CMB Constraints for Millicharged Dark Matter

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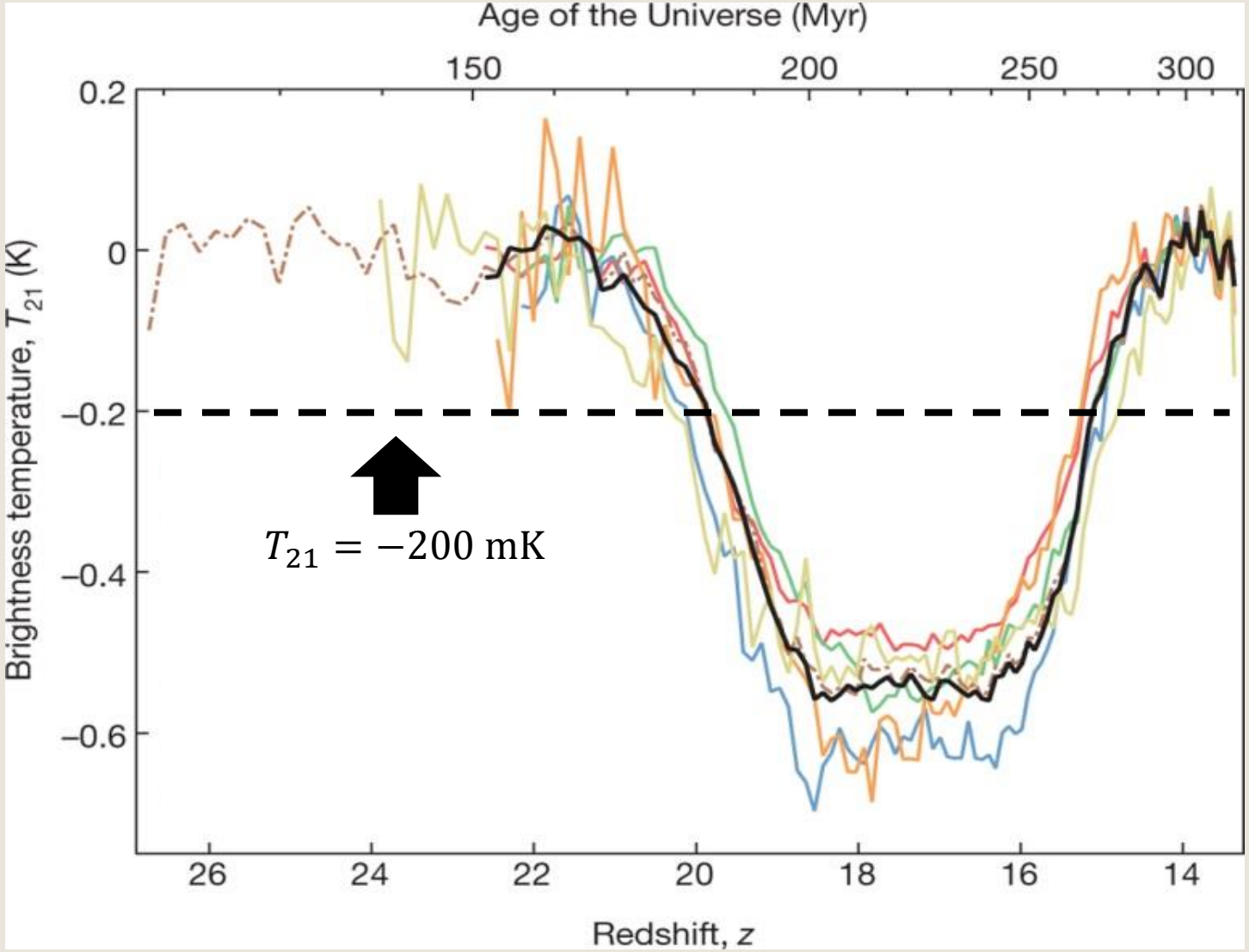
IDM 7/24/2018

Overview

- Why Millicharged Dark Matter?
- Millicharged Basics
- Millicharged Constraints

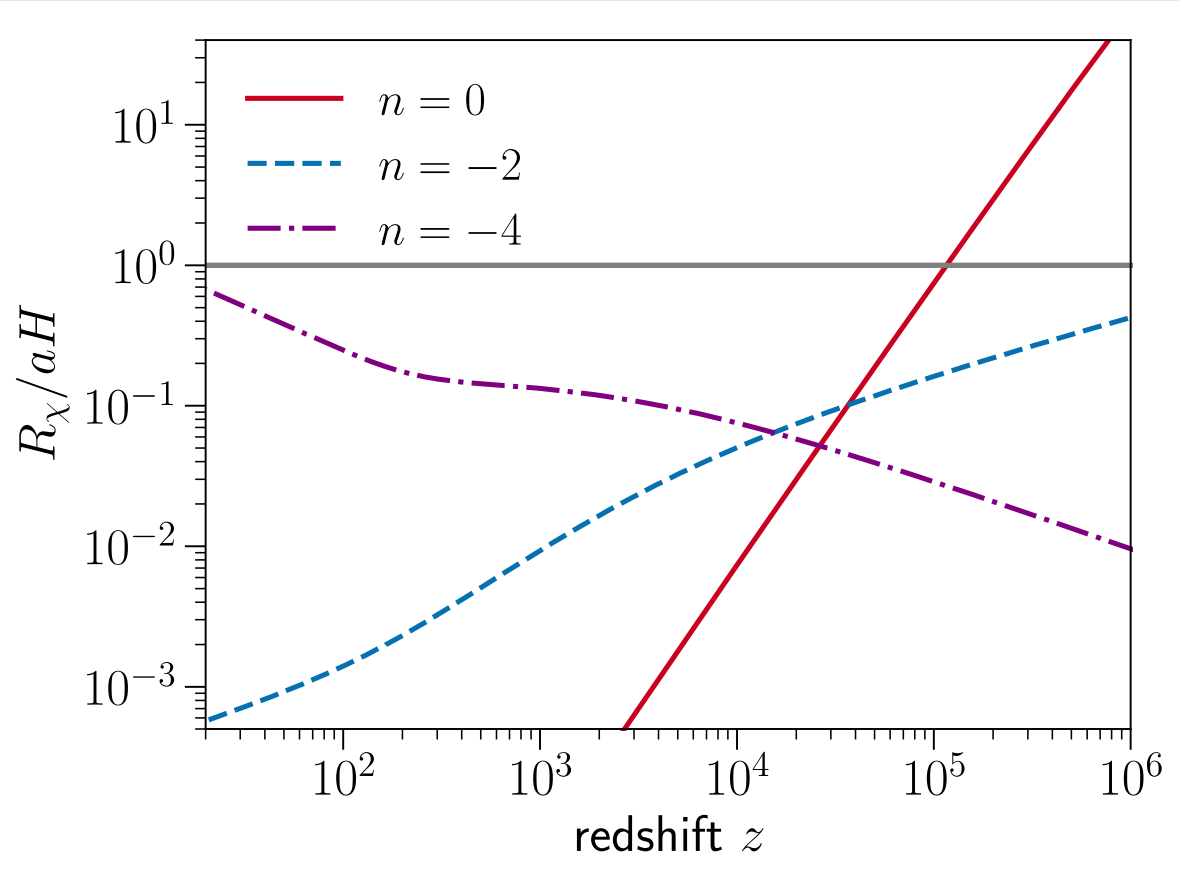
EDGES

- 21-cm Detection
- Less then expected brightness temperature
- Need a way to cool baryons



Bowman et al 2018

Cool Baryons with Dark Matter

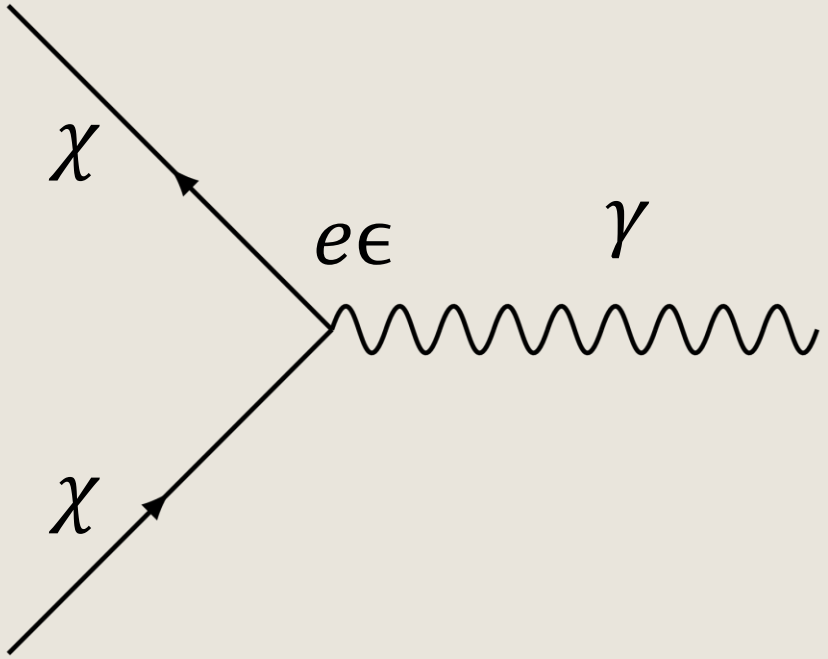


$$\sigma \propto v^n$$

- Want to transfer heat from baryons to dark matter
- Needs to happen late time ($z \sim 17$)
- v^{-4} interaction allows late time effects with minimal early time effects

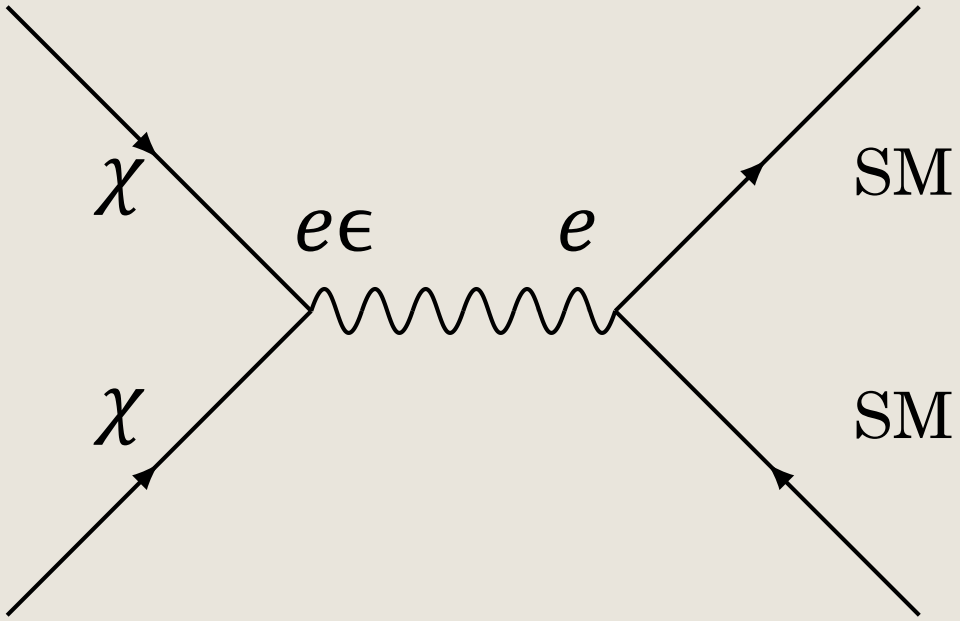
Millicharged Basics

- Dark matter with charge ϵe
- Not one "millicharged" dark matter model
- Allows v^{-4} interaction
- Has increased late time interactions with baryons

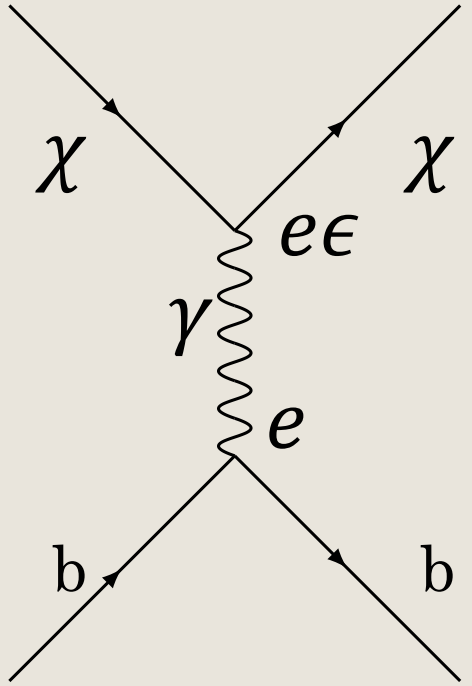


Non-gravitational Interactions

- Annihilations into Standard Model particles
  - $\frac{dE}{dVdt} \propto \epsilon^2$

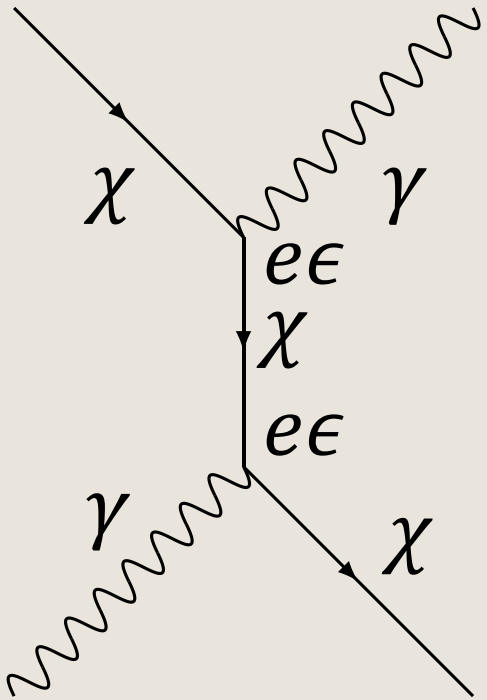


- Scattering with baryons
  - $\sigma \propto \frac{\epsilon^2}{v^4}$



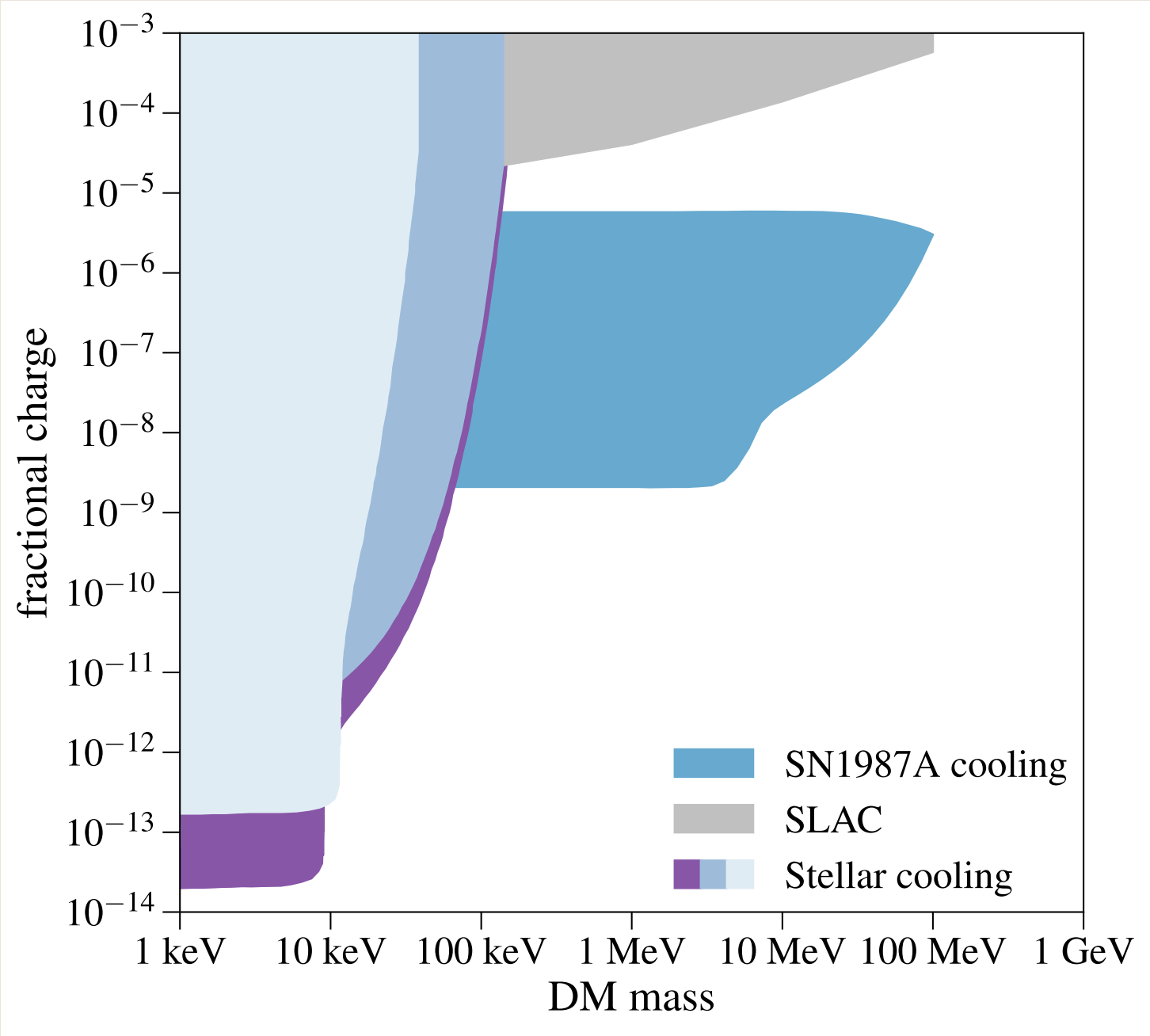
Non-gravitational Interactions II

- Scattering with photons
  - $\sigma \propto \epsilon^4$



Impacts on CMB

- Baryon scattering usually dominates
- Annihilations are mostly subdominant to baryon scattering
- Photon scattering is extremely subdominant

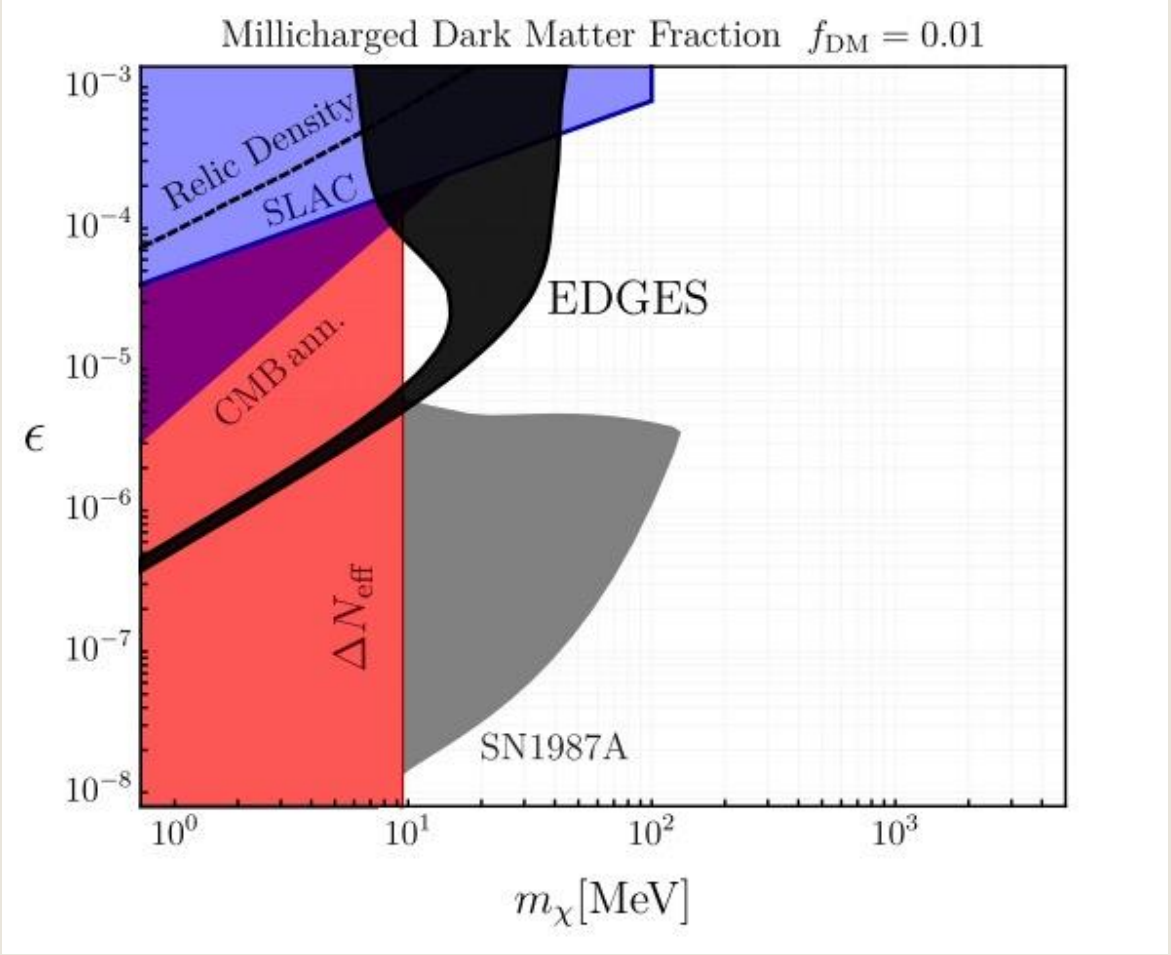


Fraction Independent Constraints

Edges Constraints

- Need to cool baryons without violating CMB constraints

- Requires $f \leq 1\%$ and $m_\chi \sim 1 - 80$ MeV
  - Munoz and Loeb 2018
  - Berlin et al 2018
  - Barkana et al 2018



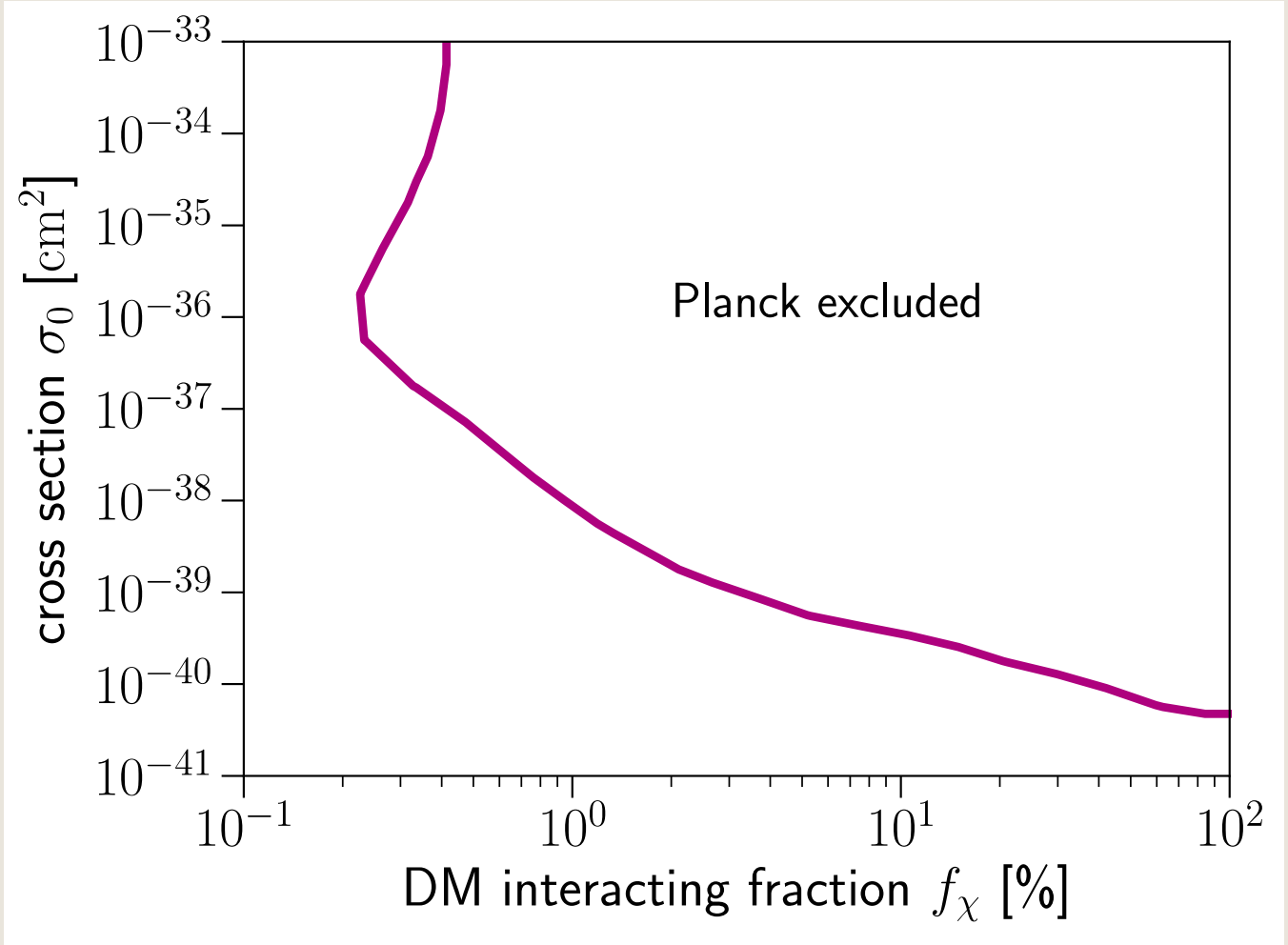
Berlin et al 2018

Cross Section v.s. Fraction

$\epsilon = 1.3 \times 10^{-4}$

$\epsilon = 4.0 \times 10^{-5}$

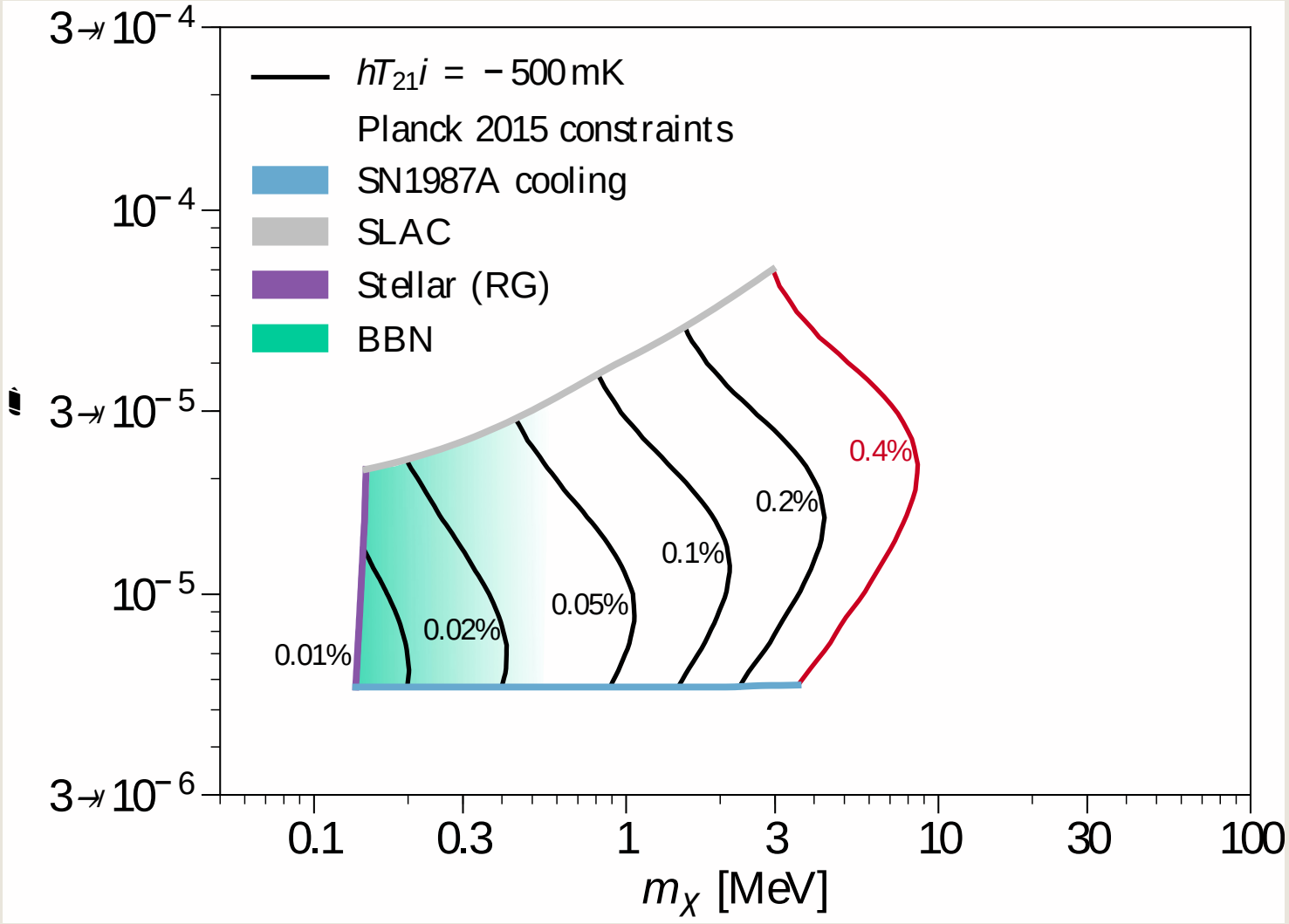
$\epsilon = 1.2 \times 10^{-5}$



$m_\chi = 1$ MeV

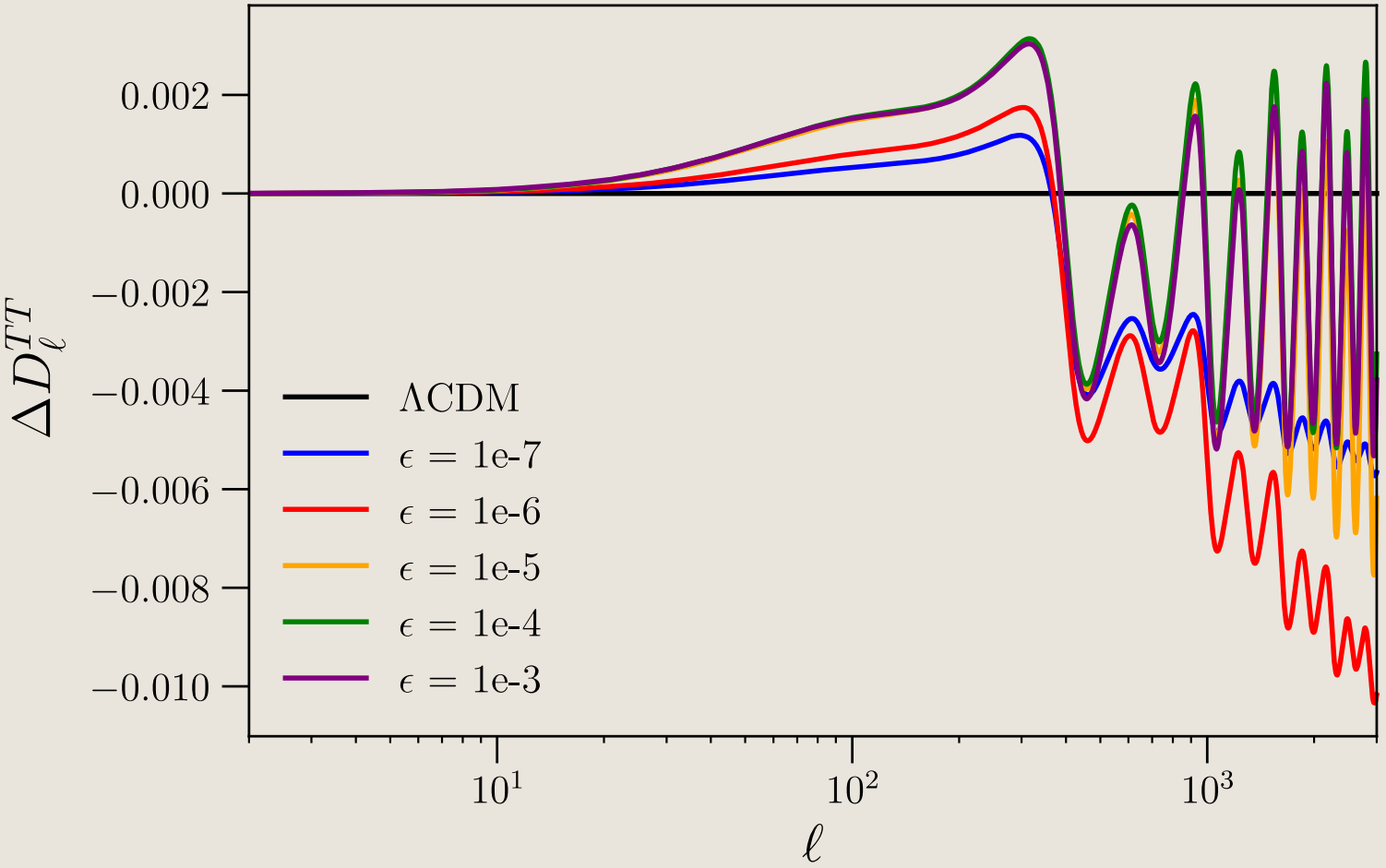
Boddy, Gluscevic, Poulin, Kovetz, Kamionkowski and Barkana (in prep)

Baryon Scattering Constraints



Kovetz, Poulin, Gluscevic, Boddy, Barkana and Kamionkowski (in prep)

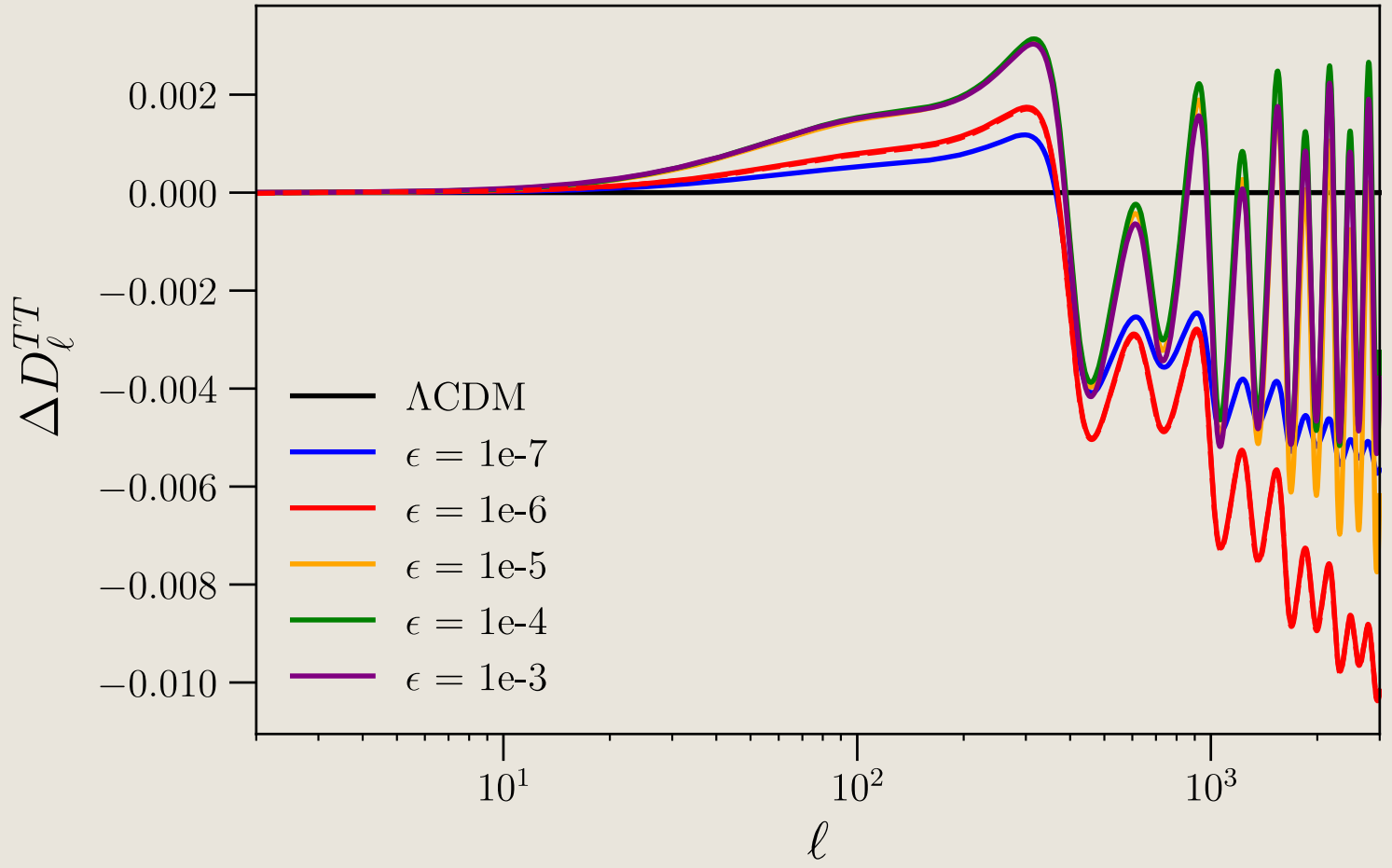
Baryon Scattering Saturation



$f = 0.1\%$

$m_\chi = 1$ MeV

Weak Annihilations



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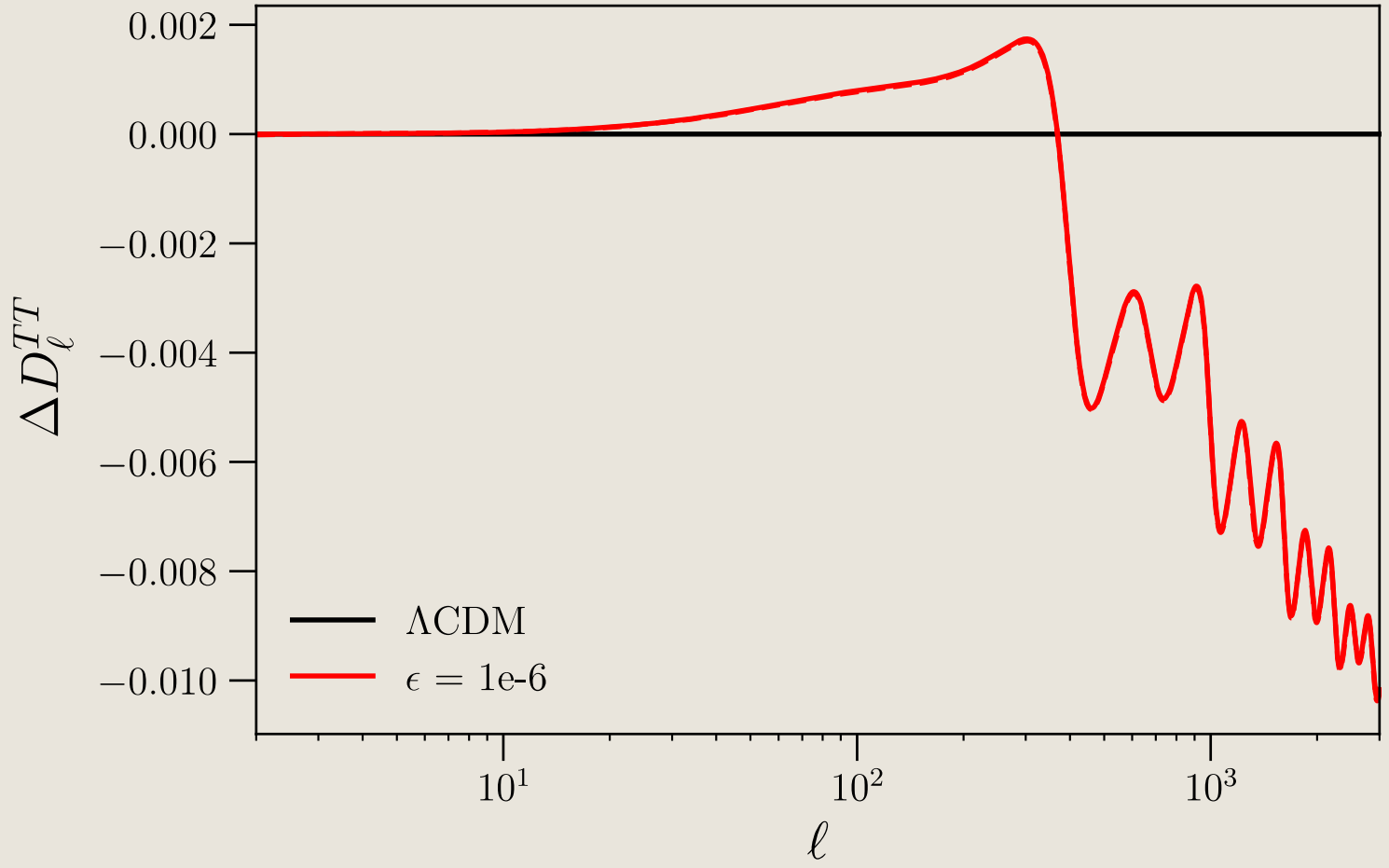
Weak Annihilations



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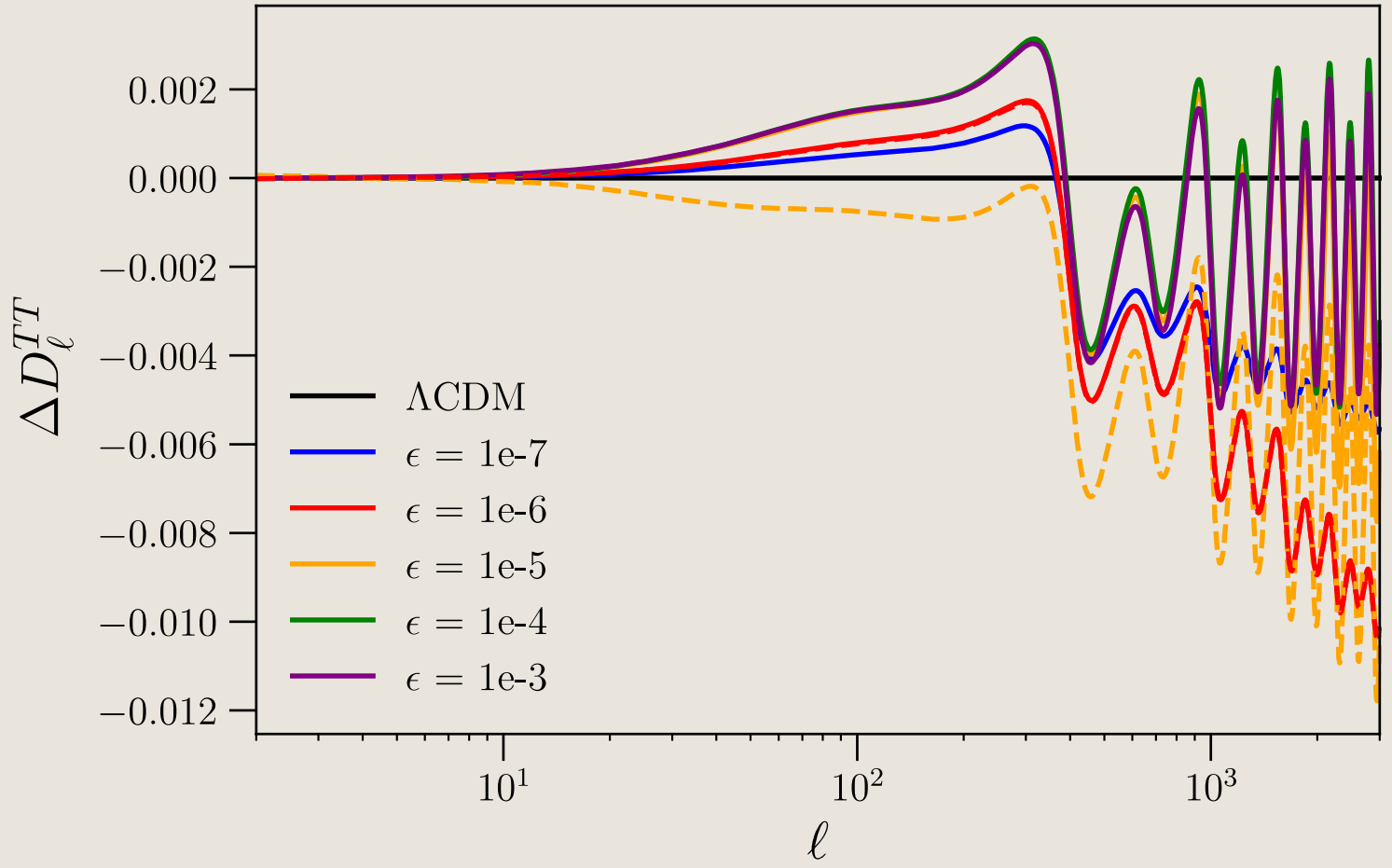
Strong Annihilations



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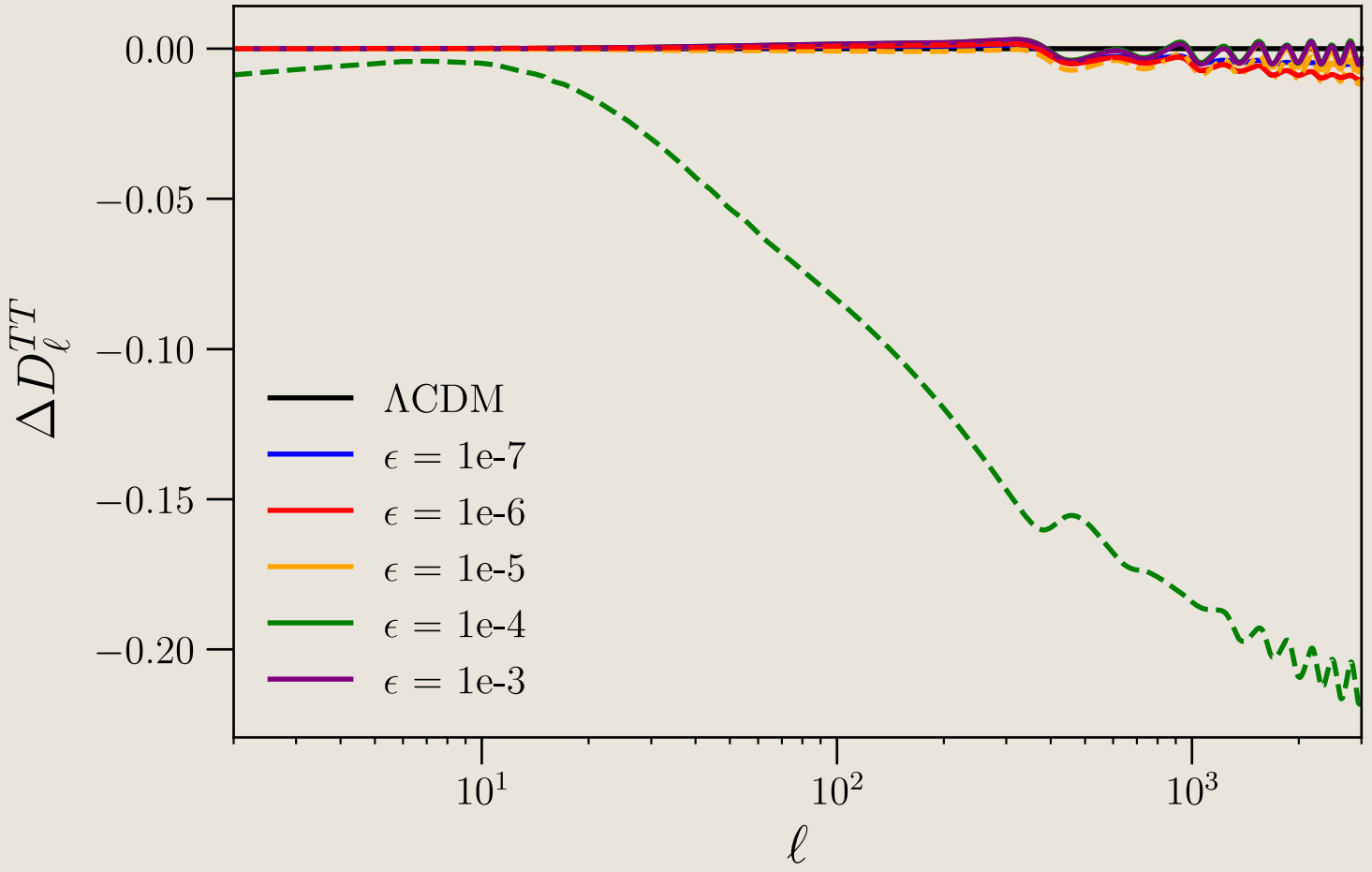
Over Annihilation



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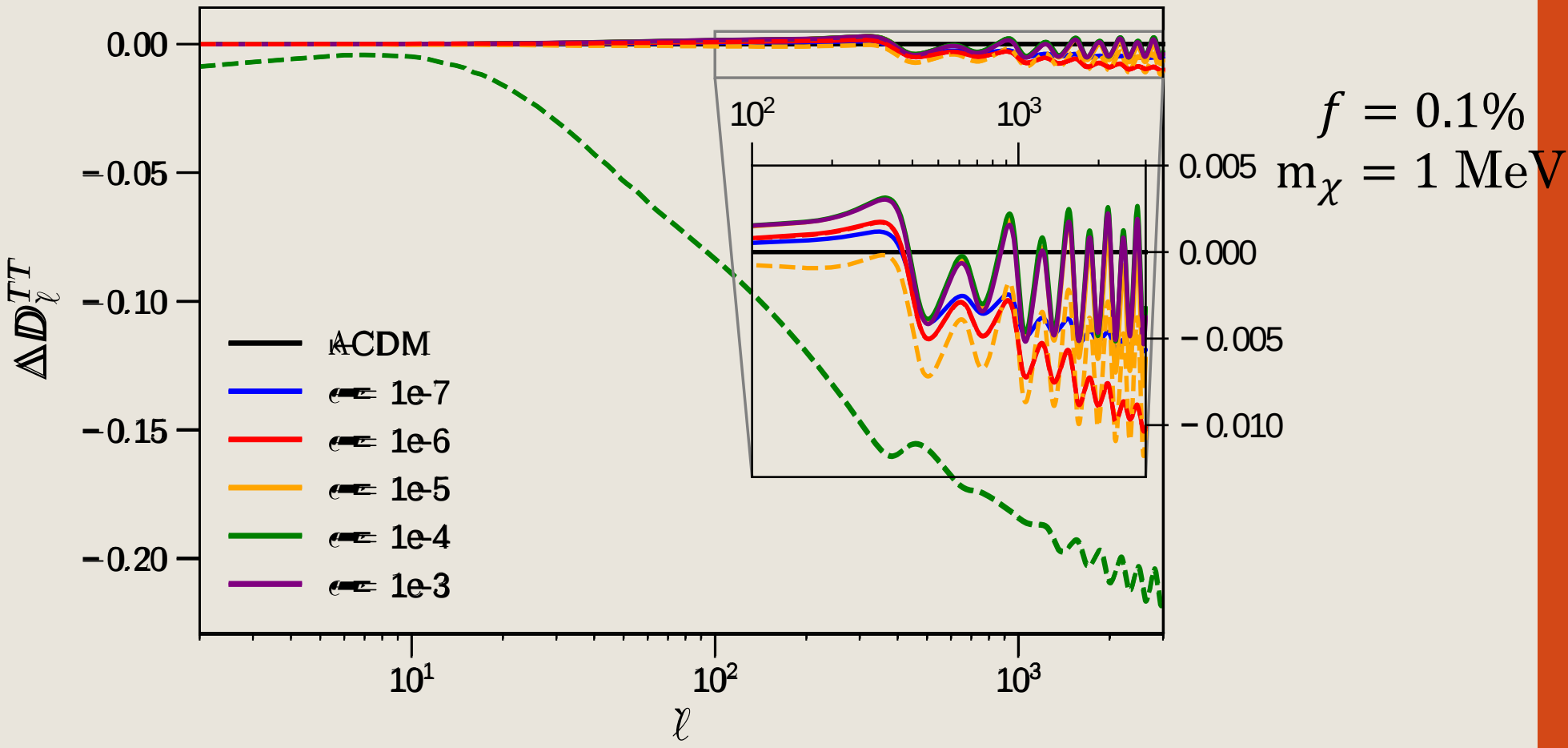

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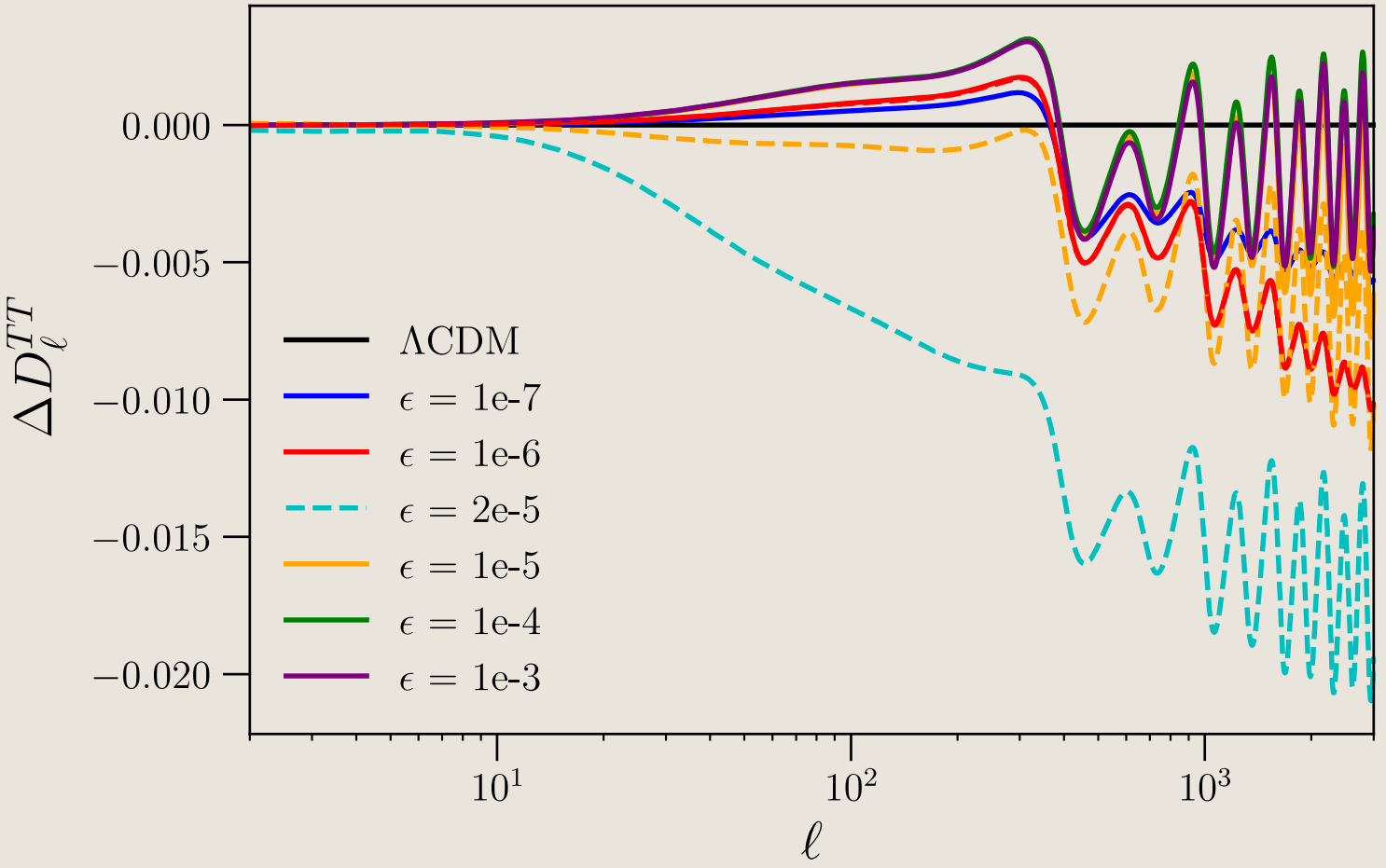

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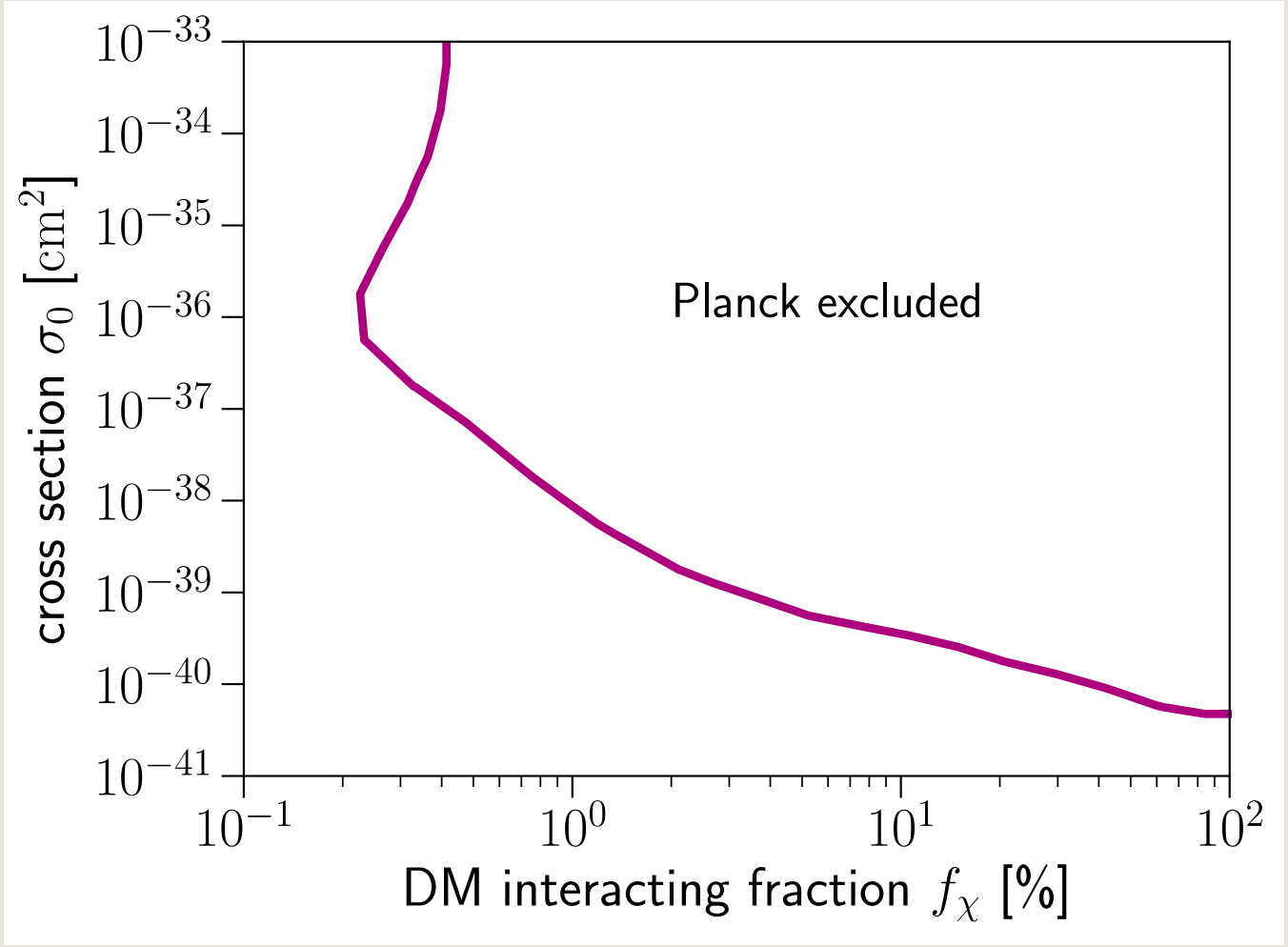

Boddy, Gluscevic, Poulin, Kovetz, Kamionkowski and Barkana (in prep)

Cross Section v.s. Fraction with Annihilations

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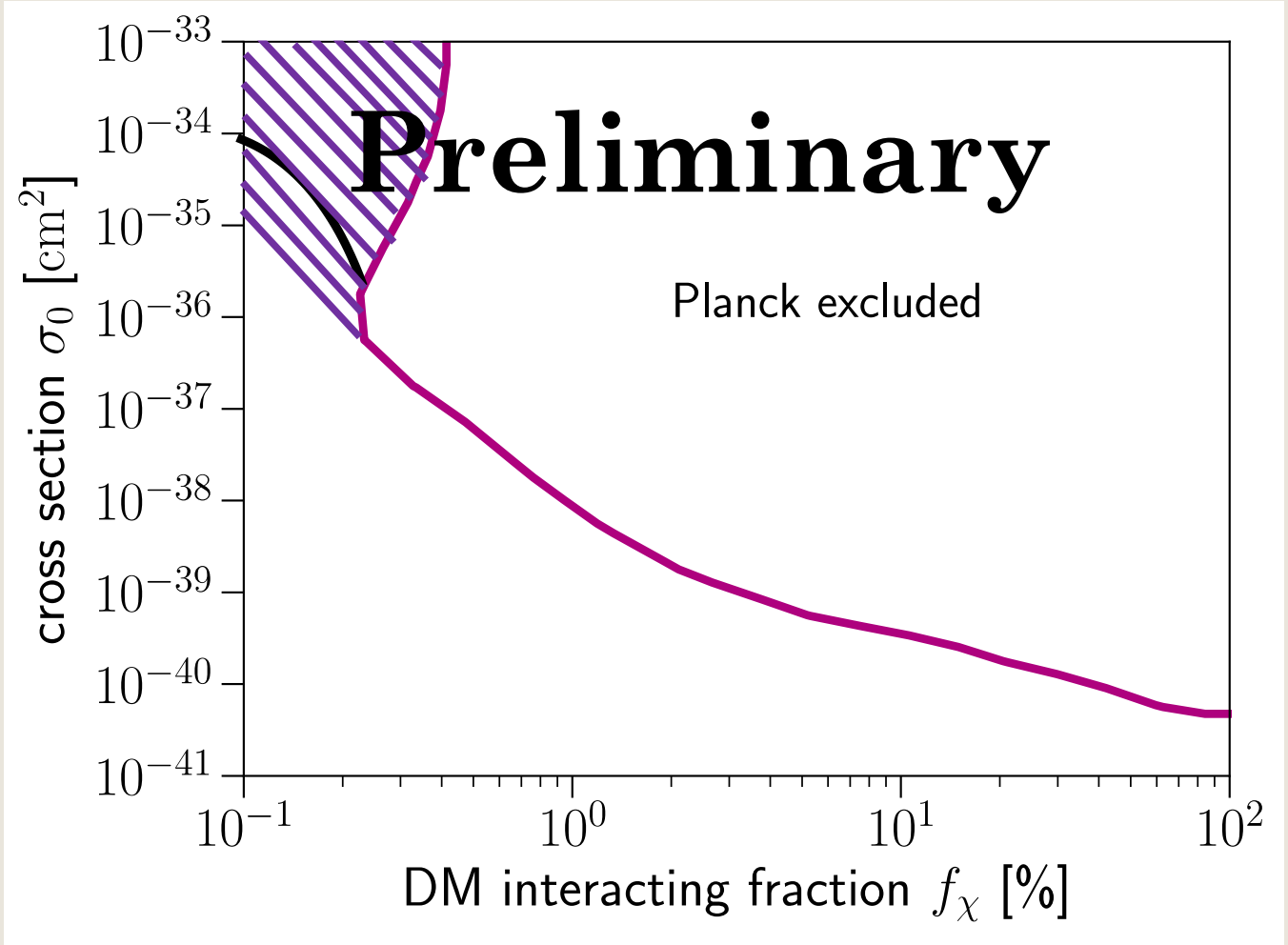
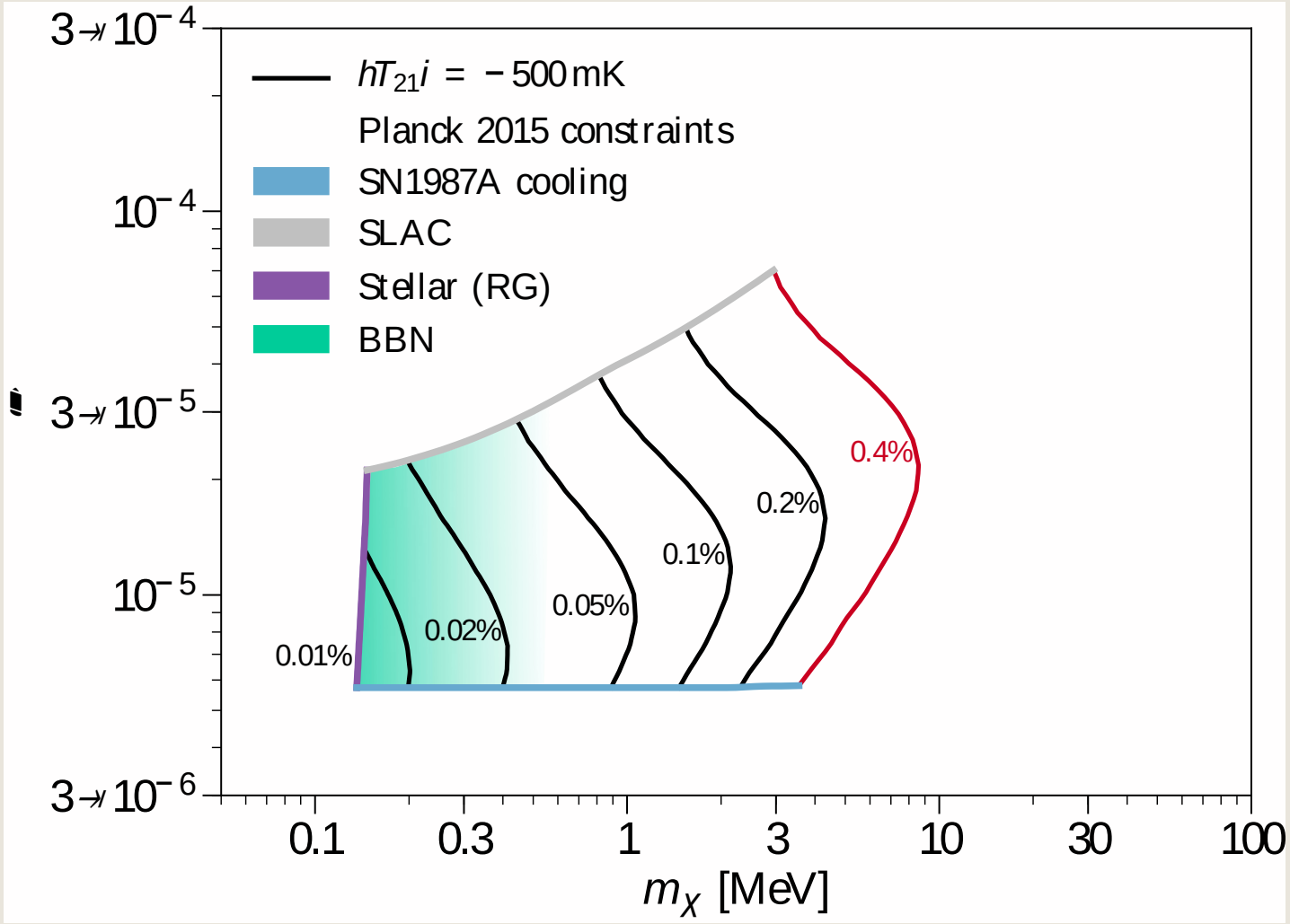
$\epsilon = 1.2 \times 10^{-5}$



Modified from Boddy, Gluscevic, Poulin, Kovetz, Kamionkowski and Barkana (in prep)

Baryon Scattering Constraints



Kovetz, Poulin, Gluscevic, Boddy, Barkana and Kamionkowski (in prep)

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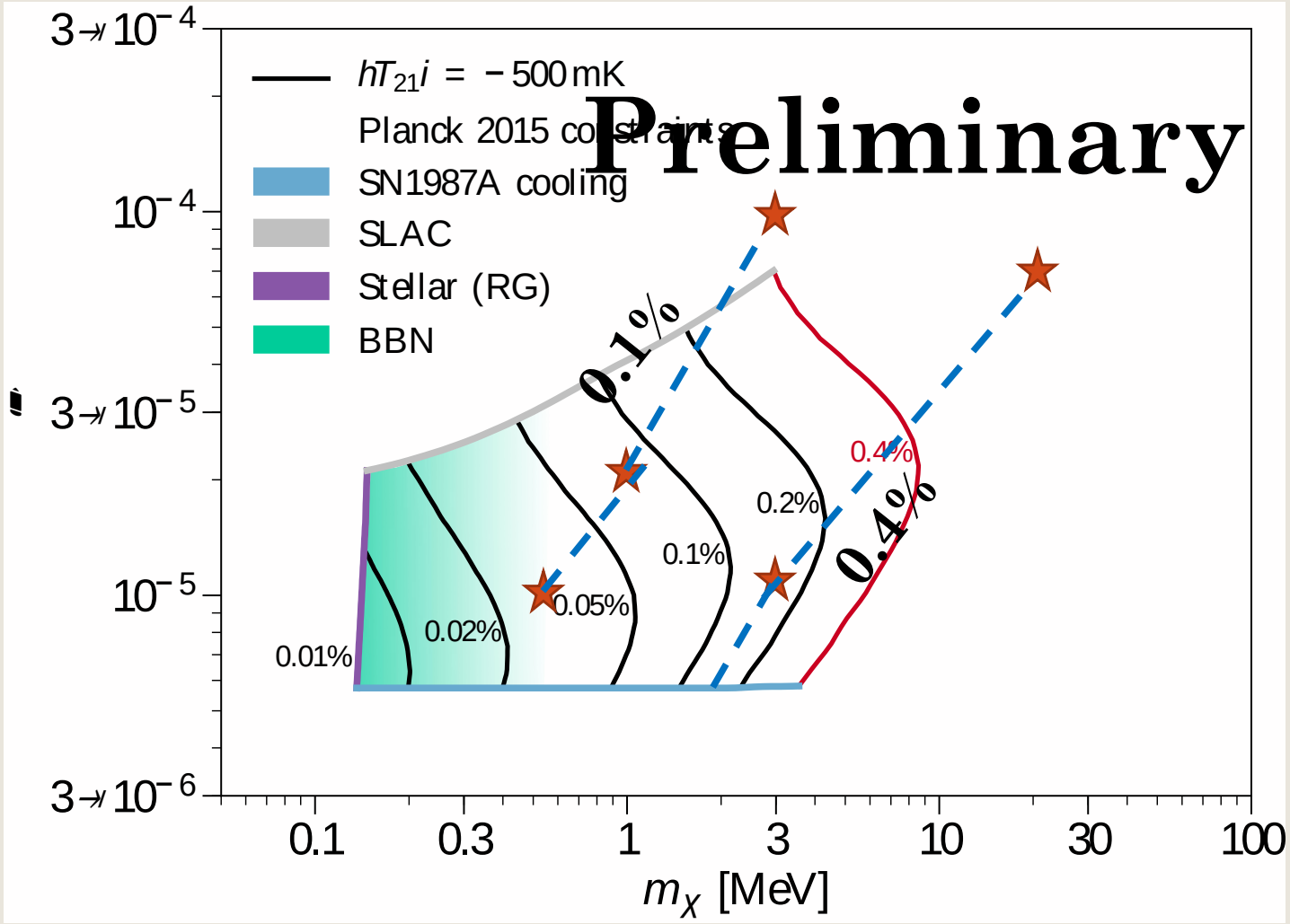

Modified from Kovetz, Poulin, Gluscevic, Boddy, Barkana and Kamionkowski (in prep)

Summary

- Constraints weaken for baryon scattering for $f < 0.3\%$

- But annihilations still give constraining power for $f < 0.3\%$.

Future Work

- More realistic millicharged model

- Effects of dark photons (N_{eff}, freeze-out constraints)