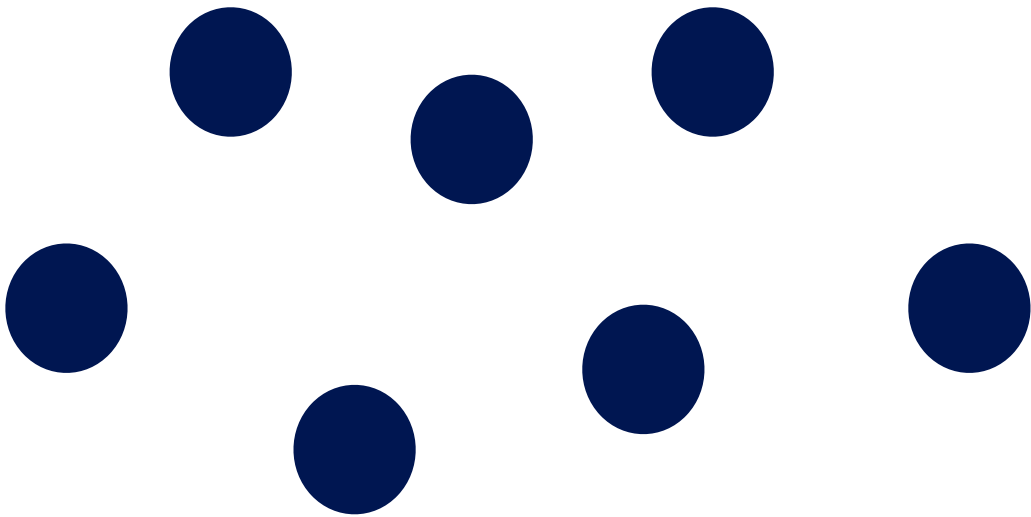
Primordial fluctuations



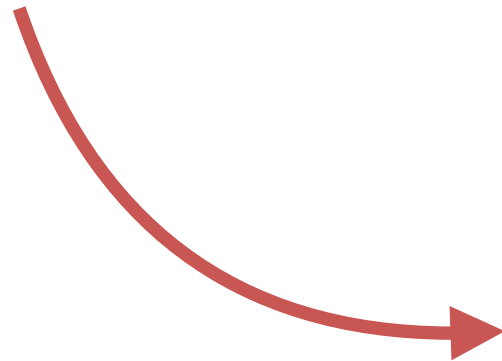
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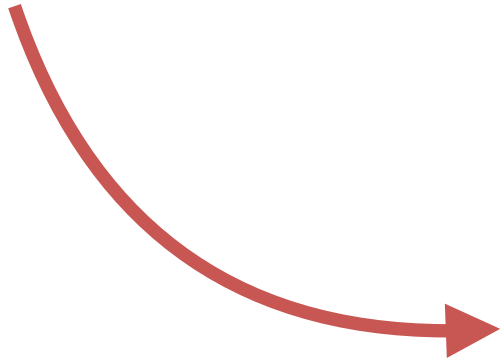
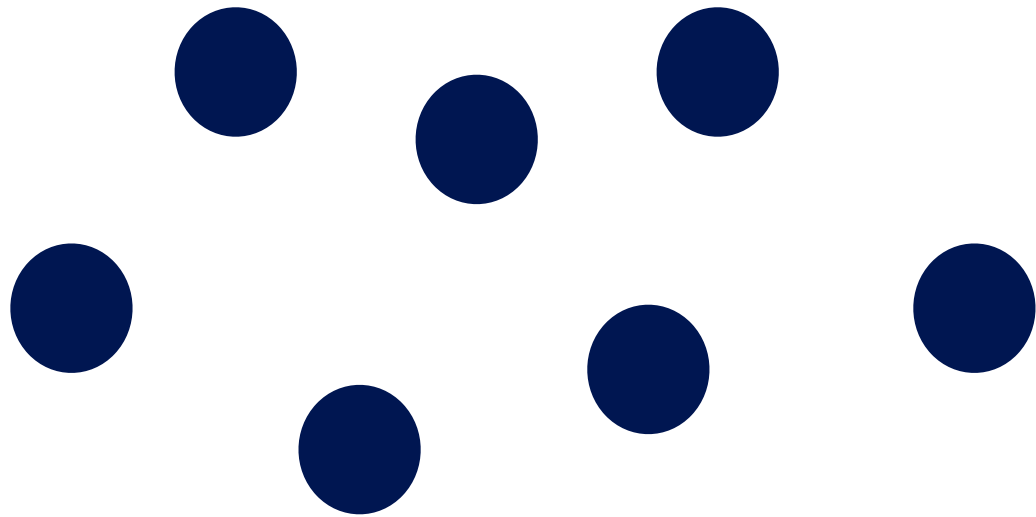
Halo collapse ($z \sim 30 - 100$)



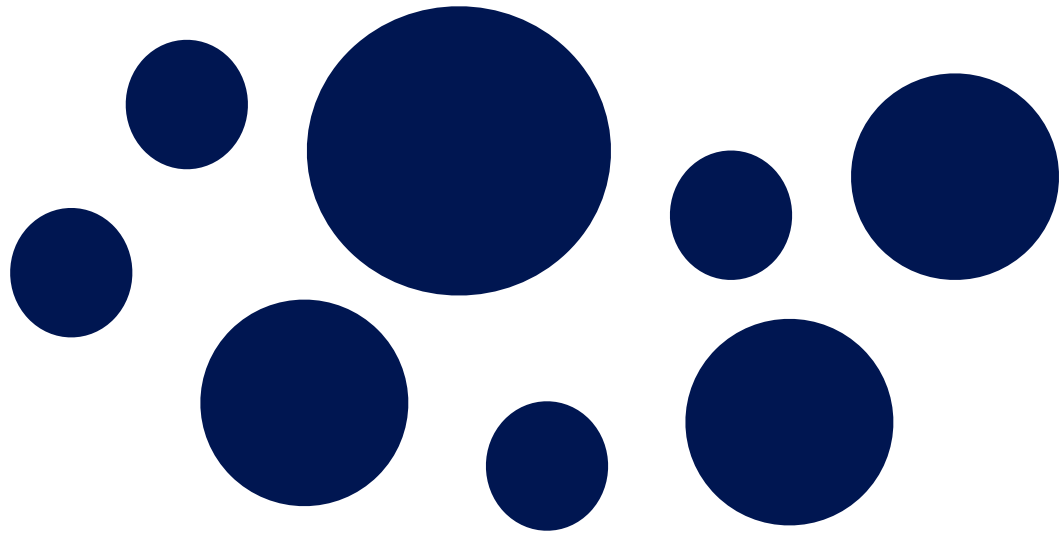
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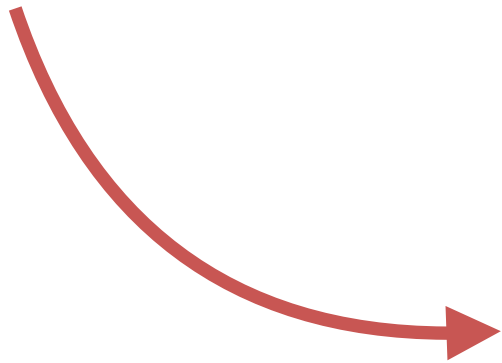
Hierarchical growth



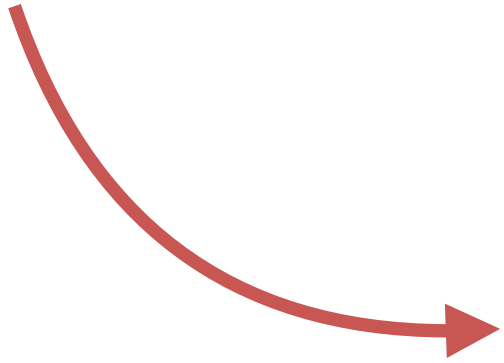
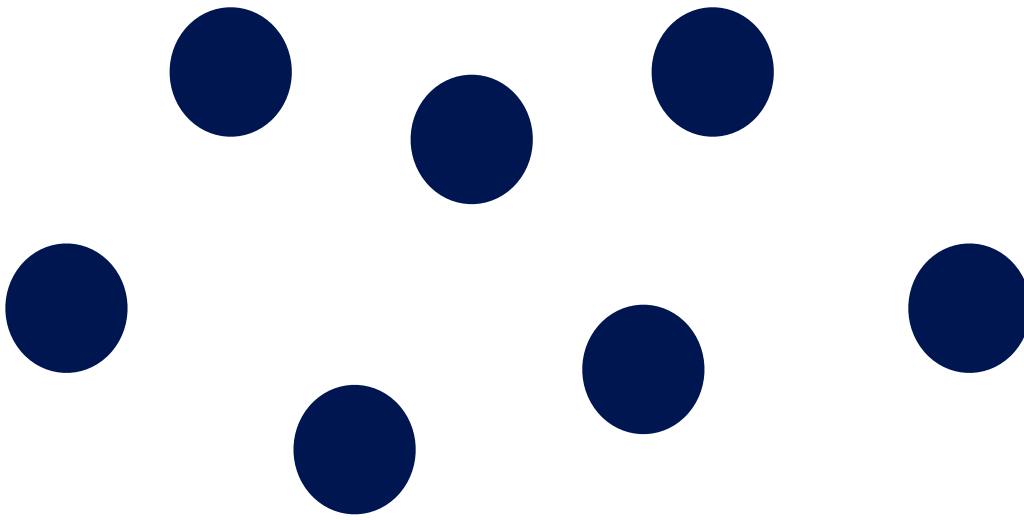
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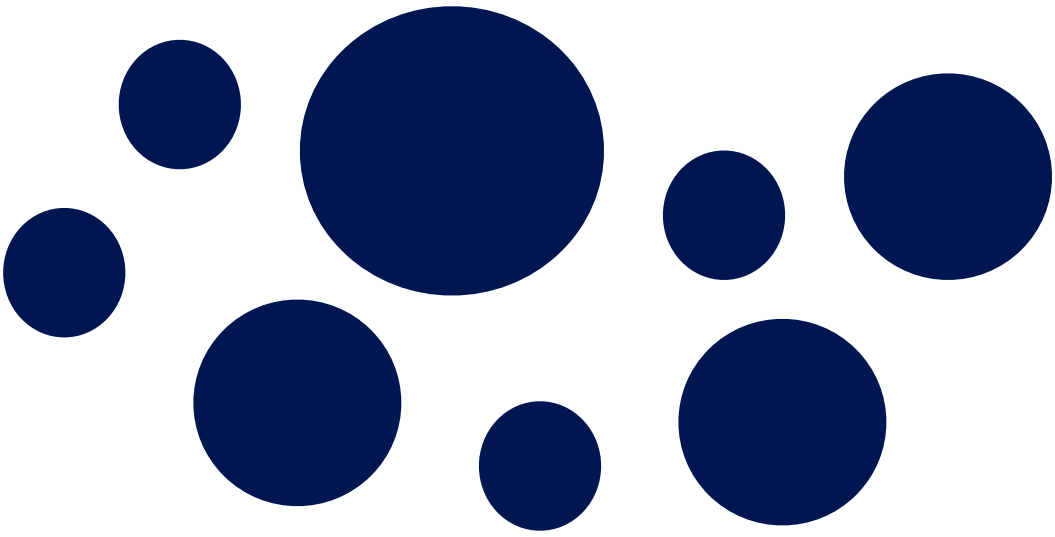
Primordial power spectrum
 $\mathcal{P}_{\mathcal{R}}(k)$

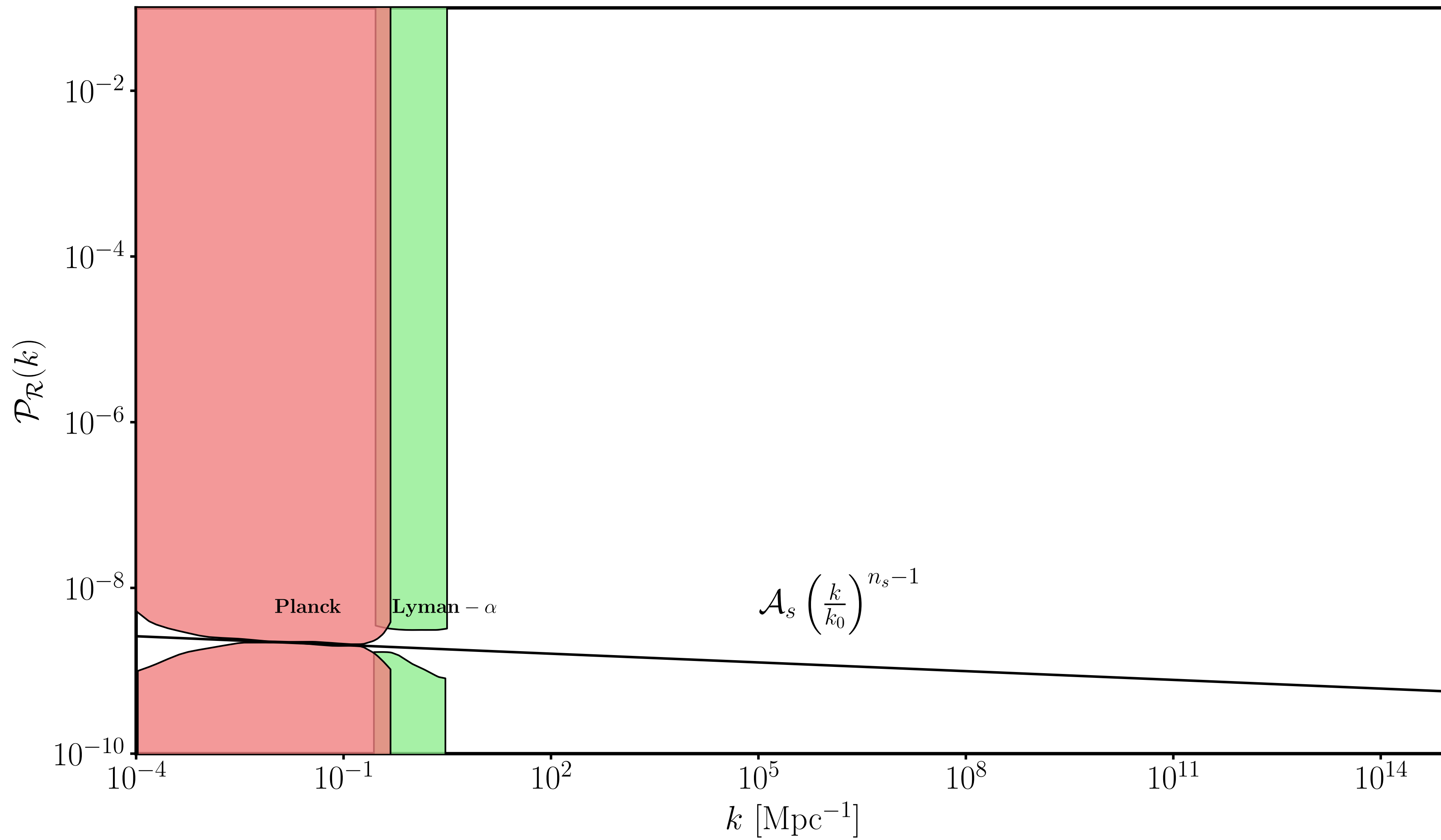


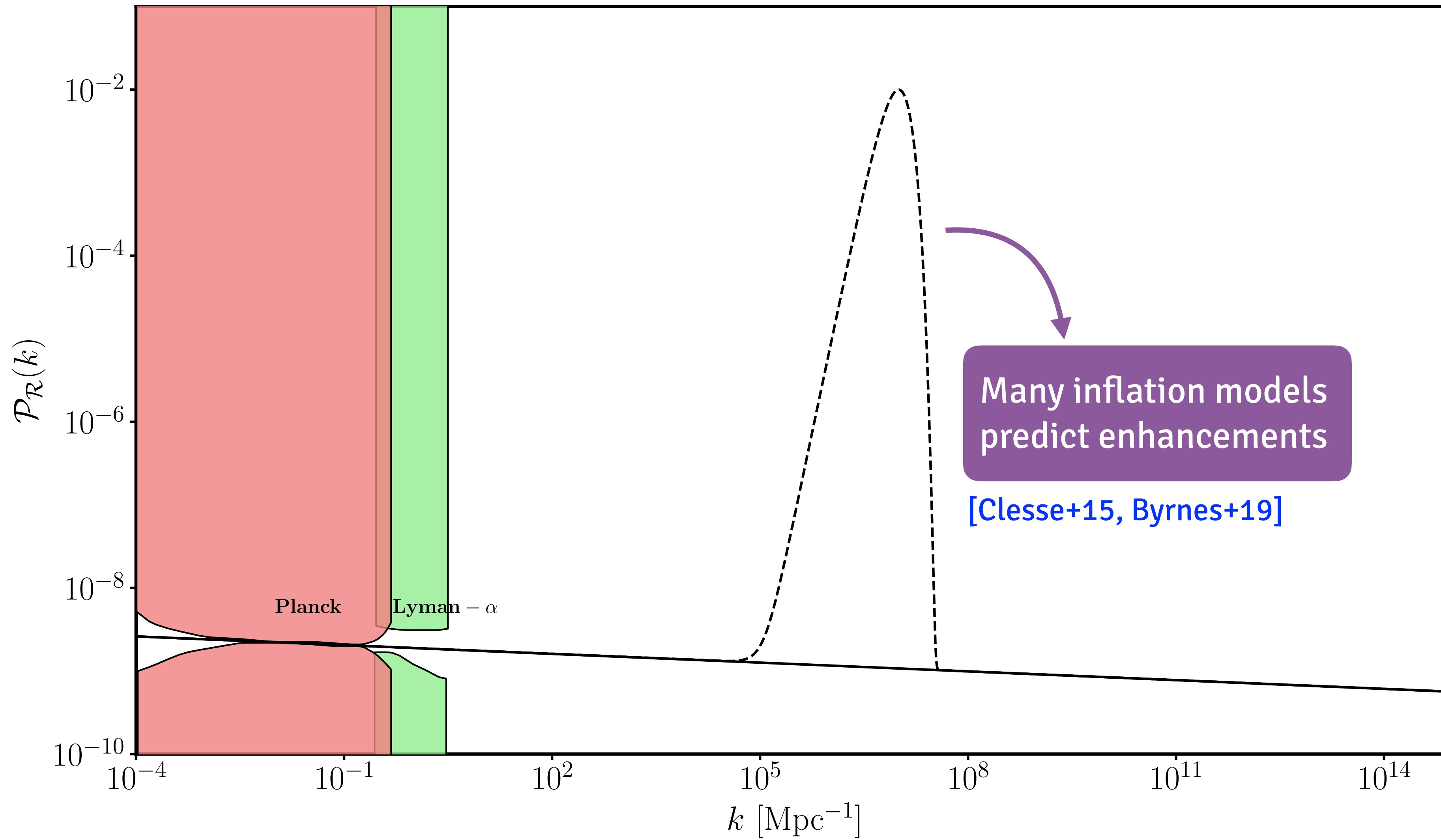
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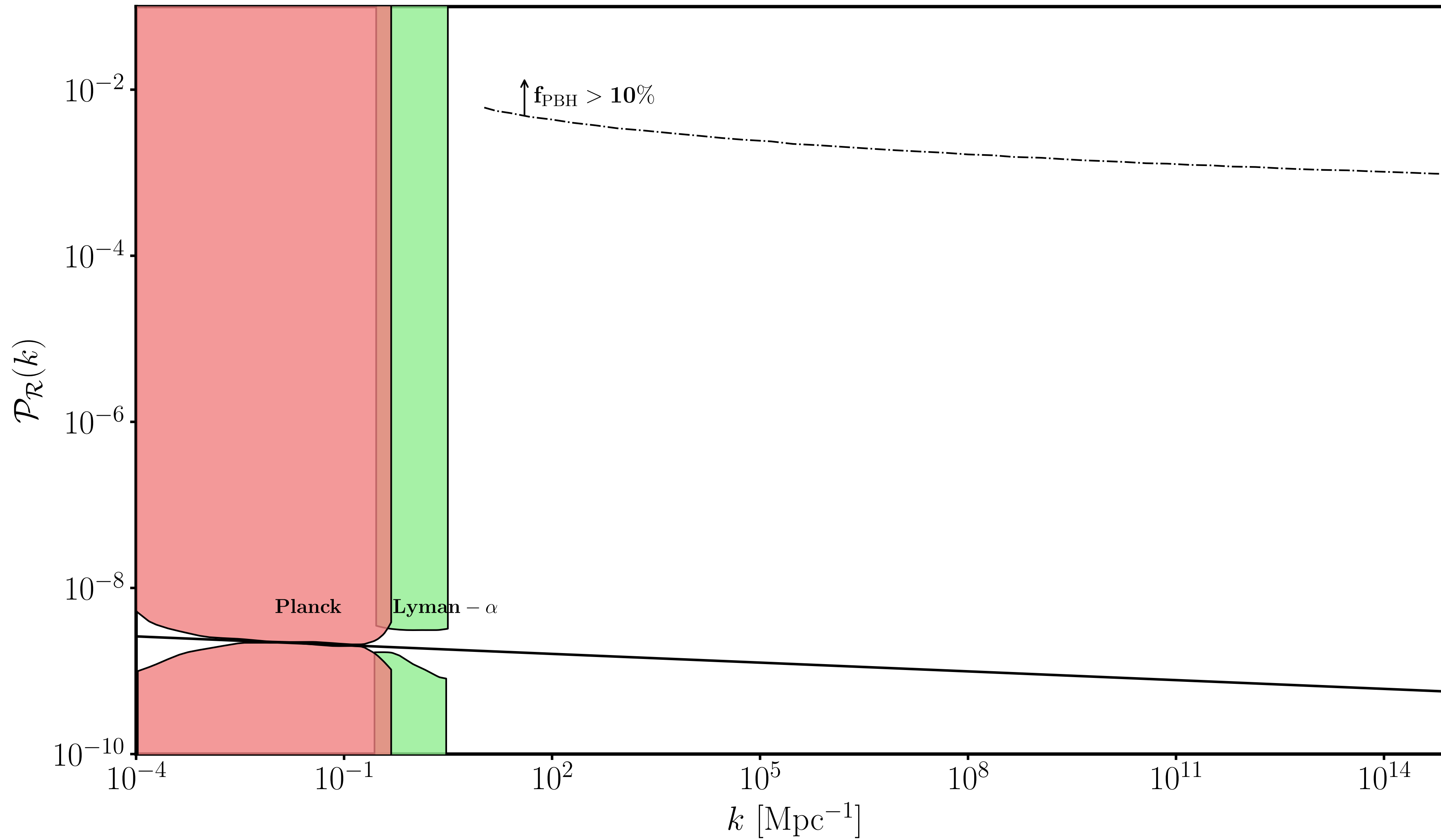


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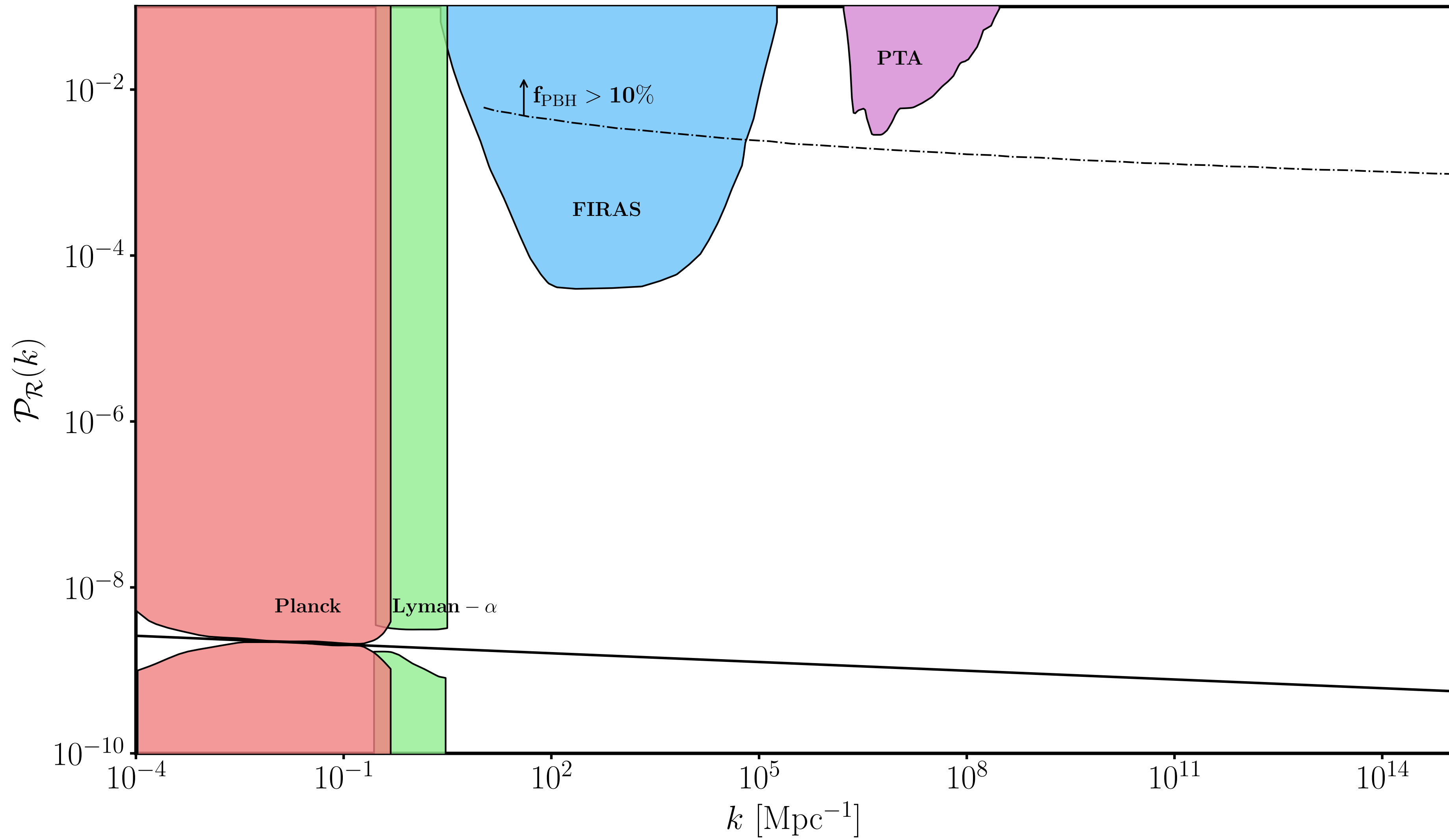


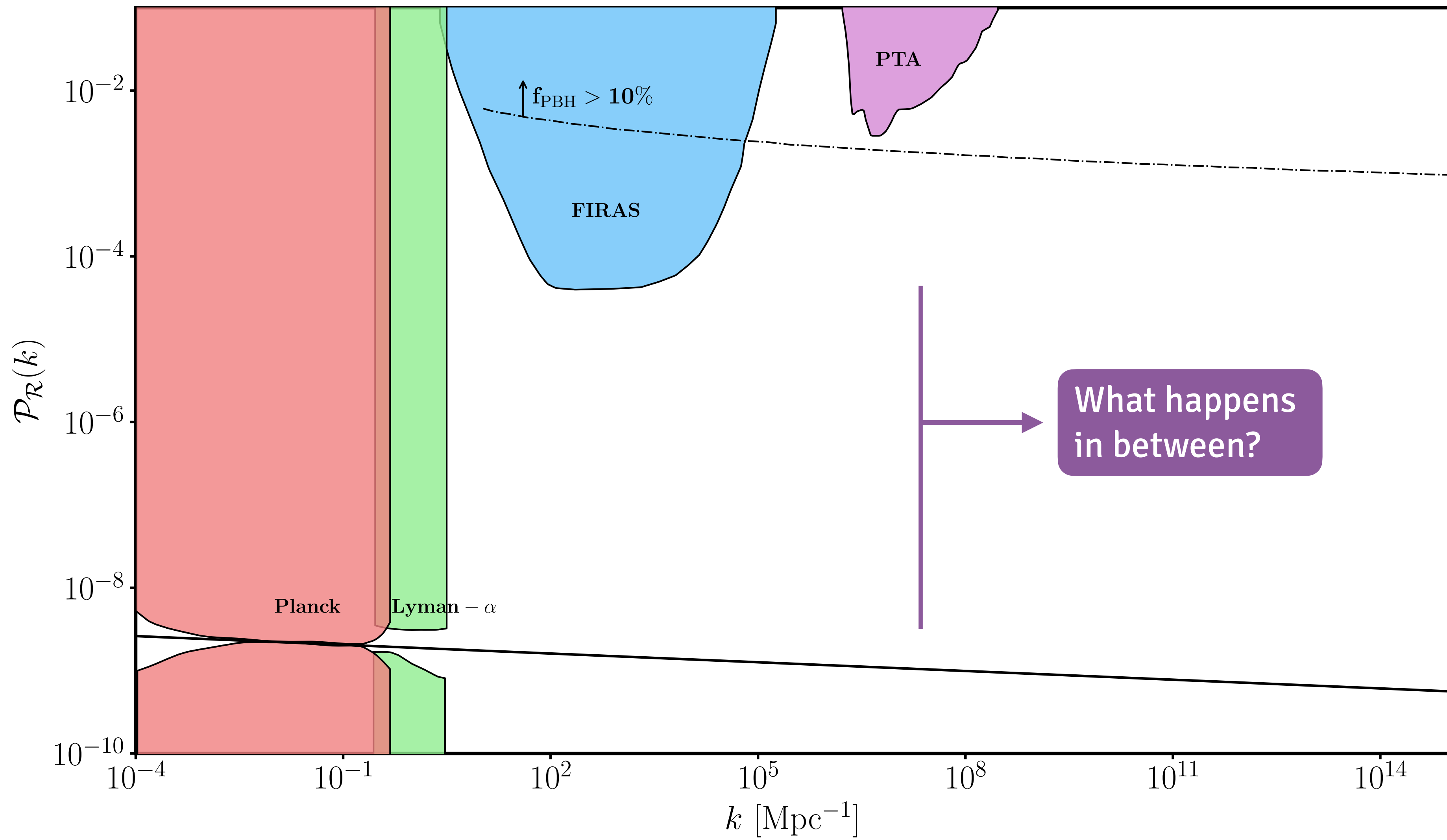




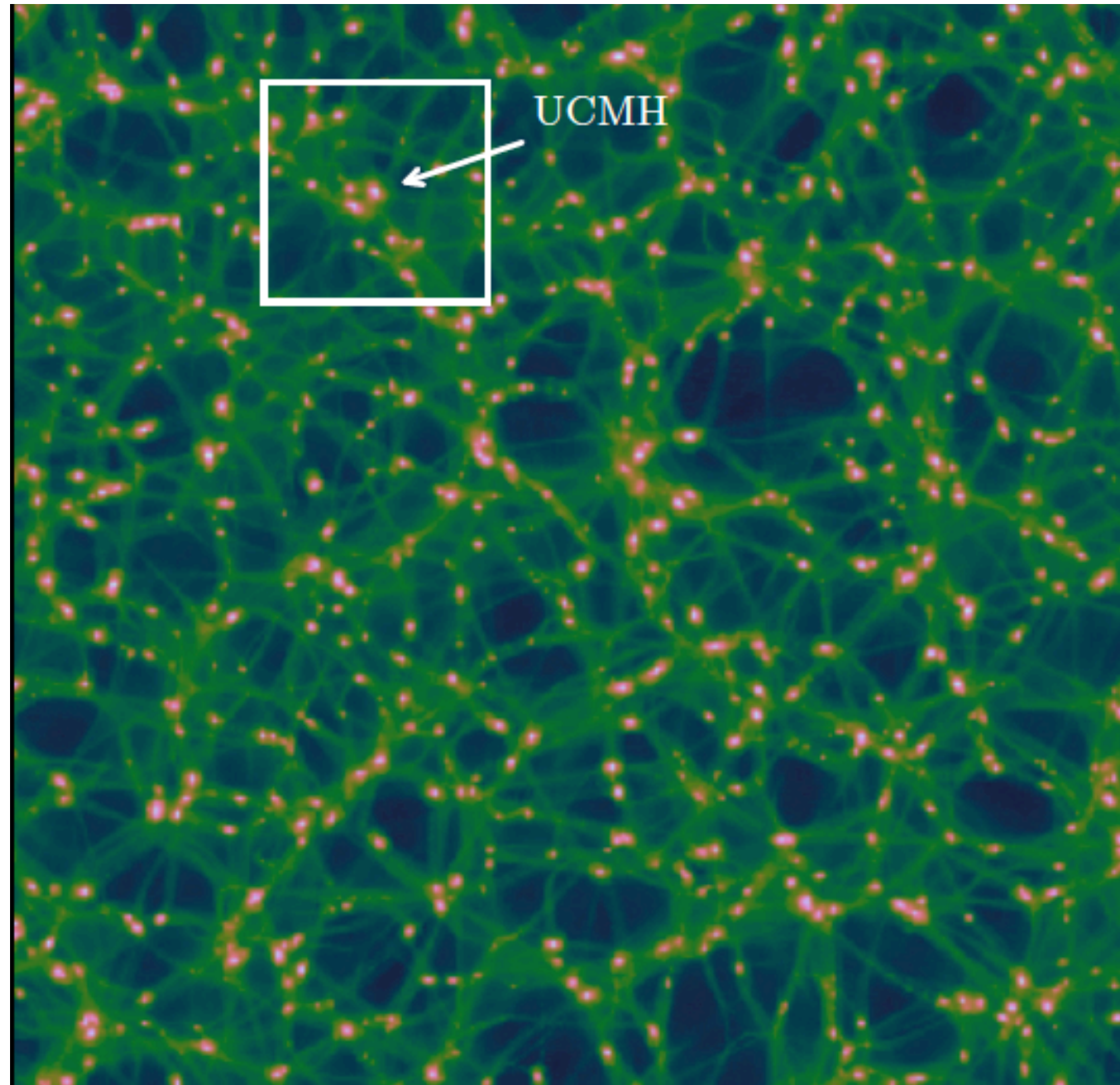


Primordial Black Hole
(PBH) formation



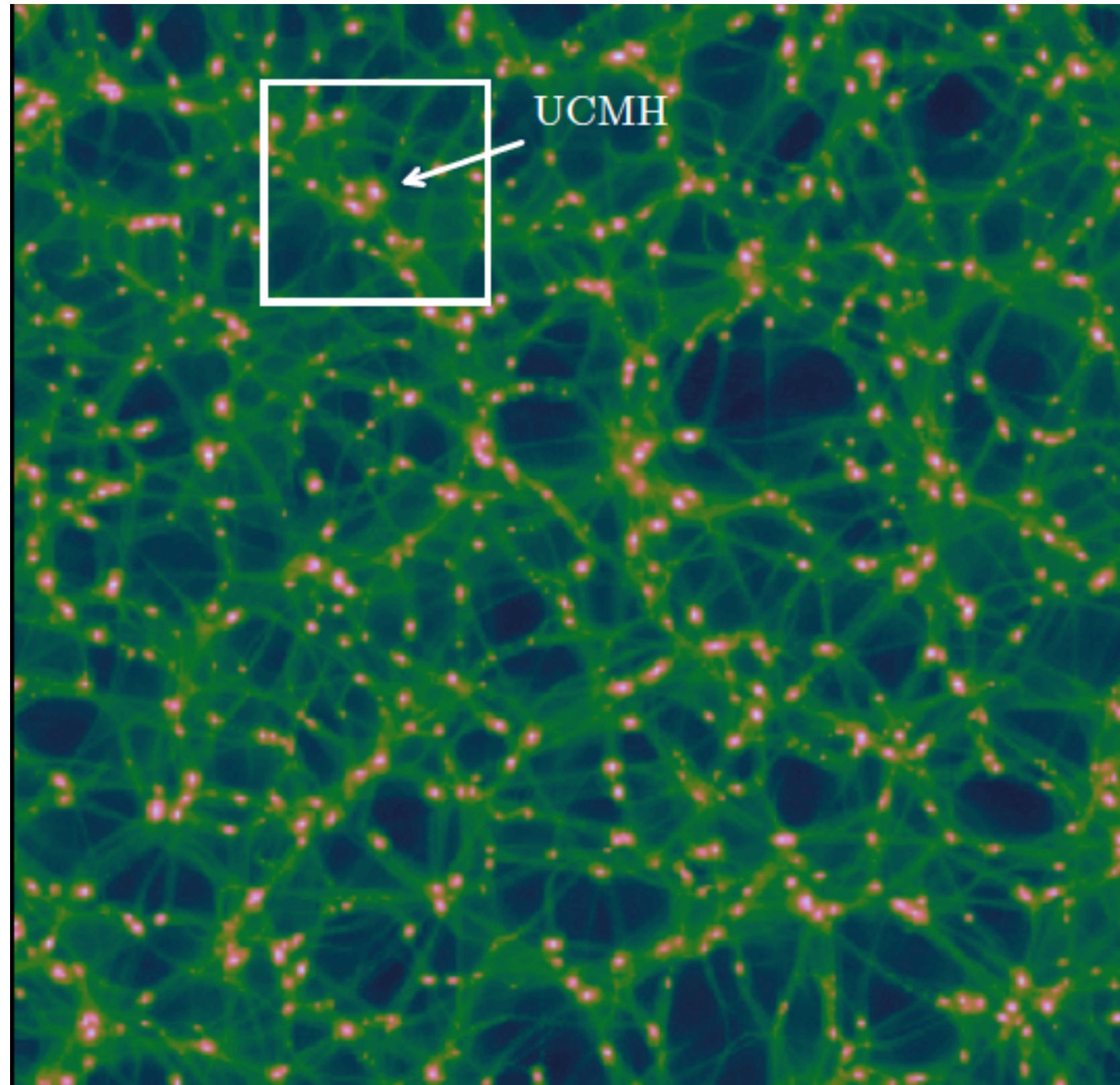


Moderate enhancements can produce
Ultra Compact Mini Halos (UCMHs) (UCMHs)



[Delos+18]

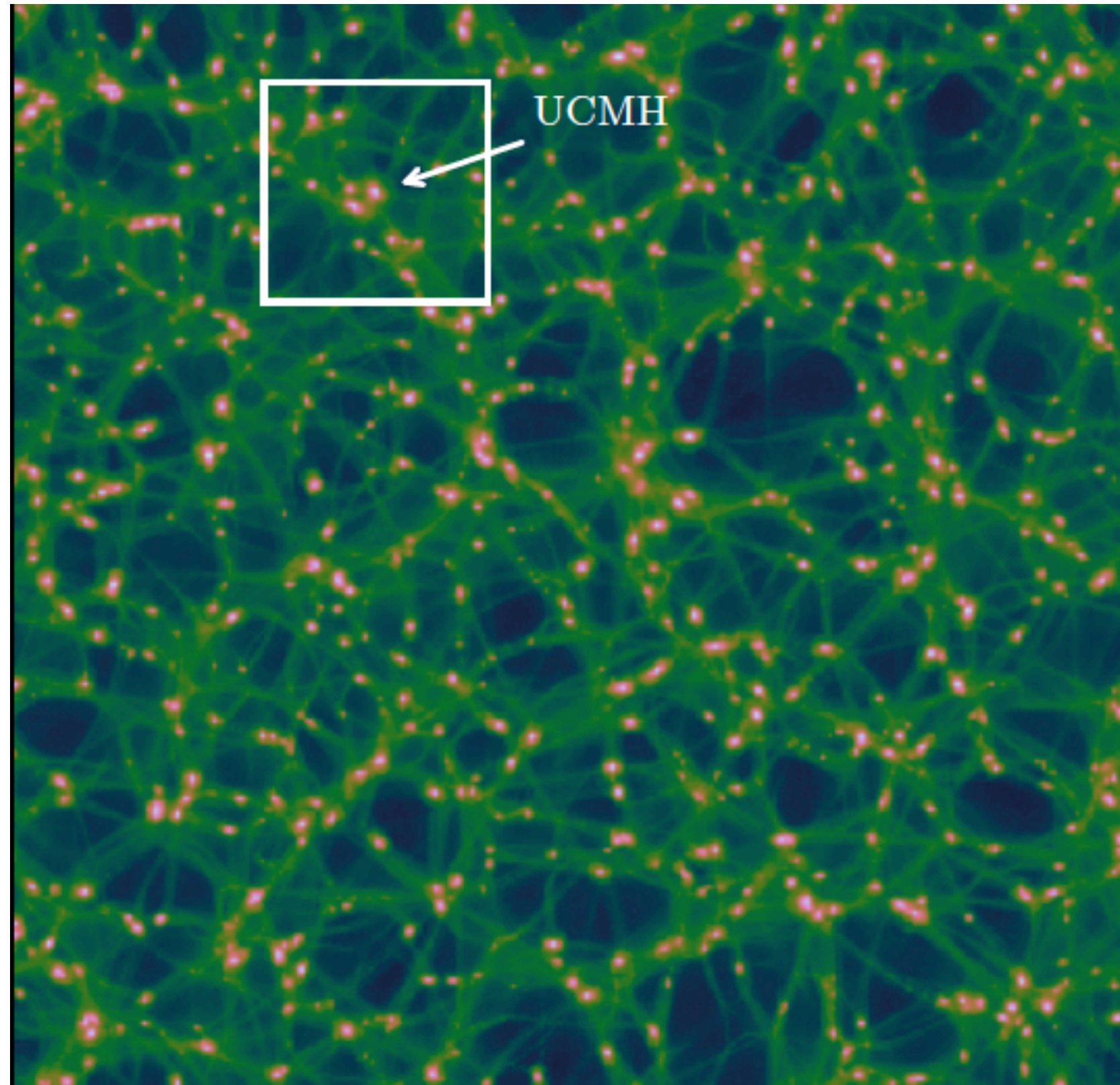
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■ Much **earlier collapse** ($z \sim 10^2 - 10^3$)

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Moderate enhancements can produce
Ultra Compact Mini Halos (UCMHs)



[Delos+18]

- Much **earlier collapse** ($z \sim 10^2 - 10^3$)
- Potentially much **stronger constraints** on the small-scale $\mathcal{P}_{\mathcal{R}}(k)$ than PBHs

The presence of minihalos has been probed by various methods

- γ -ray fluxes [[Bringmann+11](#), [Delos+18](#)]
- CMB anisotropies [[Kawasaki+21](#)]
- 21cm signal [[Yang+16](#), [Furugori+20](#)]
- Microlensing [[Erickcek+12](#)]
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If dark matter (DM) self-annihilates, minihalos can significantly **boost the DM annihilation signal**, leaving an imprint on the CMB

Deposited energy into the plasma per volume and time (**no halos**)

$$\left. \frac{dE}{dVdt} \right|_{\text{DM}}(z) = \langle \rho_{\text{DM}}^0 \rangle^2 (1+z)^6 p_{\text{ann}}$$

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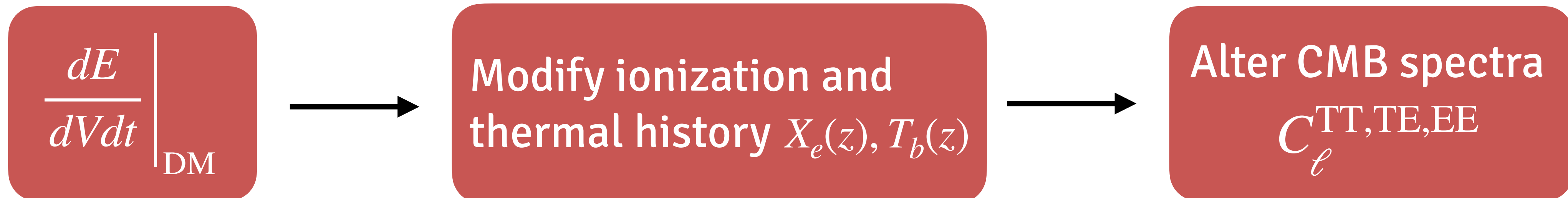
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(depends on annihilation channel)

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- In presence of halos, deposited energy is modified as

$$\left. \frac{dE}{dVdt} \right|_{\text{DM}}(z) = (1 + B(z)) \langle \rho_{\text{DM}}^0 \rangle^2 (1 + z)^6 p_{\text{ann}}$$

where $B(z) \equiv \frac{\langle \rho_{\text{DM}}^2 \rangle}{\langle \rho_{\text{DM}} \rangle^2} - 1$ is the **cosmological boost factor**

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How do we compute B(z)?

■ In the framework of the halo model

$$B(z) = \frac{1}{\langle \rho_m^0 \rangle} \int M \frac{dn(M|z)}{dM} B_h(z_f(M), z) dM$$

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Depends on $\mathcal{P}_{\mathcal{R}}(k)$

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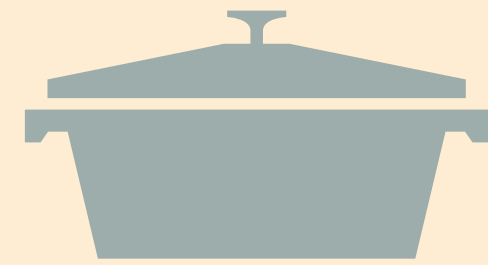
New formalism (based on ext. Press-Schechter) to account for a **mixed population of halos** with different profiles

(expected to arise as a result of accretion and mergers)

NFW: $\rho_h(\mathbf{r}) \propto \mathbf{r}^{-1}$
UCMHs: $\rho_h(\mathbf{r}) \propto \mathbf{r}^{-3/2}$

[Delos+17]

RECIPE



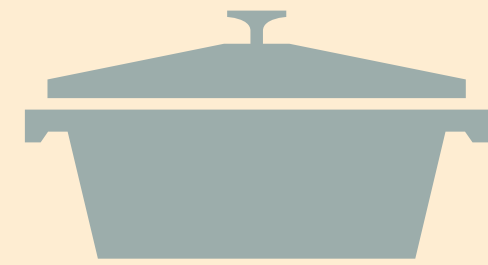
to get the constraints

Ingredients

- Modified version of ExoCLASS
[Stocker+18]
- Planck legacy data

Instructions

RECIPE



to get the constraints

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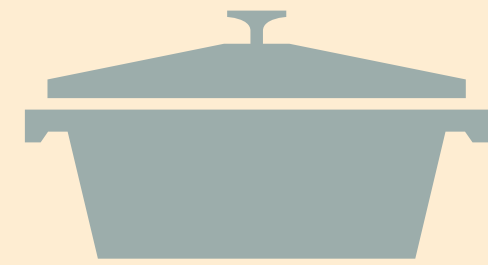
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Instructions

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$$\mathcal{P}_{\mathcal{R}}(k) = \mathcal{A}_s \left(\frac{k}{k_0} \right)^{n_s - 1} + \mathcal{A}_* k_* \delta(k - k_*)$$

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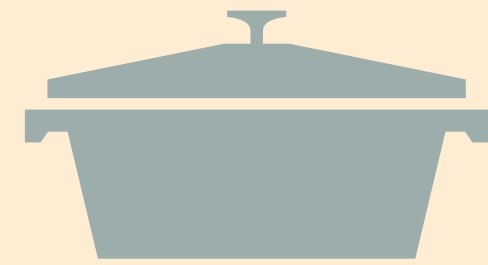
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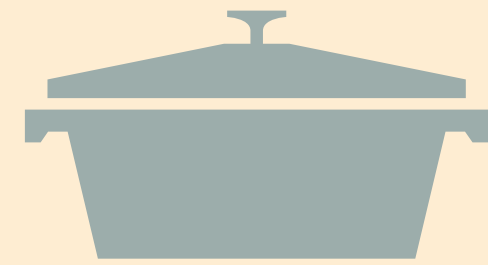
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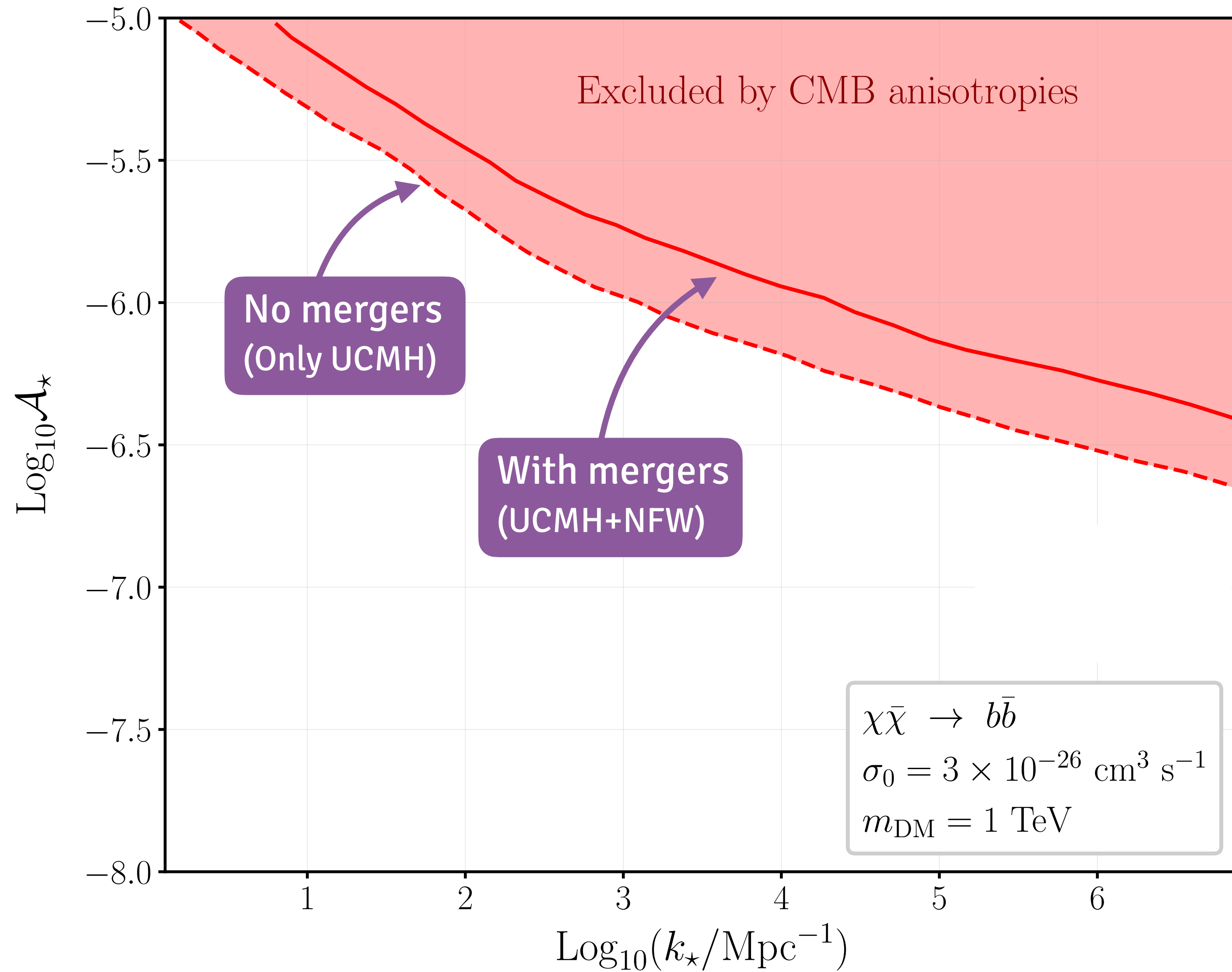
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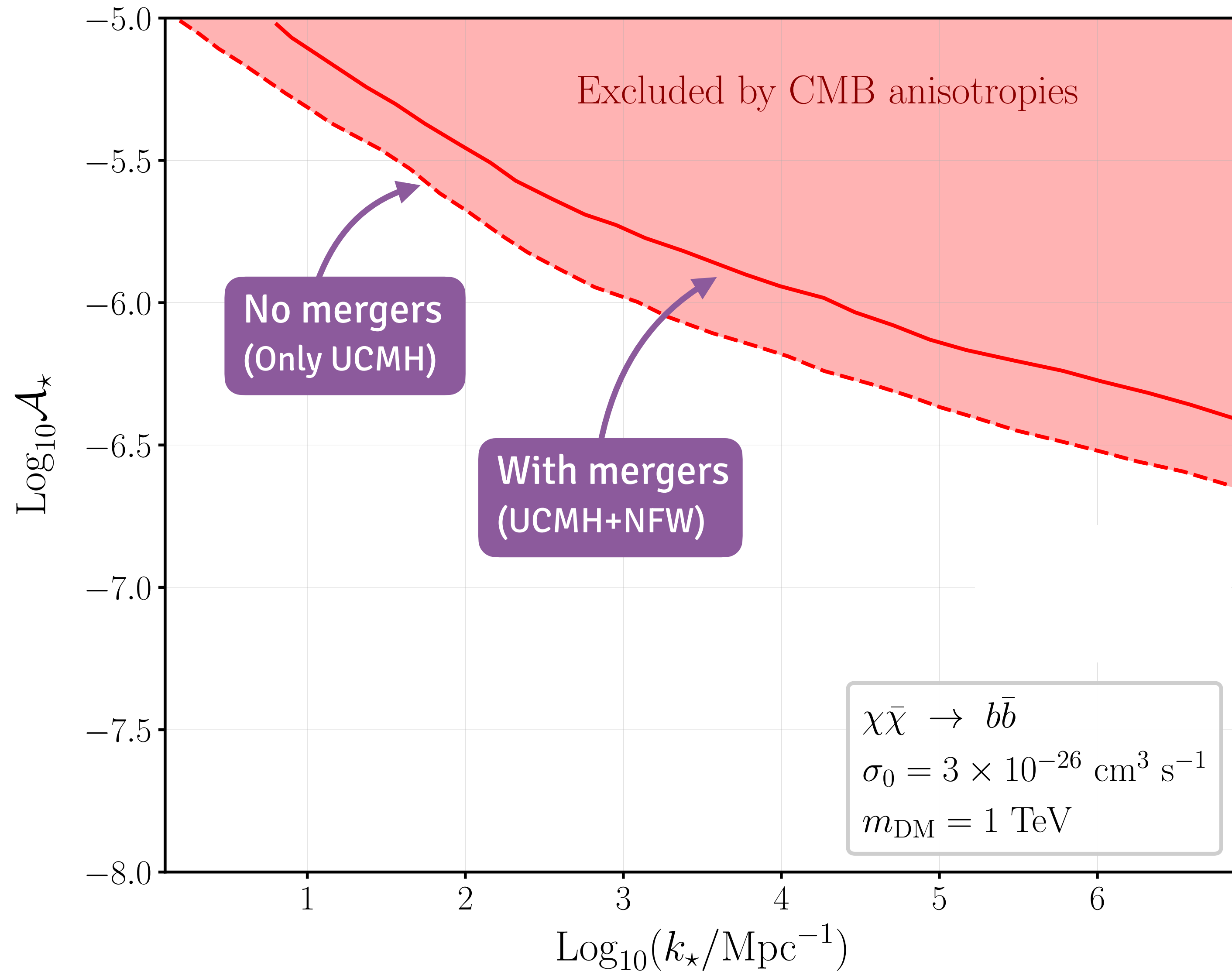
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4. Obtain constraints on \mathcal{A}_* vs. k_*
(for a fiducial param. $p_{\text{ann}} \propto \langle \sigma v \rangle / m_{\text{DM}}$)

RESULTS

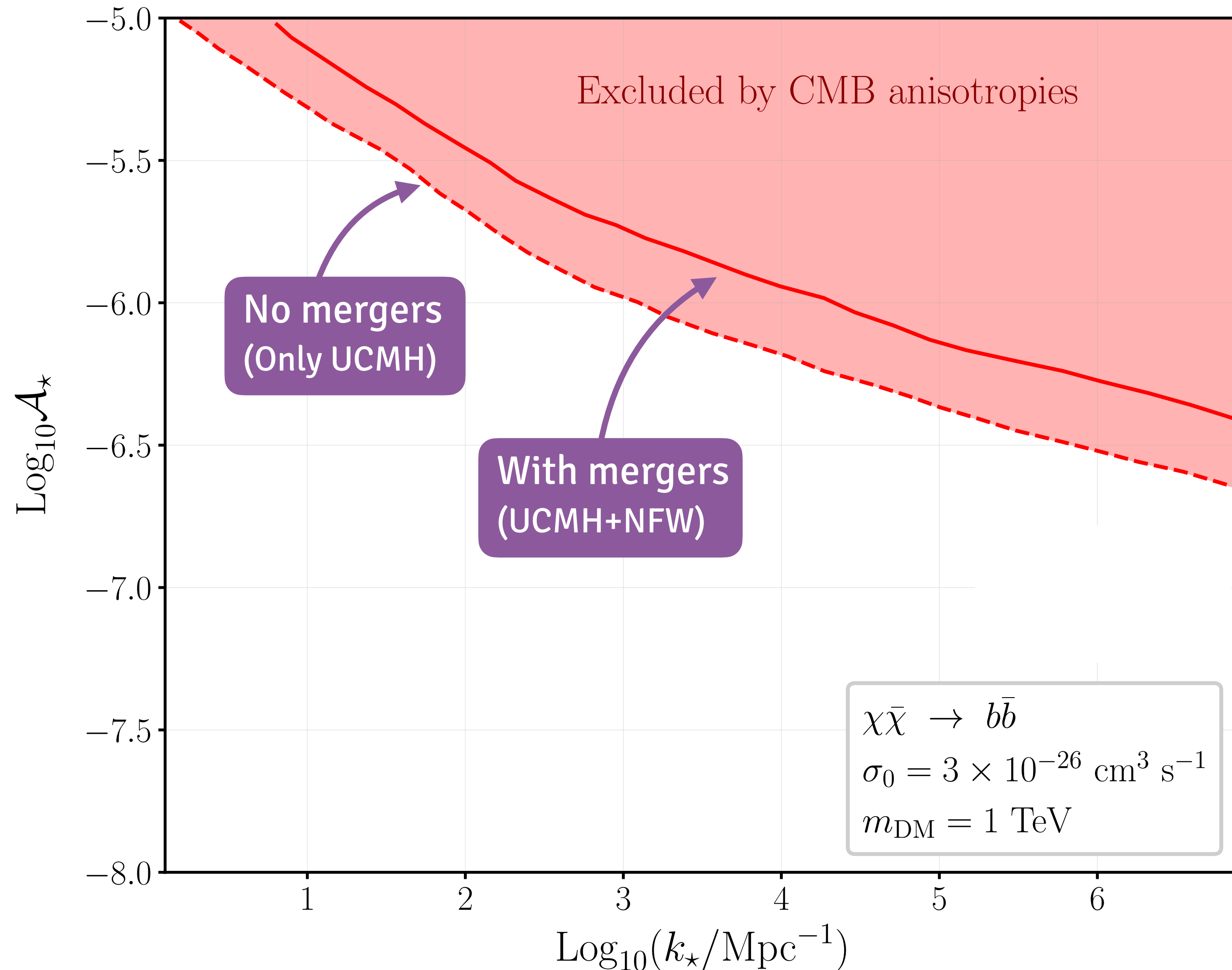


RESULTS



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- Expected to be much more relevant for **low-z probes** (e.g. 21 cm)

RESULTS

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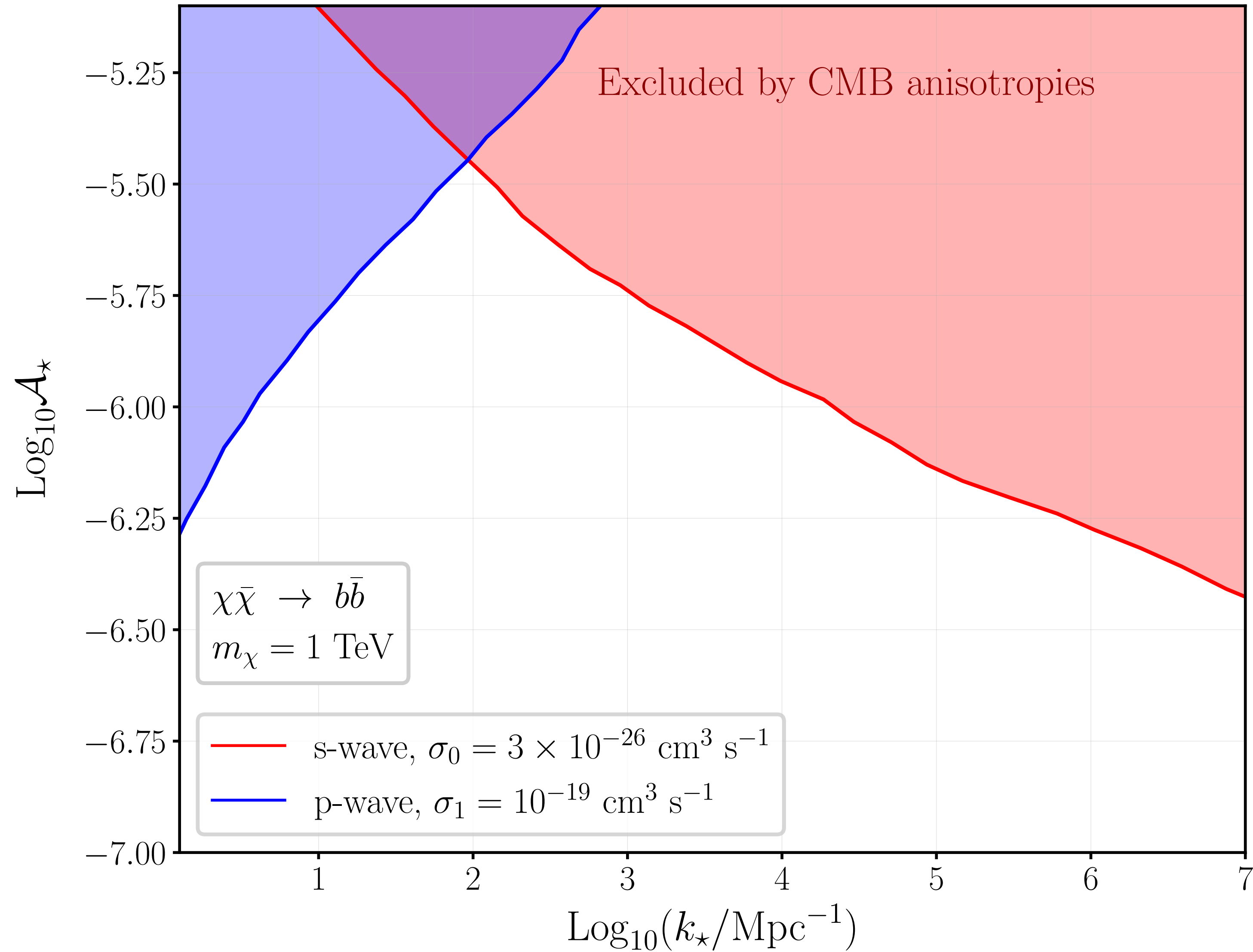
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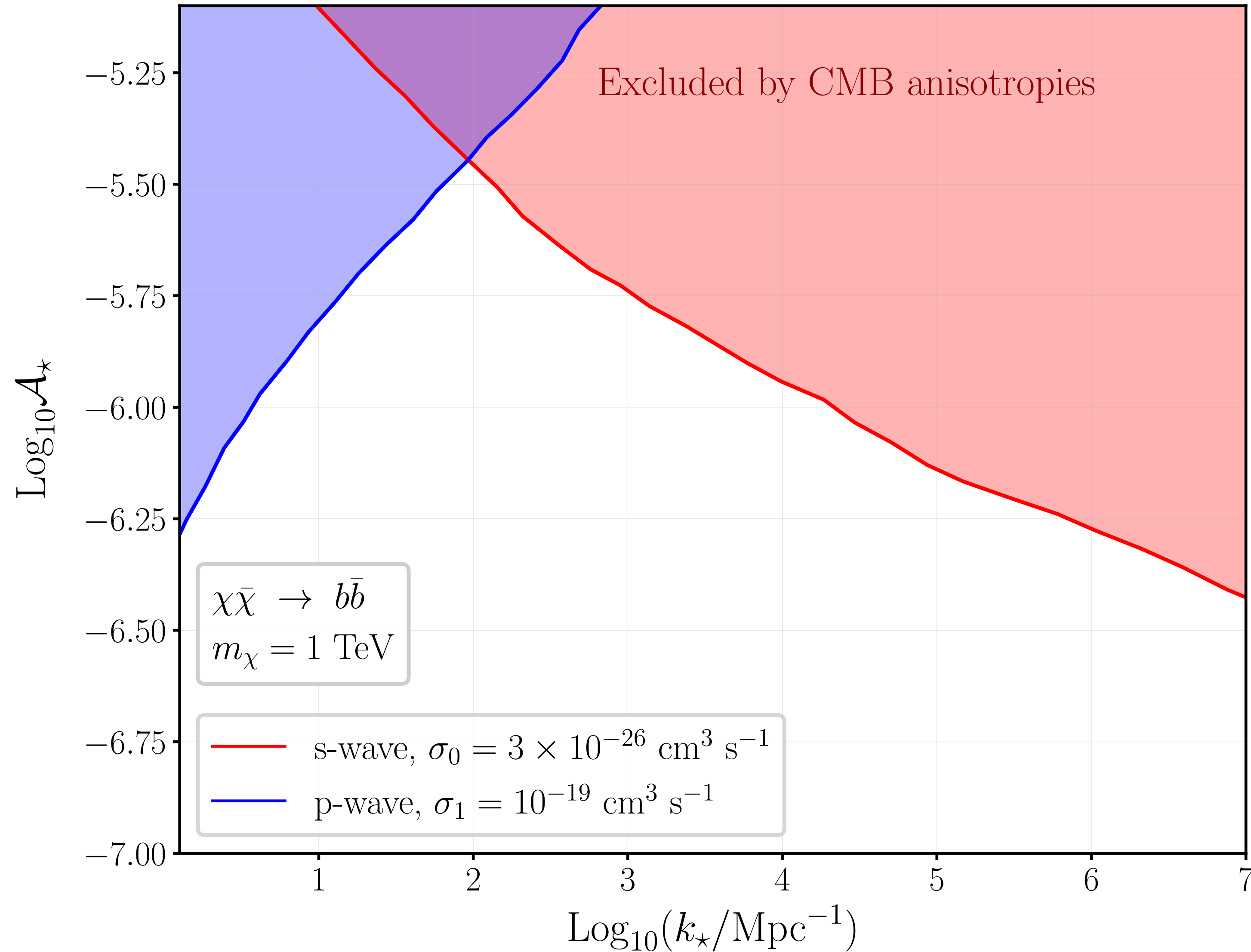
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RESULTS

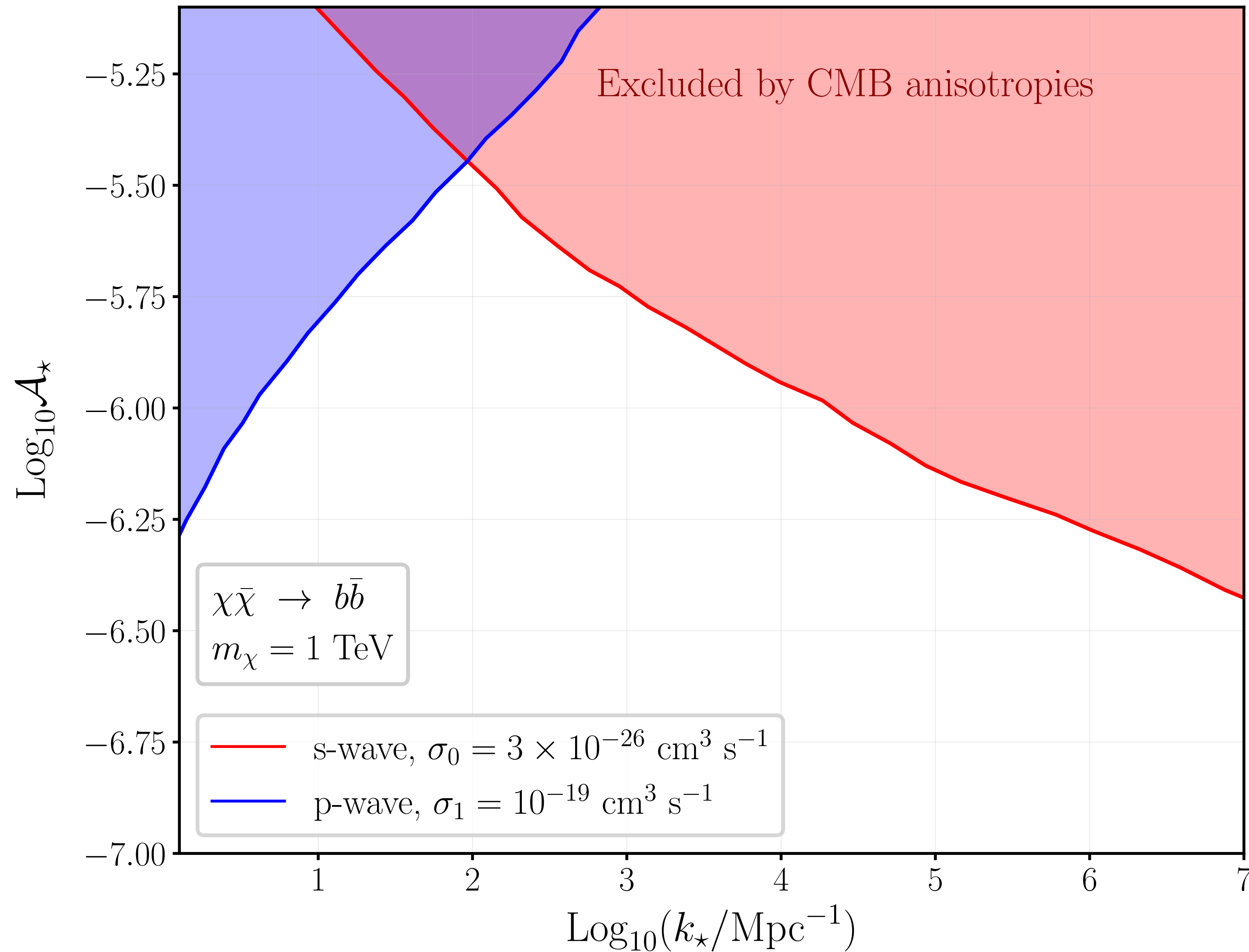


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 p-wave constraints are competitive at small k

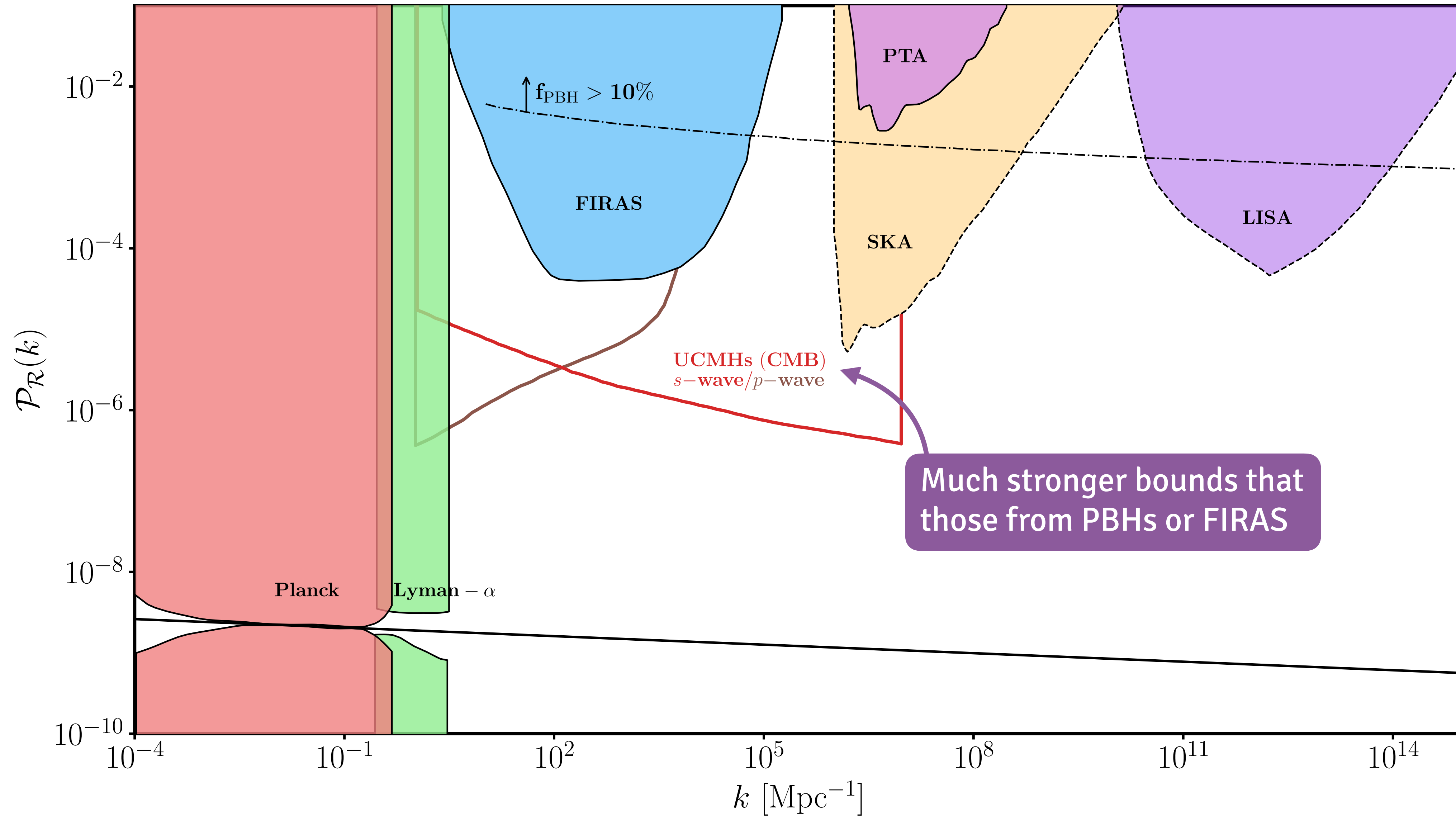
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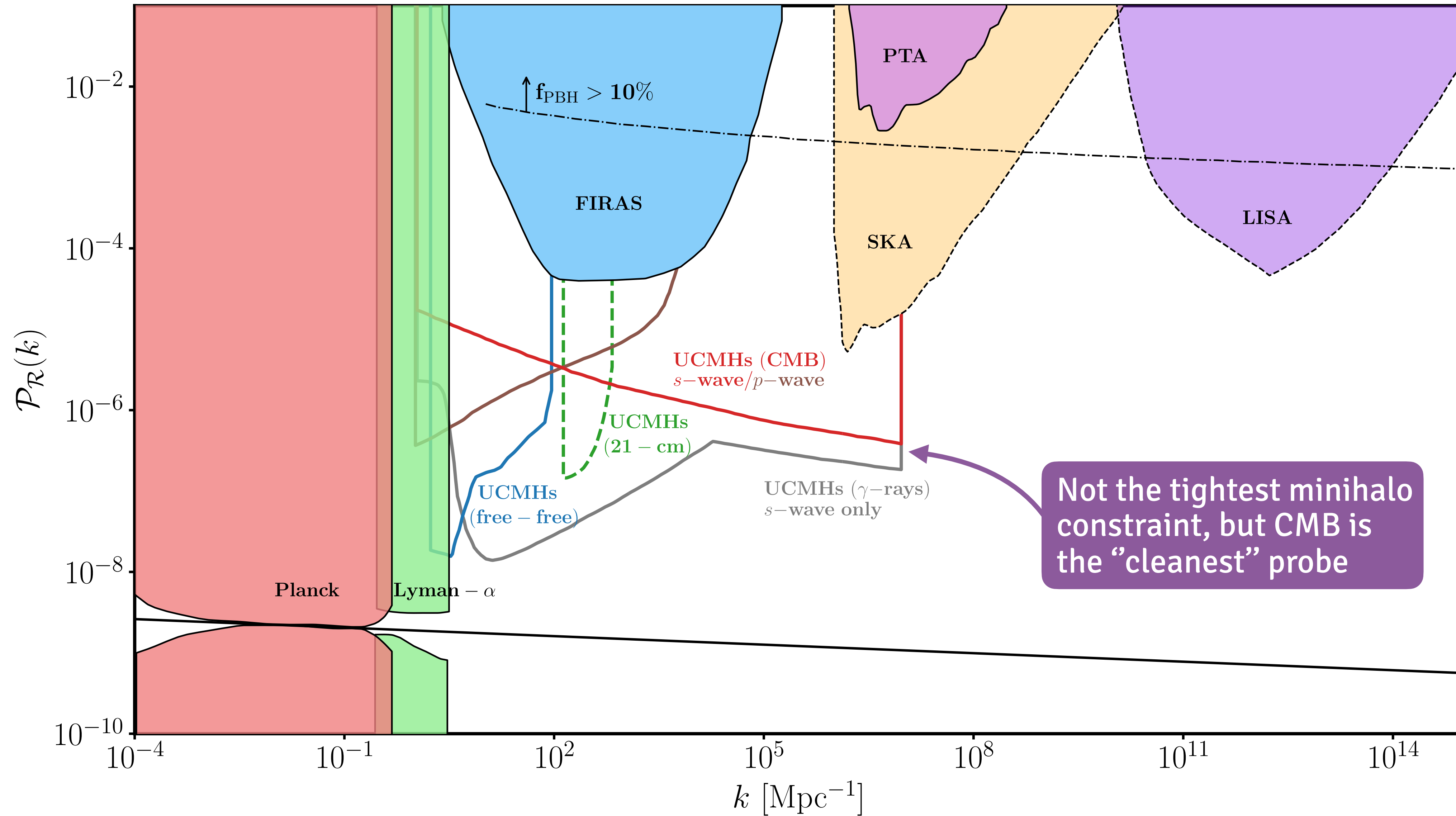
█ p-wave constraints are competitive at small k

█ Relevant for models that predict vanishing s-wave terms

RESULTS



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Conclusions and prospects

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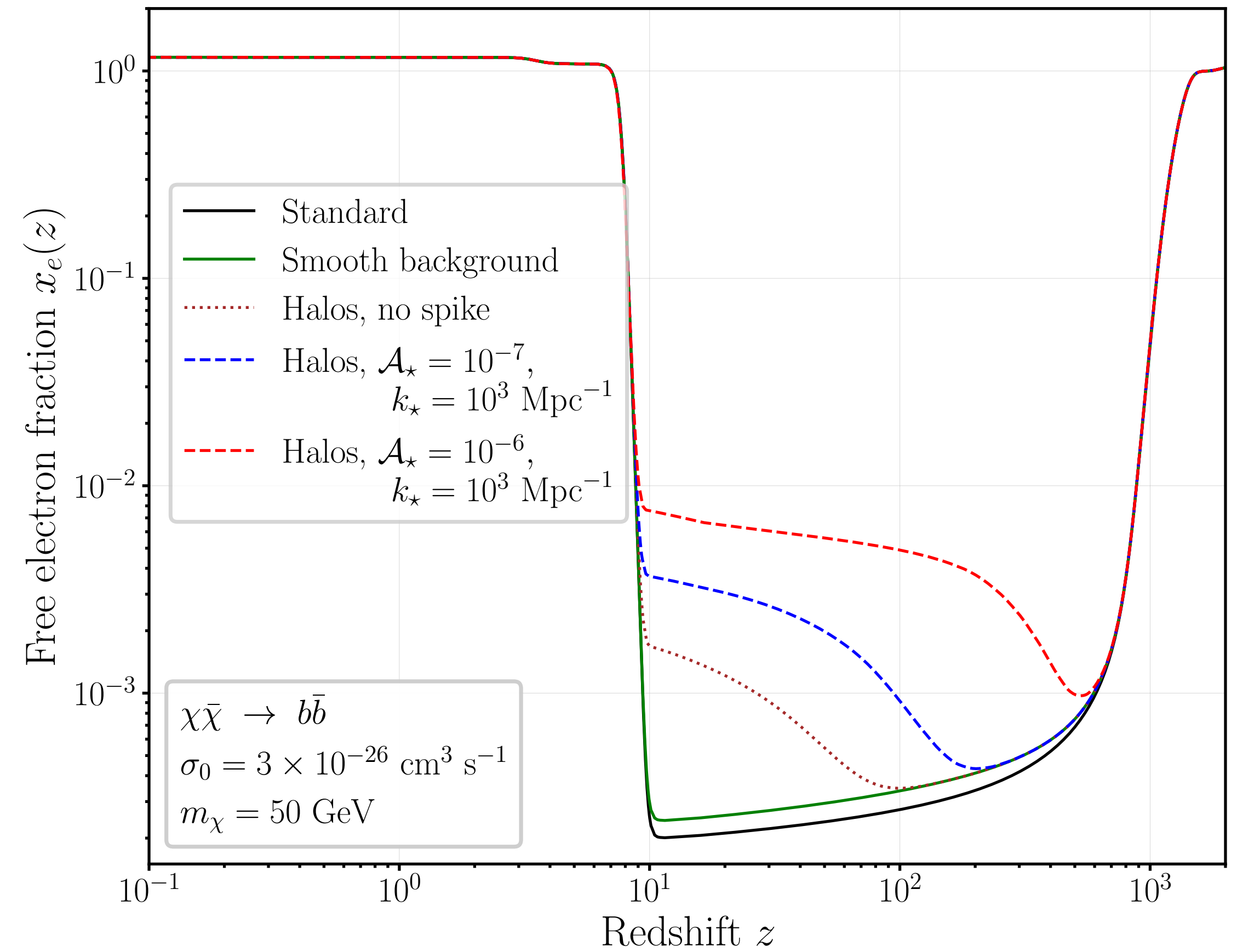
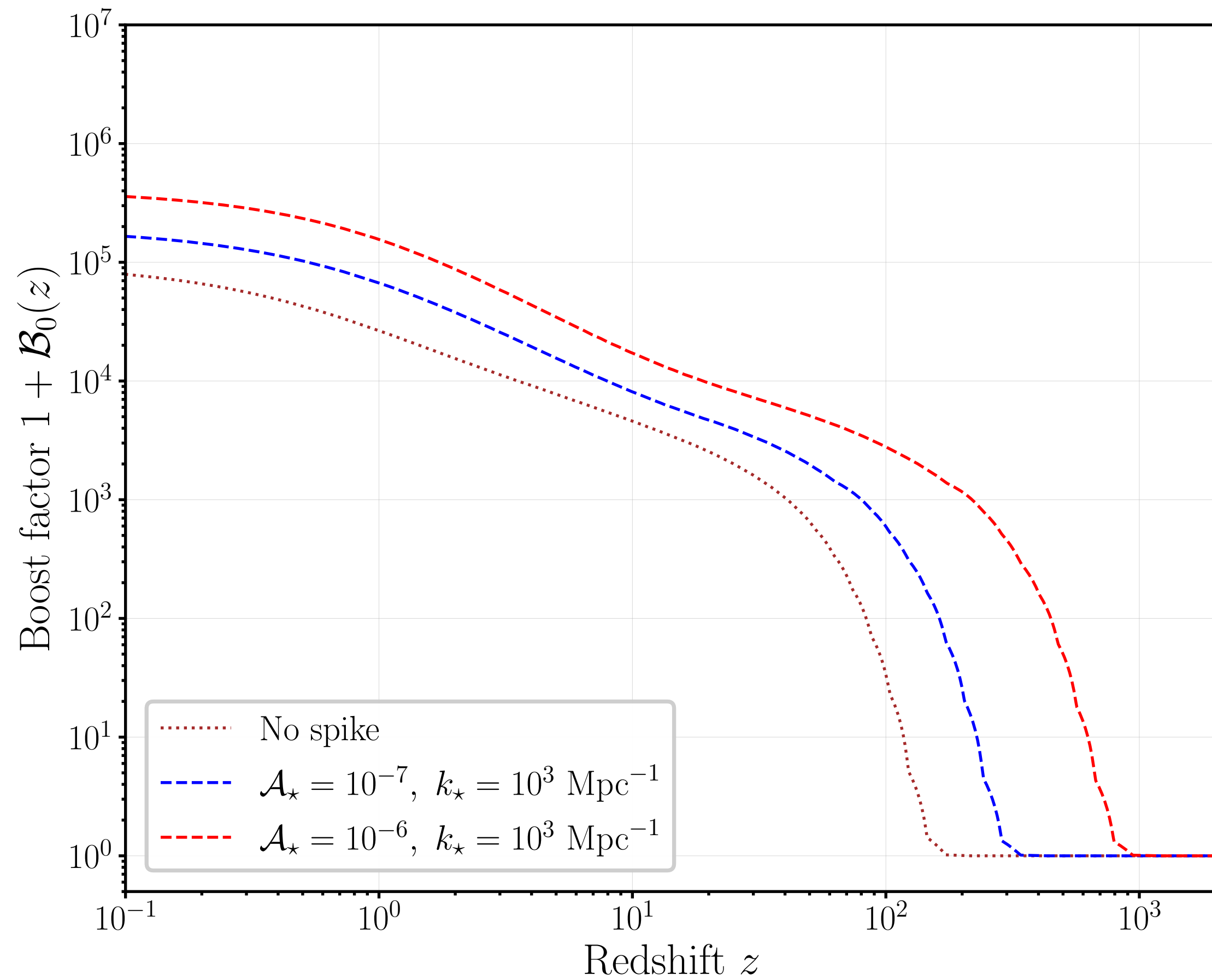
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THANKS FOR
YOUR ATTENTION

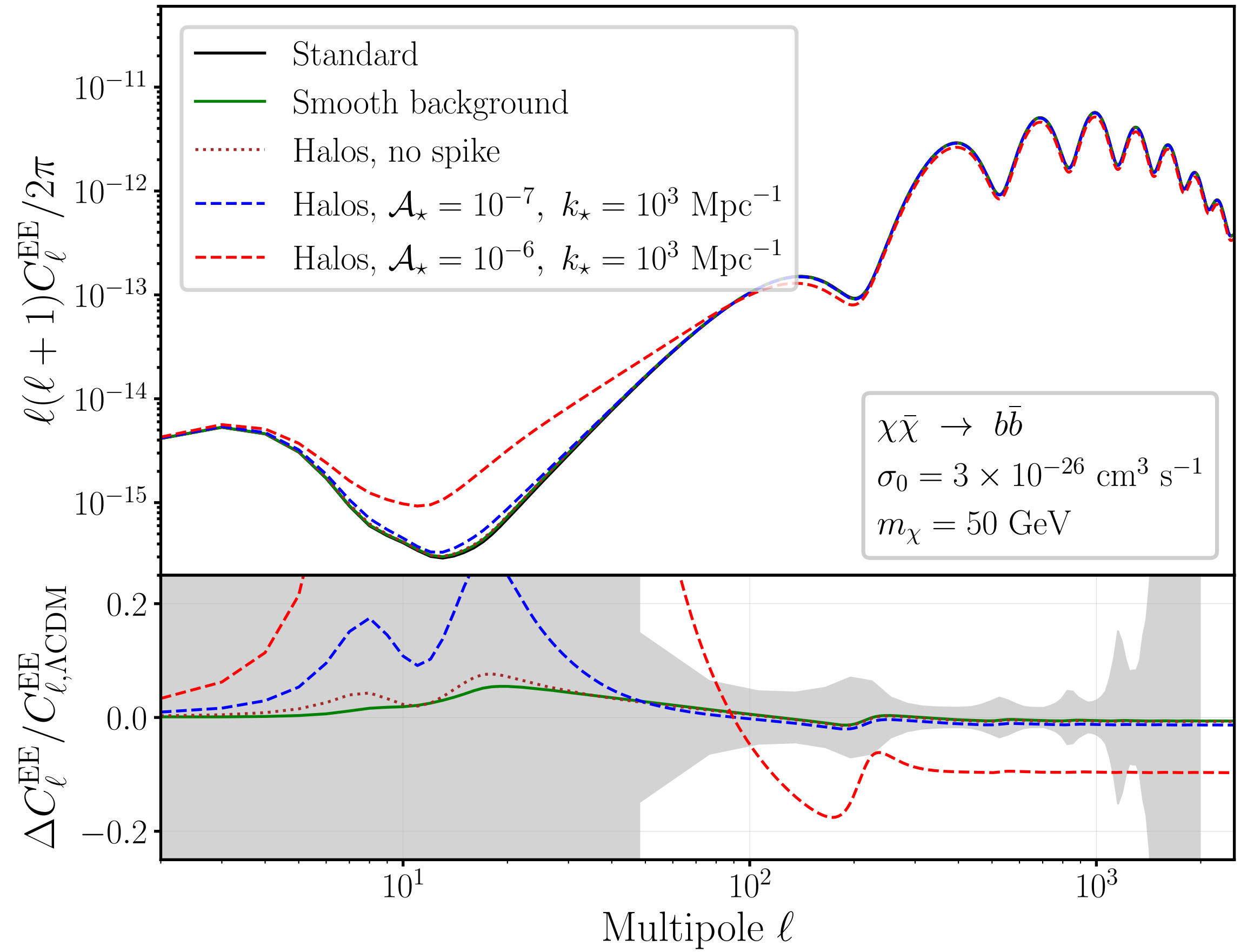
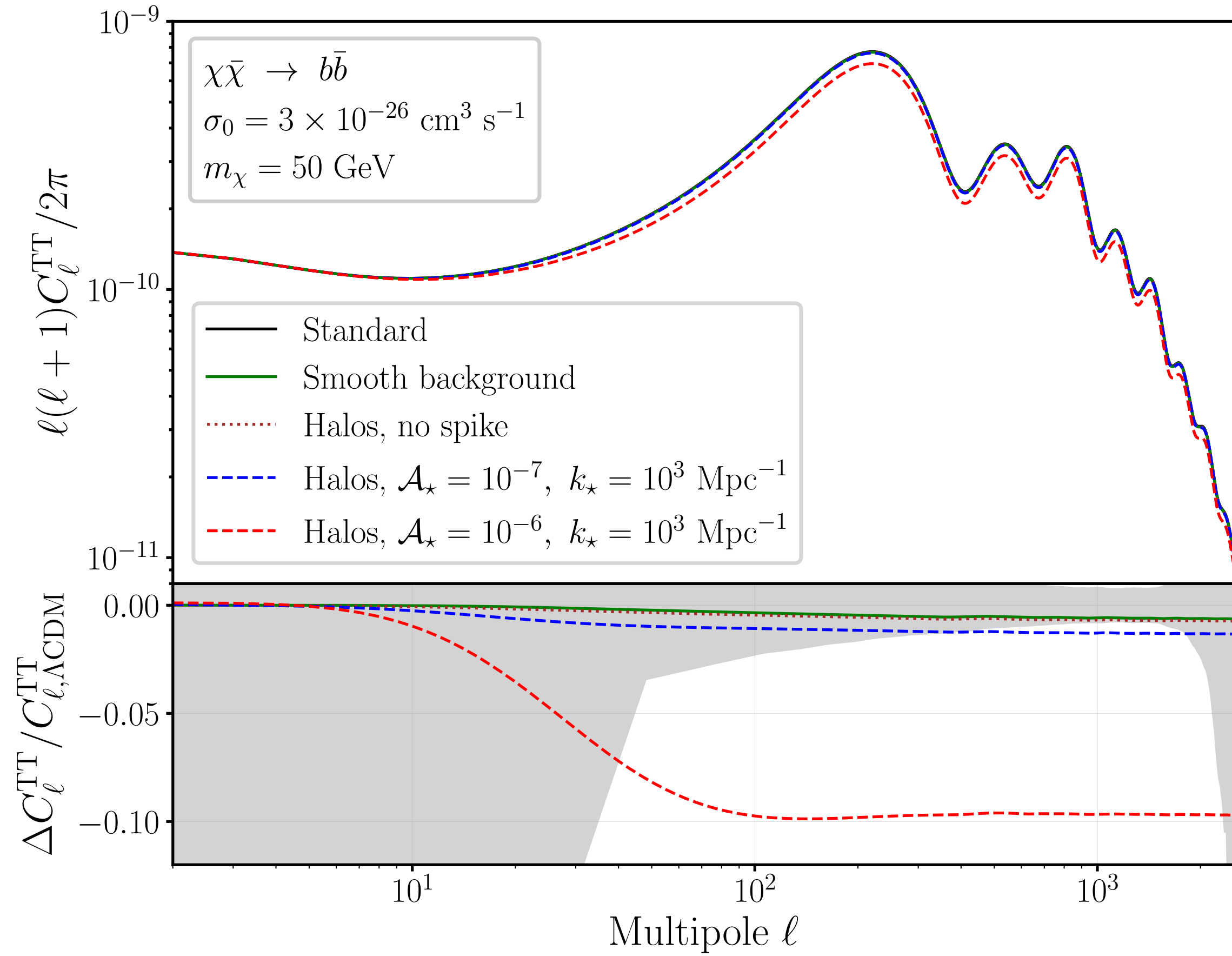
g.francoabellan@uva.nl

BACK-UP

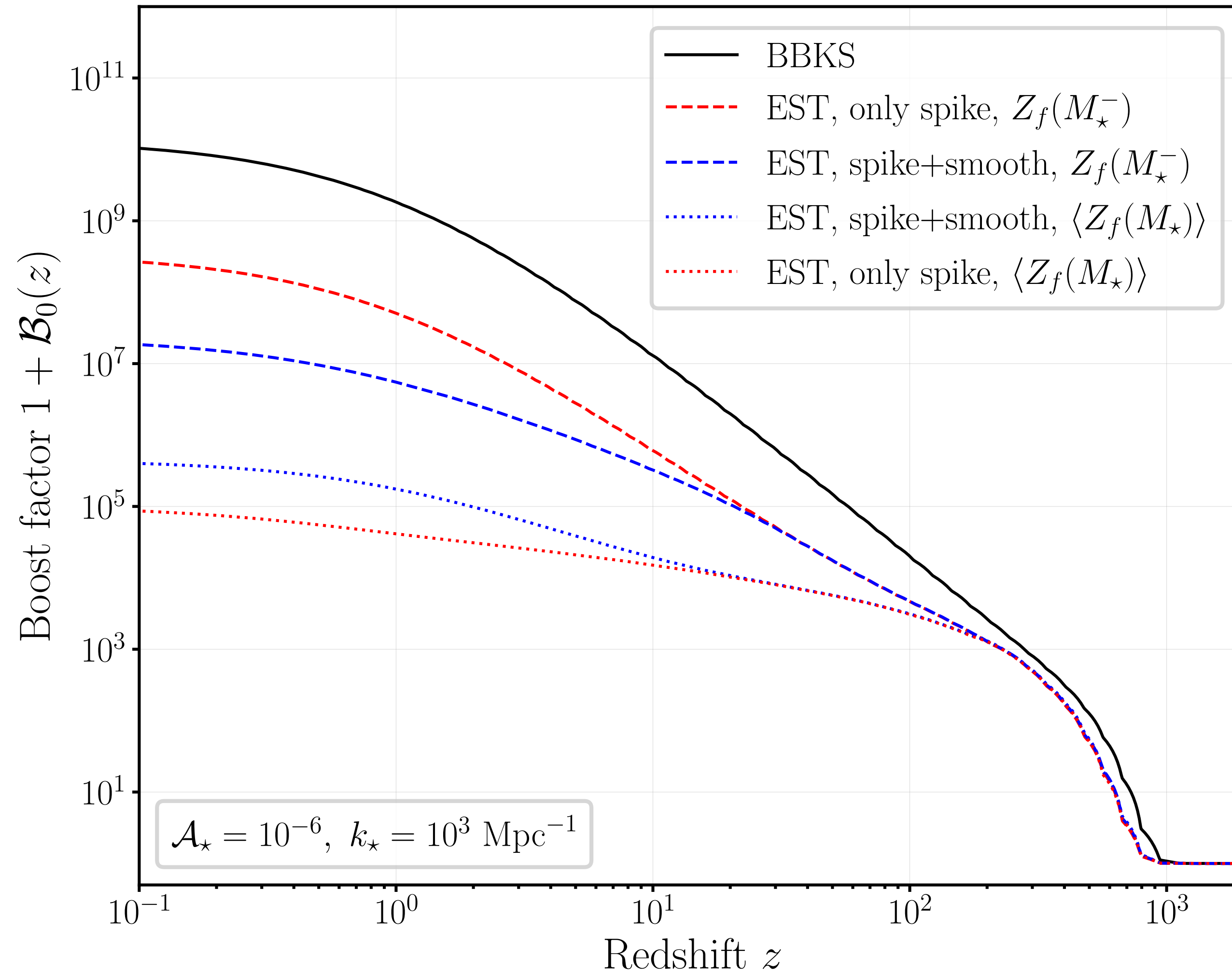
Impact of UCMHs on ionisation history



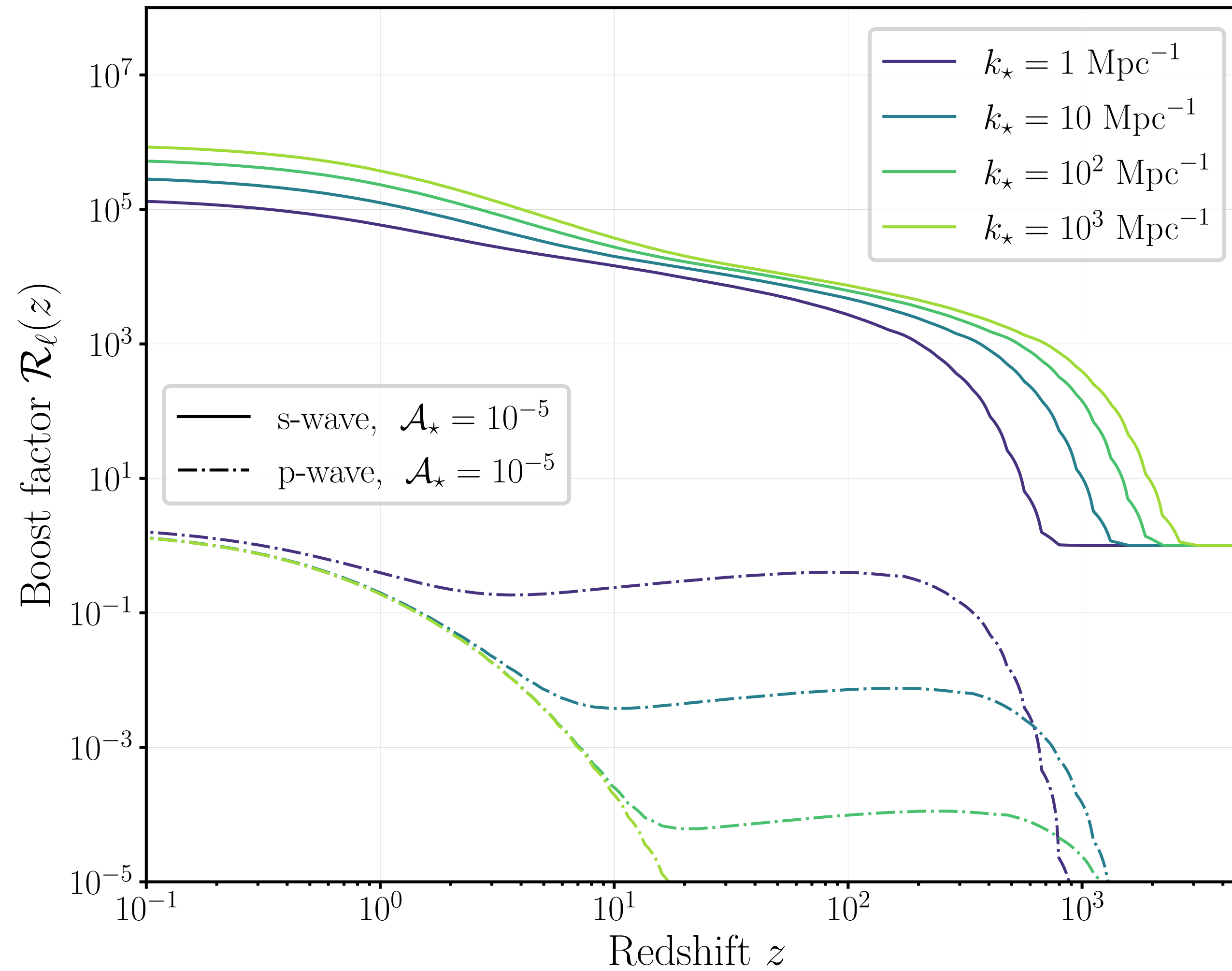
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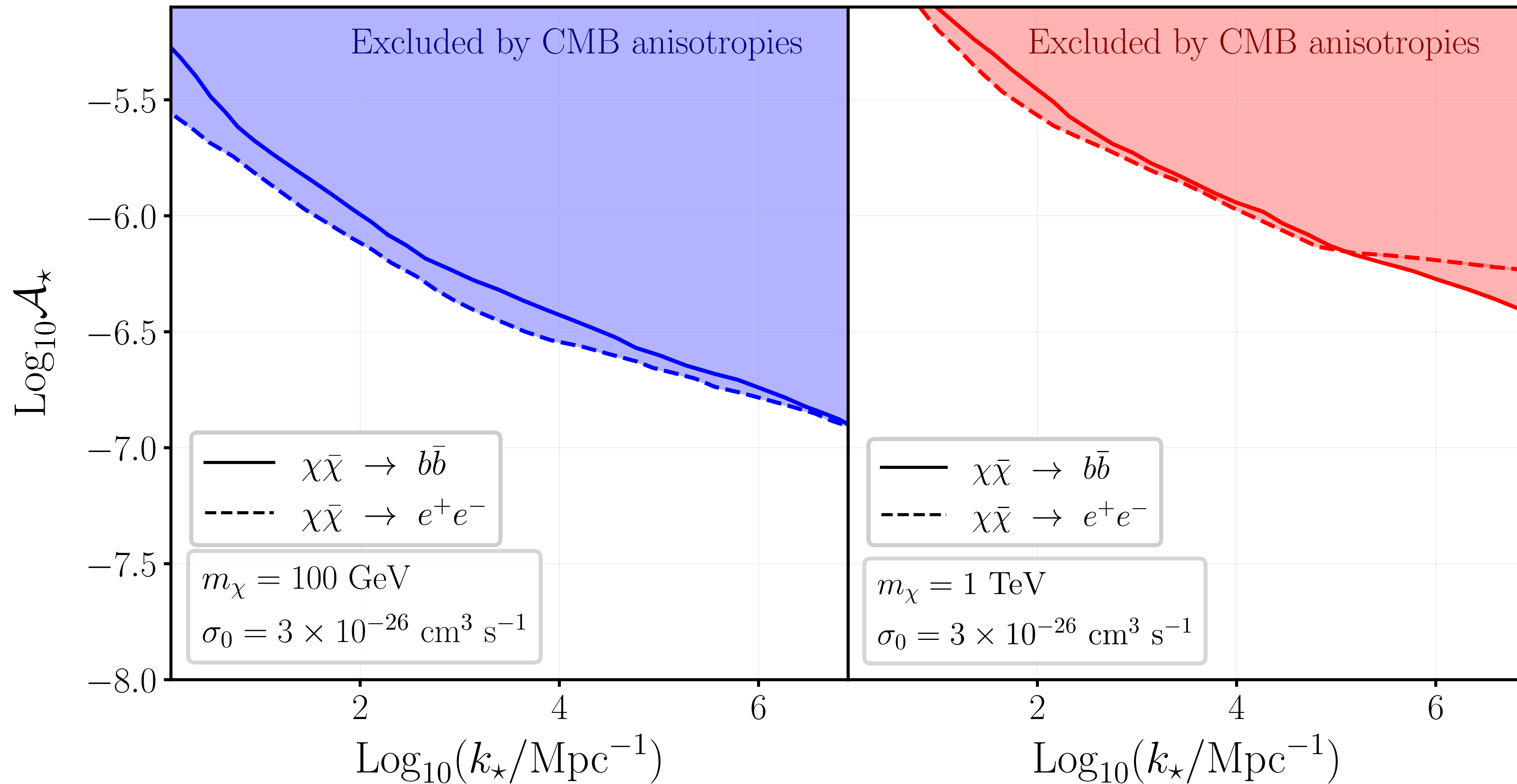
Boost factor: comparison between formalisms



Boost factor: s-wave vs. p-wave



Constraints for different DM masses and annihil. channels



Prior range for the amplitude and location of the spike

$$0 \leq \text{Log}_{10}(k_{\star}/\text{Mpc}^{-1}) \leq 7$$

Typical value for the
free-streaming scale of WIMPs

$$-8 \leq \text{Log}_{10}\mathcal{A}_{\star} \leq -4$$

Larger amplitudes may
lead to PBH formation
or minihalo formation
during the radiation era

