

# Probing Dark Matter Particle Properties with Ultra-Deep, High-Resolution CMB Lensing

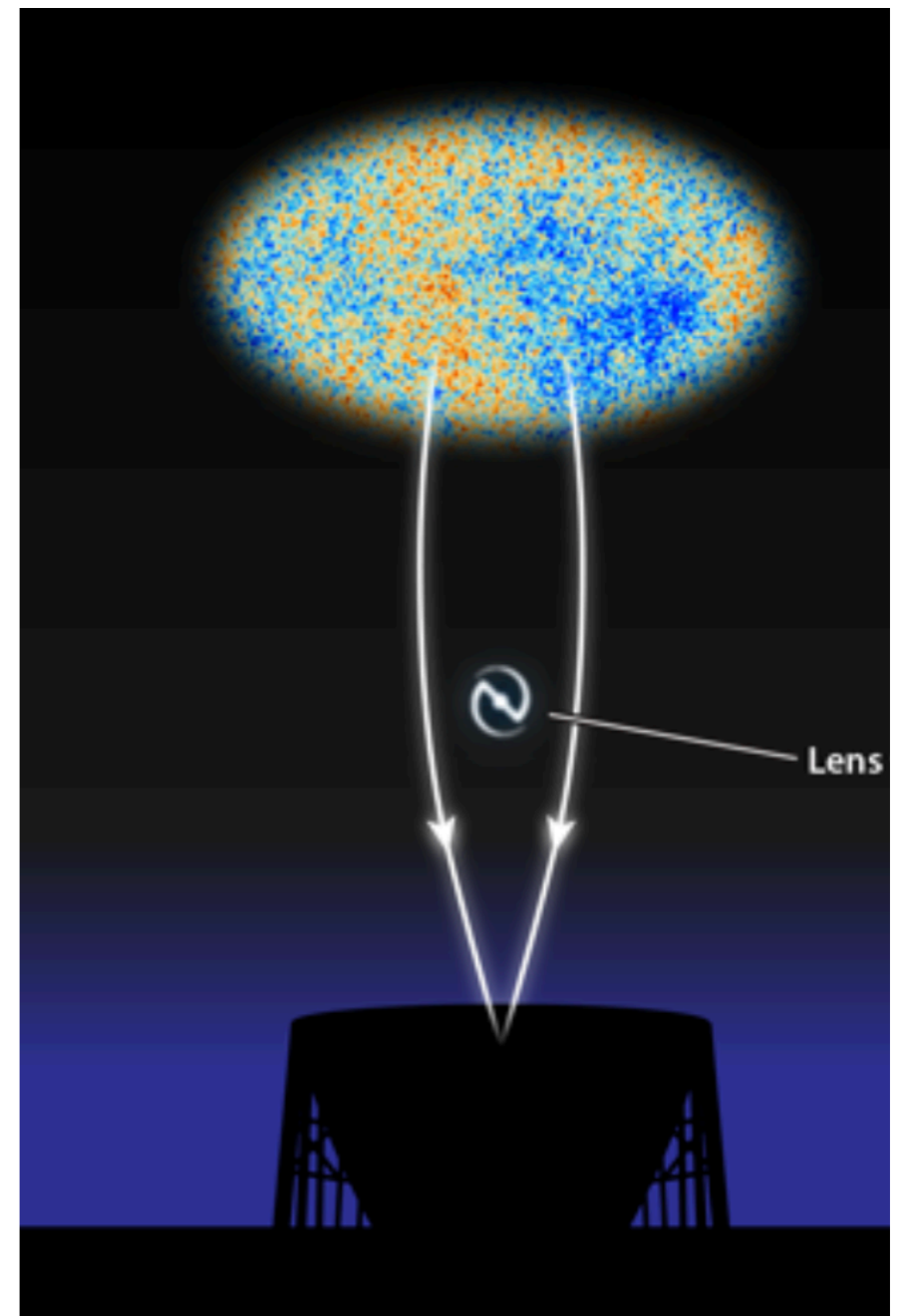
Neelima Sehgal

Aspen Winter 2019  
In Pursuit of New Particles and Paradigms

March 26th, 2019

Ho Nam Nguyen, NS, Mathew Madhavacheril,  
PRD, 2019, (arXiv:1710.03747)

NS et al. 2019, White Paper for Astro2020 Decadal  
(arXiv:1903.03263)



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**Key Question: What do matter fluctuations look like on small-scales?**

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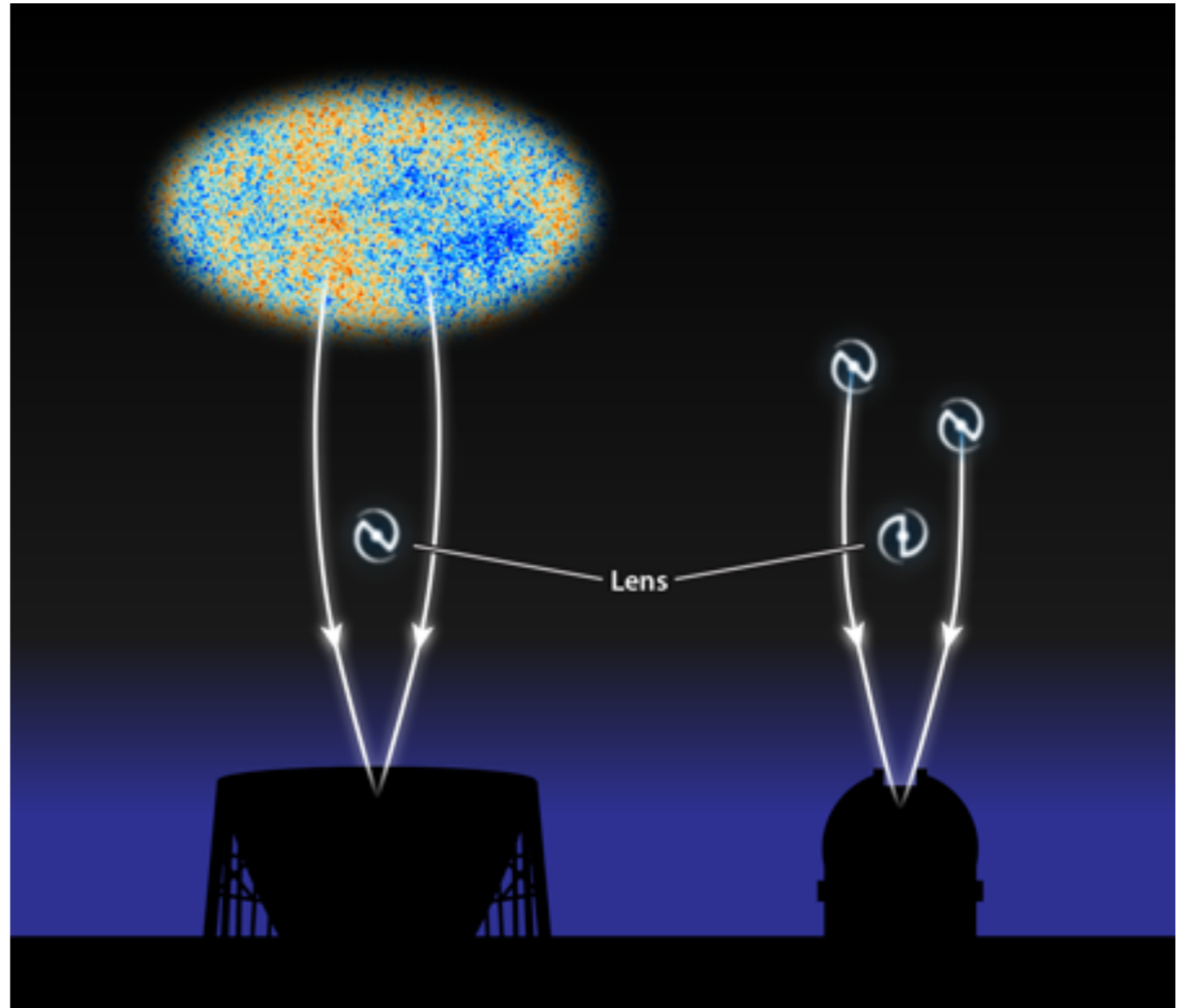
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- Galaxy-galaxy strong lensing in optical and mm-wavelengths - need to disentangle complex structure of background source from substructure

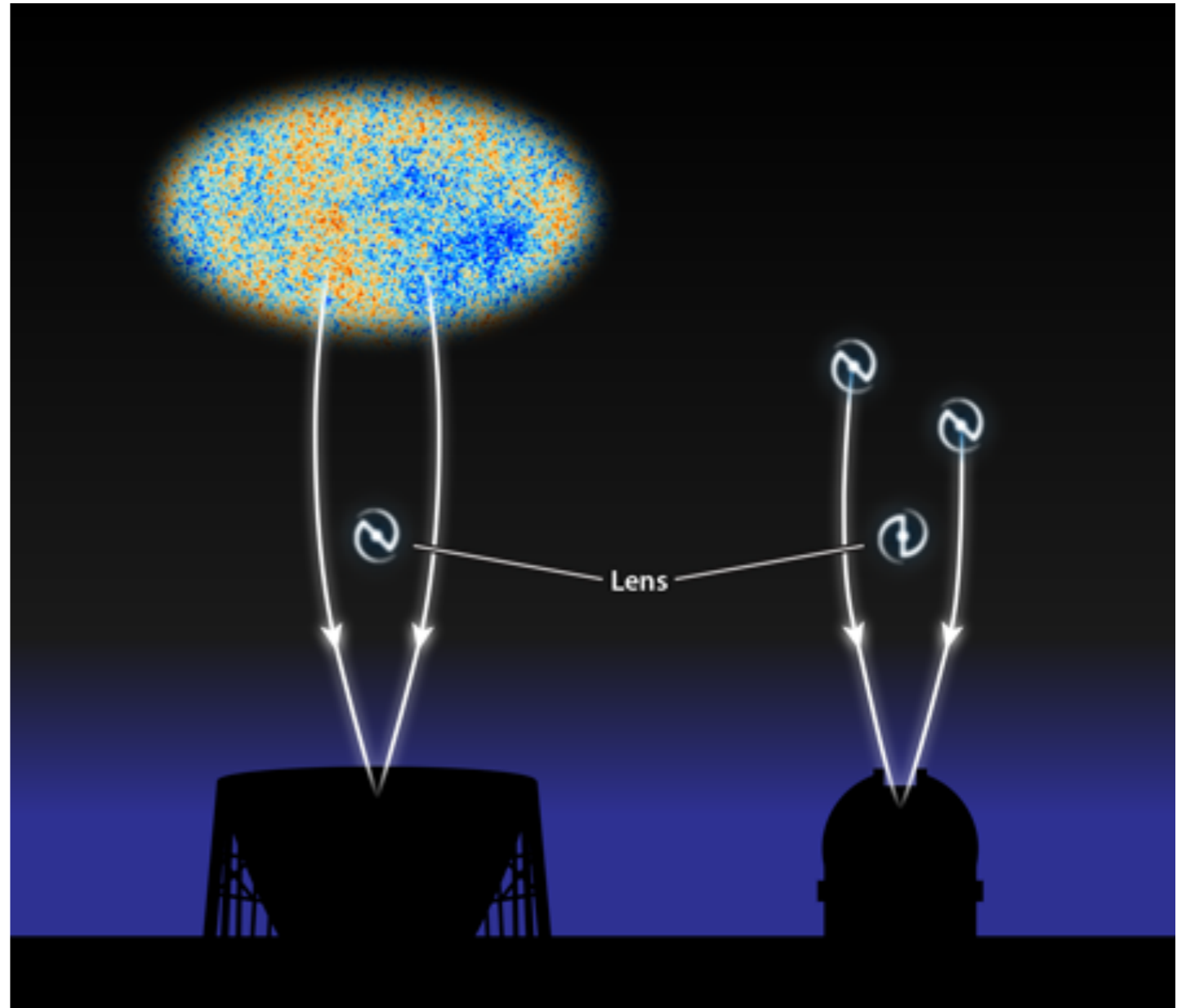


# Gravitational Lensing of the Cosmic Microwave Background



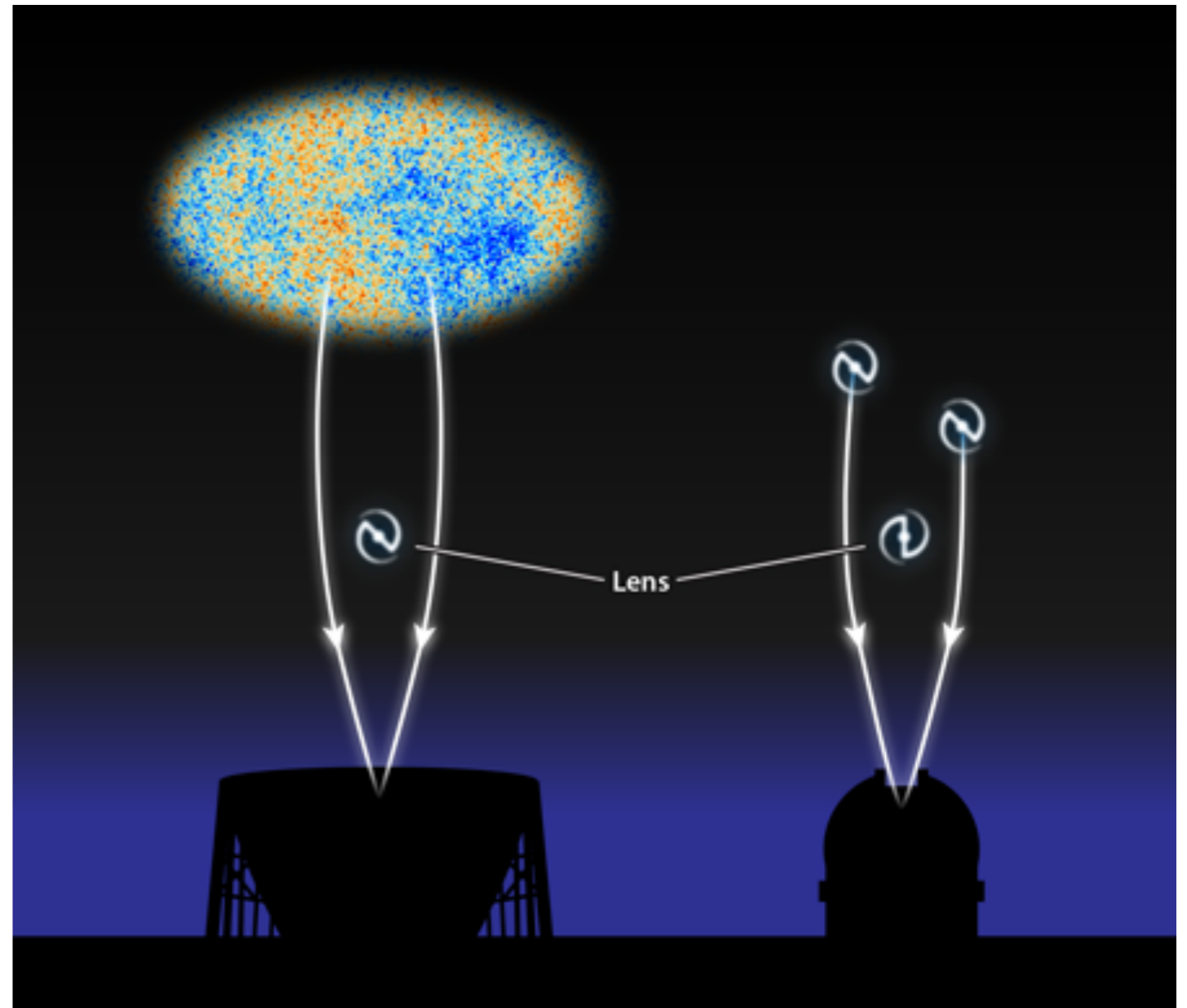
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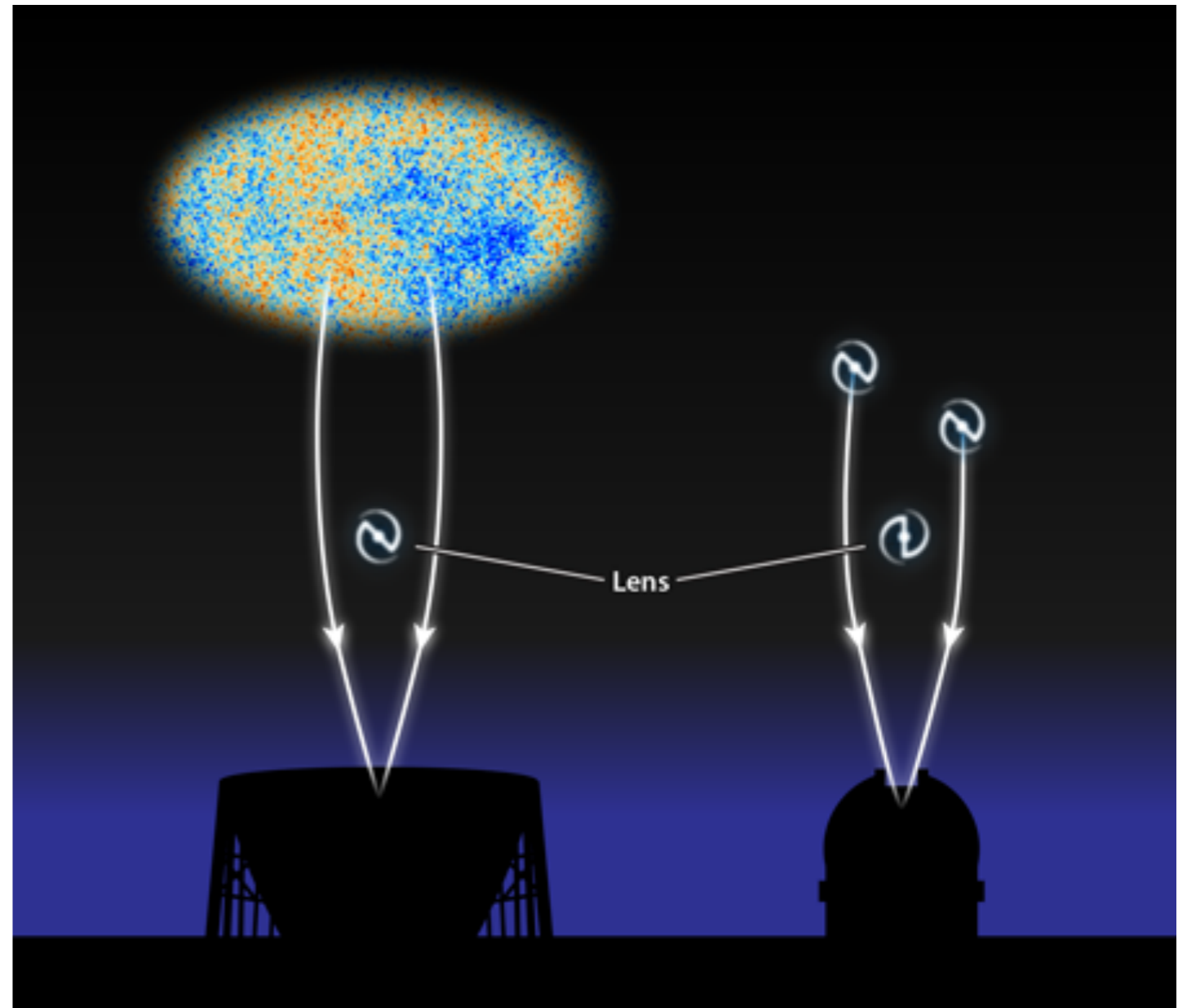
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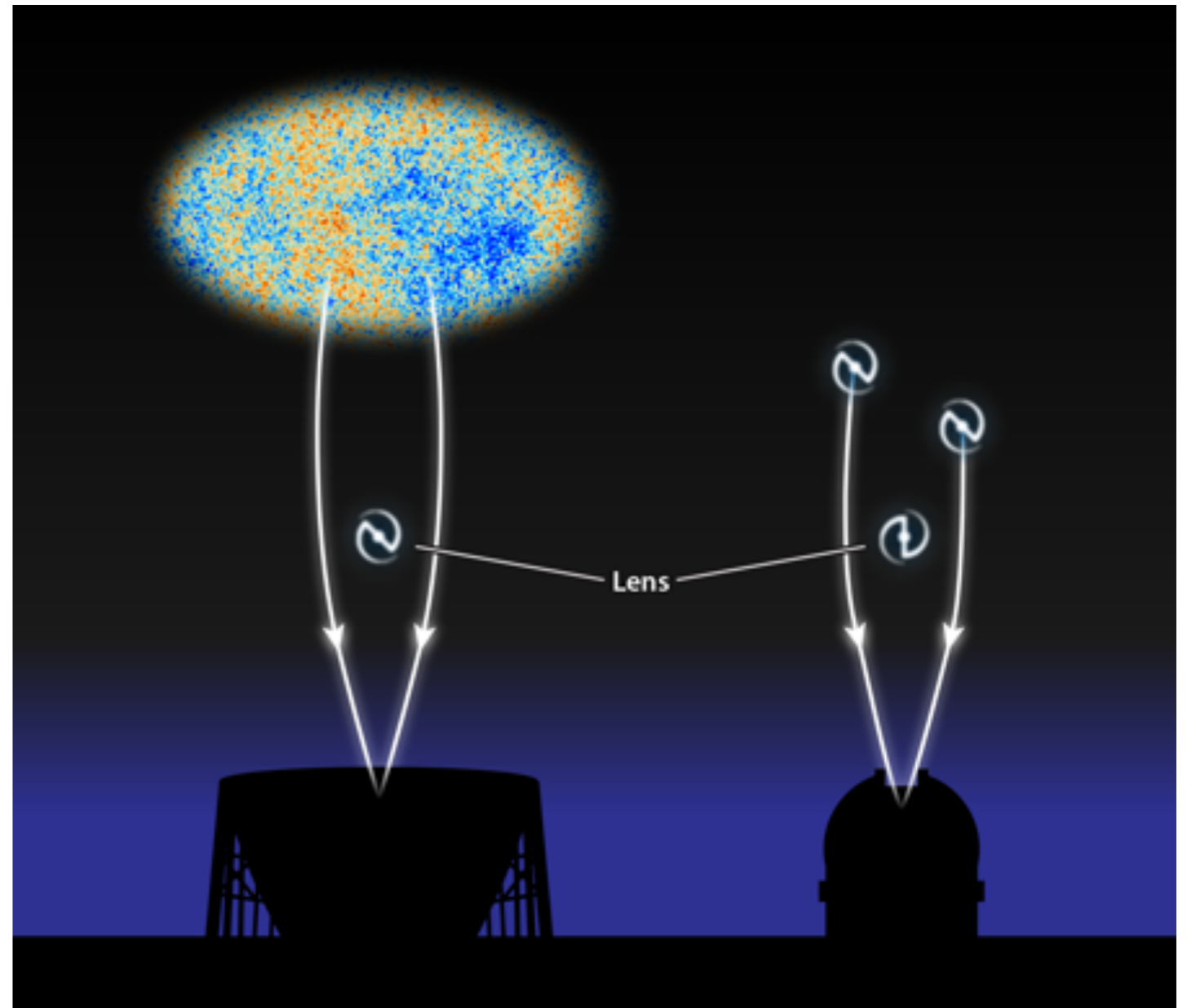
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First Measurement of CMB Lensing on Halo Scales  
Madhavacheril, NS, for the ACT Collaboration  
PRL, 114, 2015

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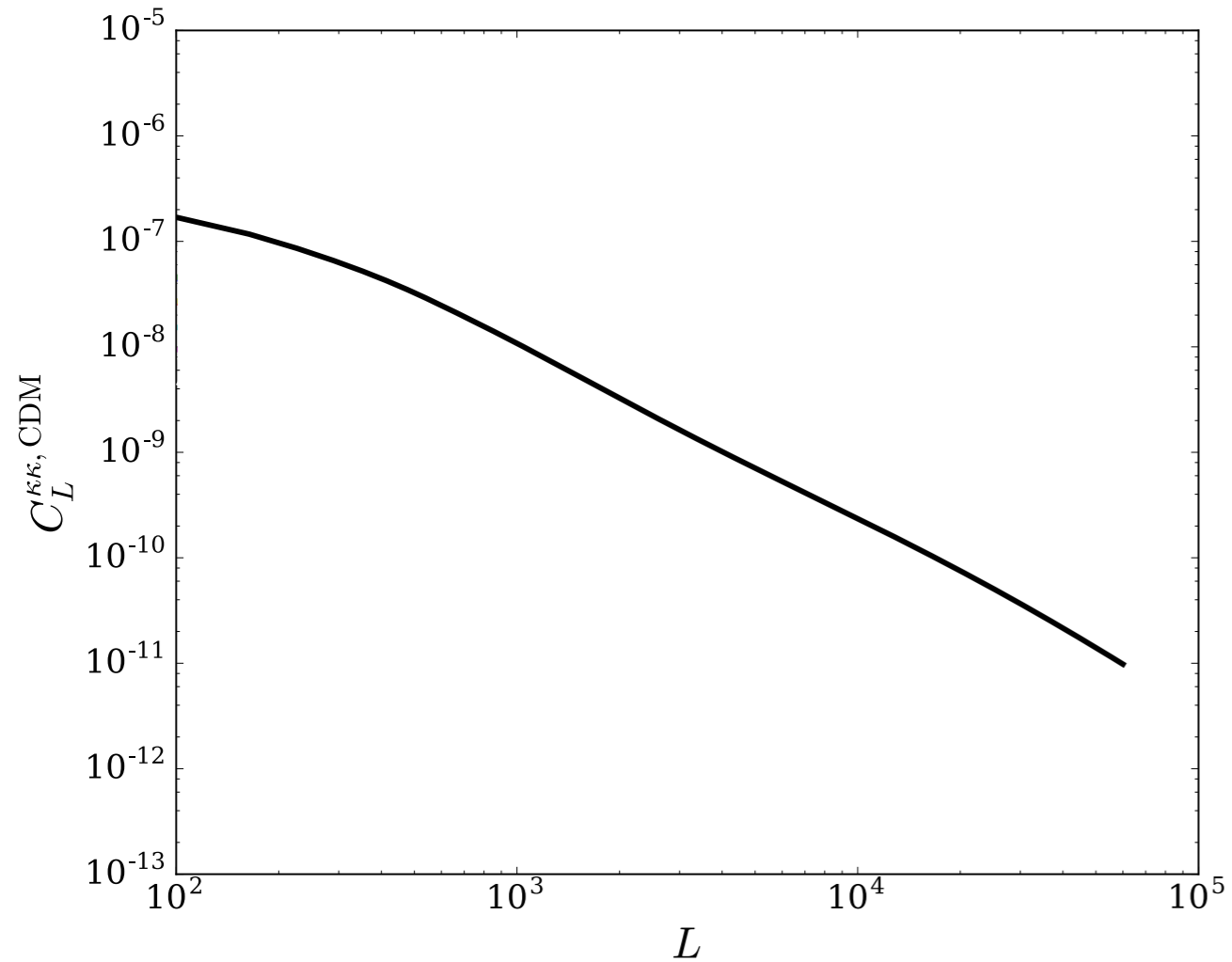
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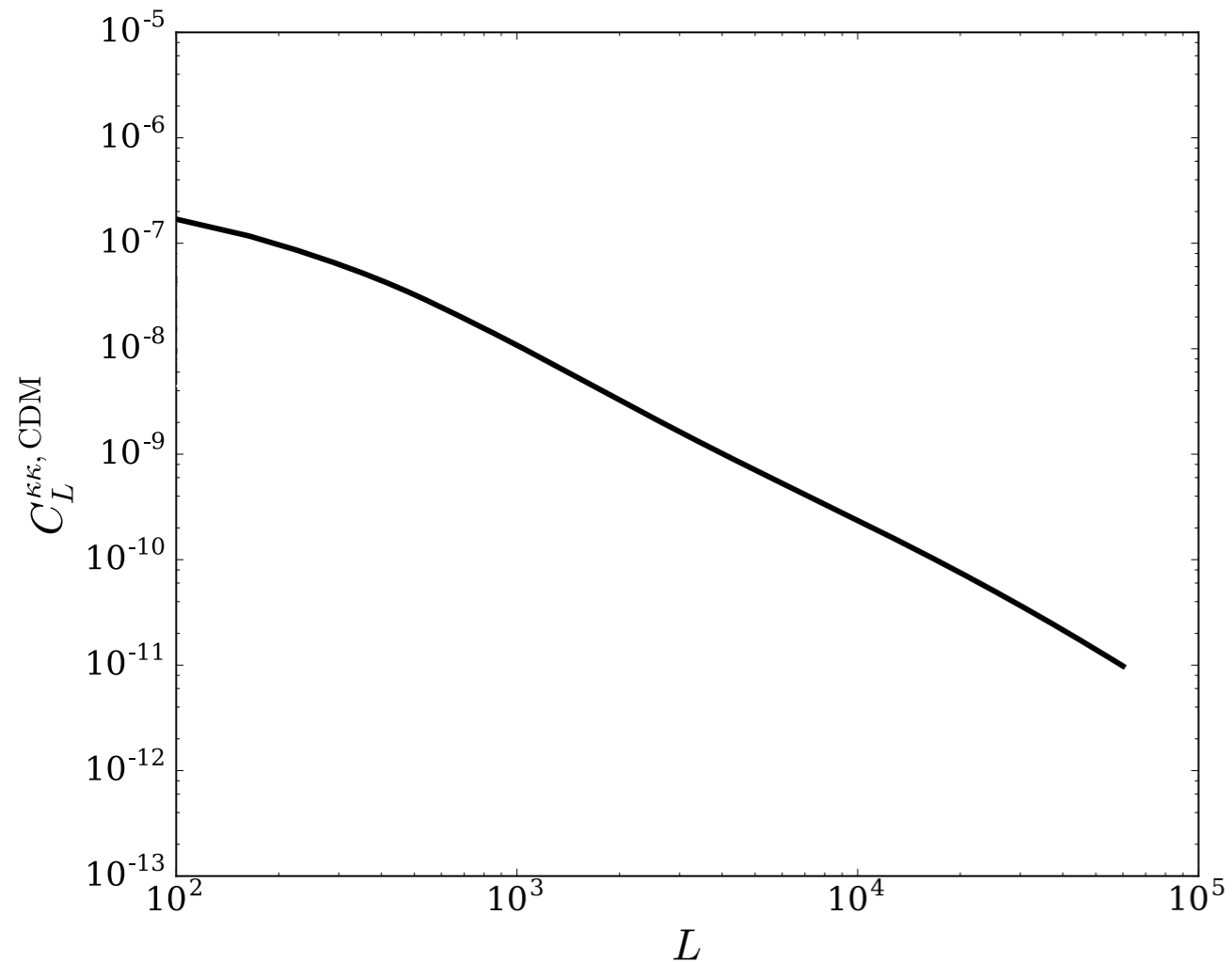
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4. Sensitive to structure at higher redshifts than other gravitational lensing probes; this makes it more sensitive to FDM/WDM-type models

# CMB Lensing Power Spectrum

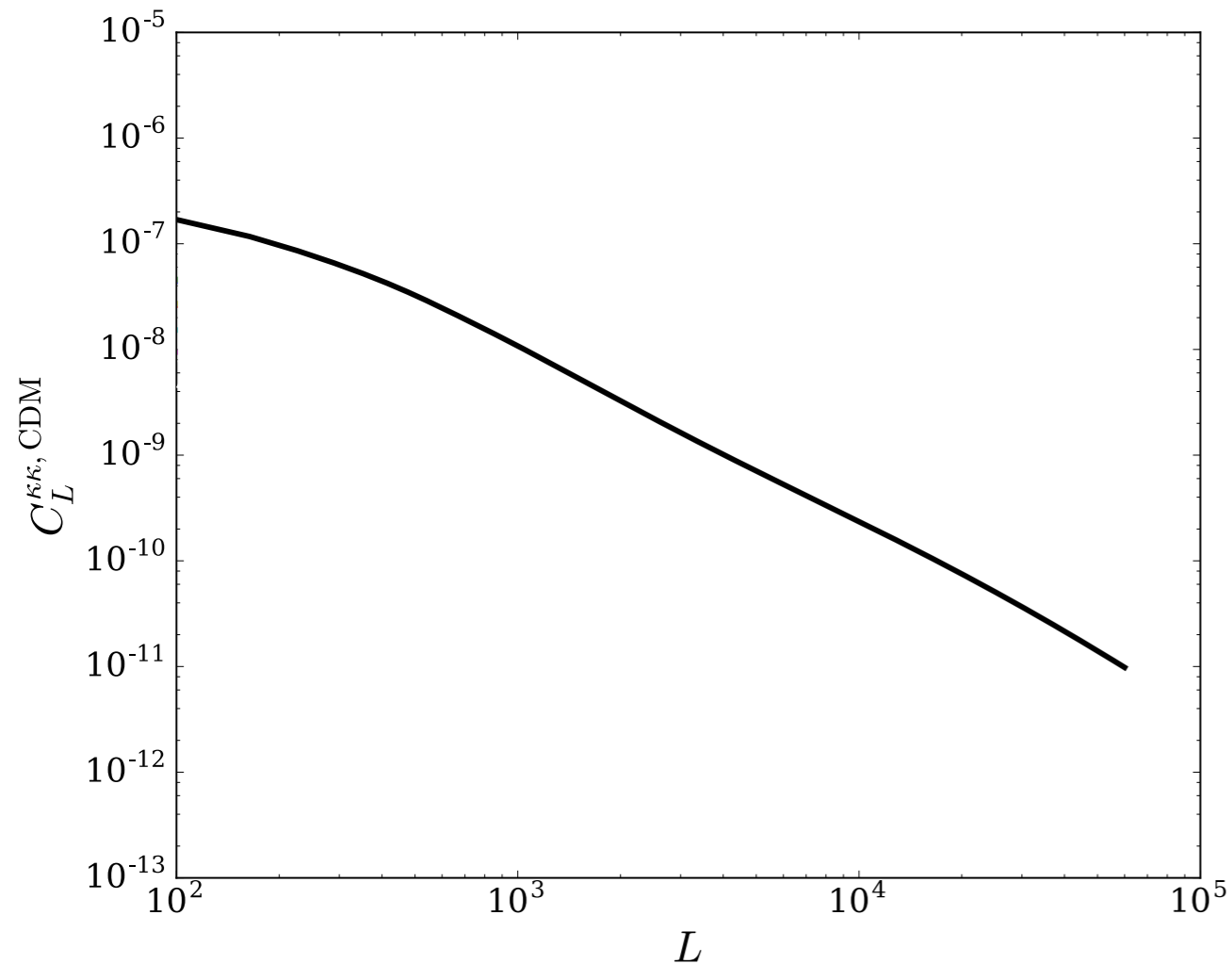


# CMB Lensing Power Spectrum



**CMB Lensing Power Spectrum**  
is matter power spectrum  
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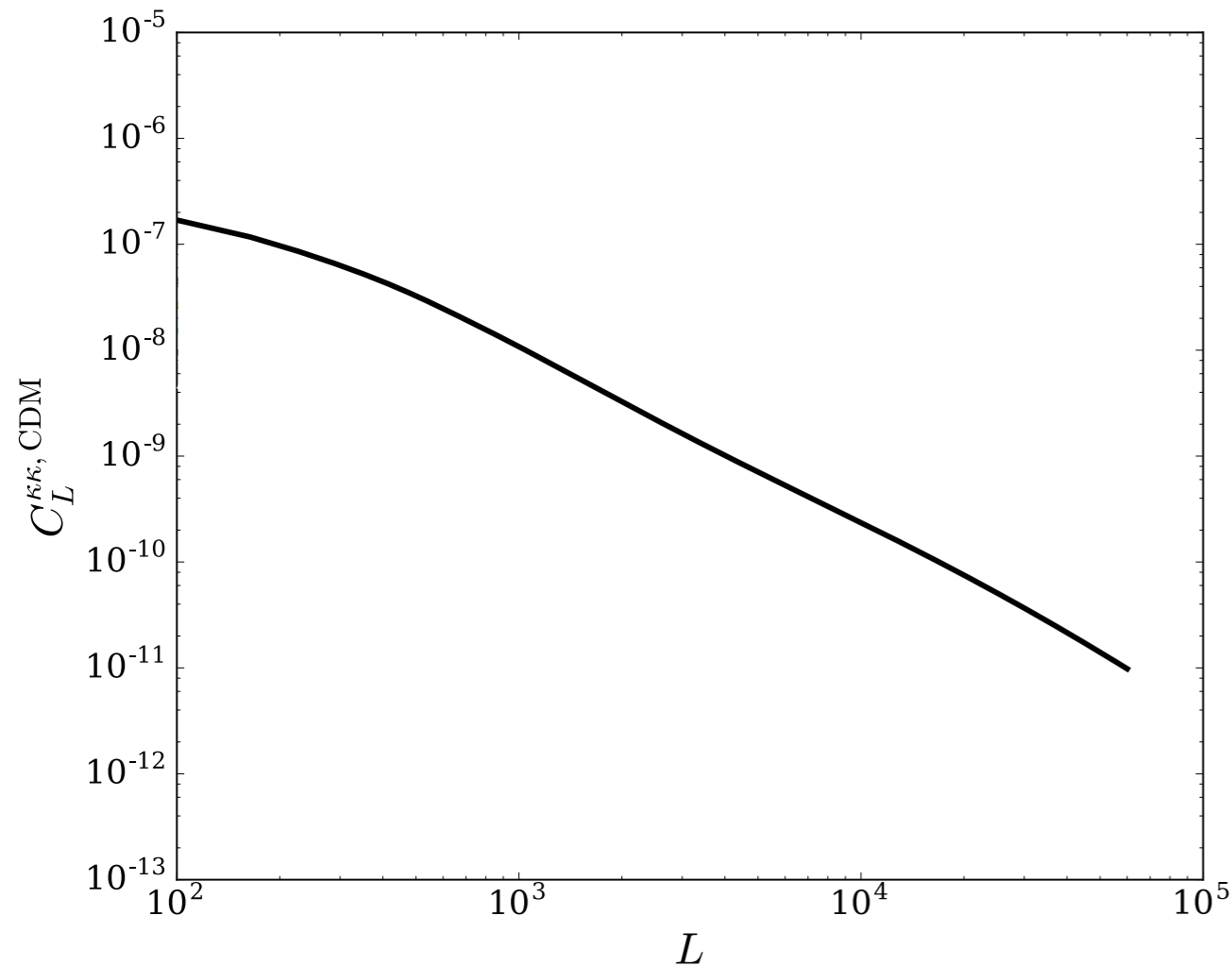
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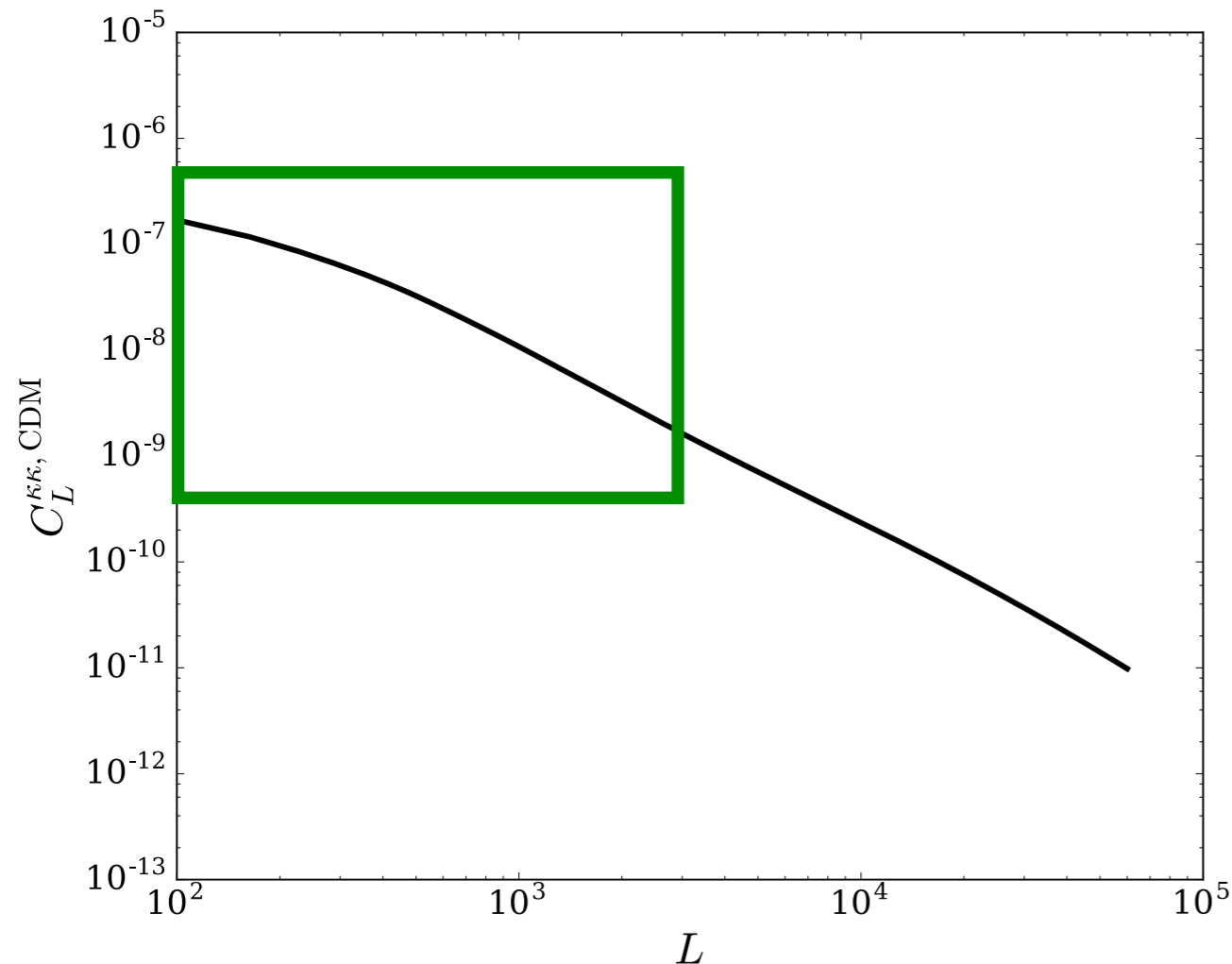


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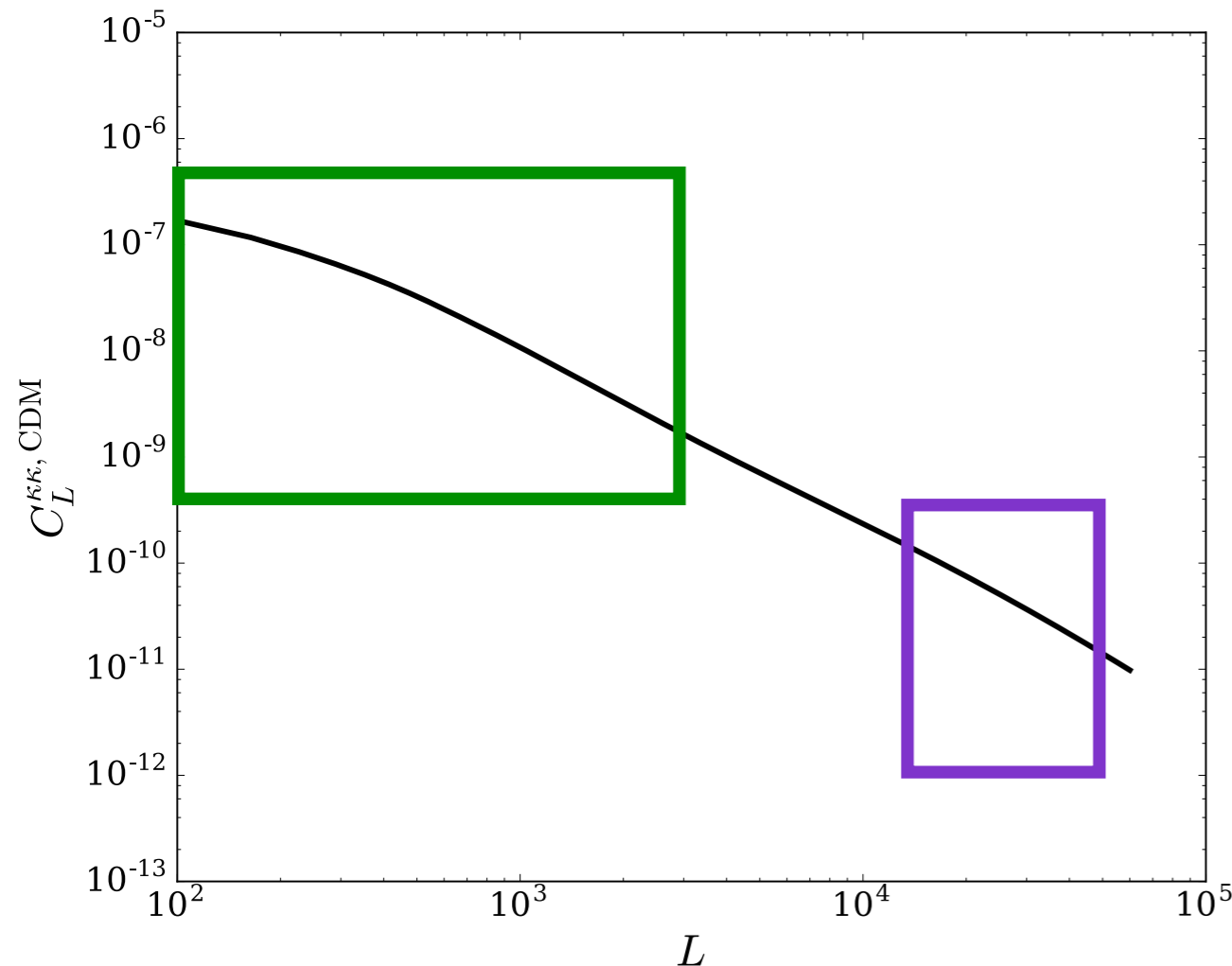
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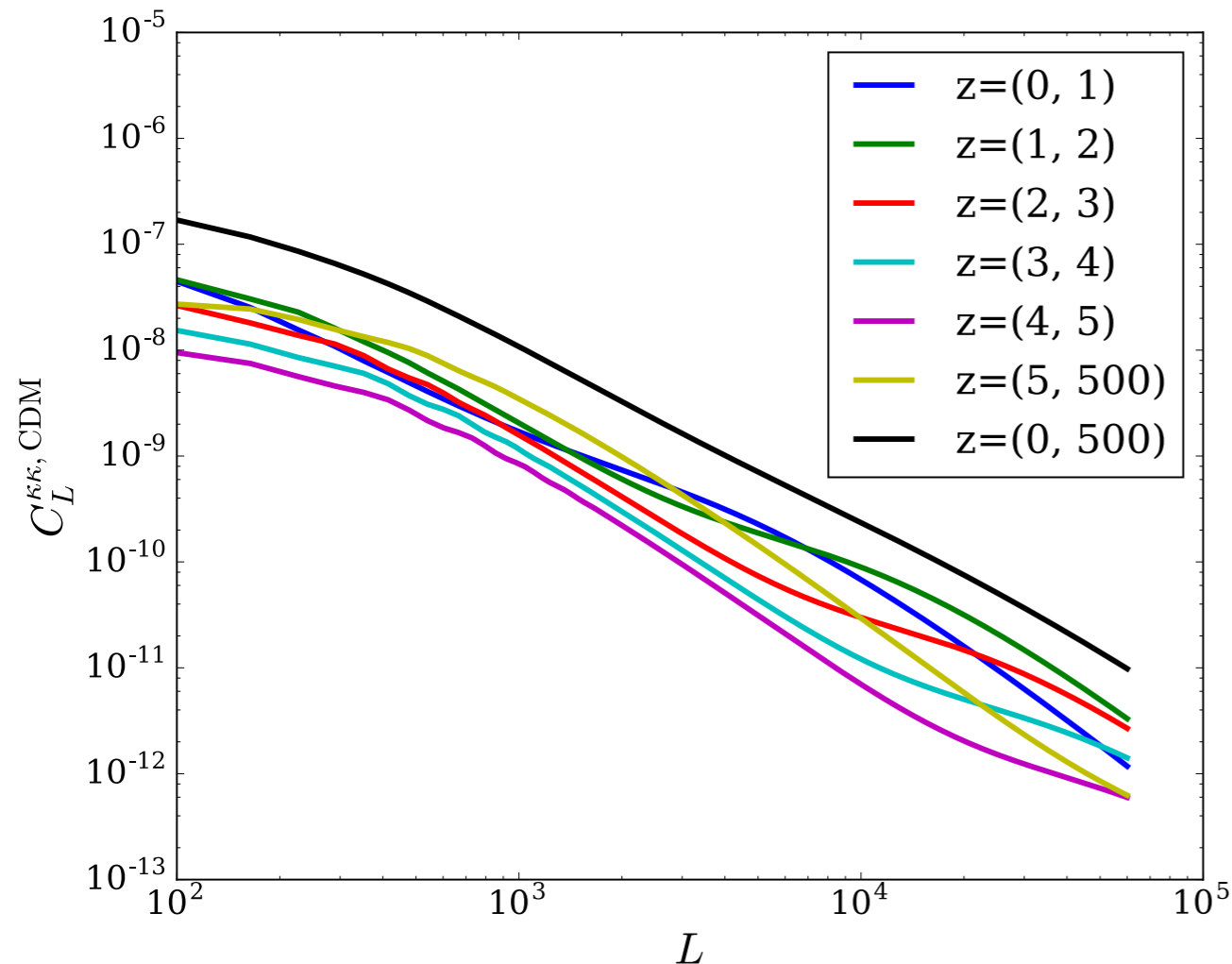
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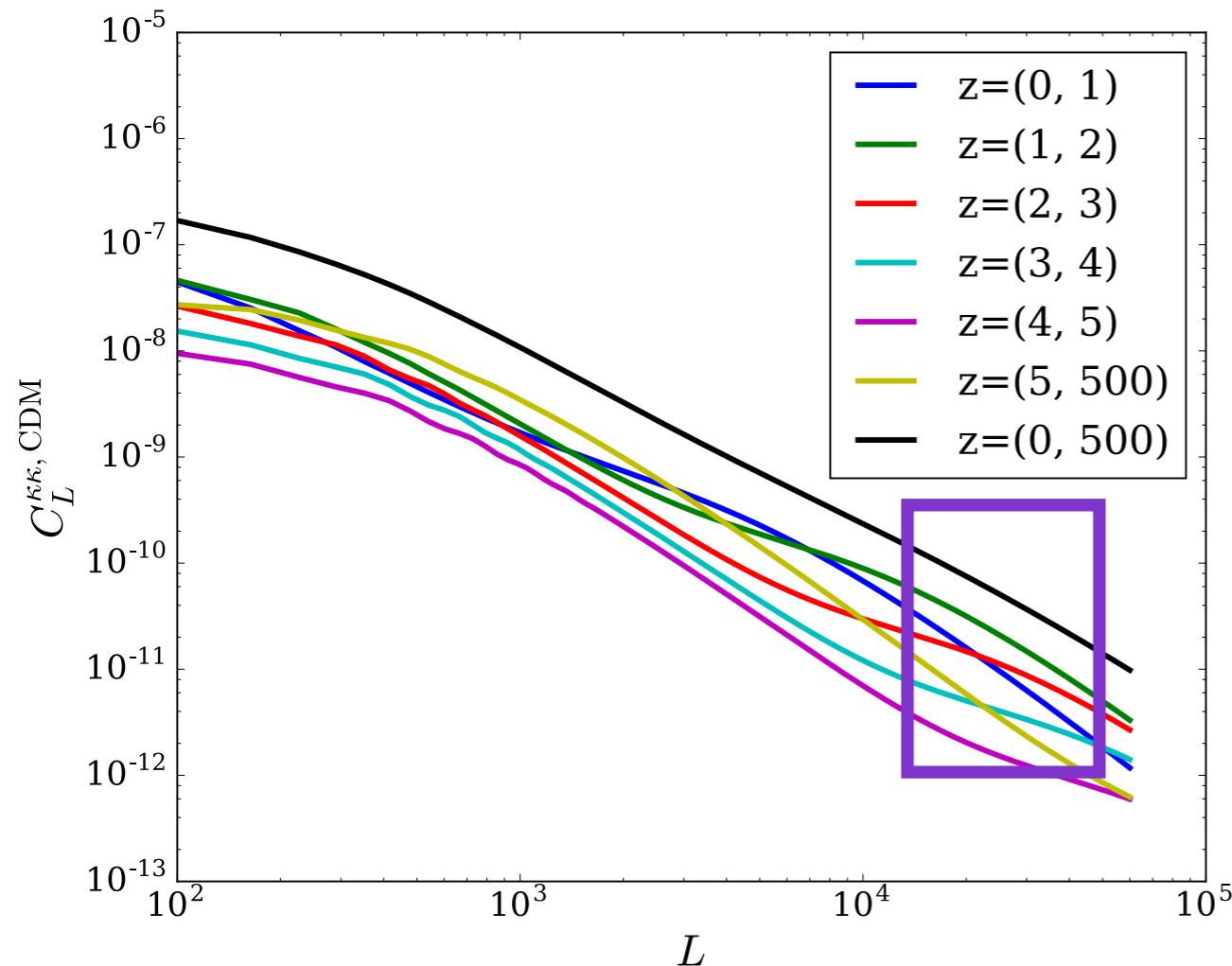
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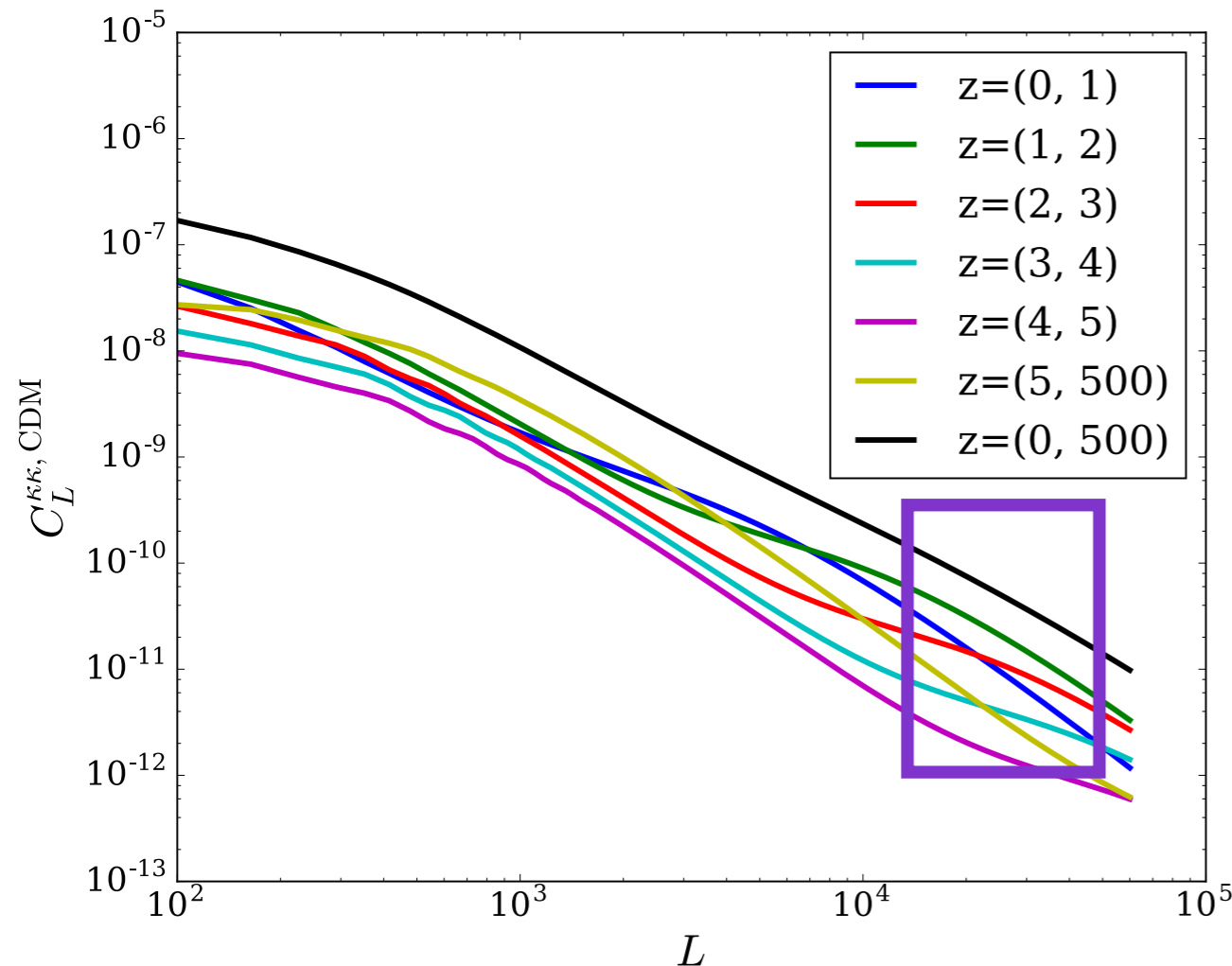
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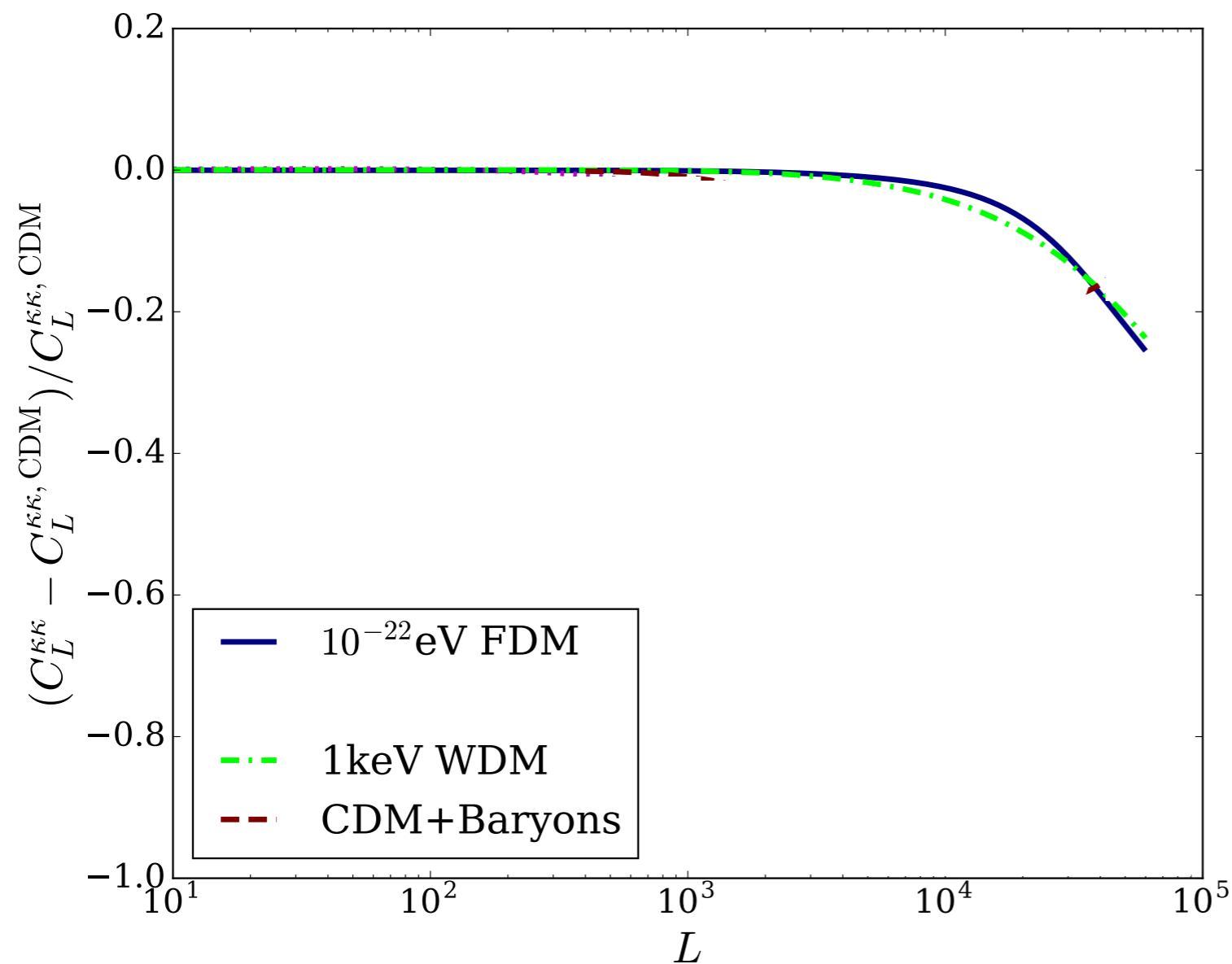
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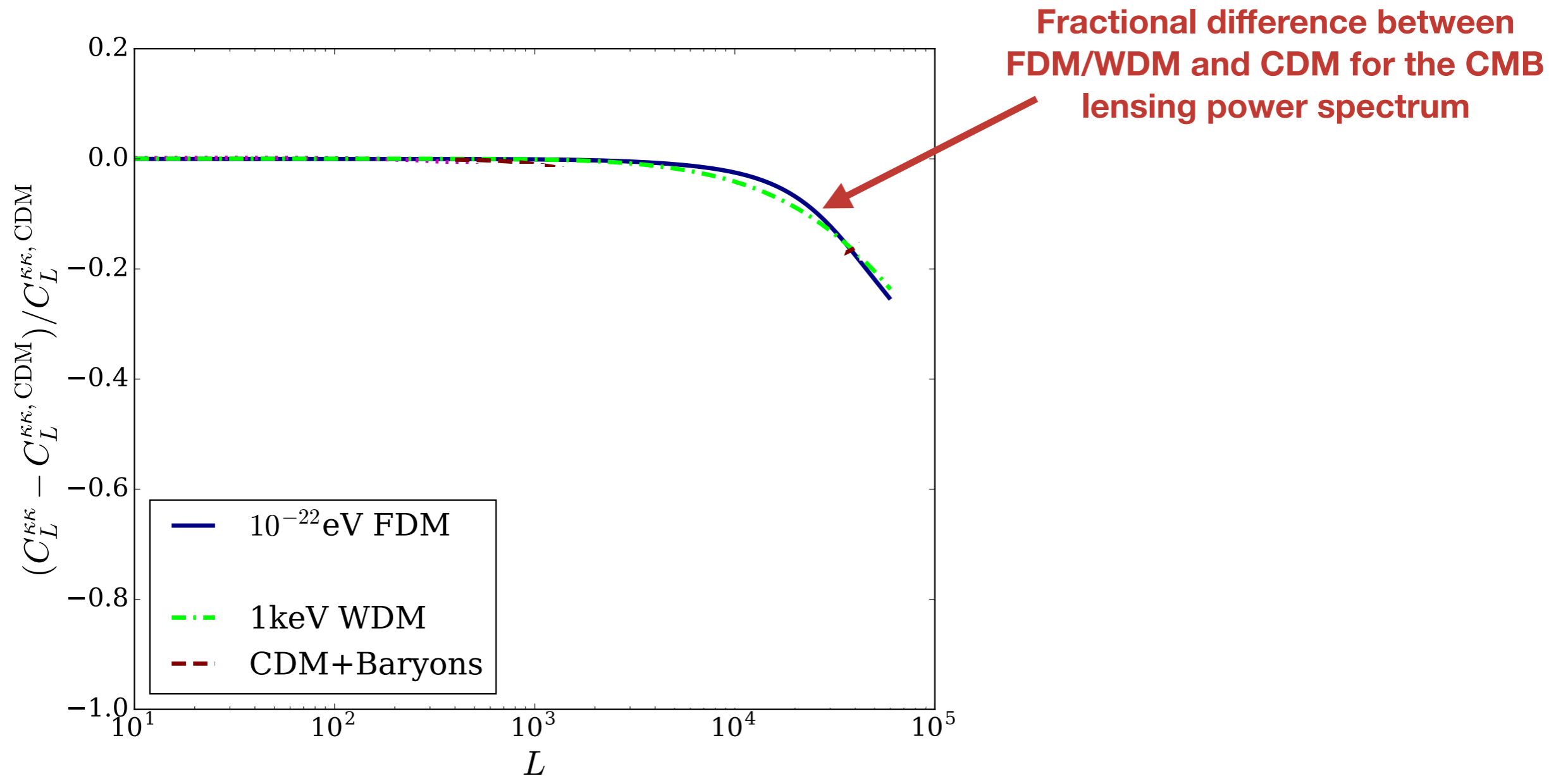
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**Contrast between CDM and models that wash out small-scale structure is larger at higher redshifts**

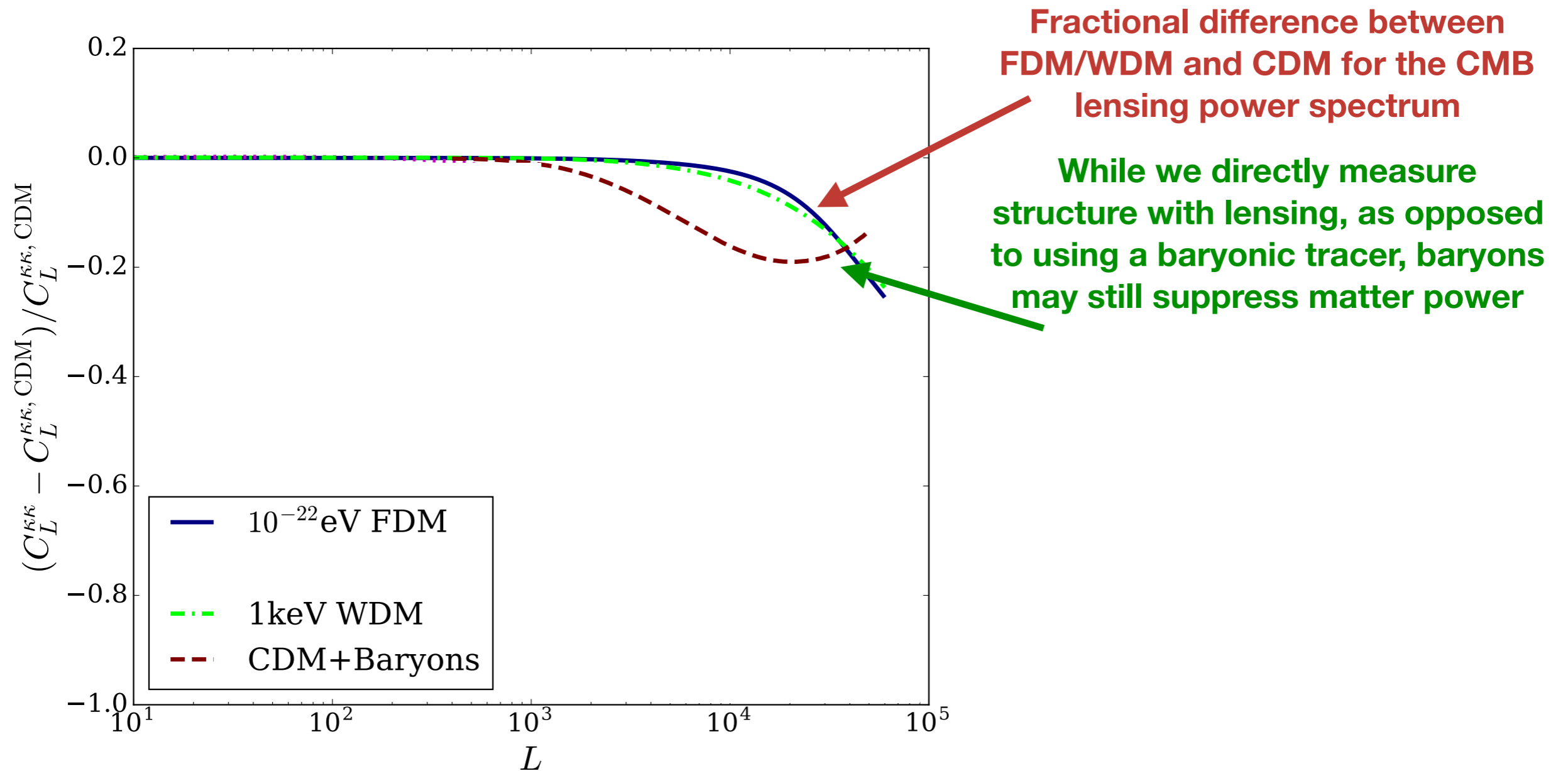
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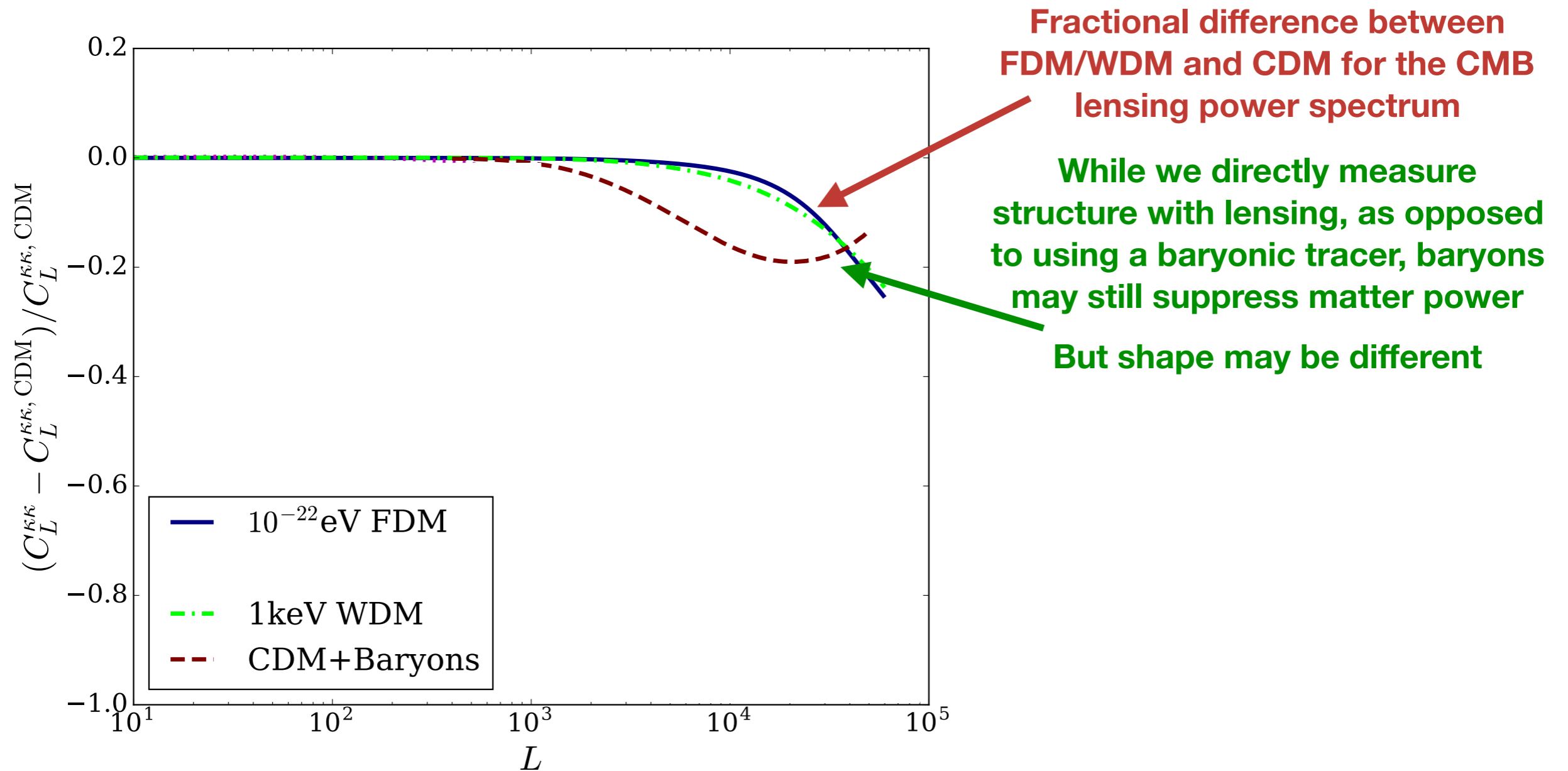
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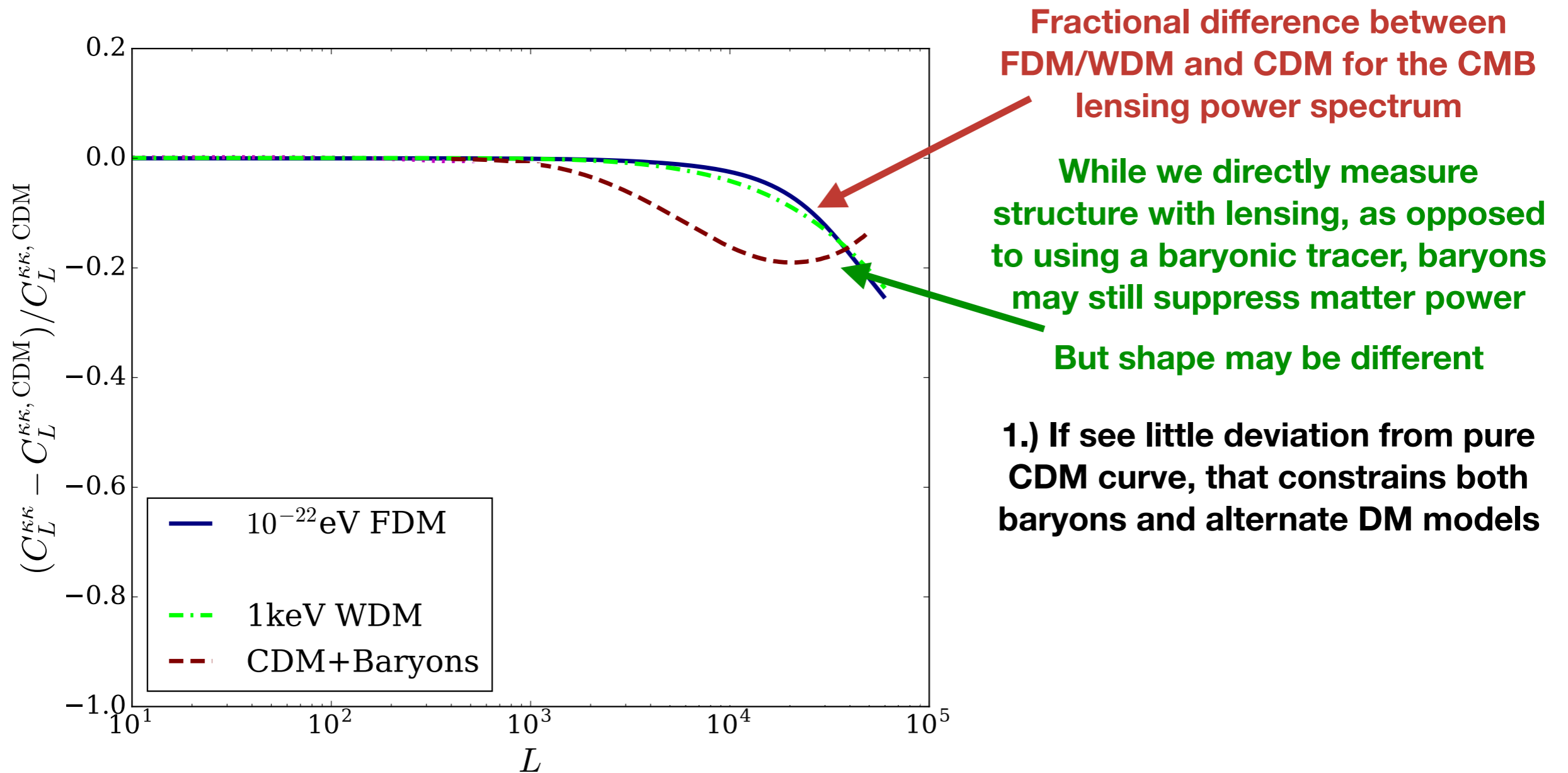
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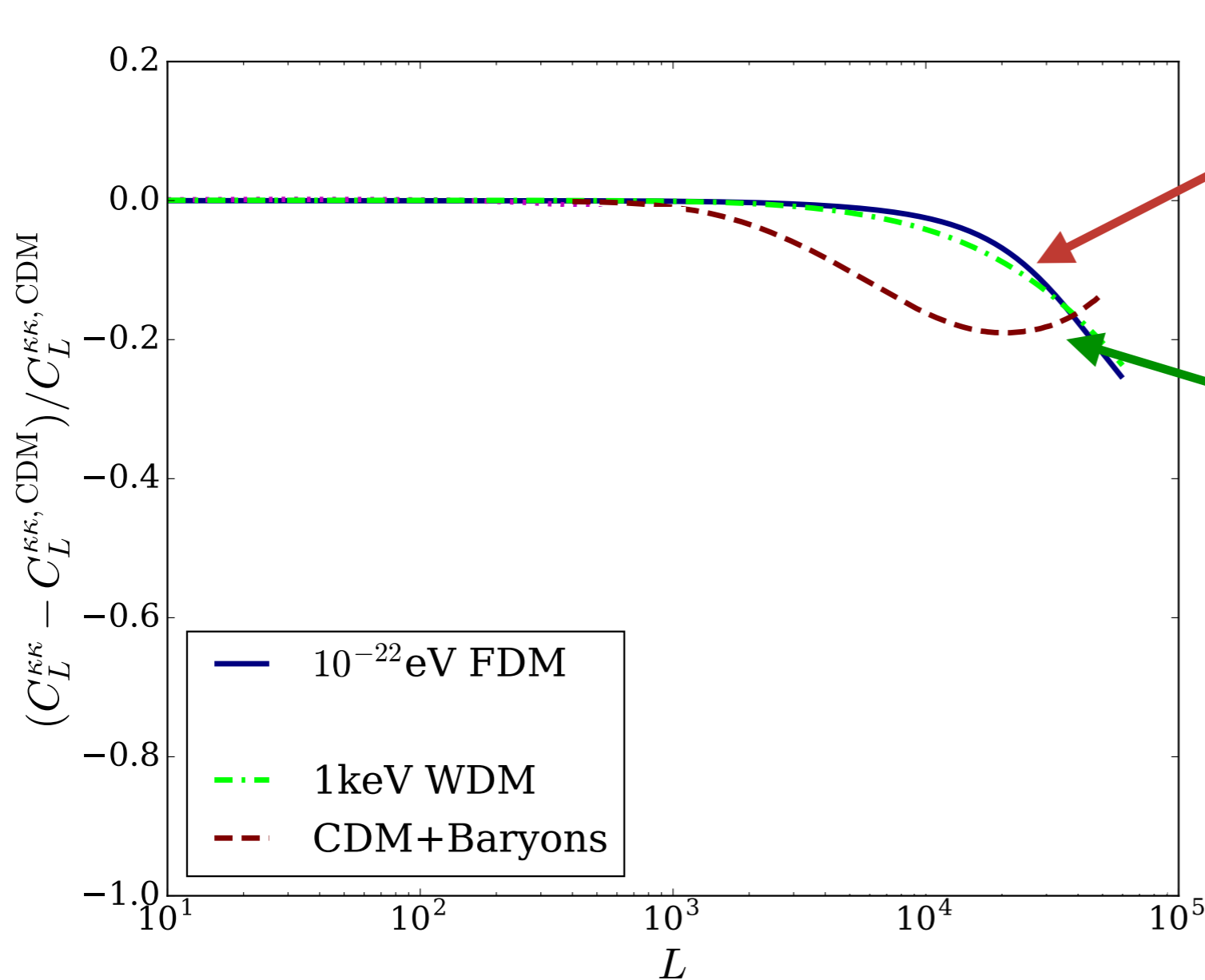


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Fractional difference between FDM/WDM and CDM for the CMB lensing power spectrum

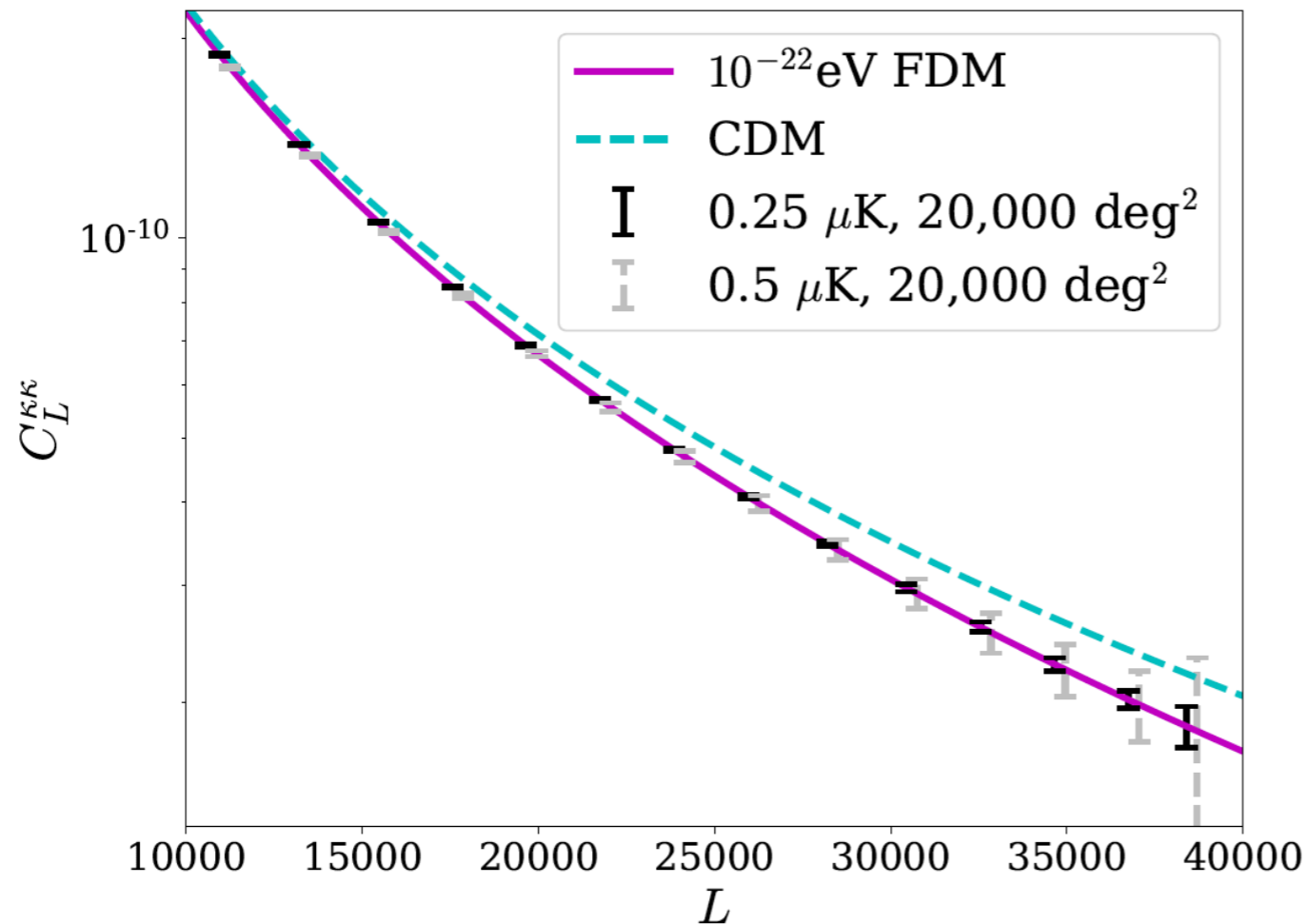
While we directly measure structure with lensing, as opposed to using a baryonic tracer, baryons may still suppress matter power

But shape may be different

1.) If see little deviation from pure CDM curve, that constrains both baryons and alternate DM models

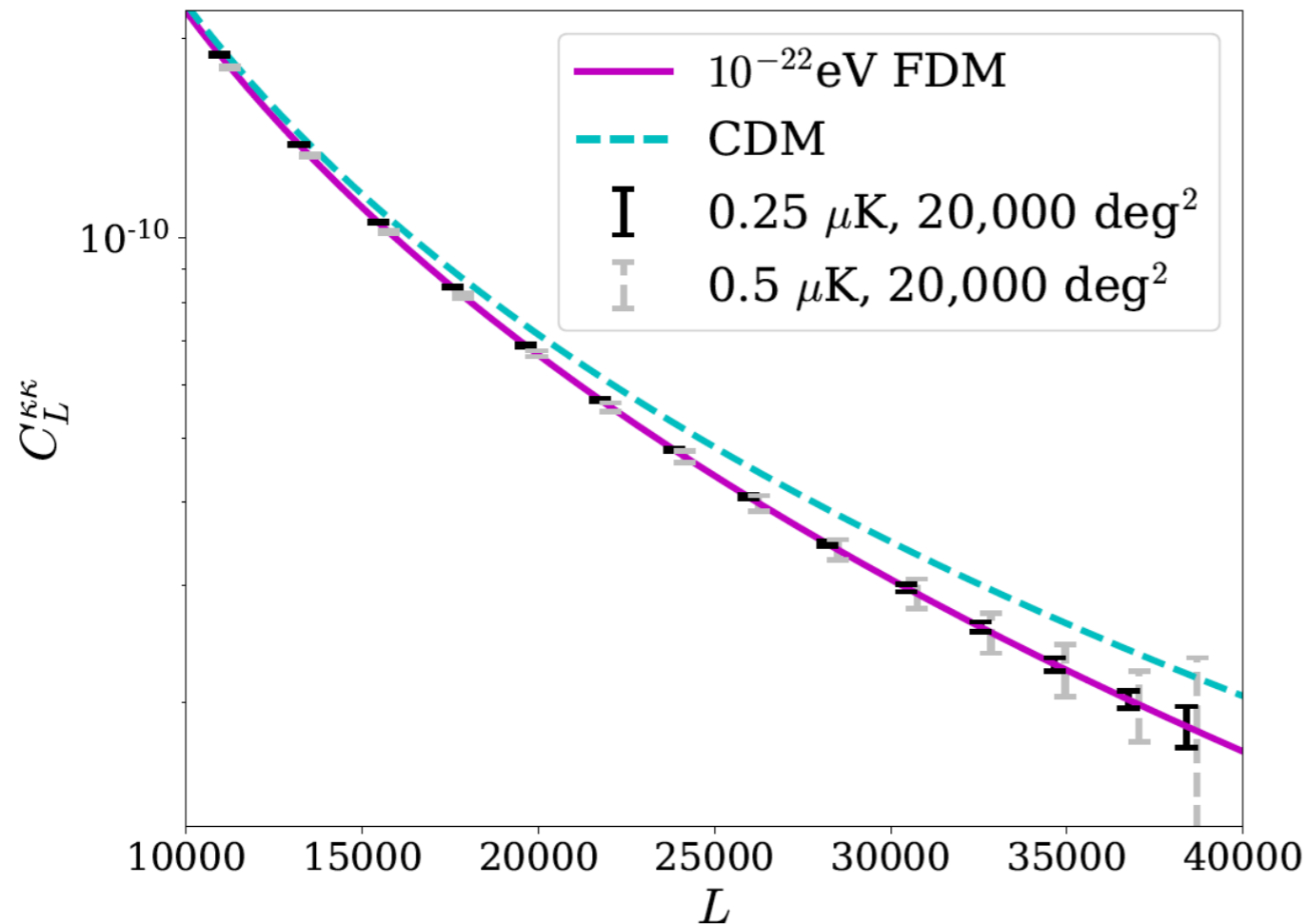
2.) If see significant deviation, then can potentially use shape of curve to determine whether it is due to baryons or alternative to CDM

# Potential Ability to Distinguish Between Dark Matter Models



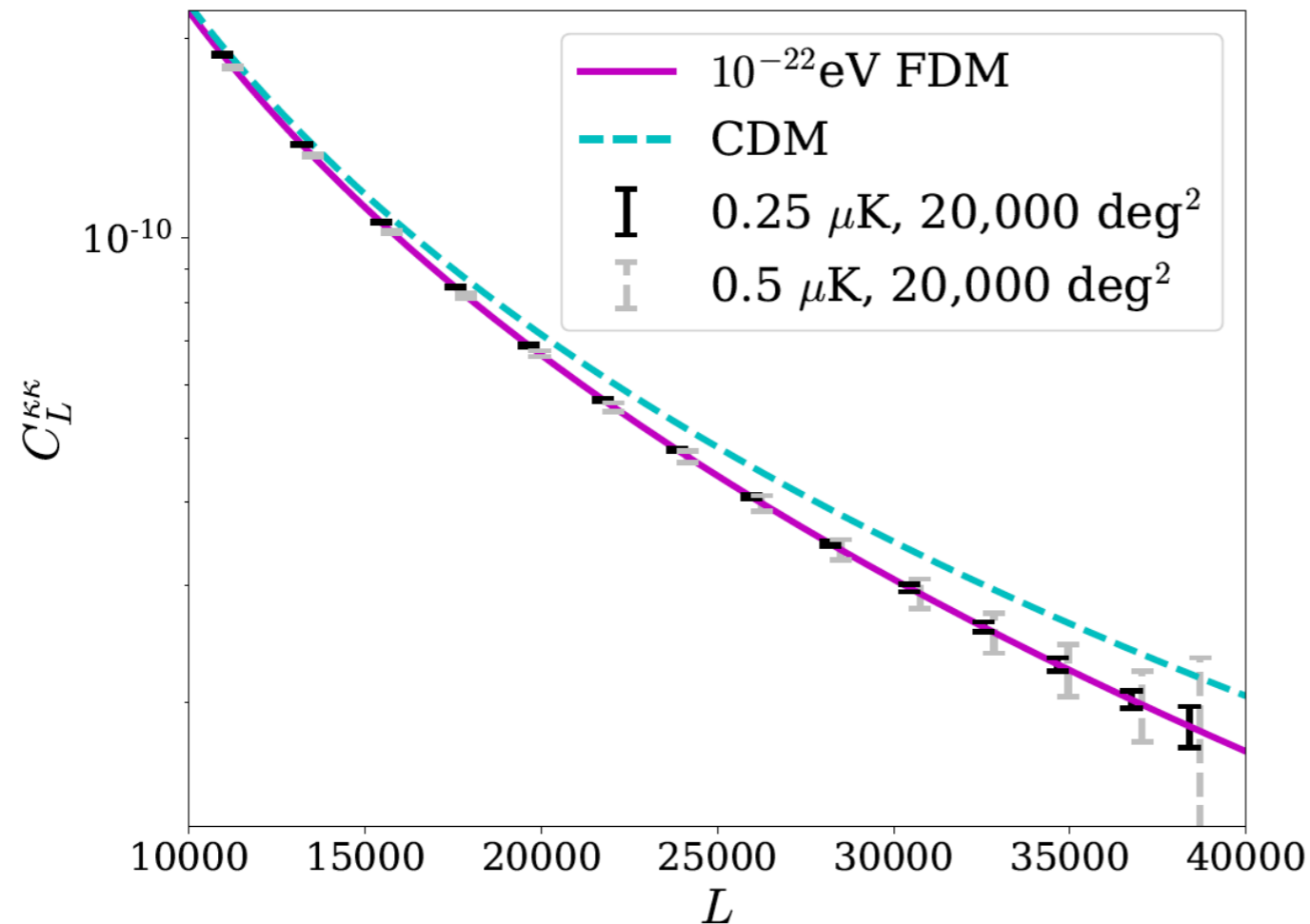
Sky fraction ( $f_{\text{sky}}$ )	Noise at 150 GHz ( $\mu$ K-arcmin)	Dark matter signal-to-noise ratio		
		no kSZ	reion kSZ	reion+late kSZ
0.5	0.5	11	9	5
0.5	0.25	24	19	7

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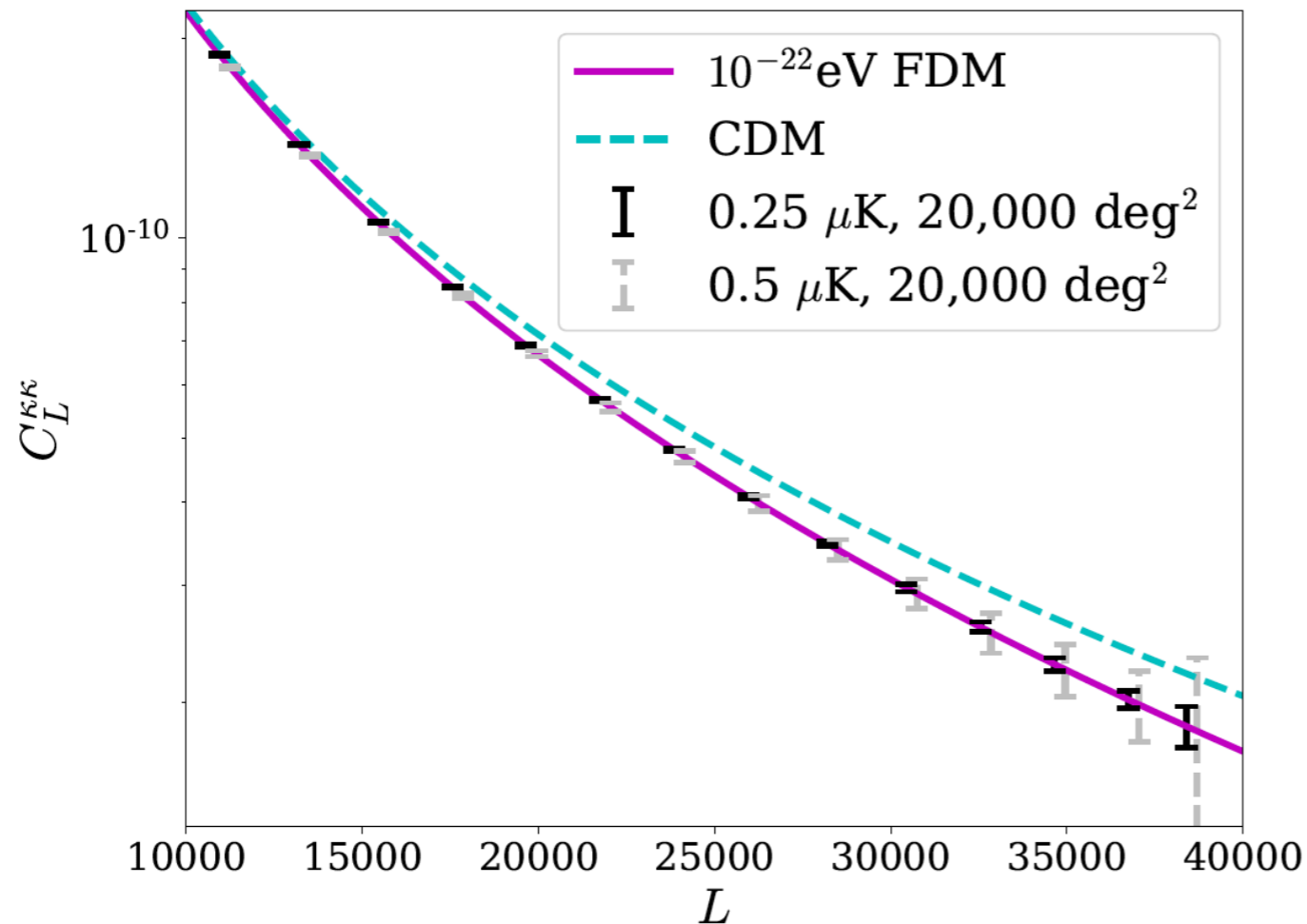
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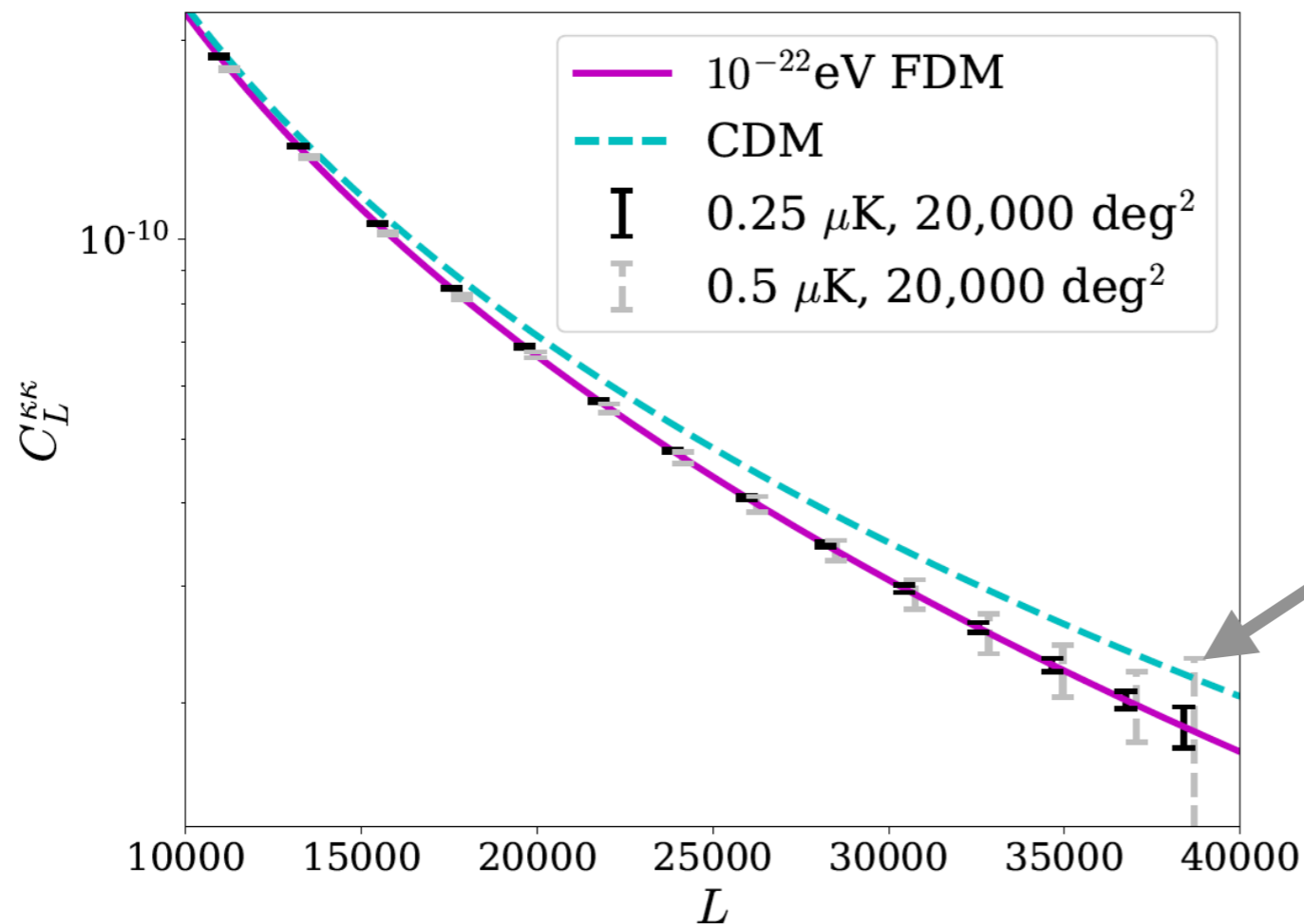
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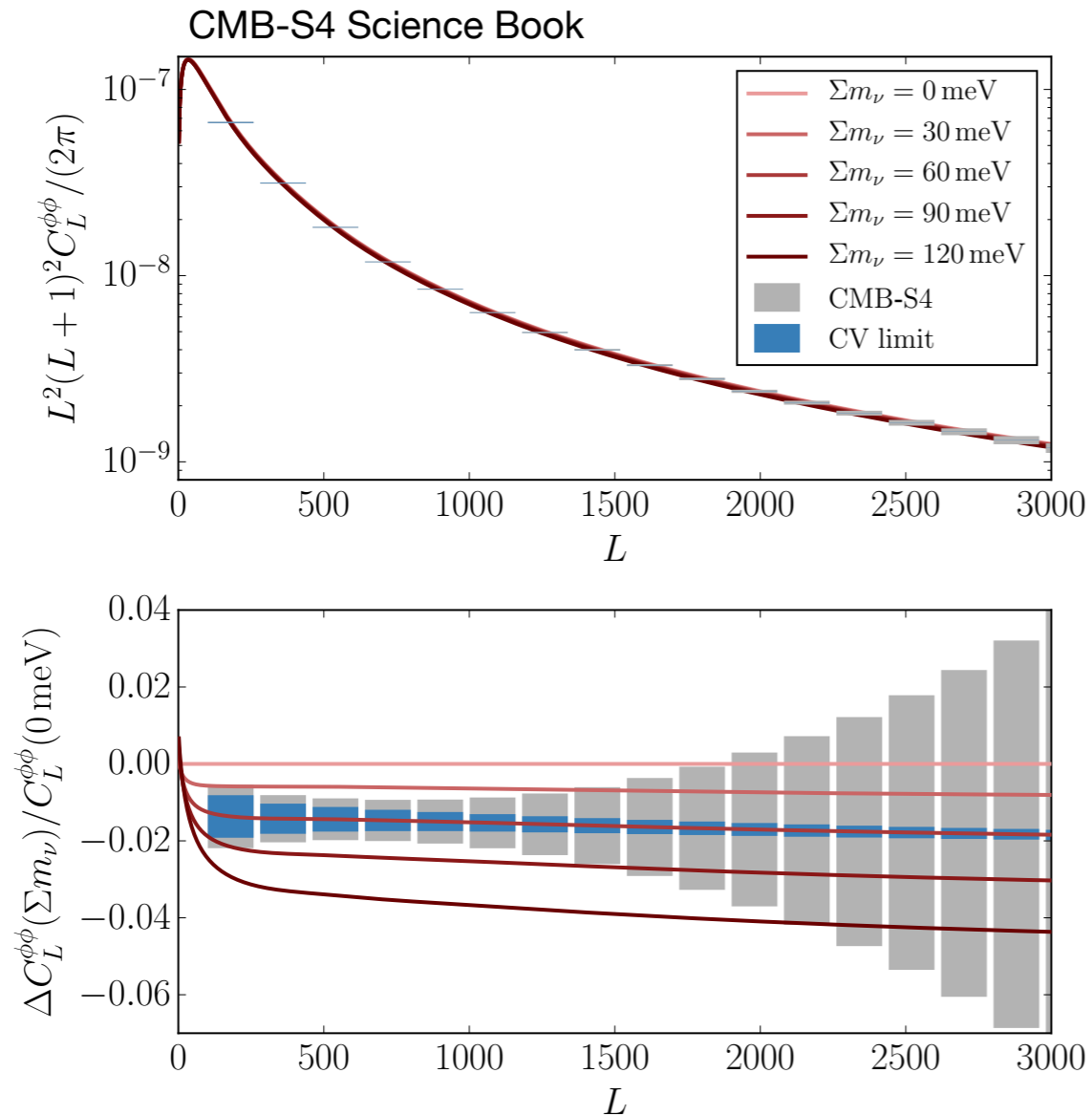
**Grey:** S/N  $\sim$  10 for distinguishing between CDM and FDM/WDM

**Requires:** Sensitivity three times better than CMB-S4 on 30-meter telescopes

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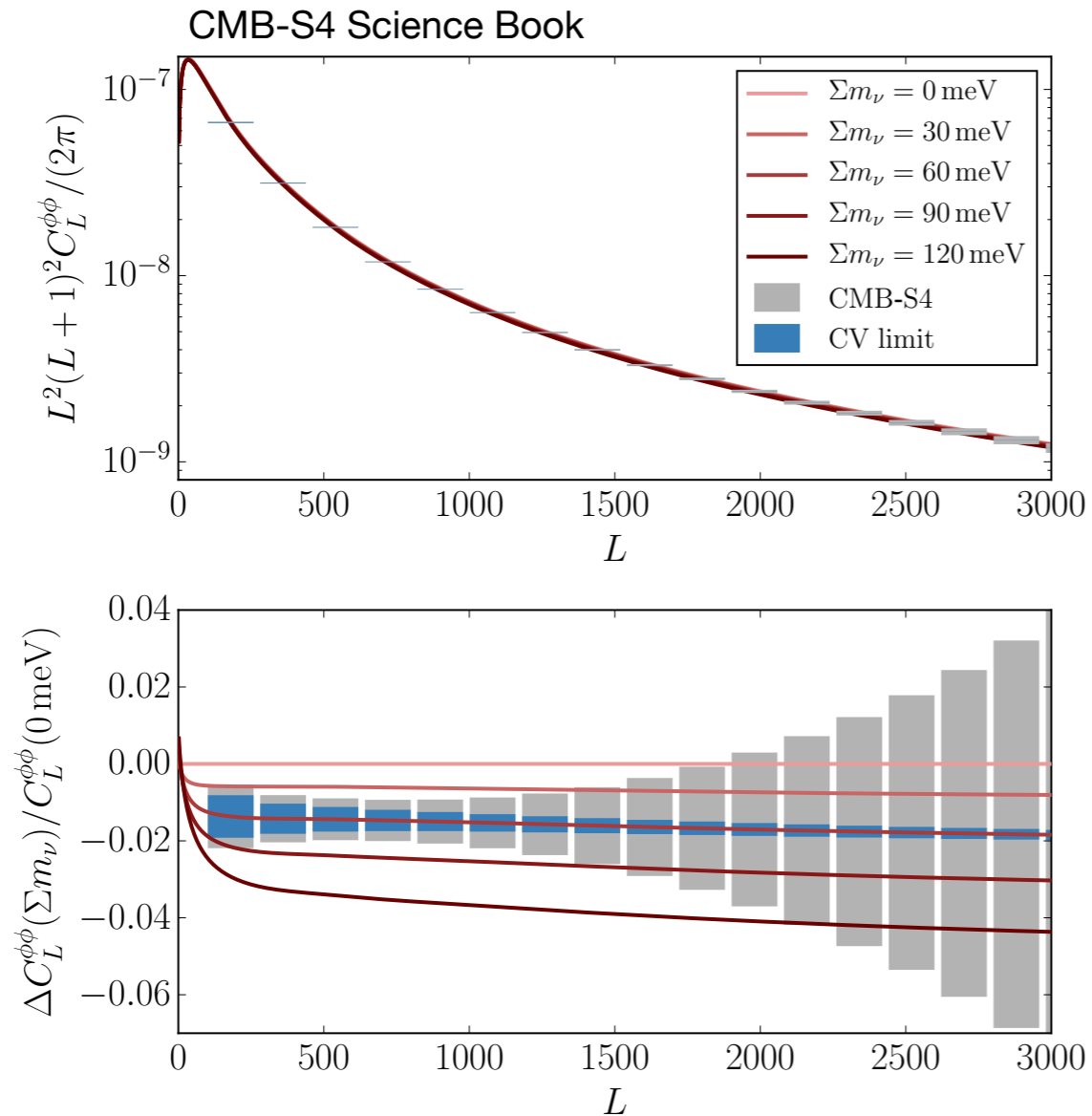
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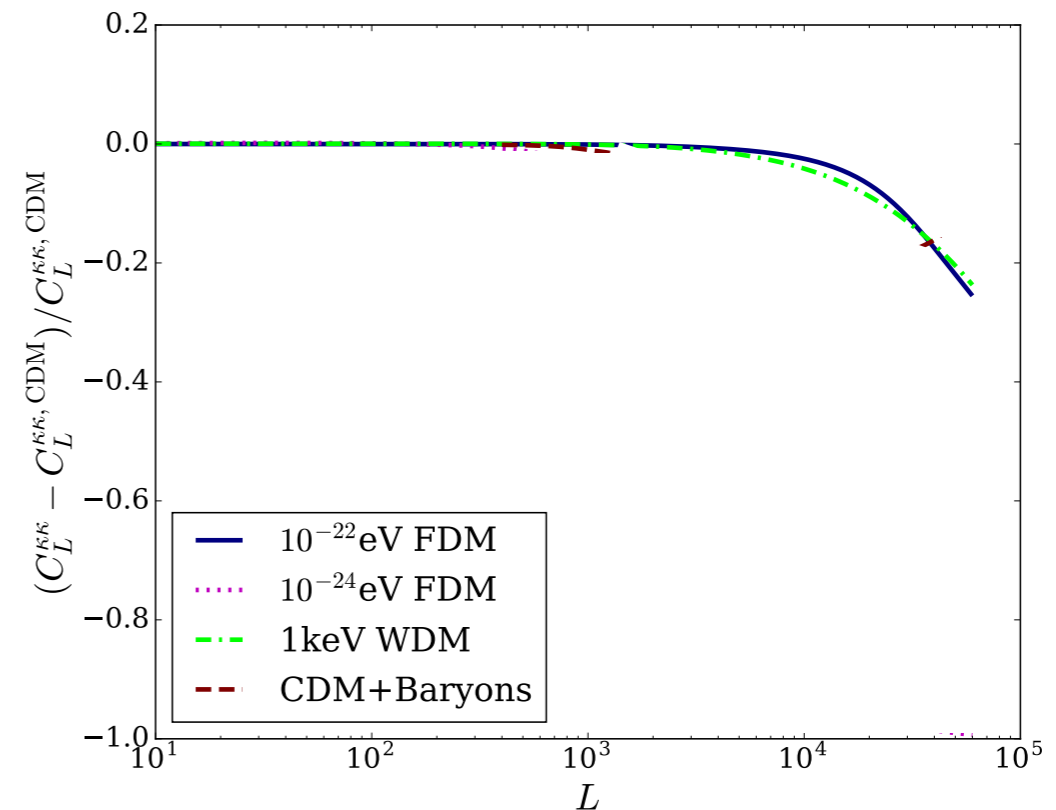
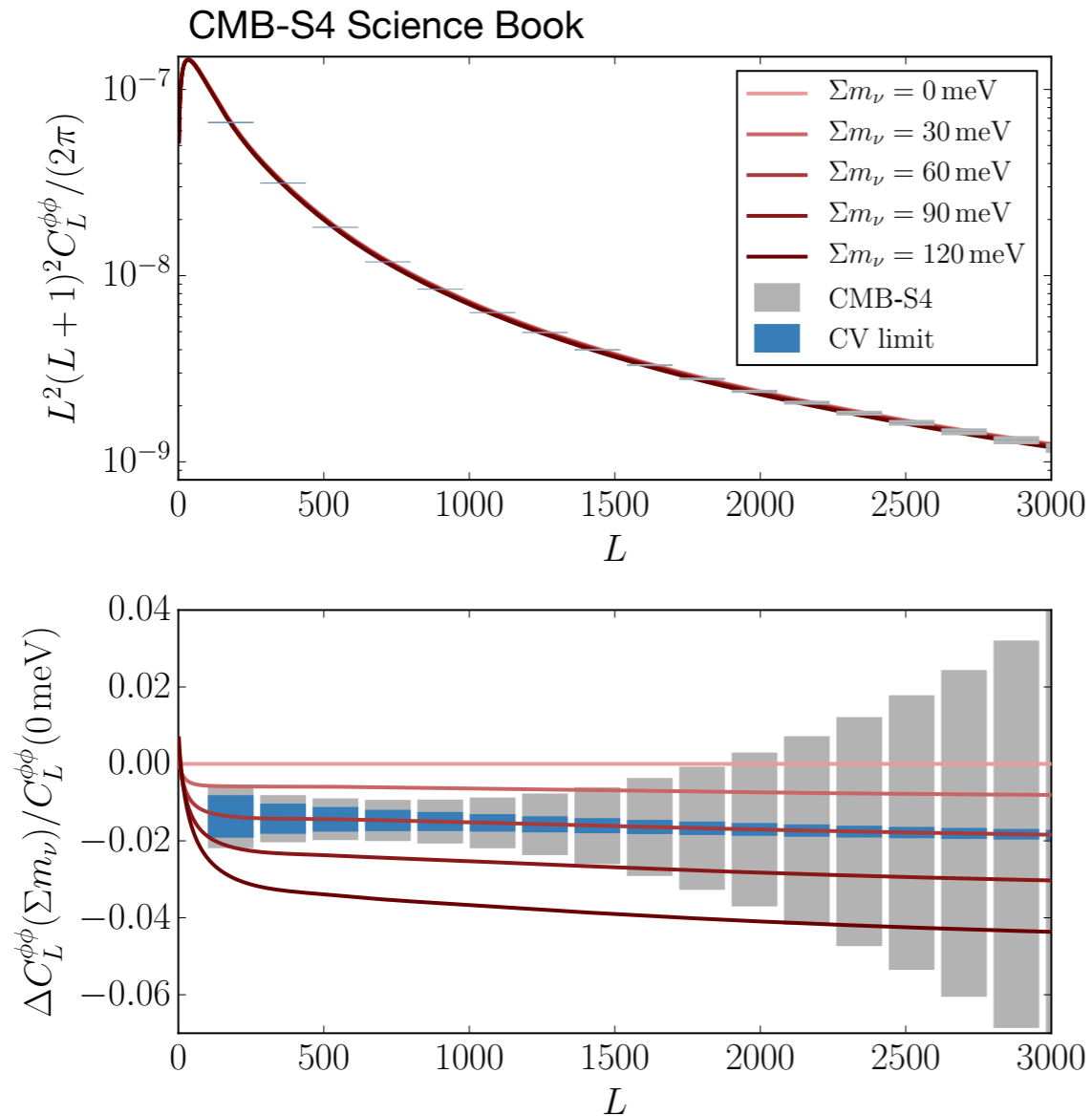


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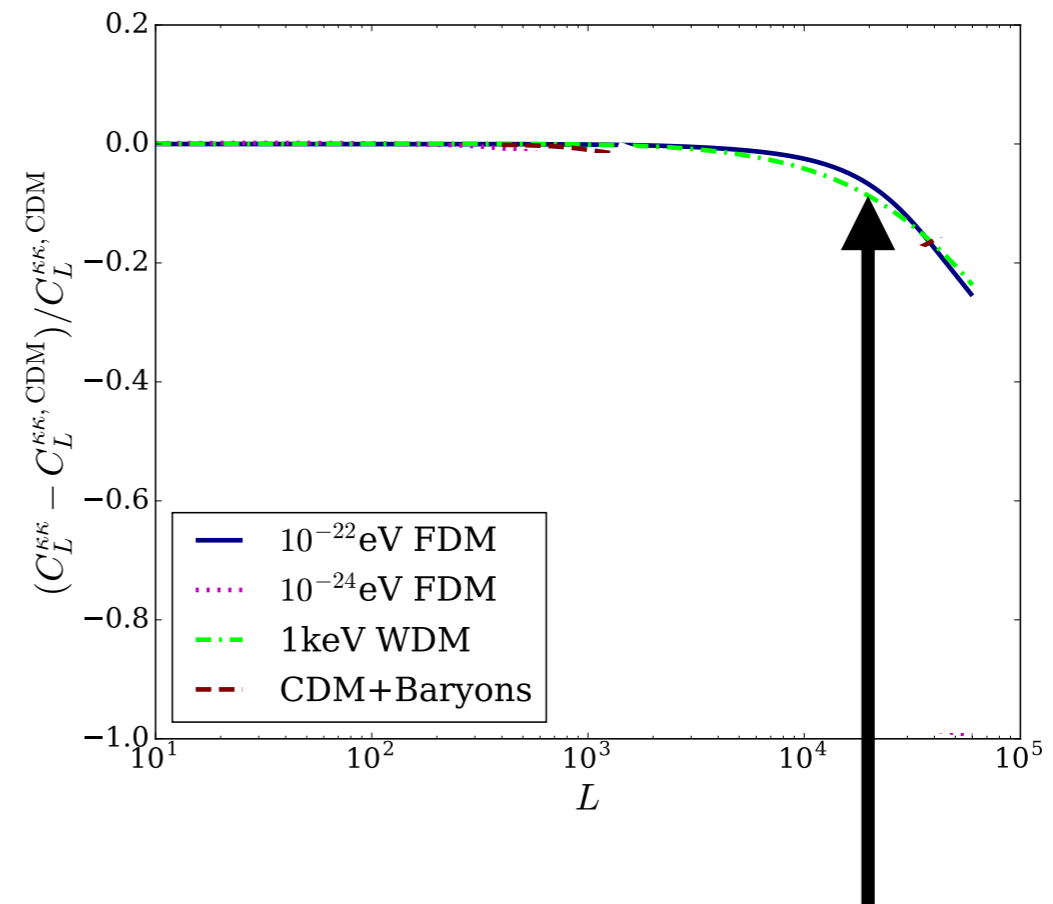
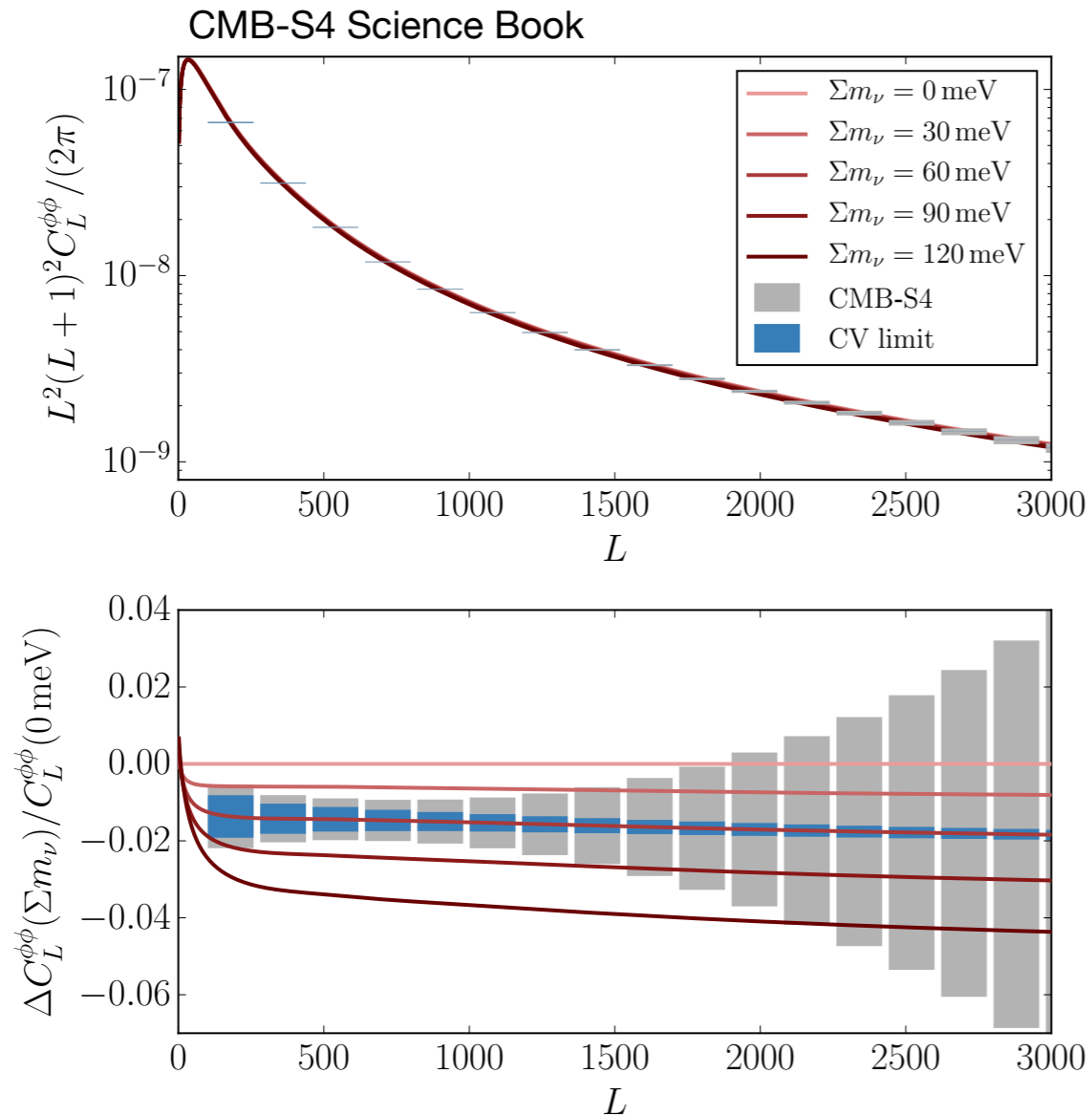
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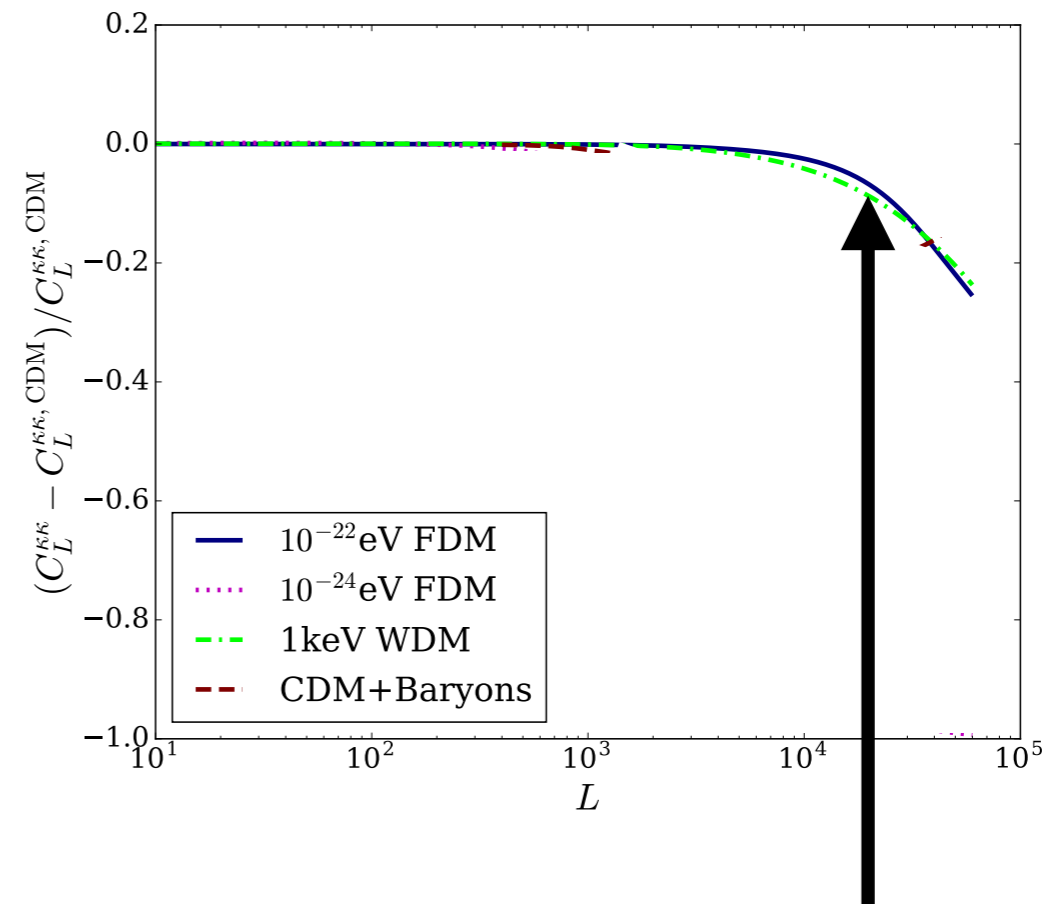
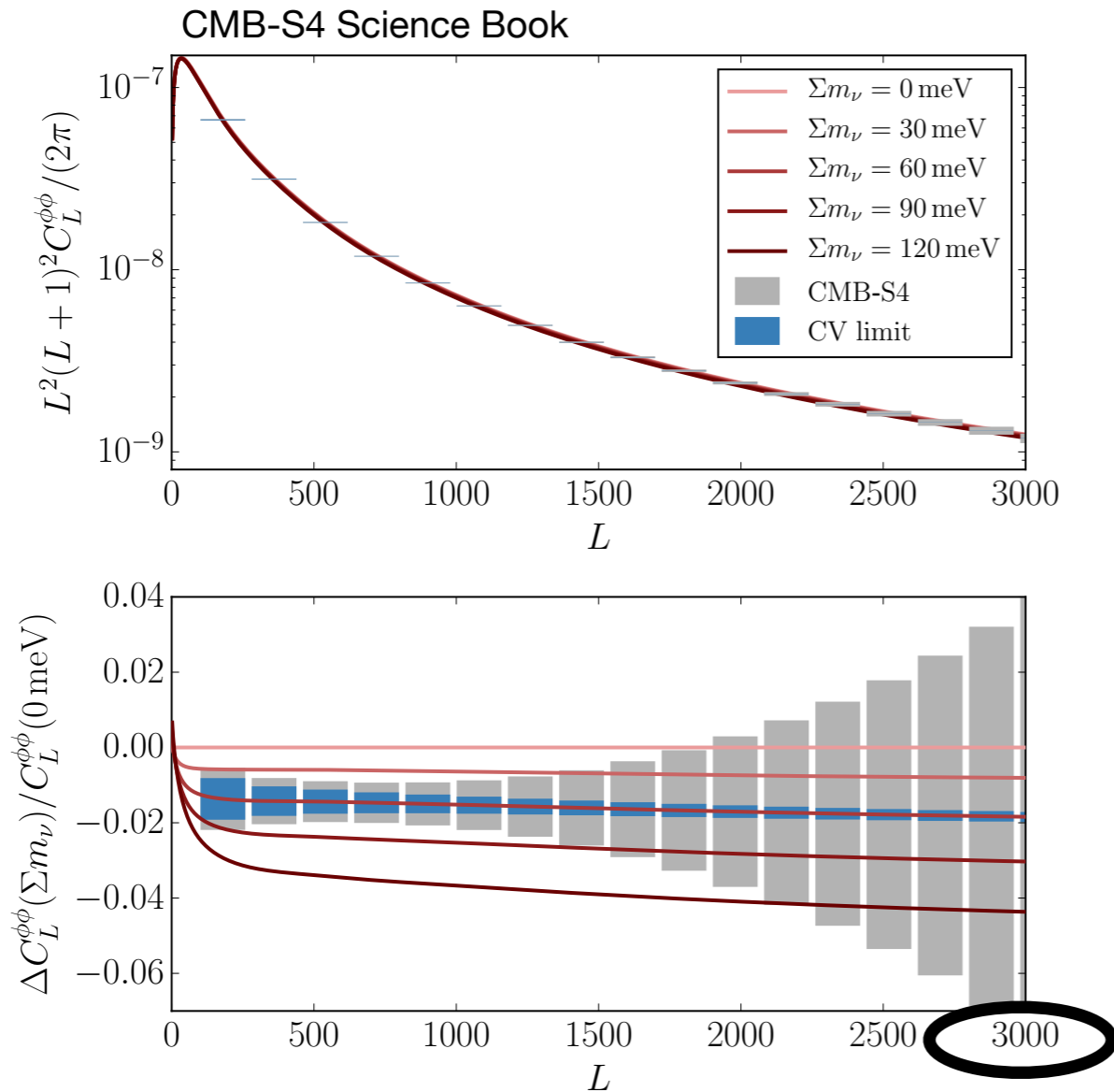
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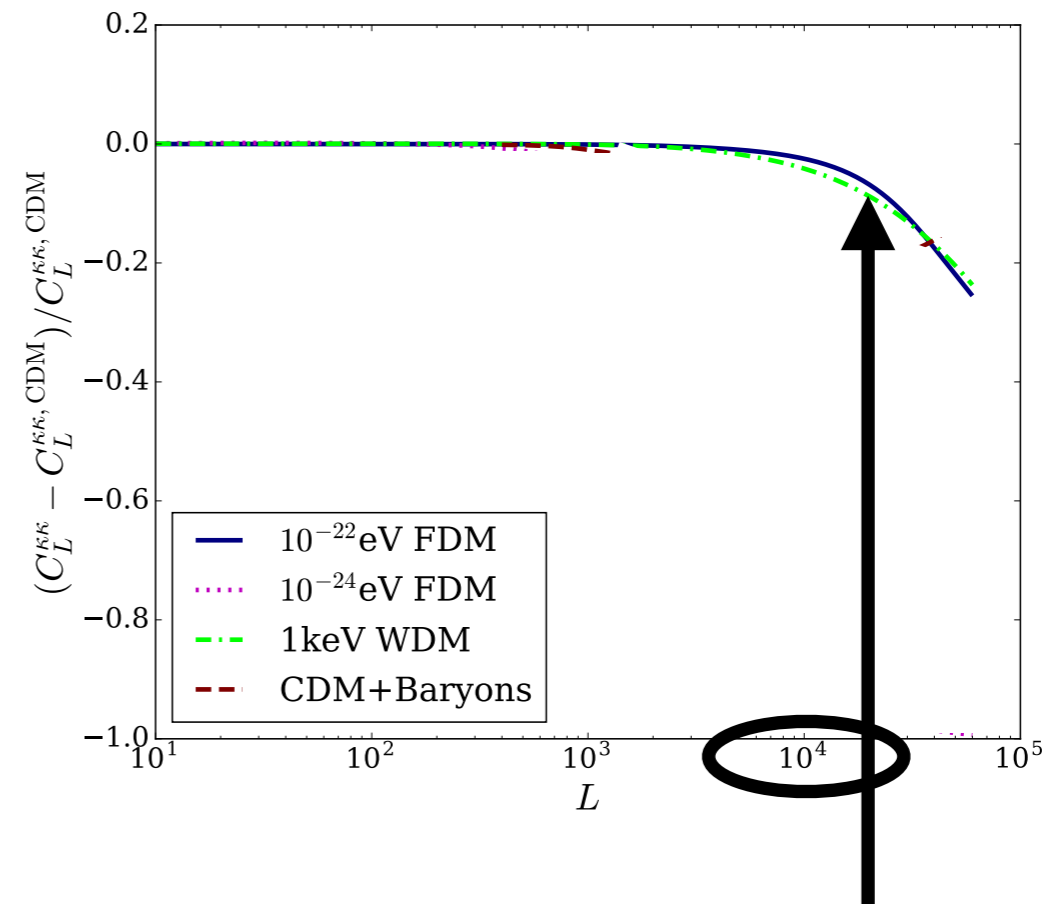
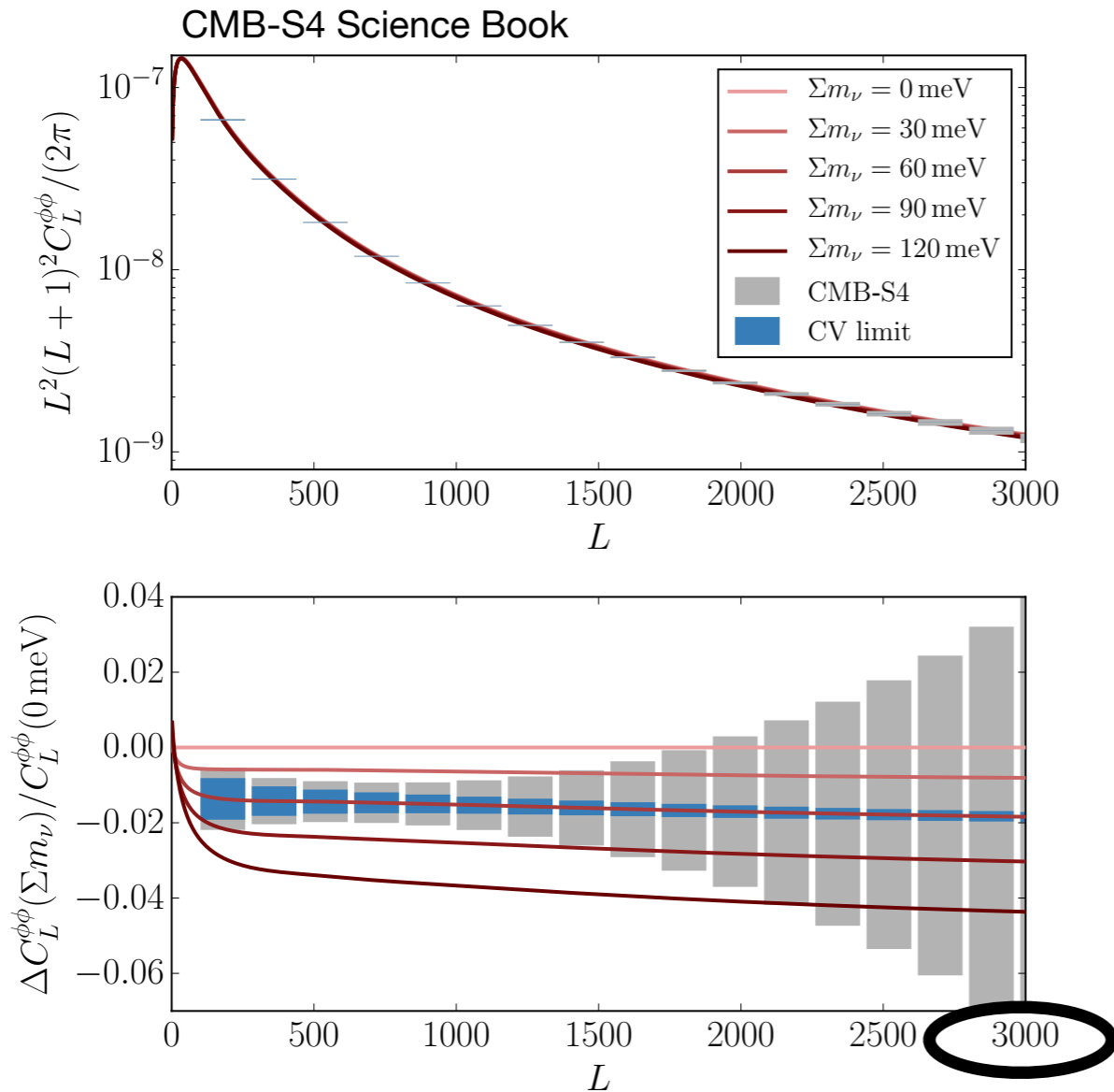
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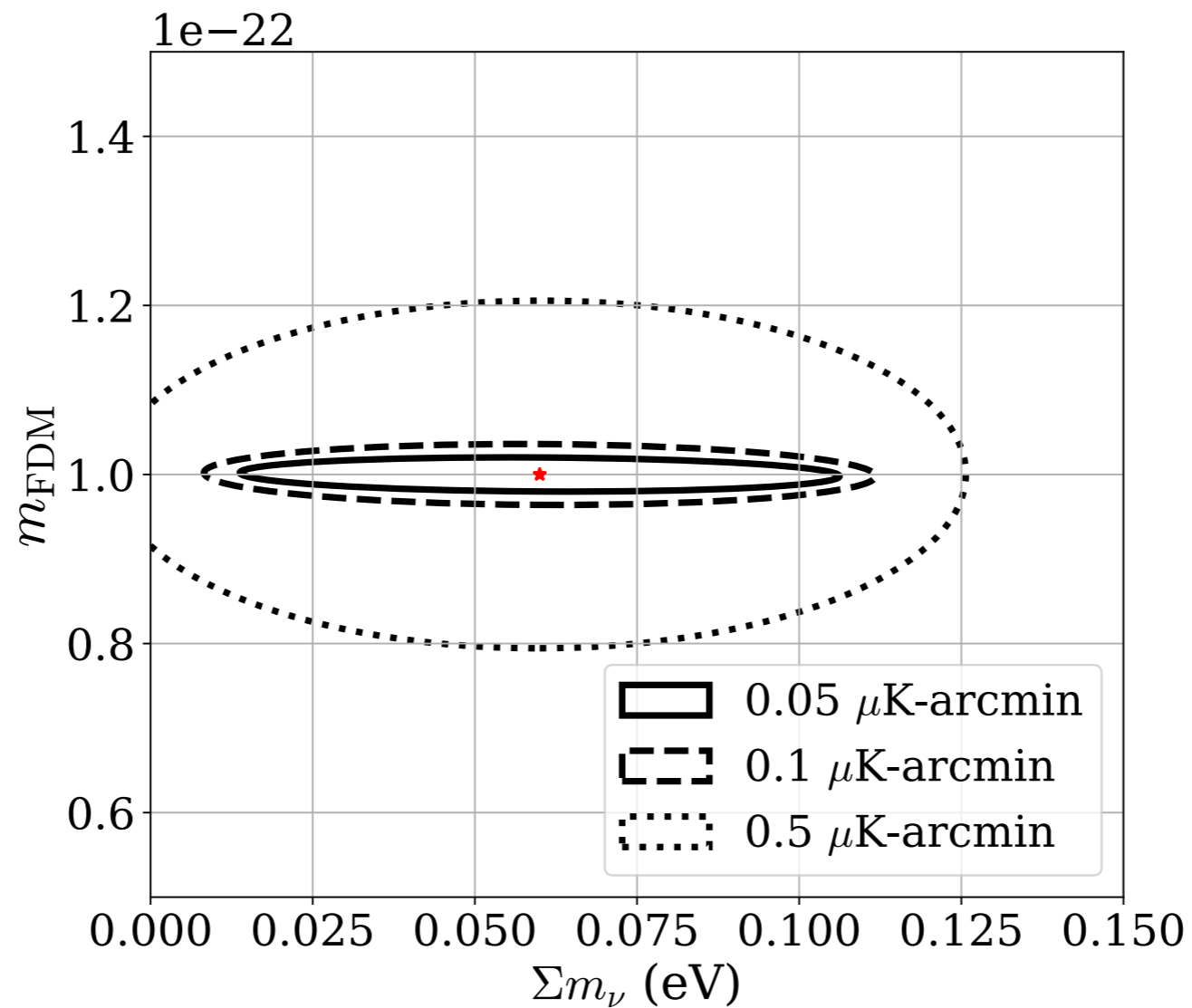
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# Instrument Path

New 30-meter mm-wave telescopes in Atacama Desert with total sensitivity 3 times deeper than CMB-S4 == CMB-HD



# Motivation of CMB-HD

## Rich Science from CMB-HD:

Dark Matter Properties from Small-Scale  
Matter Power Spectrum

Number of Relativistic Species

Delensing for Primordial Gravitational Waves

Neutrino Mass

Dark Energy

Galaxy Cluster Astrophysics

Galaxy Formation

Reionization

Planetary Studies

Mapping Transient Sky

Synergy with Optical Lensing Surveys

Novel Ideas

NS et al. 2019, Science White  
Paper for Astro2020 Decadal  
(arXiv:1903.03263)



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- Traditional CMB science would also gain from this ( $r$  and  $N_{\text{eff}}$ )
- Good motivation for future ground-based CMB experiment, i.e. CMB-HD