

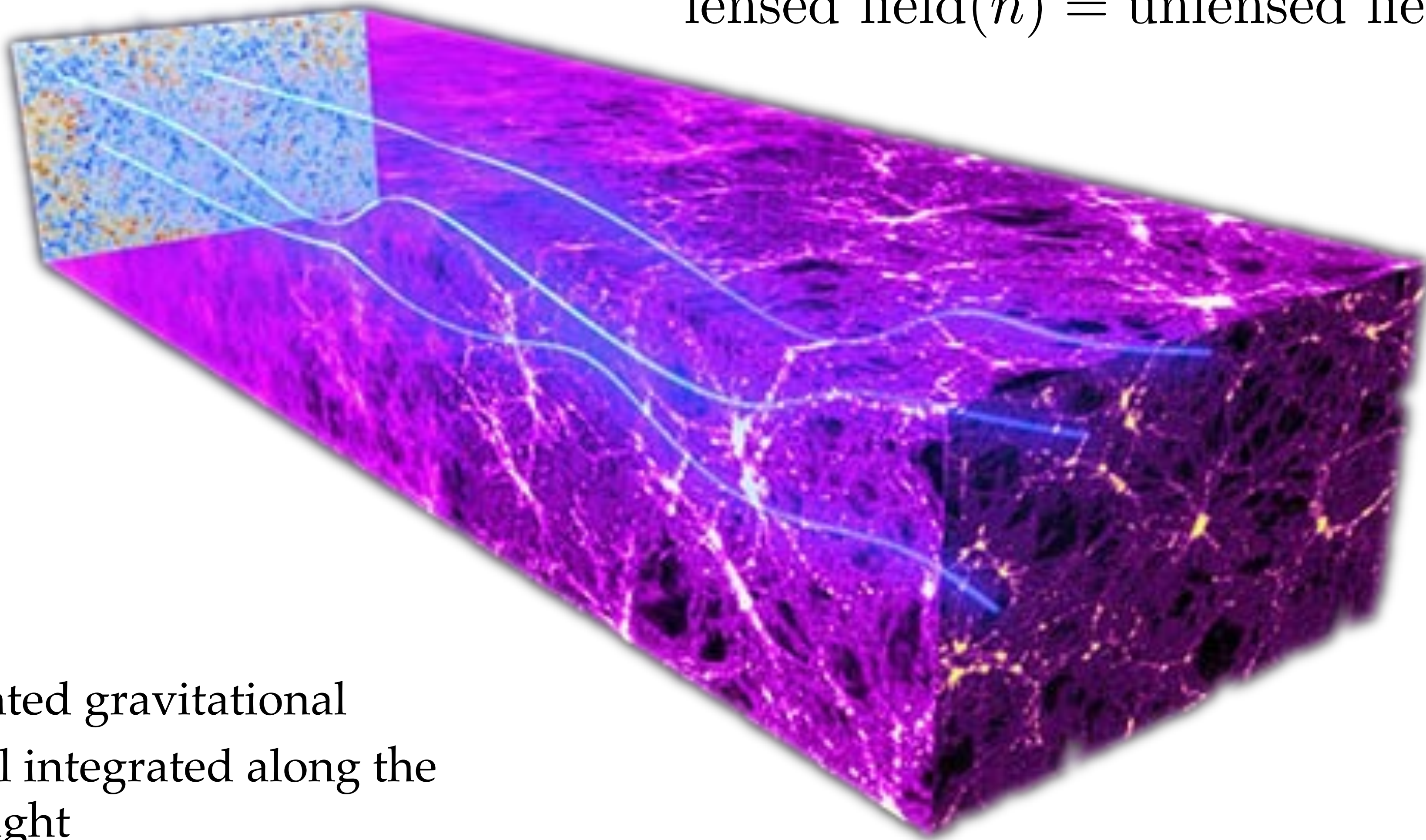
CMB lensing and cosmology: current status and future outlook

W.L. Kimmy Wu
Caltech

Ad ASTRA Workshop @ Pasadena
September 1, 2026

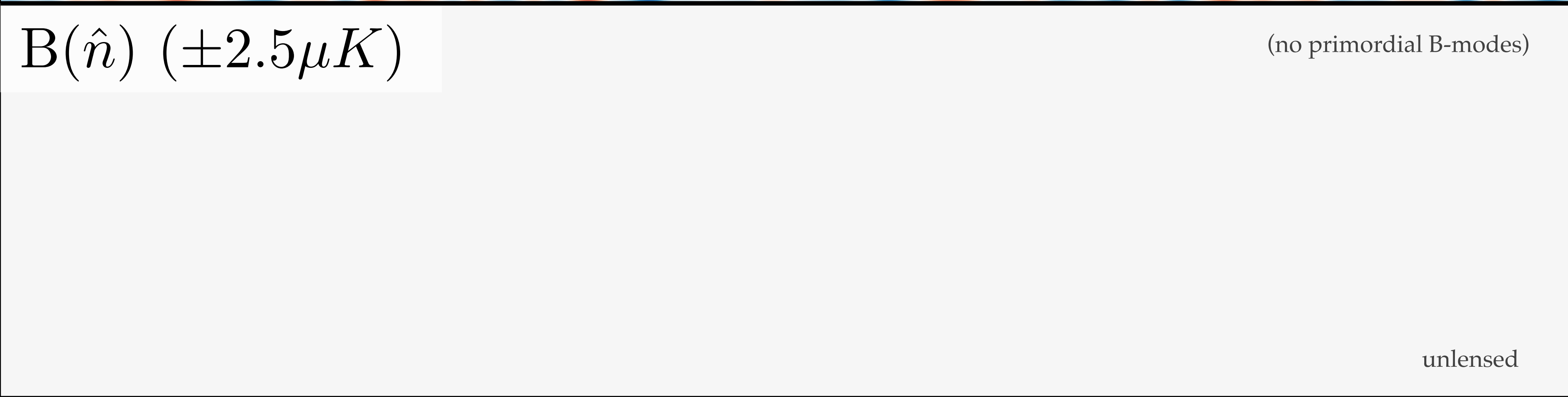
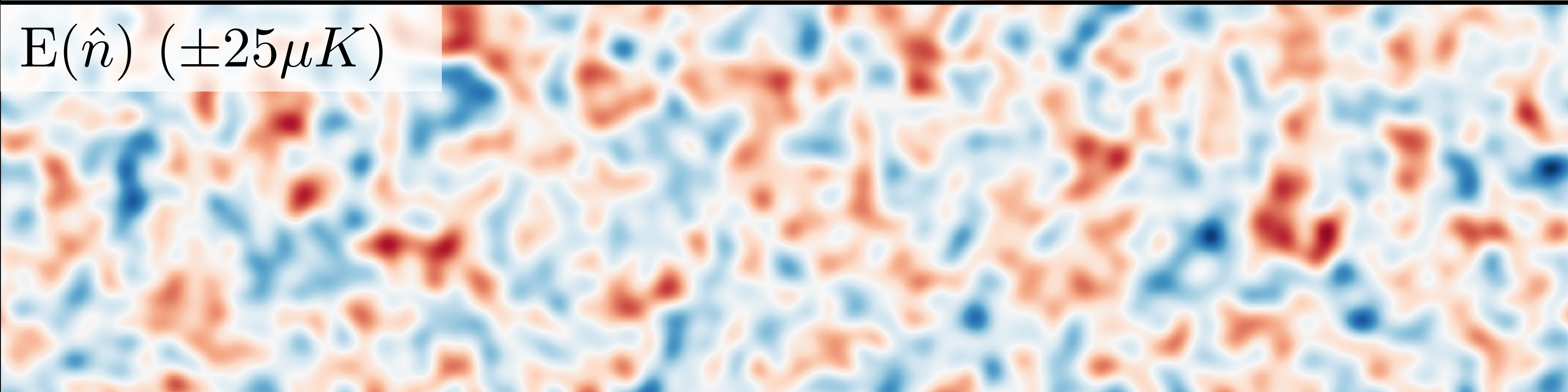
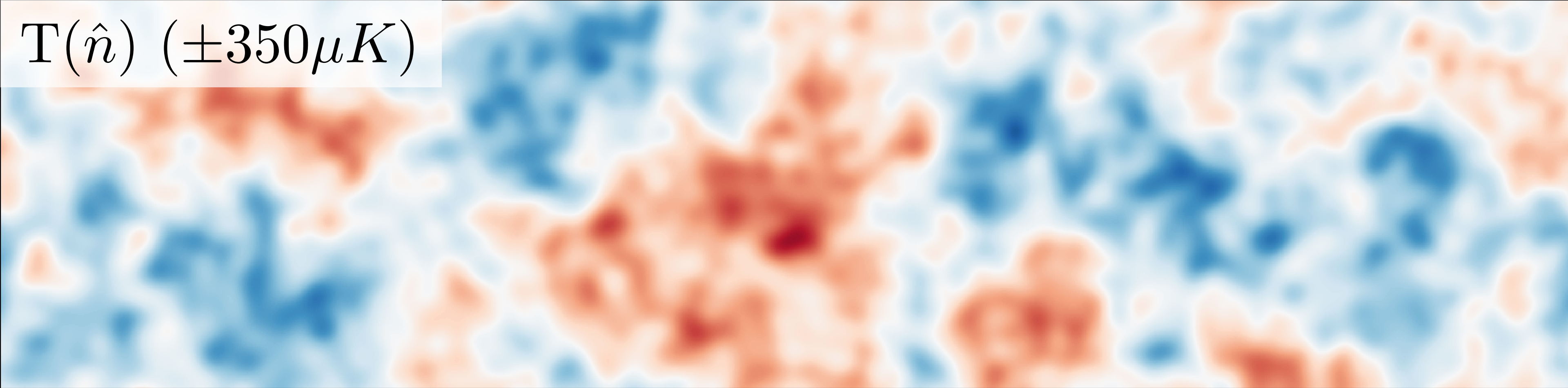
CMB lensing

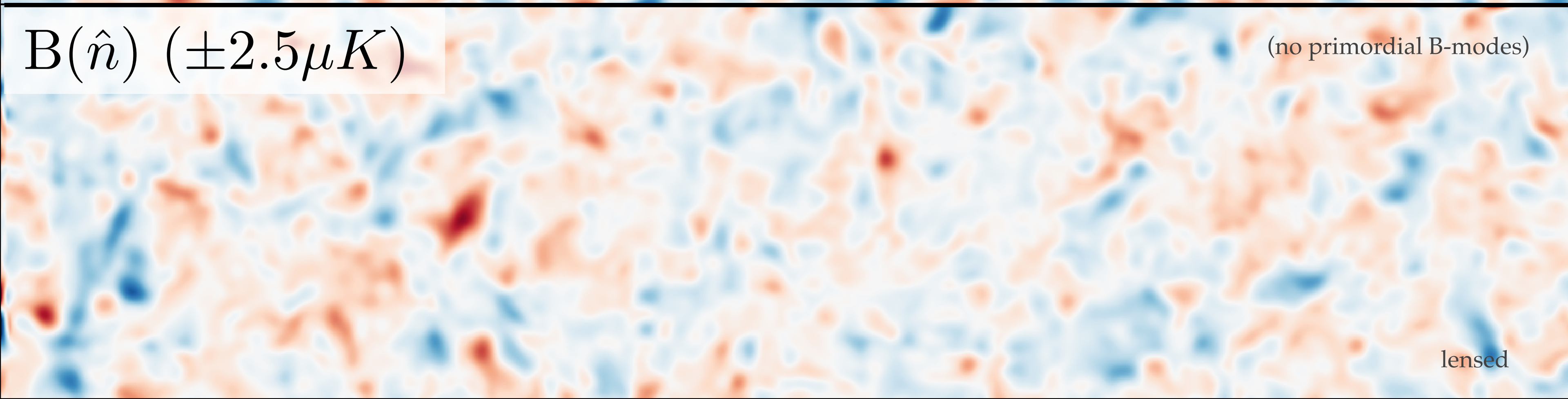
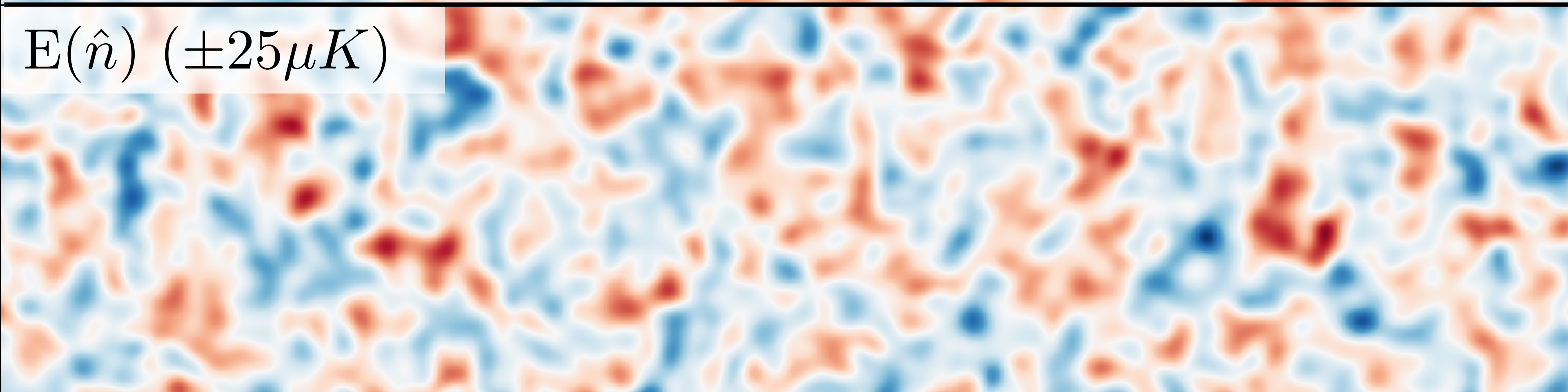
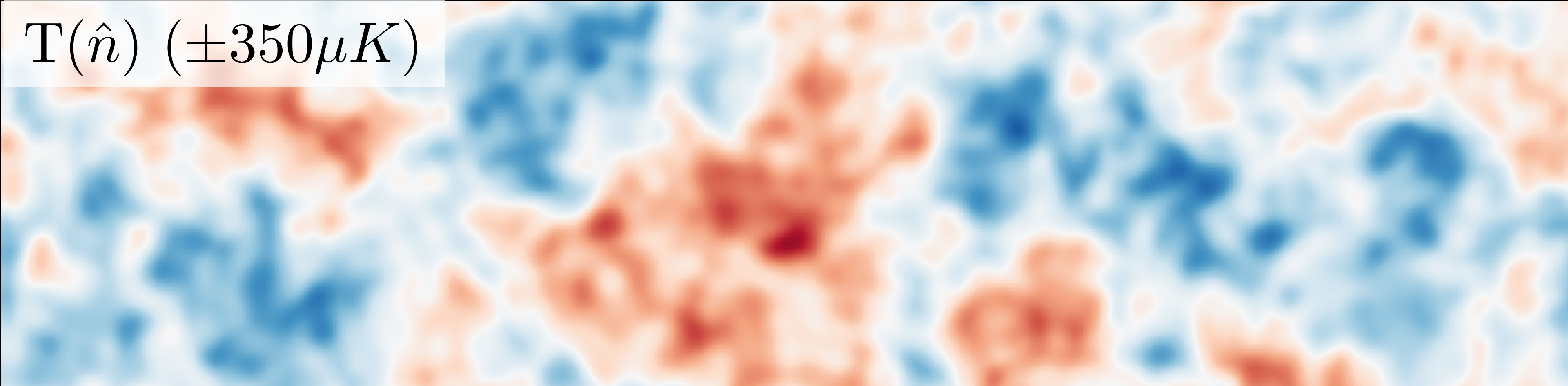
$$\text{lensed field}(\hat{n}) = \text{unlensed field}(\hat{n} + \nabla\phi)$$

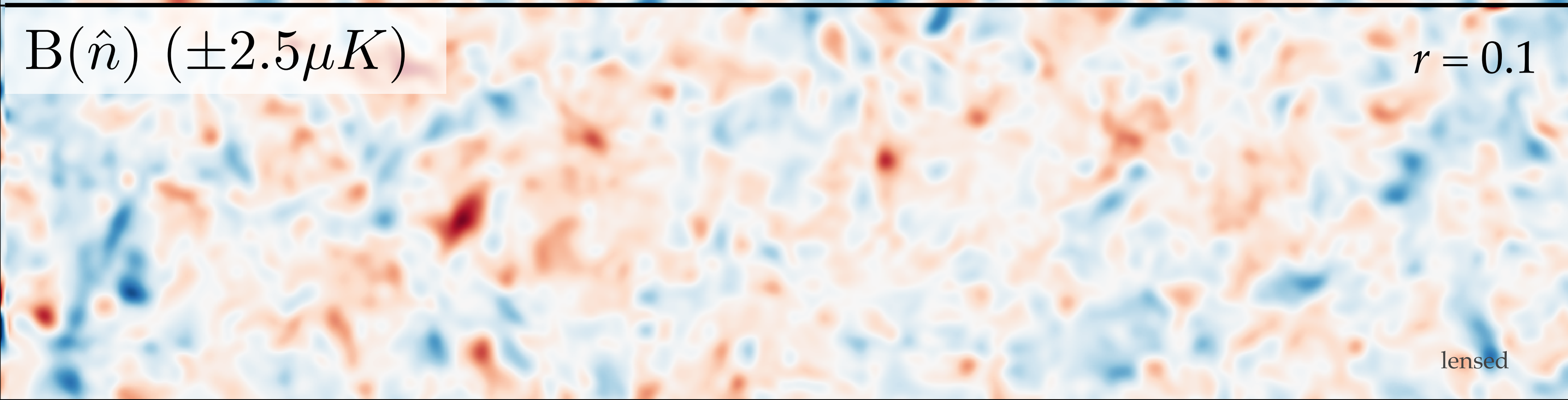
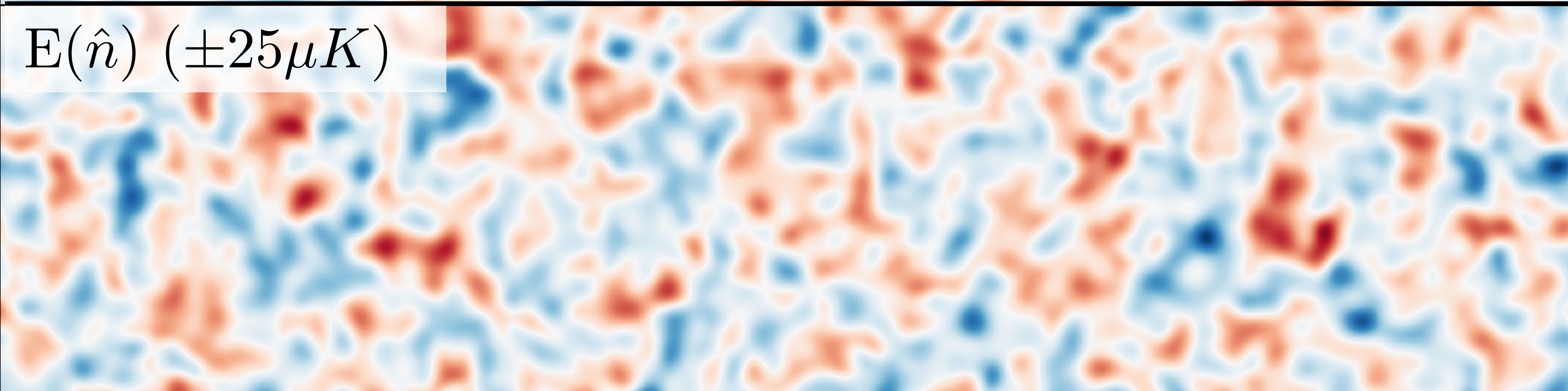
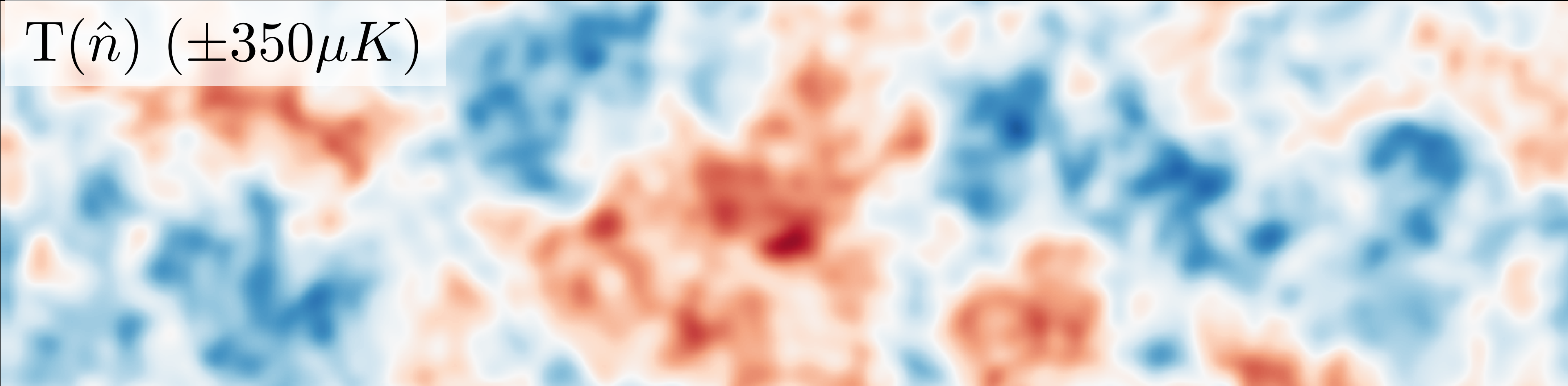


ϕ : weighted gravitational potential integrated along the line of sight

Image credit: ESA





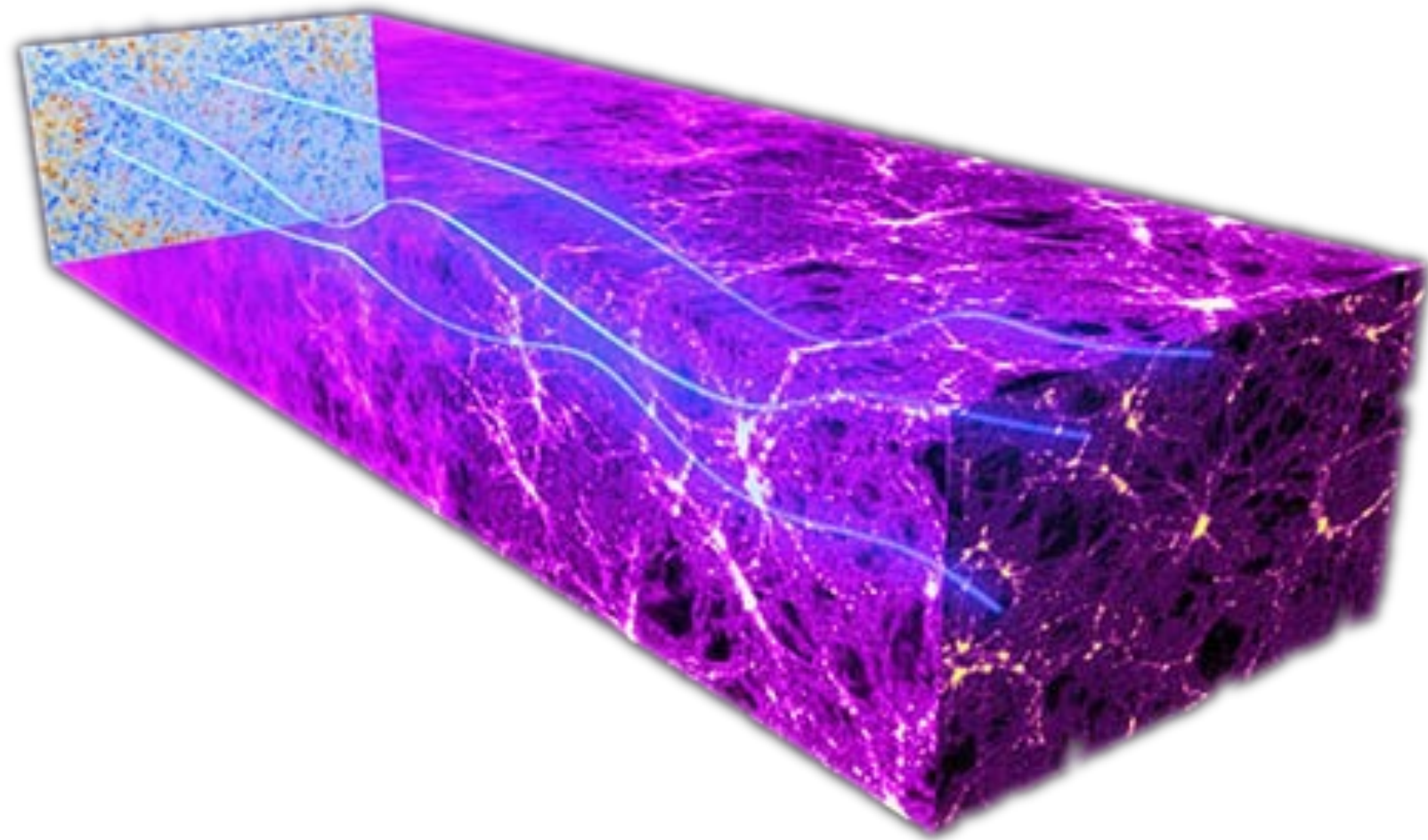


Can we use the lensed CMB to compute ϕ ? Yes!

Lensing introduces off-diagonal power in CMB map covariances

$$\langle X(\mathbf{l})Y^*(\mathbf{l} - \mathbf{L}) \rangle = 0 \quad \xrightarrow{\text{With lensing}} \quad \langle X(\mathbf{l})Y^*(\mathbf{l} - \mathbf{L}) \rangle \propto \phi(\mathbf{L})$$

$X, Y \in \{T, E, B\}$

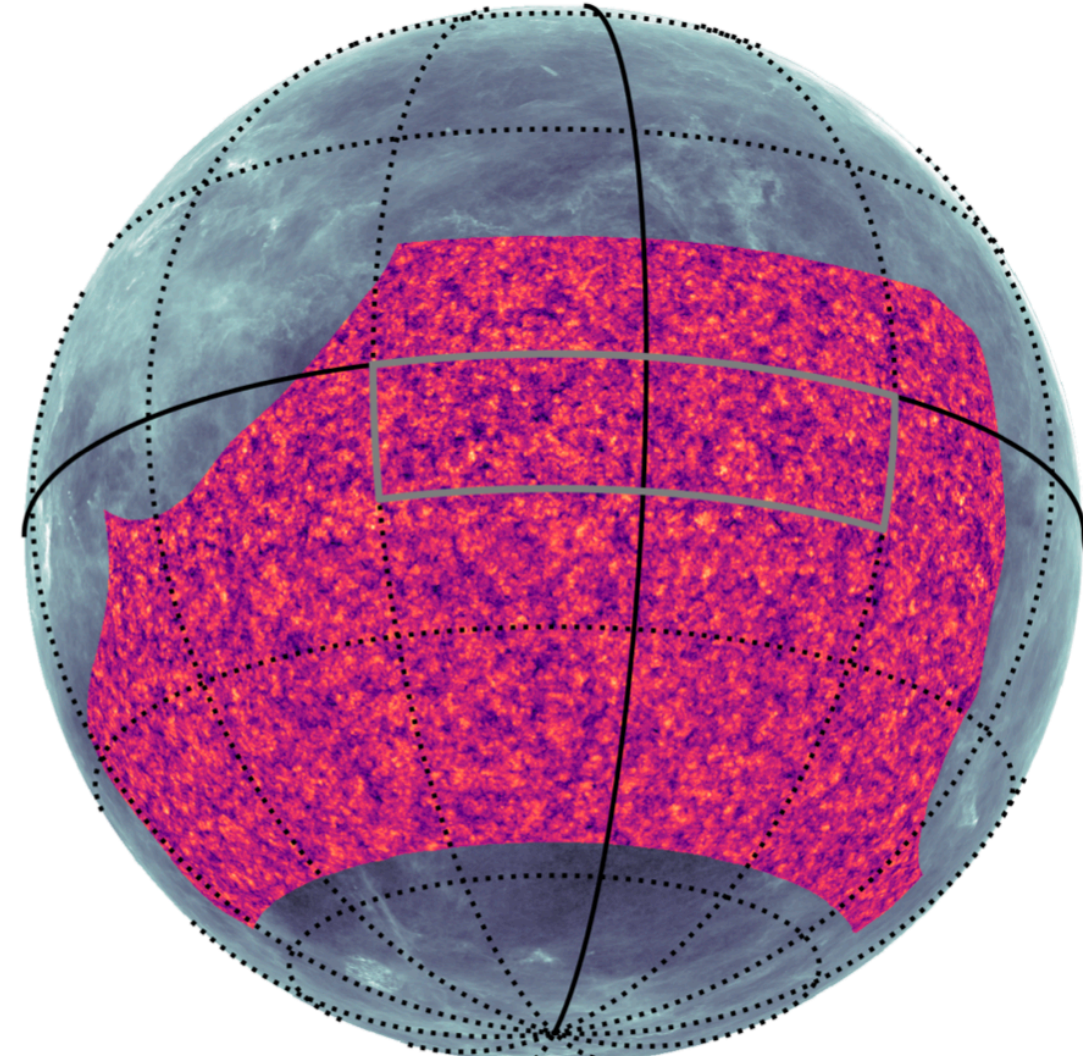


$$\langle x(\boldsymbol{\ell})x'(\boldsymbol{\ell}') \rangle_{\text{CMB}} = f_{\alpha}(\boldsymbol{\ell}, \boldsymbol{\ell}')\phi(\mathbf{L})$$

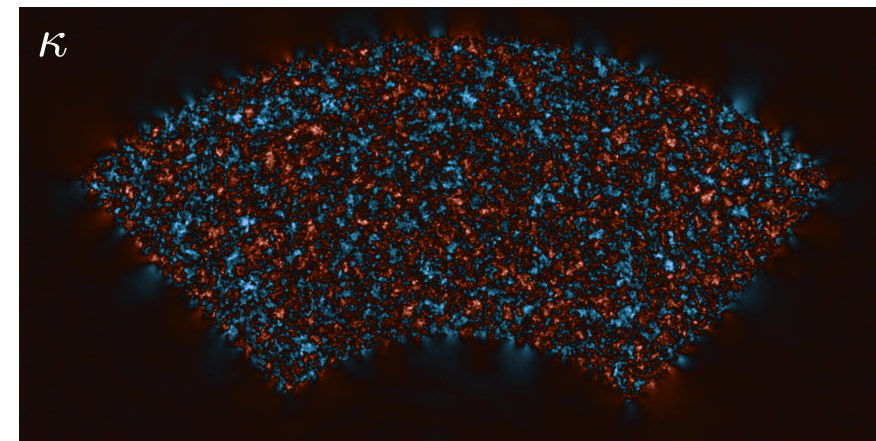
functions of unlensed
T/E/B spectra
(Hu & Okamoto, 2002)

CMB lensing measurements now at high signal-to-noise and a precision cosmology tool

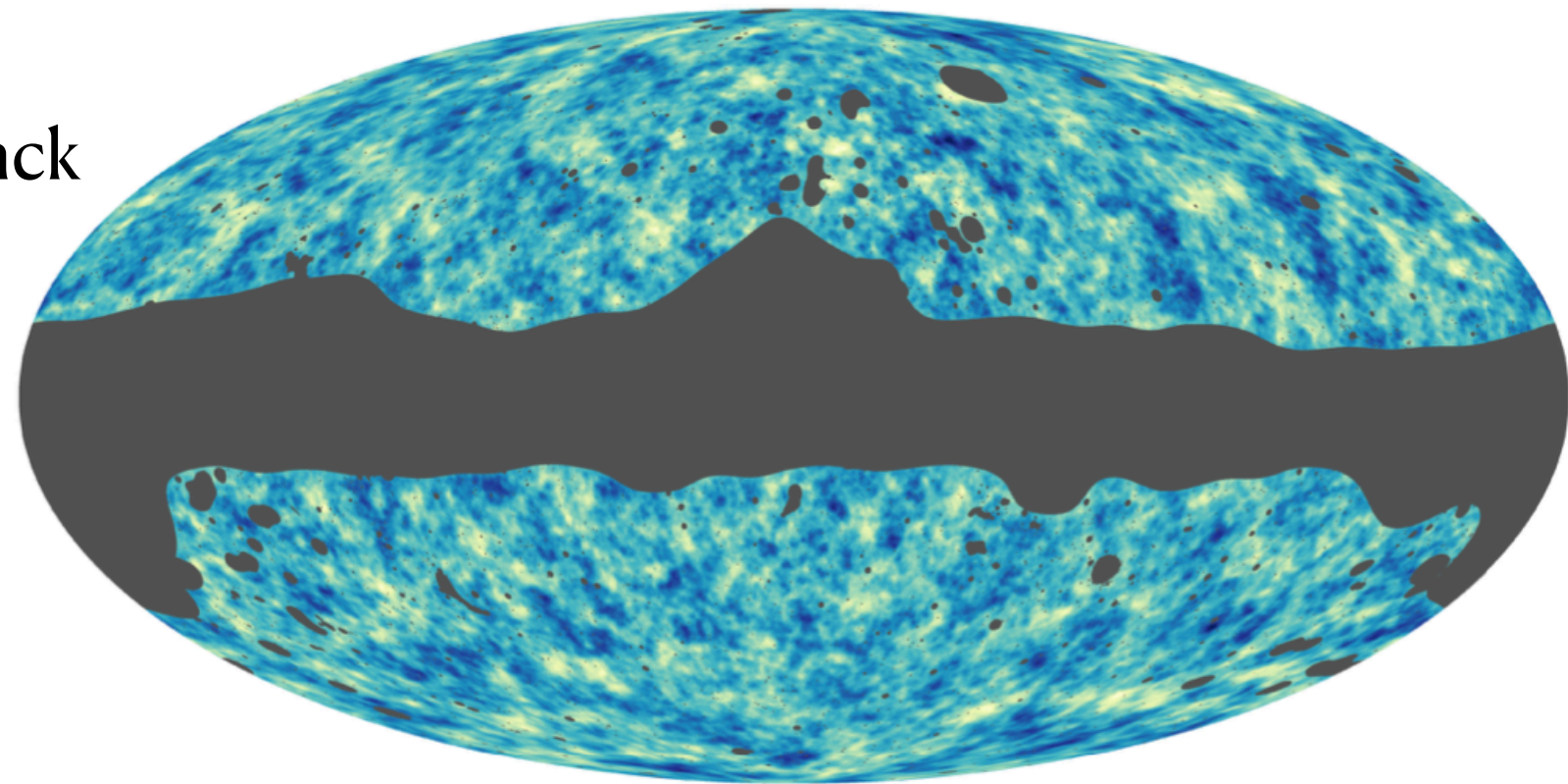
Atacama Cosmology Telescope



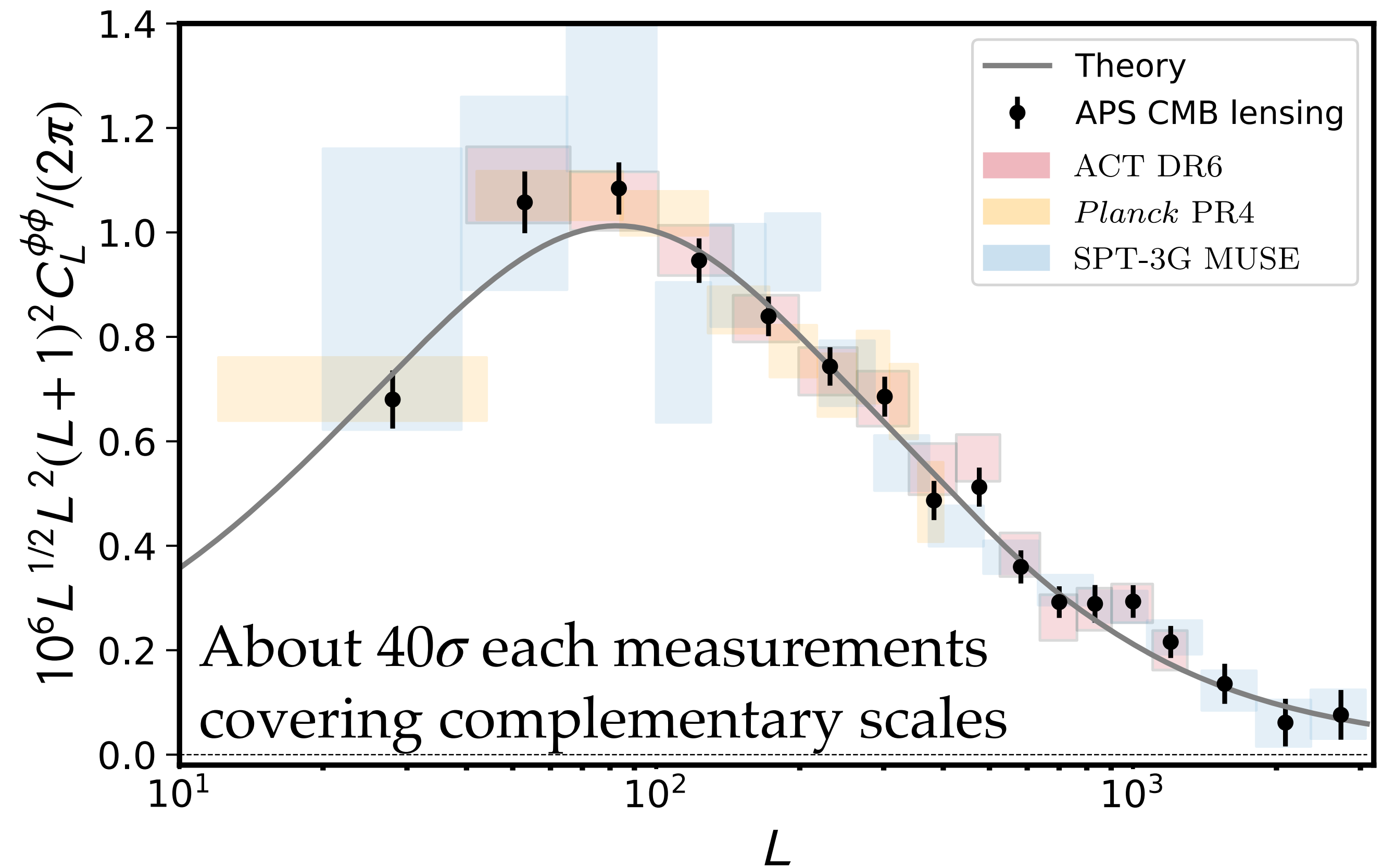
South Pole Telescope



Planck



CMB lensing power spectrum



Qu, Ge, KW et al.(ACT+SPT-3G collaborations)
PRL 136, 021001 (2026)

Primary CMB + CMB lensing measurements from the three experiments are consistent with each other; all supporting Λ CDM.



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Distance between CMB vs DESI BAO in LCDM: $2.8\sigma \rightarrow$
dynamical dark energy, “negative” neutrino mass, etc.

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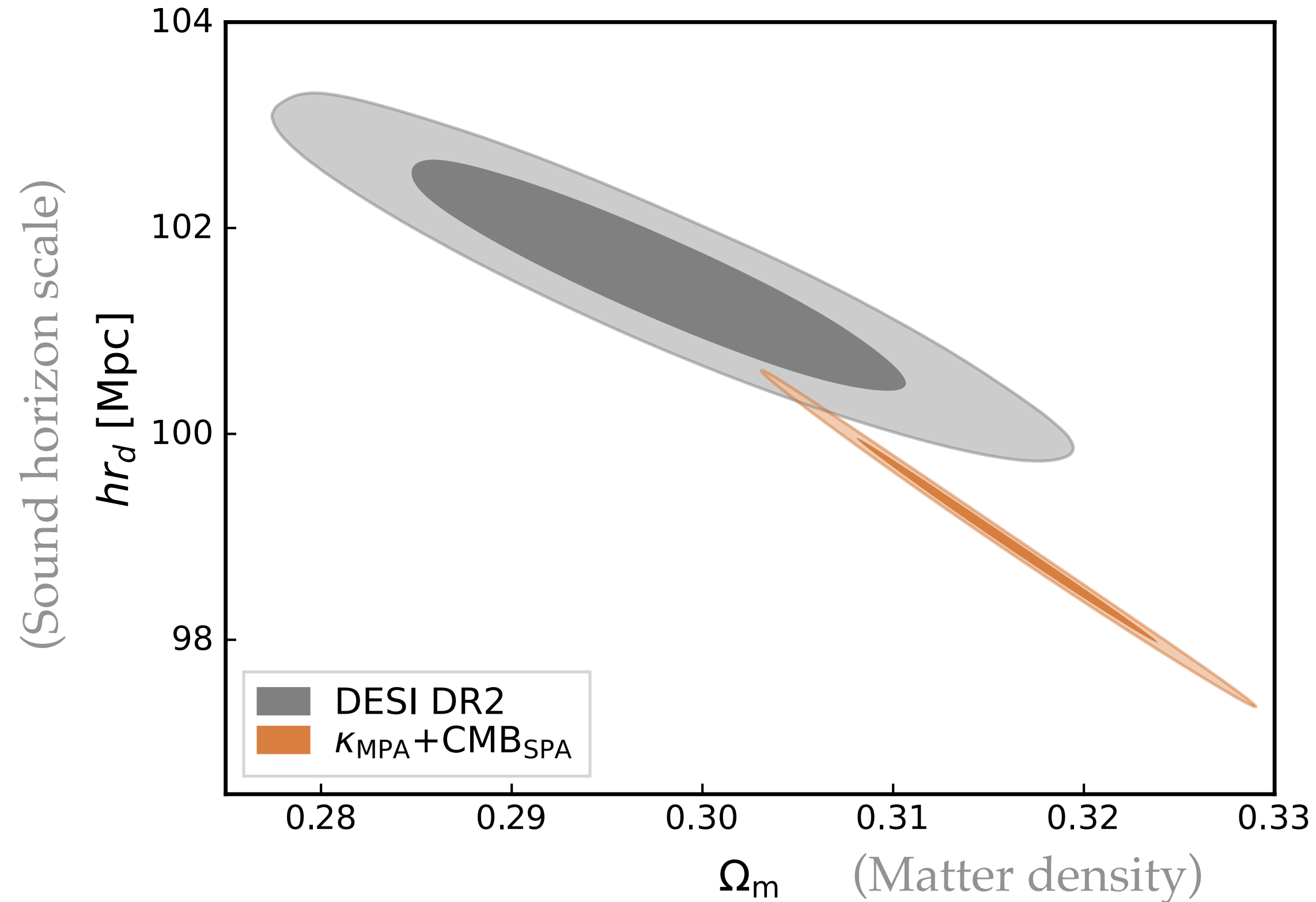
New (just posted!) CMB lensing measurement reduces that.

Example: latest SPT-3G CMB lensing reduces preference for w_0w_a CDM

Status of DESI vs CMB distance in LCDM prior to latest CMB lensing

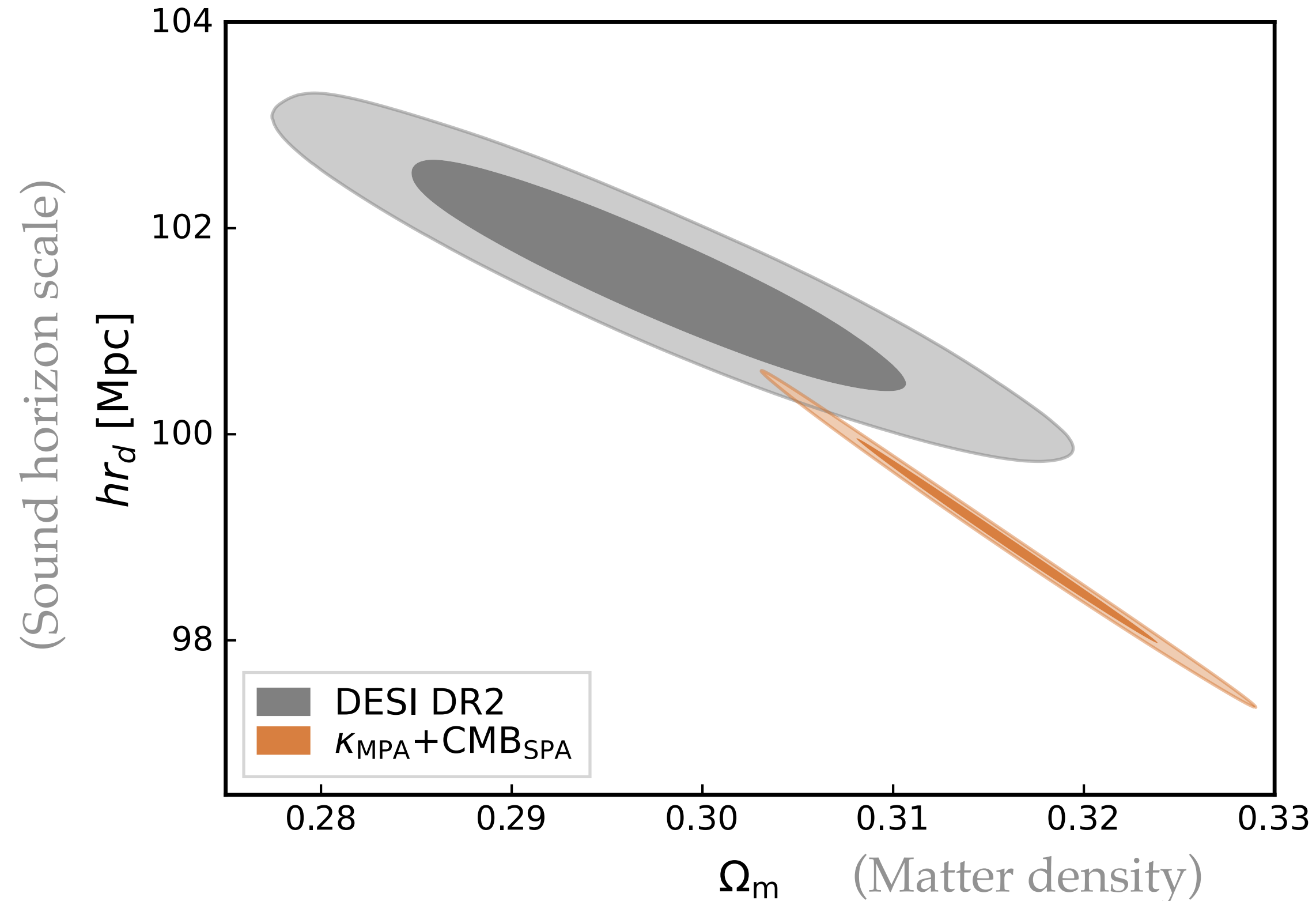
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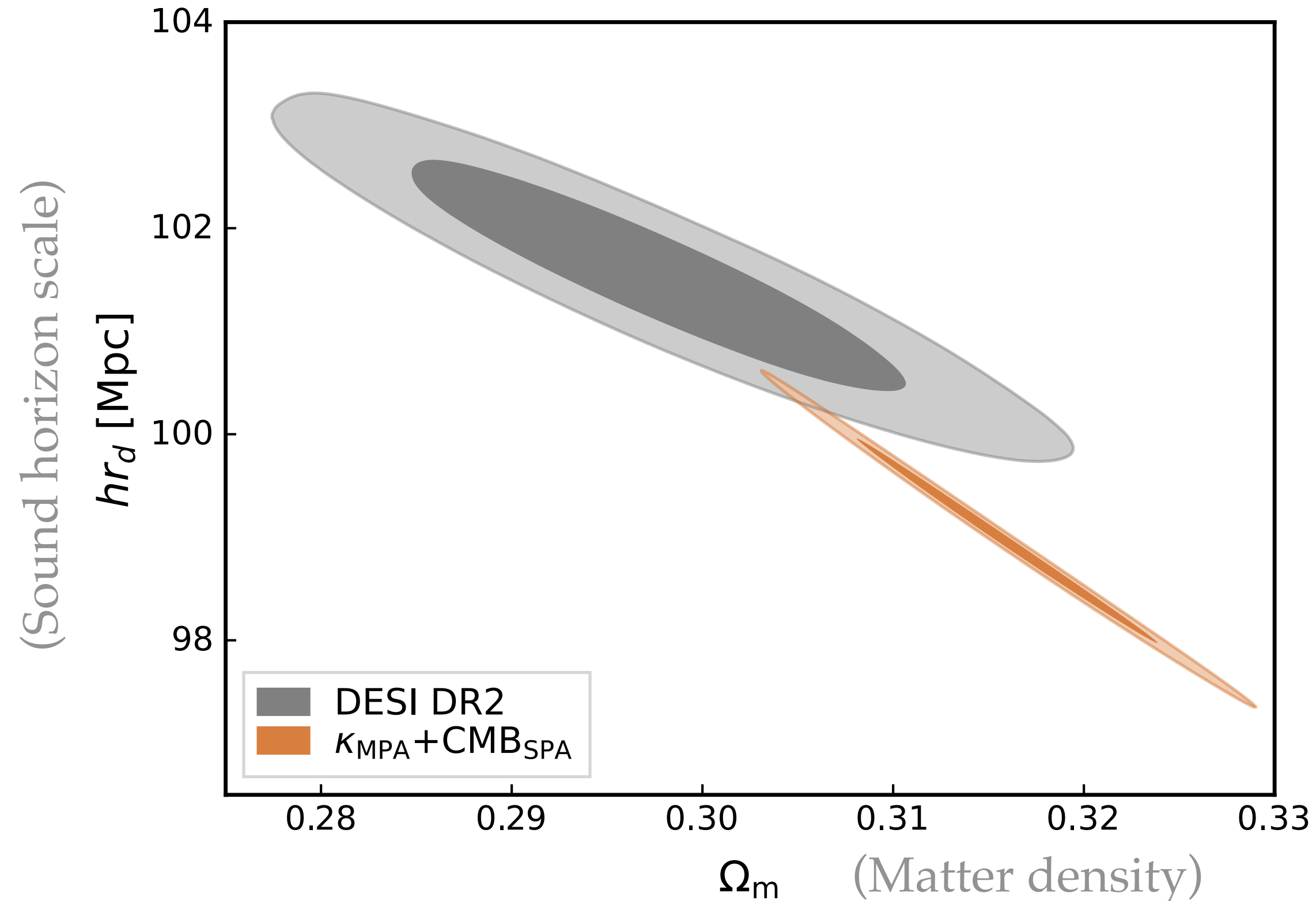
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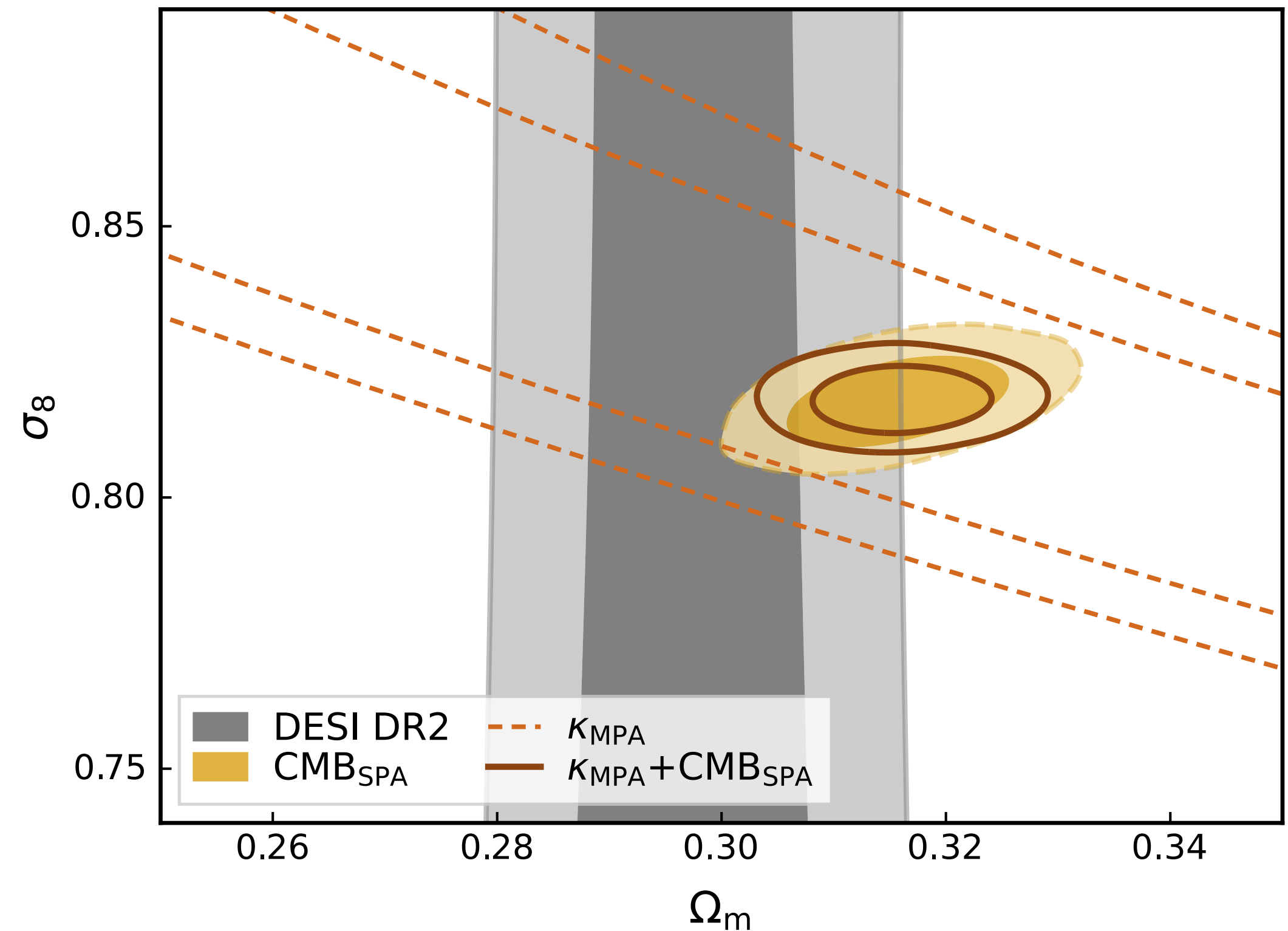
2.8σ in $hr_d - \Omega_m$ plane between
DESI BAO and CMB + CMB Lensing
(2.5σ with SRoll2 τ)

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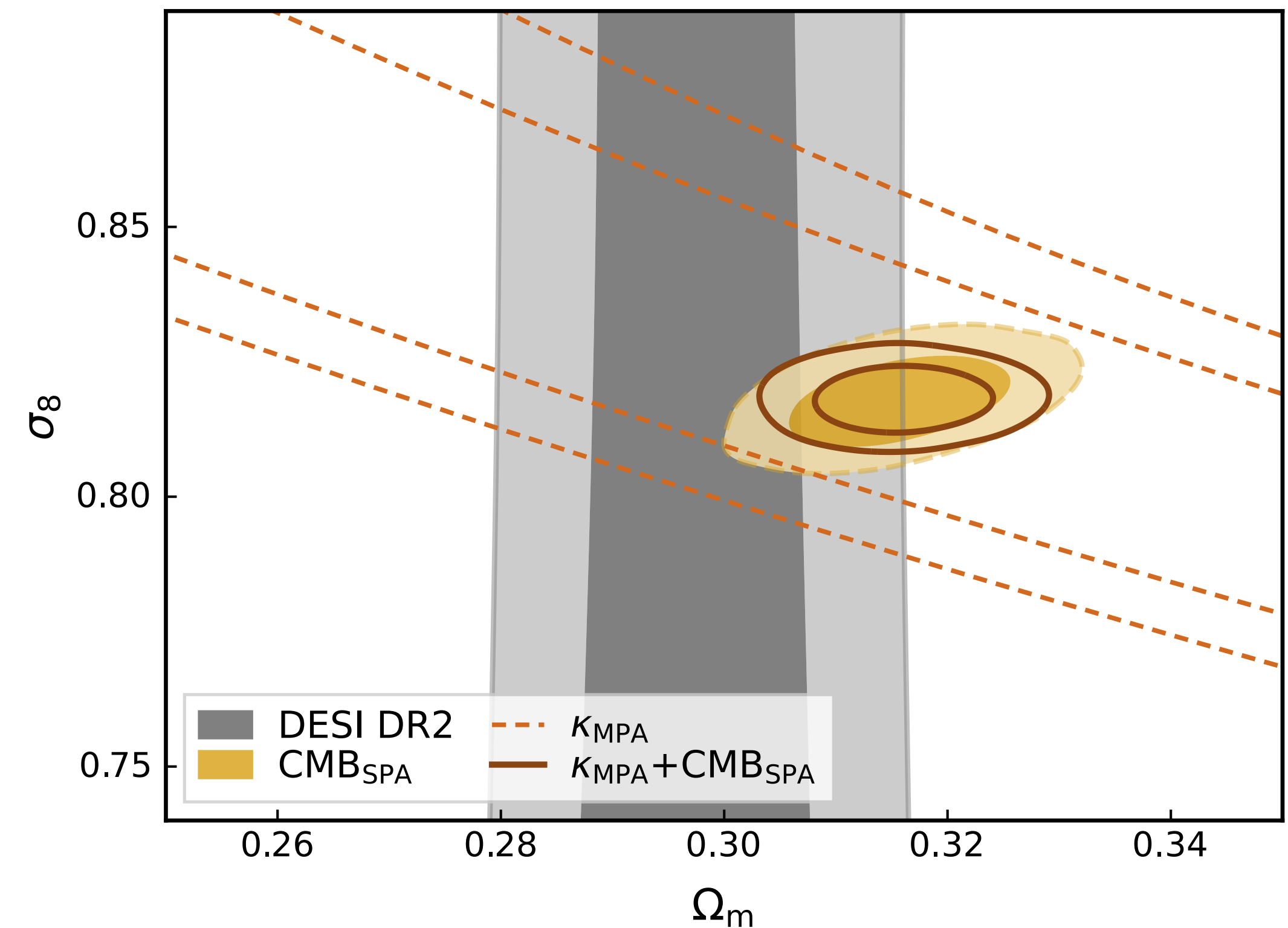
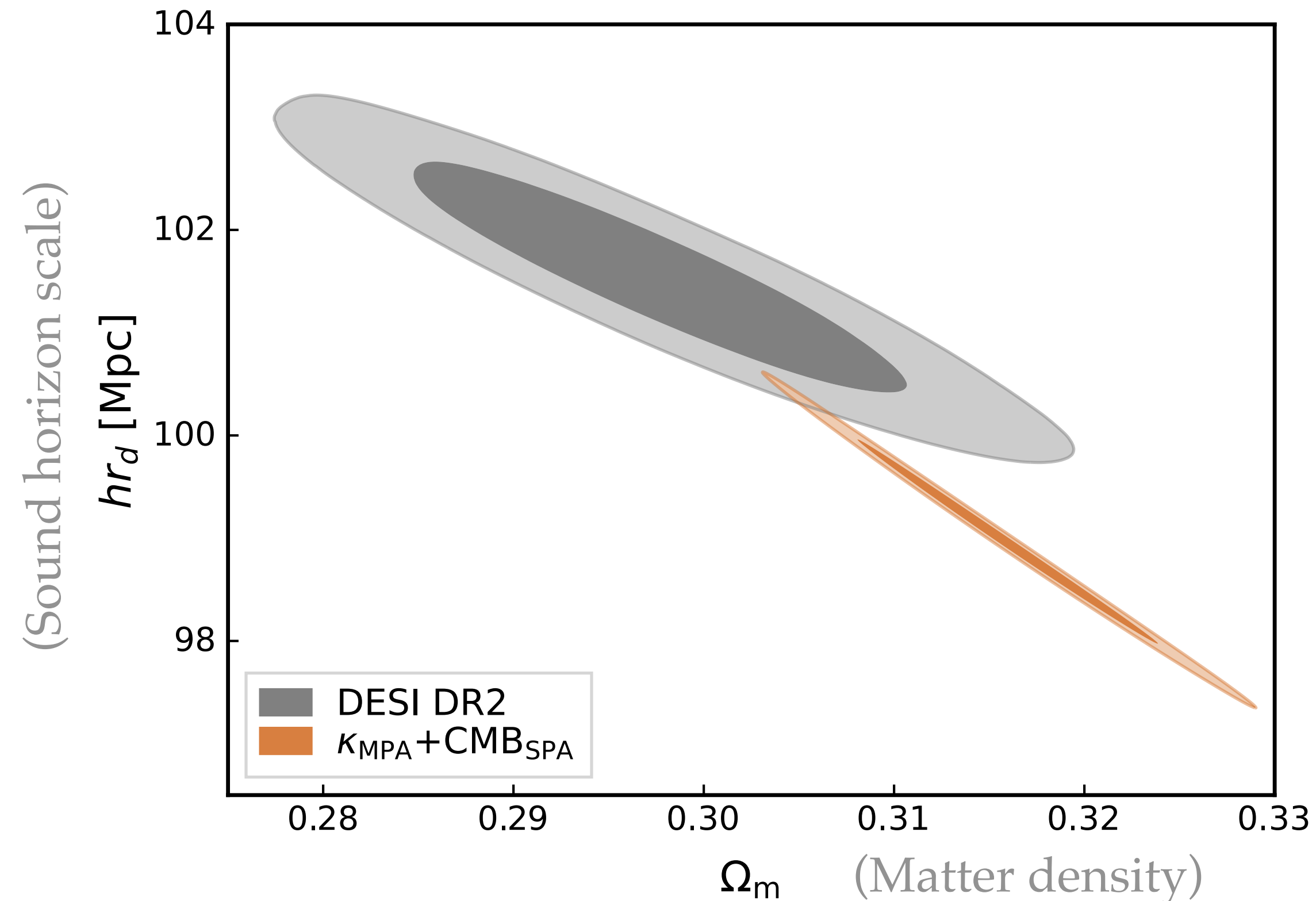
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CMB lensing focused view:
If CMB lensing gives higher or lower $\sigma_8 \Omega_m^{0.25}$,
that'll increase or decrease the distance to BAO

Example: latest SPT-3G CMB lensing reduces preference for w_0w_a CDM

With new CMB lensing from SPT-3G (on arXiv yesterday!)

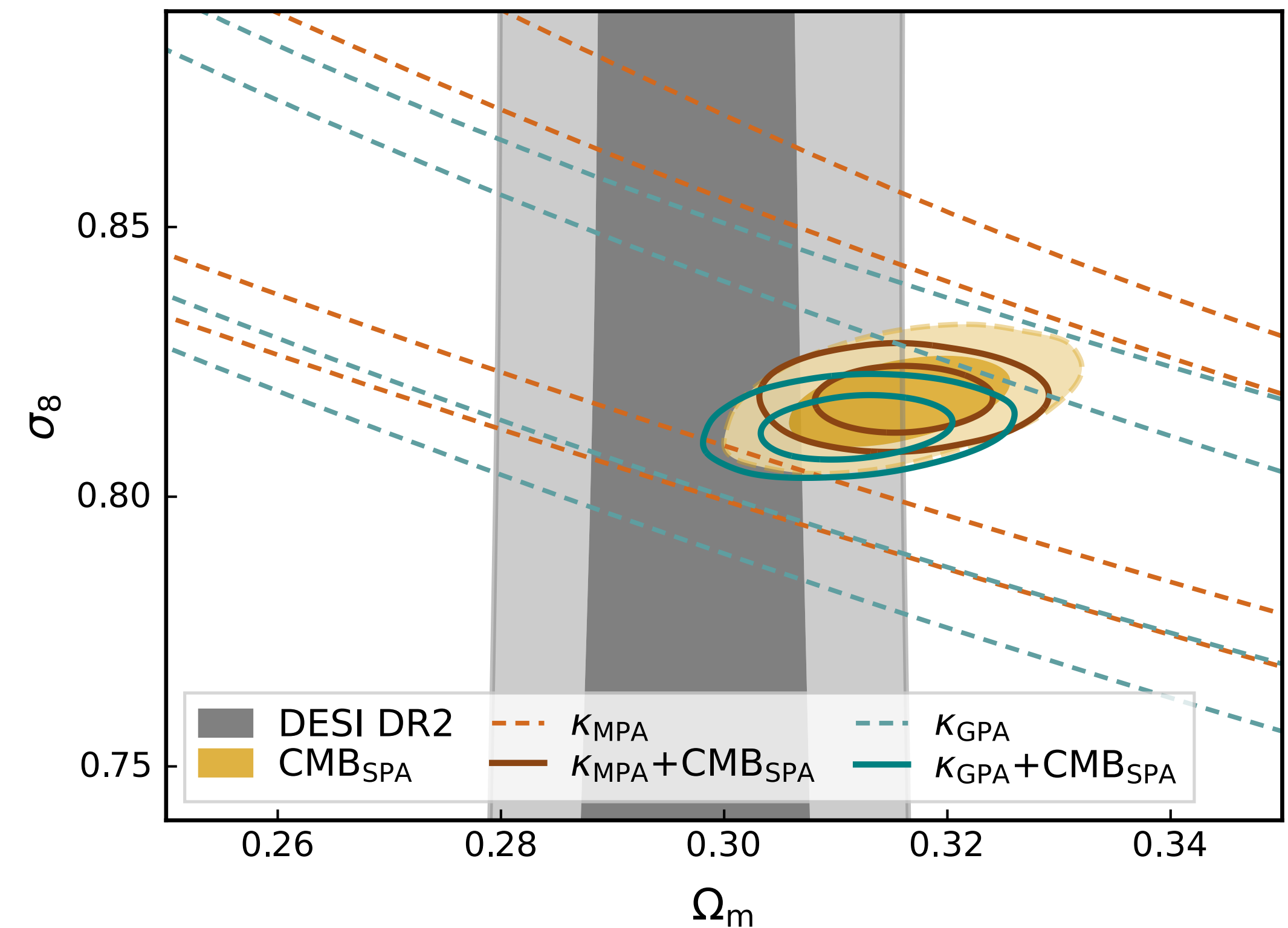
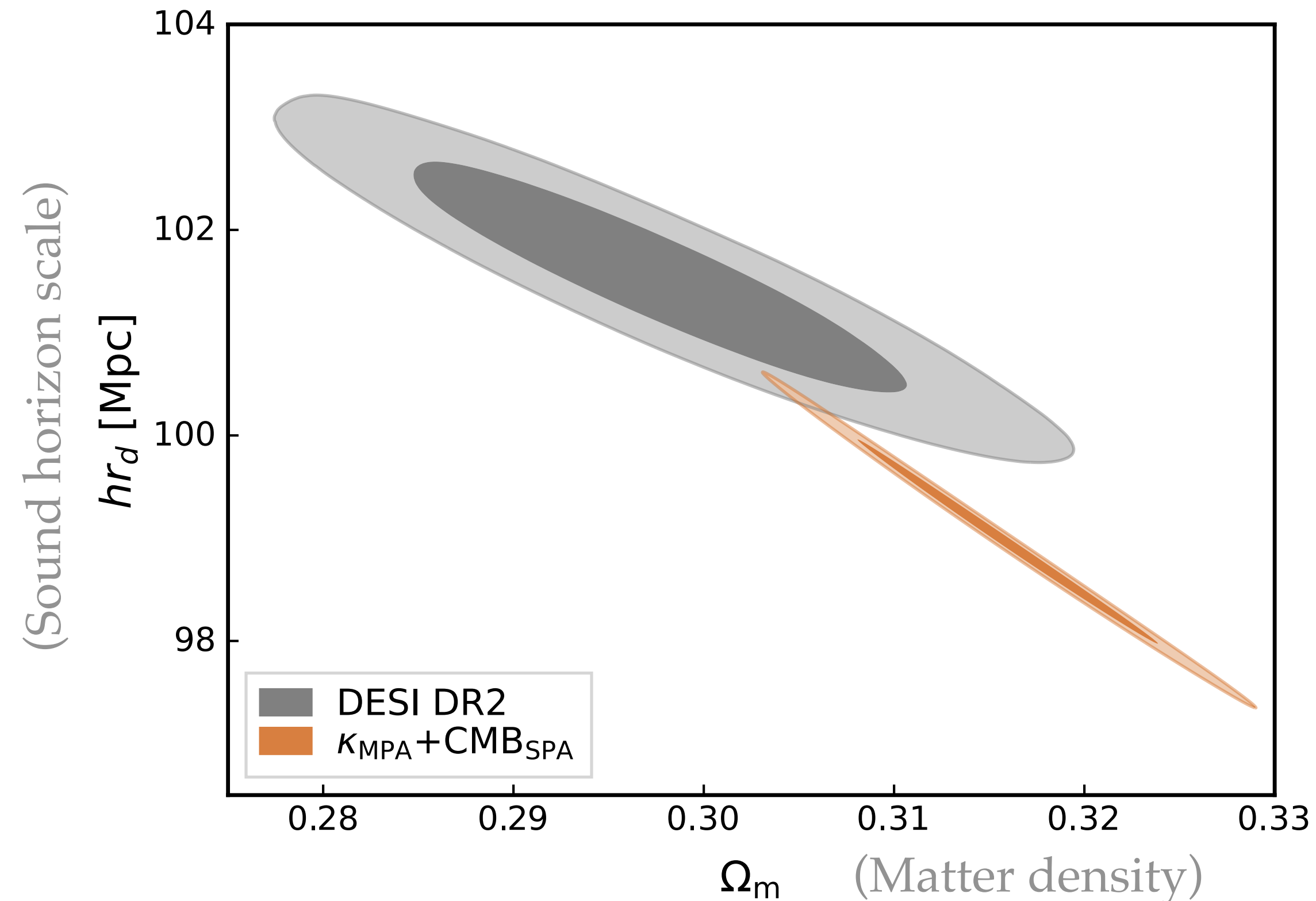


CMB lensing reduced distance between
CMB+CMB lensing and DESI BAO

Omori, KW et al. (SPT-3G collaboration)
(arXiv: 2608.31136)

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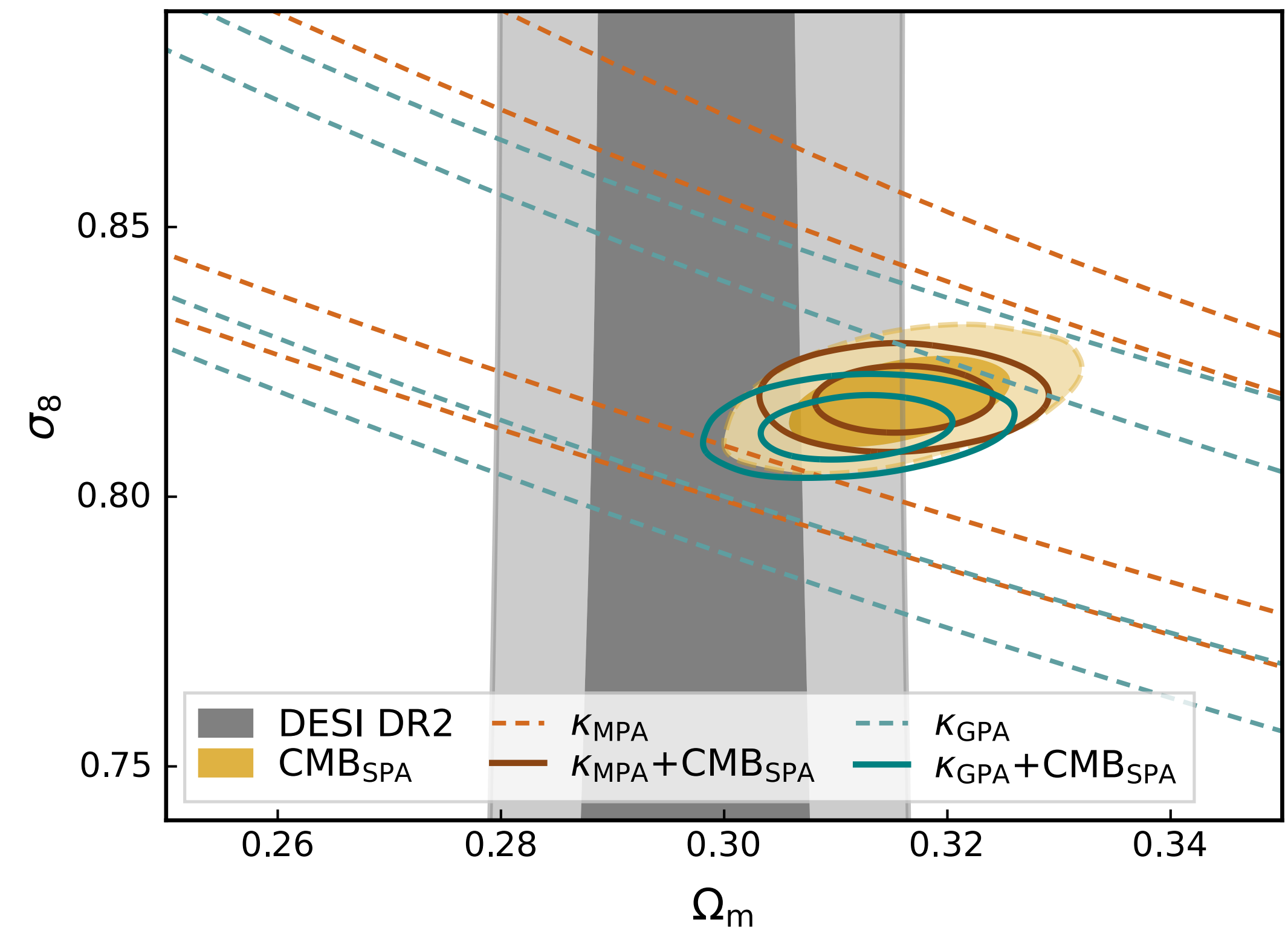
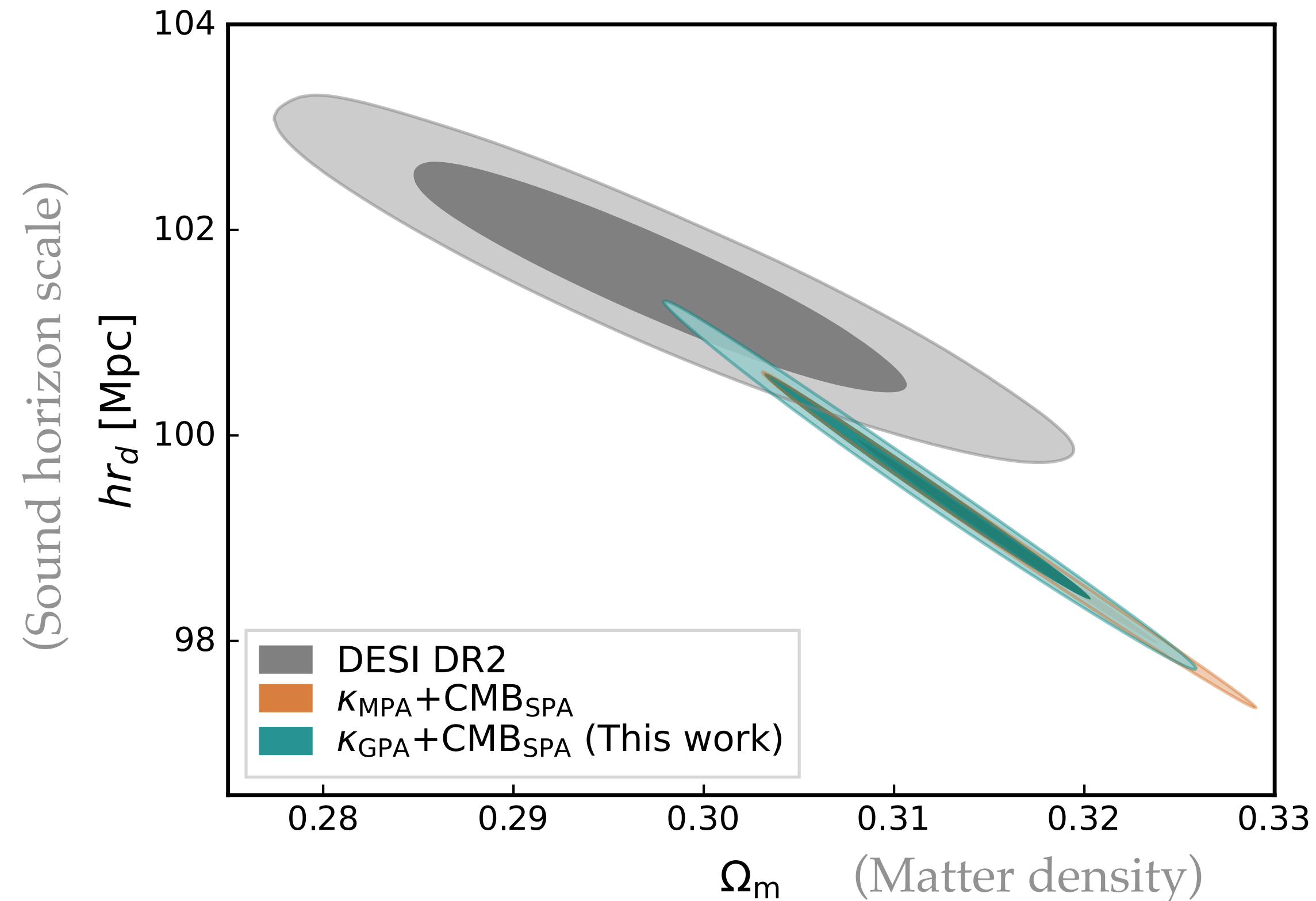


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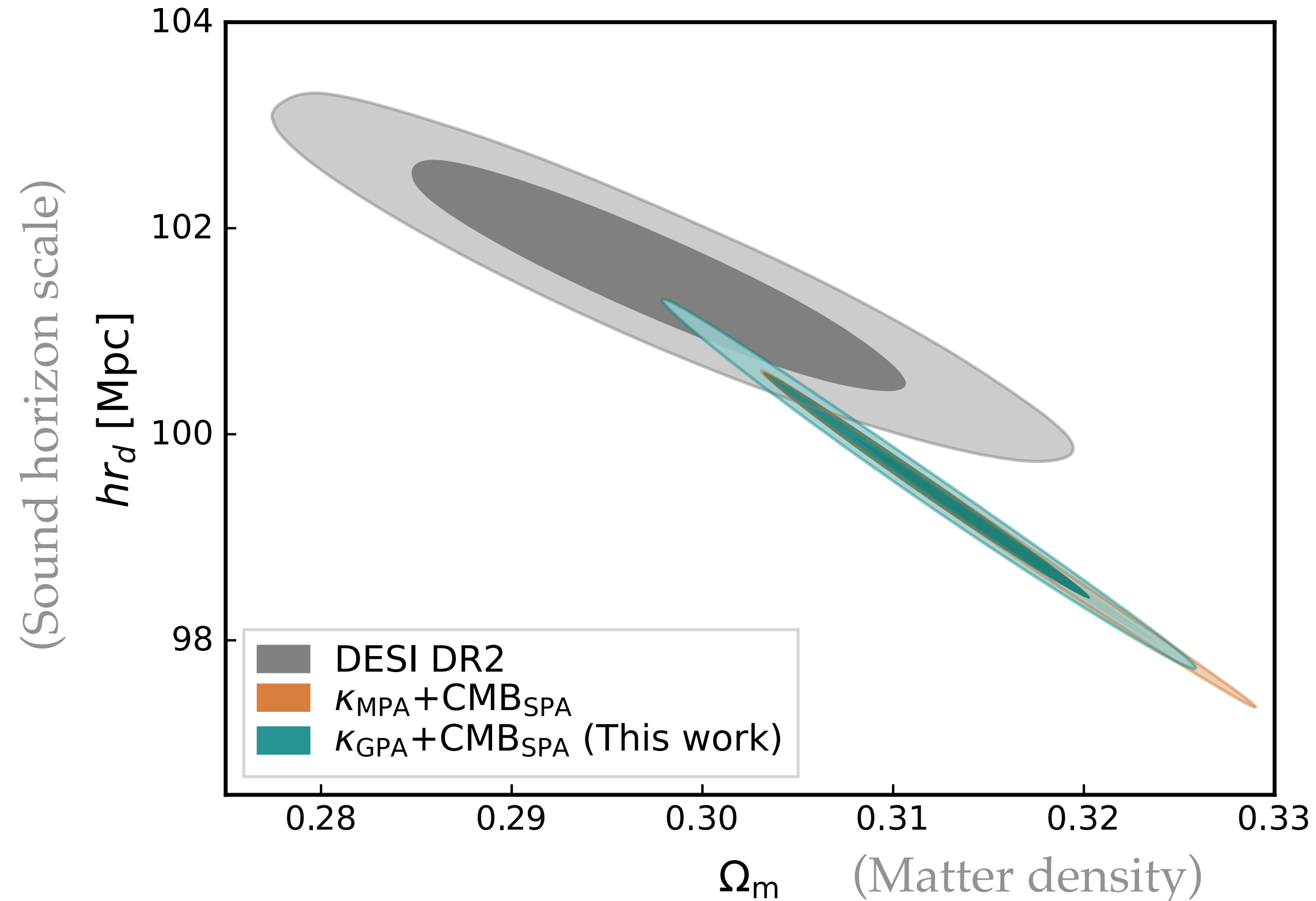


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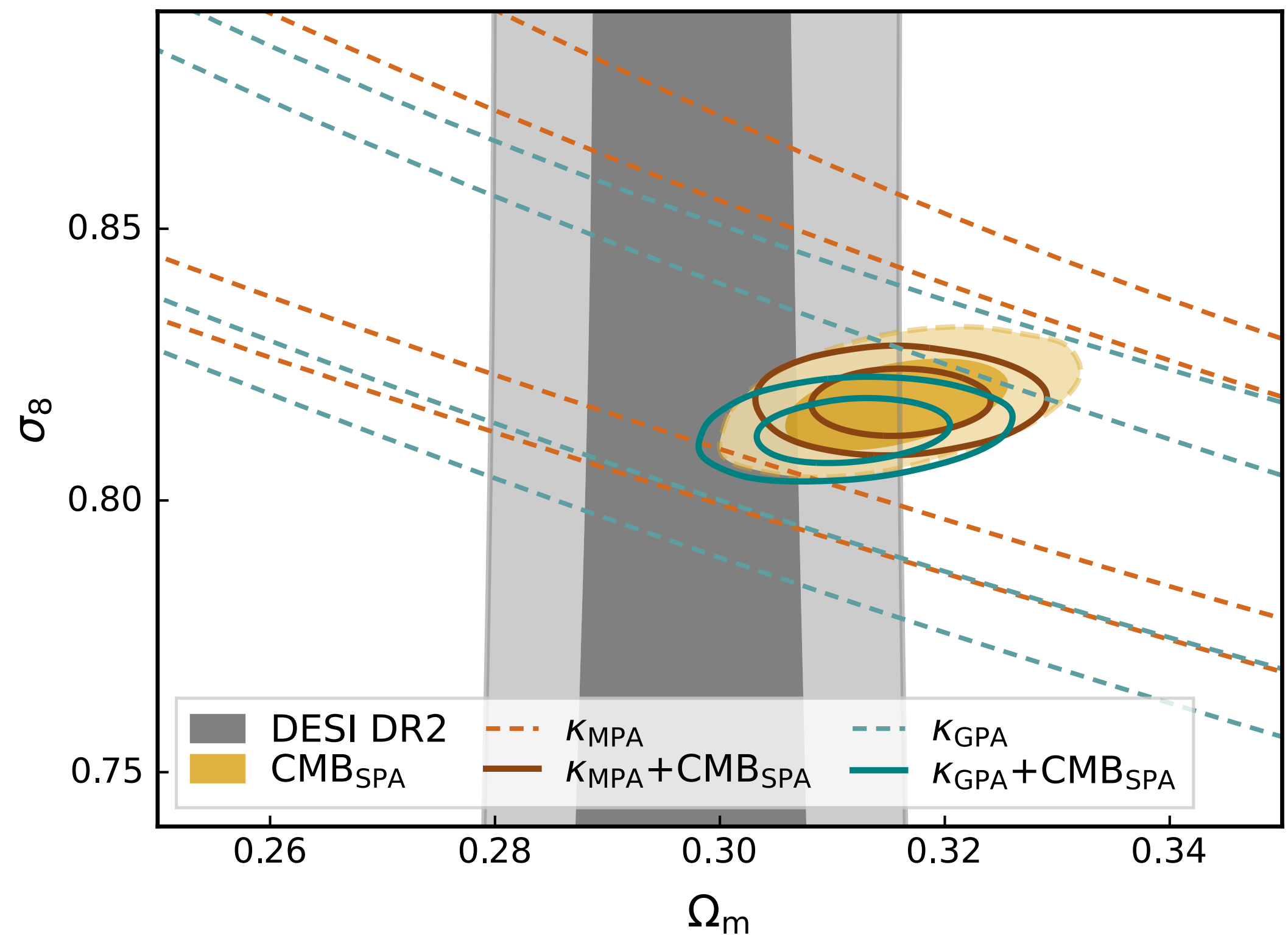
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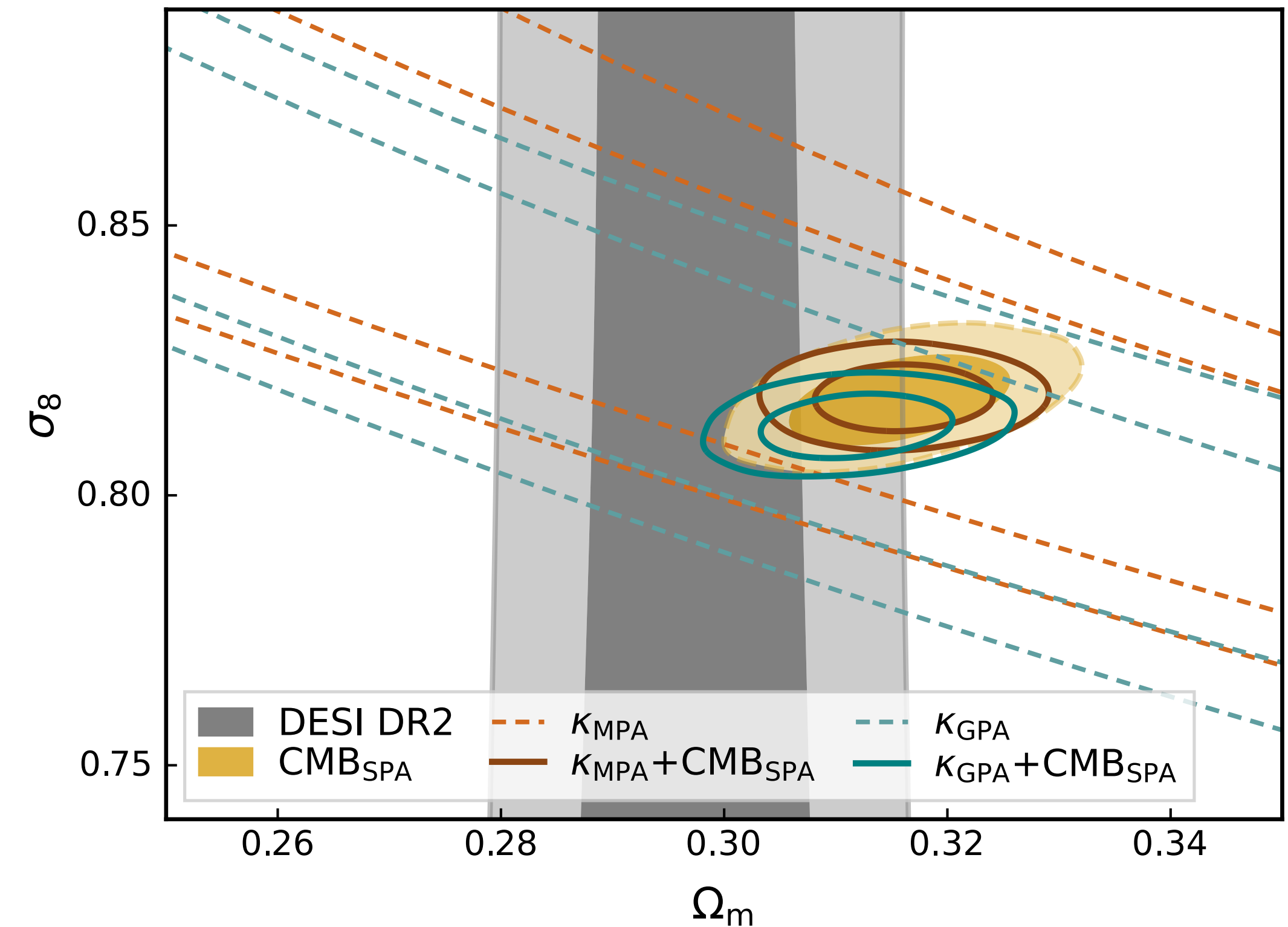
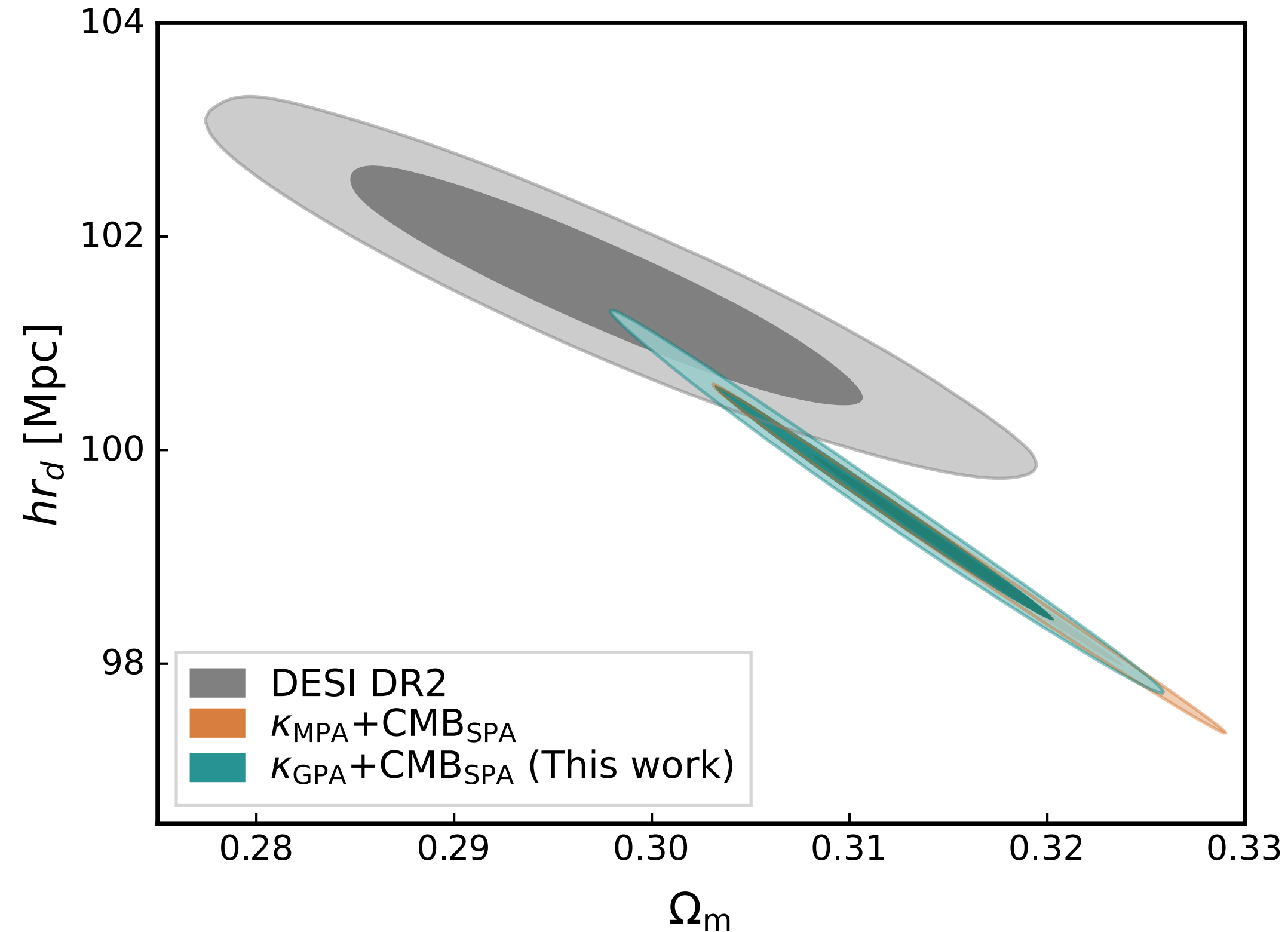
Distance now at 1.9σ in $hr_d - \Omega_m$ plane between DESI BAO and CMB + CMB Lensing (teal)



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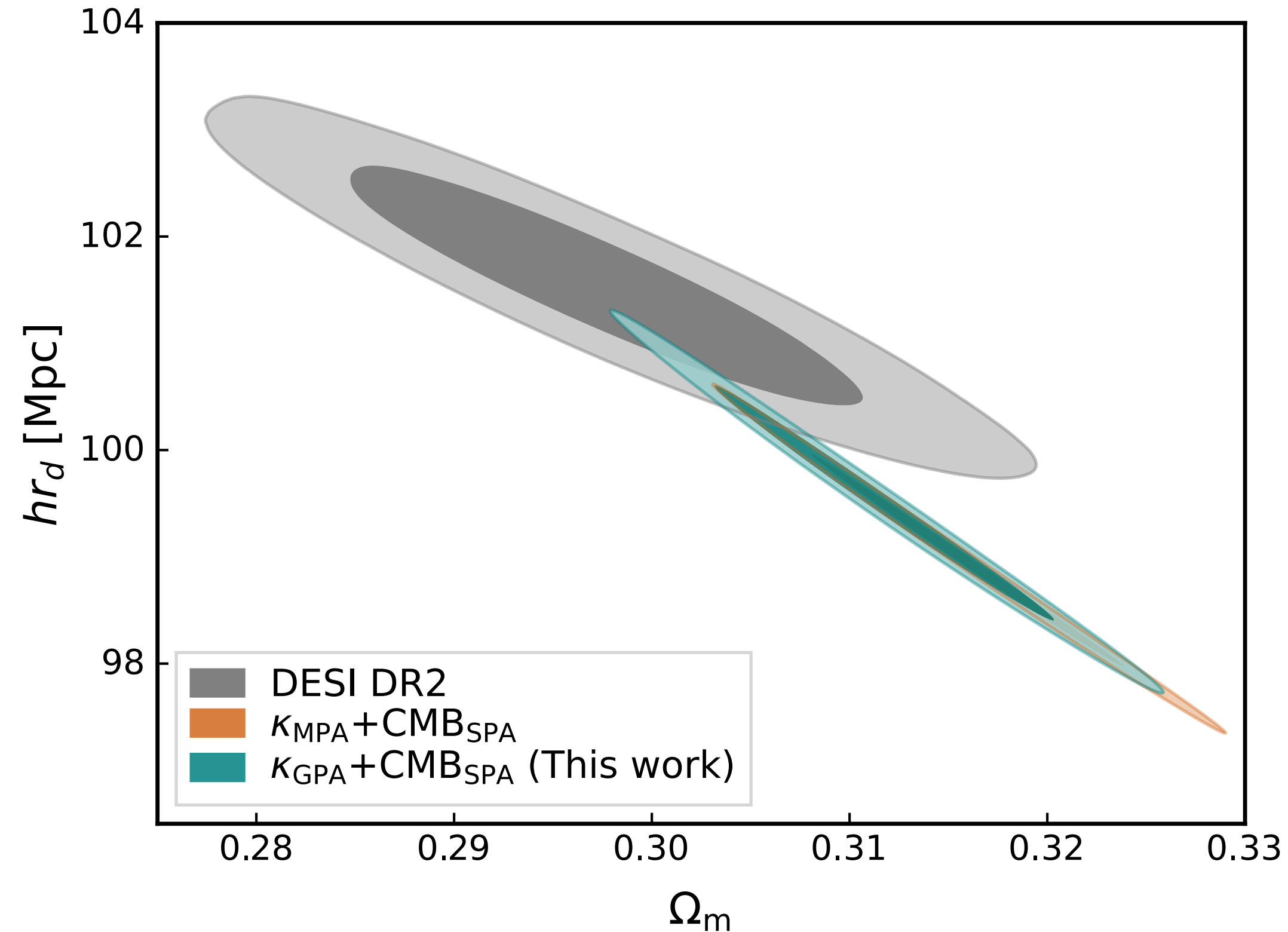
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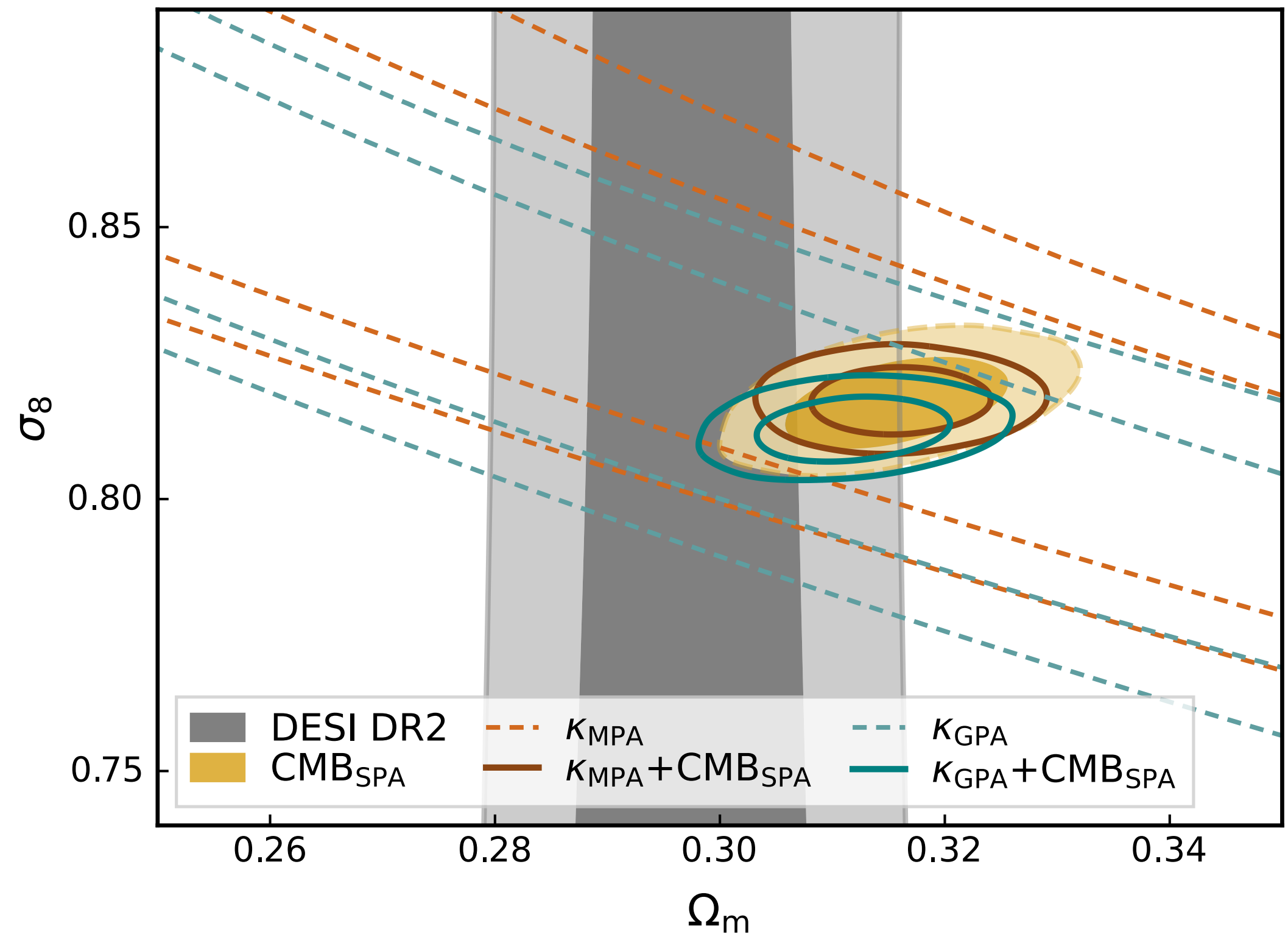


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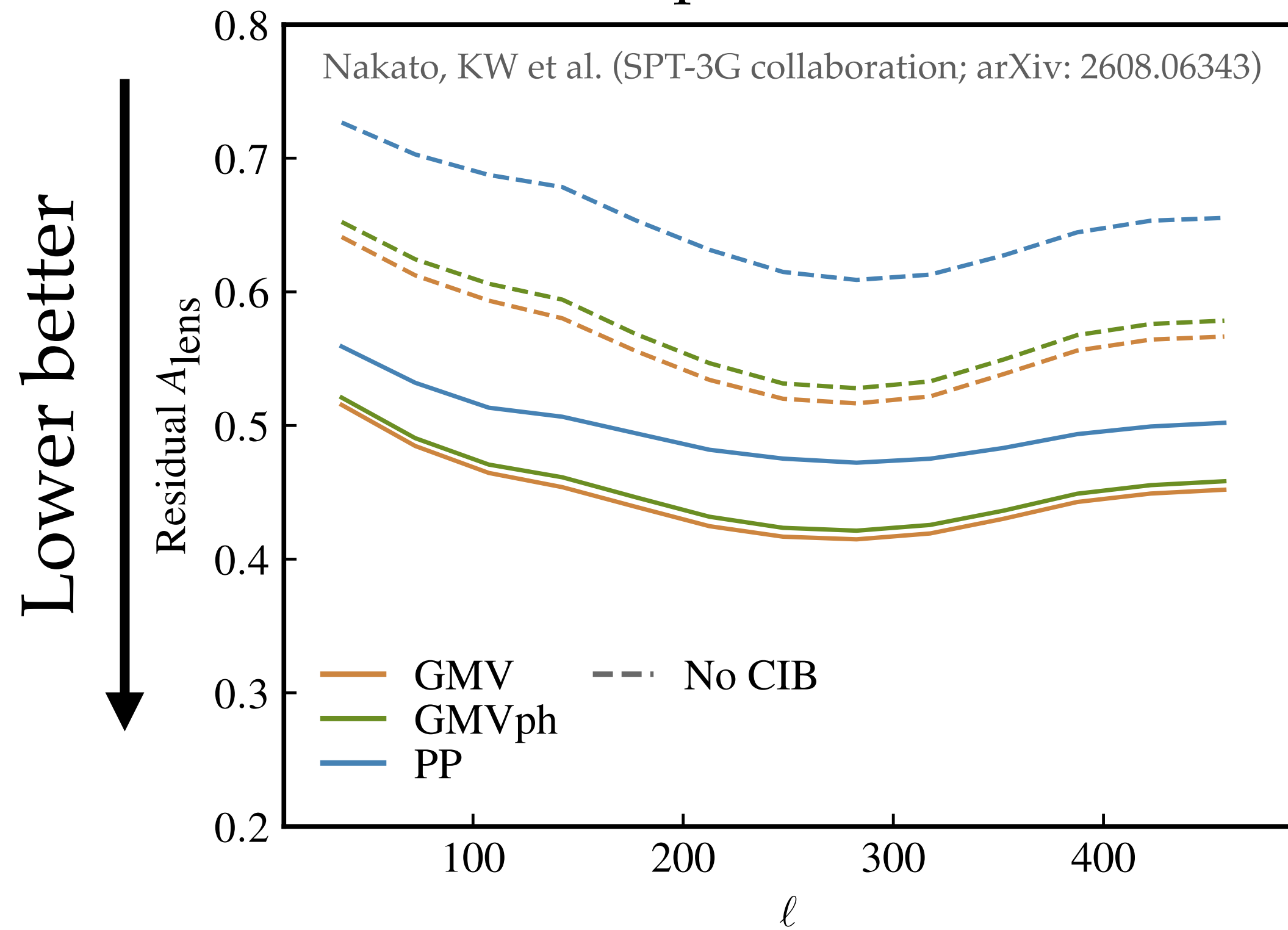


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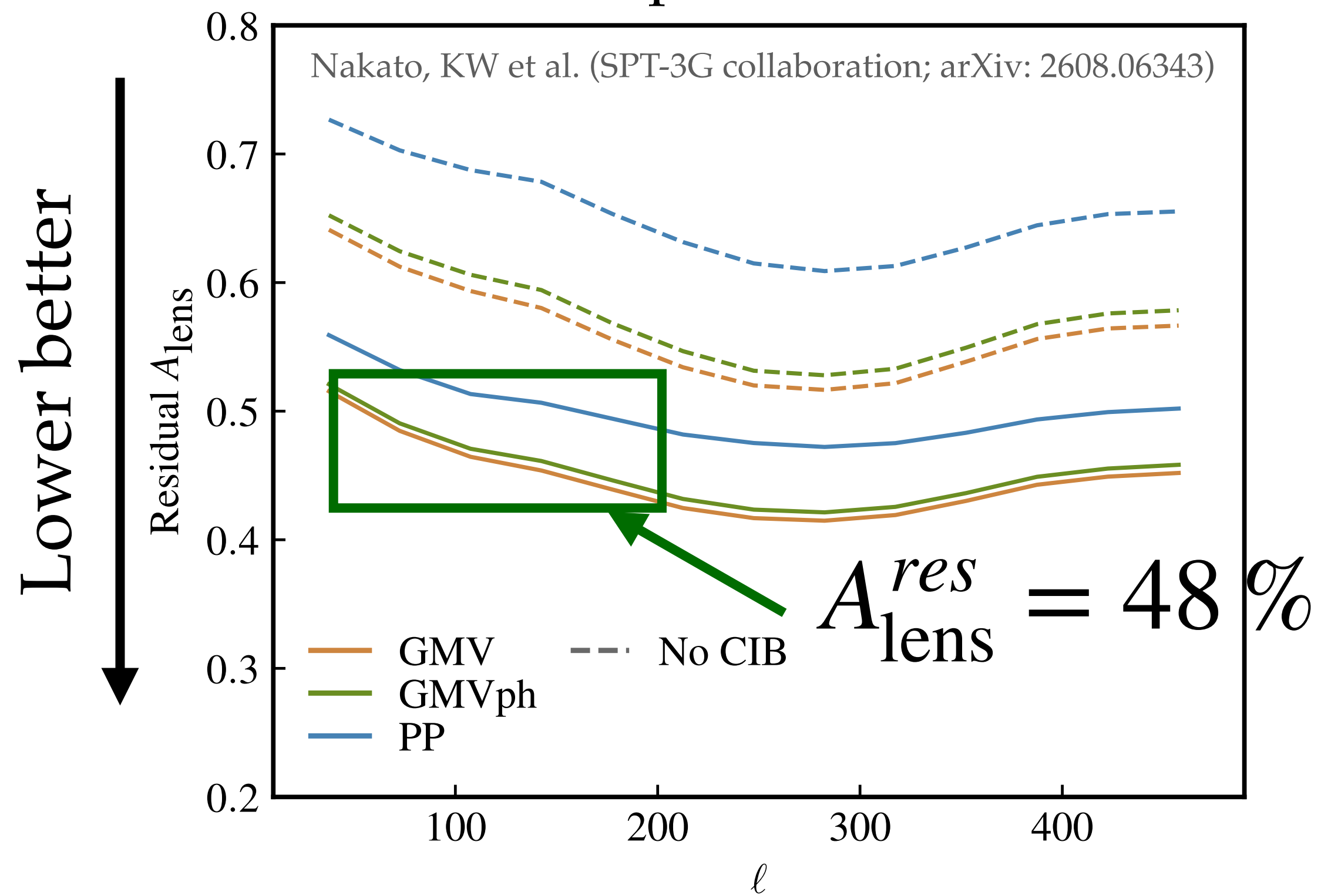
Delensing already making a
difference for r

Highest delensing-efficiency
template to date



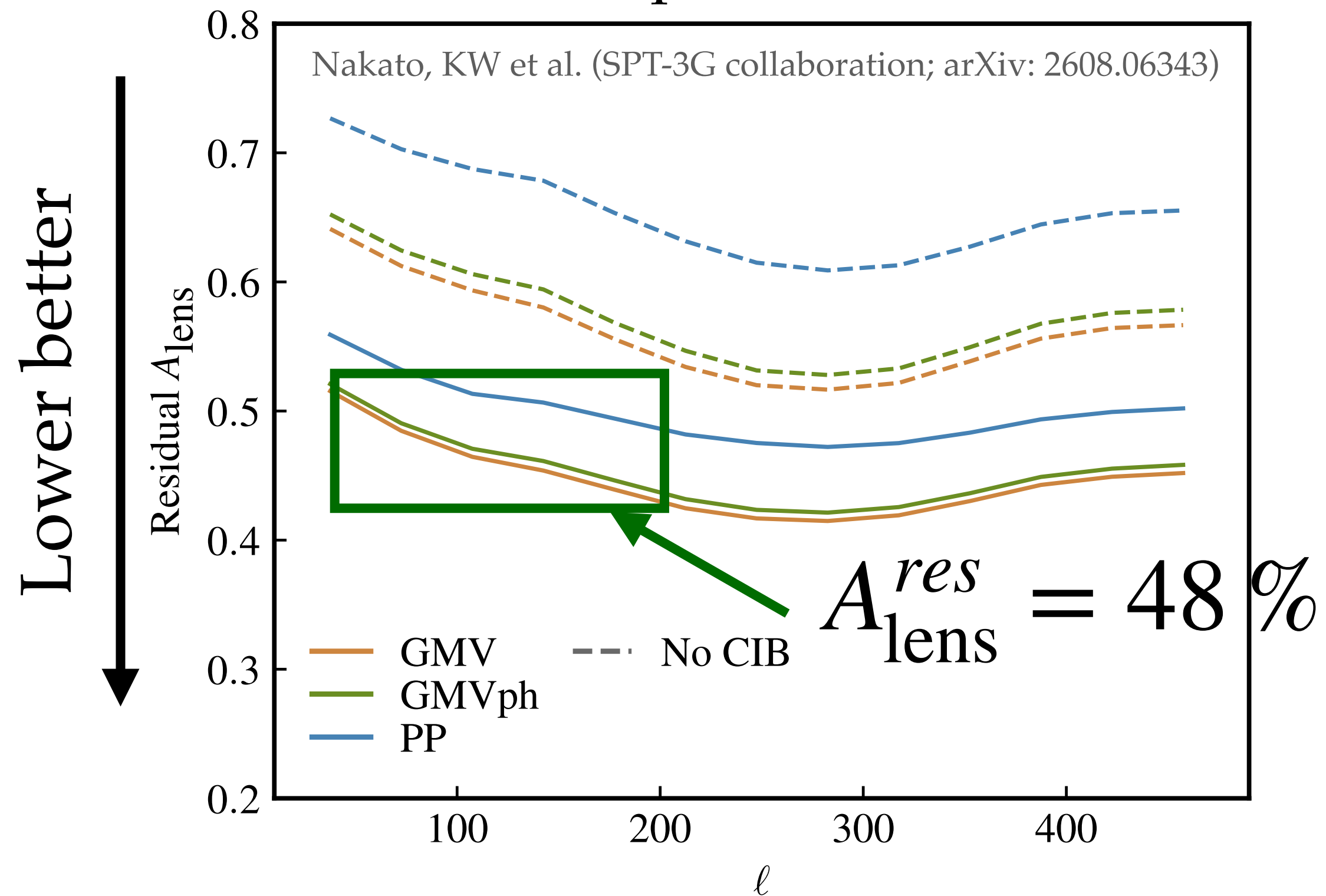
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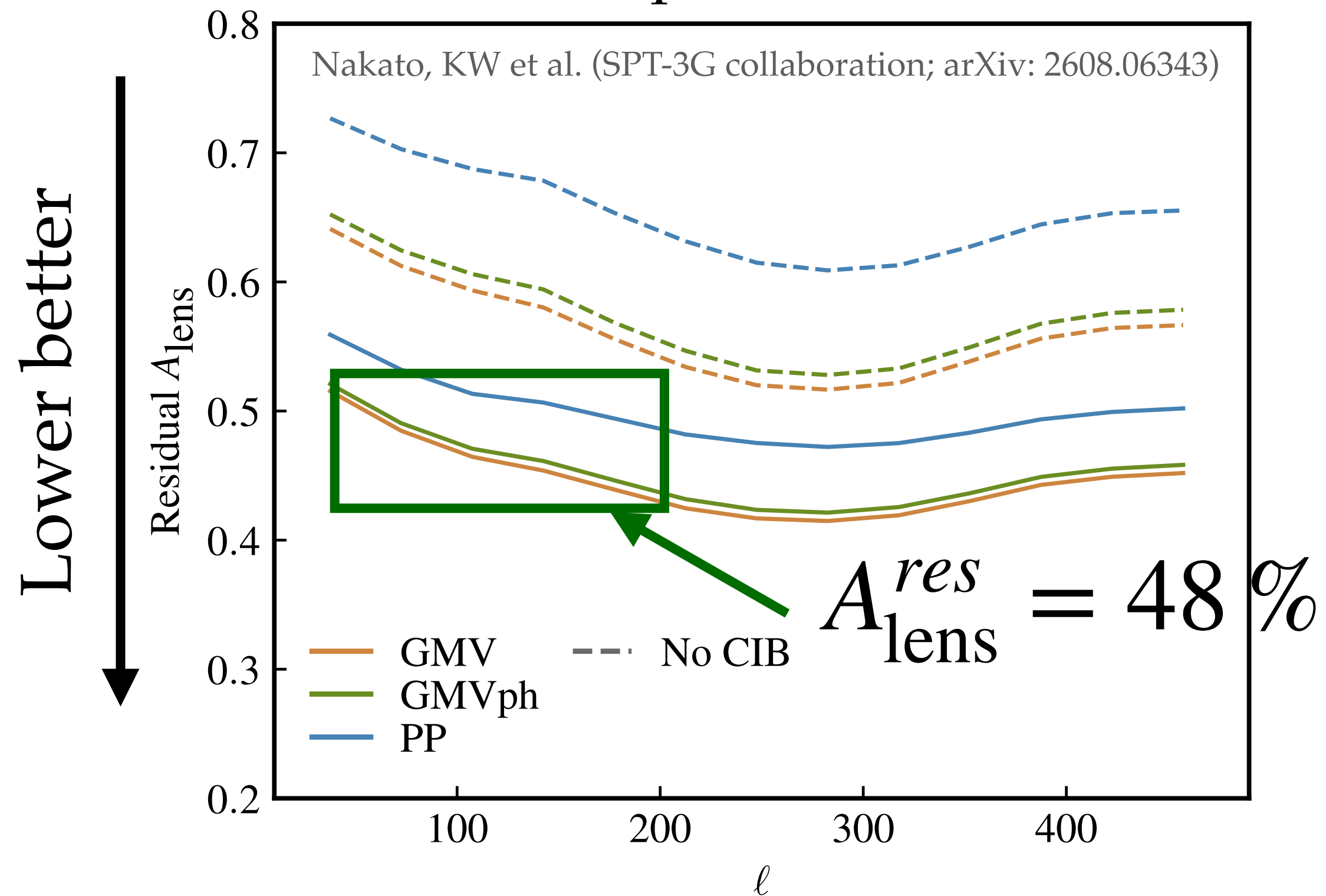


If delensing most recent BICEP dataset, improve $\sigma(r)$ by $\sim 29\%$. Larger fractional improvement for upcoming SPO r result.

Delensing already making a difference for r

Need large sky+deep maps
(like from CMB Probe+) to improve N_{eff}

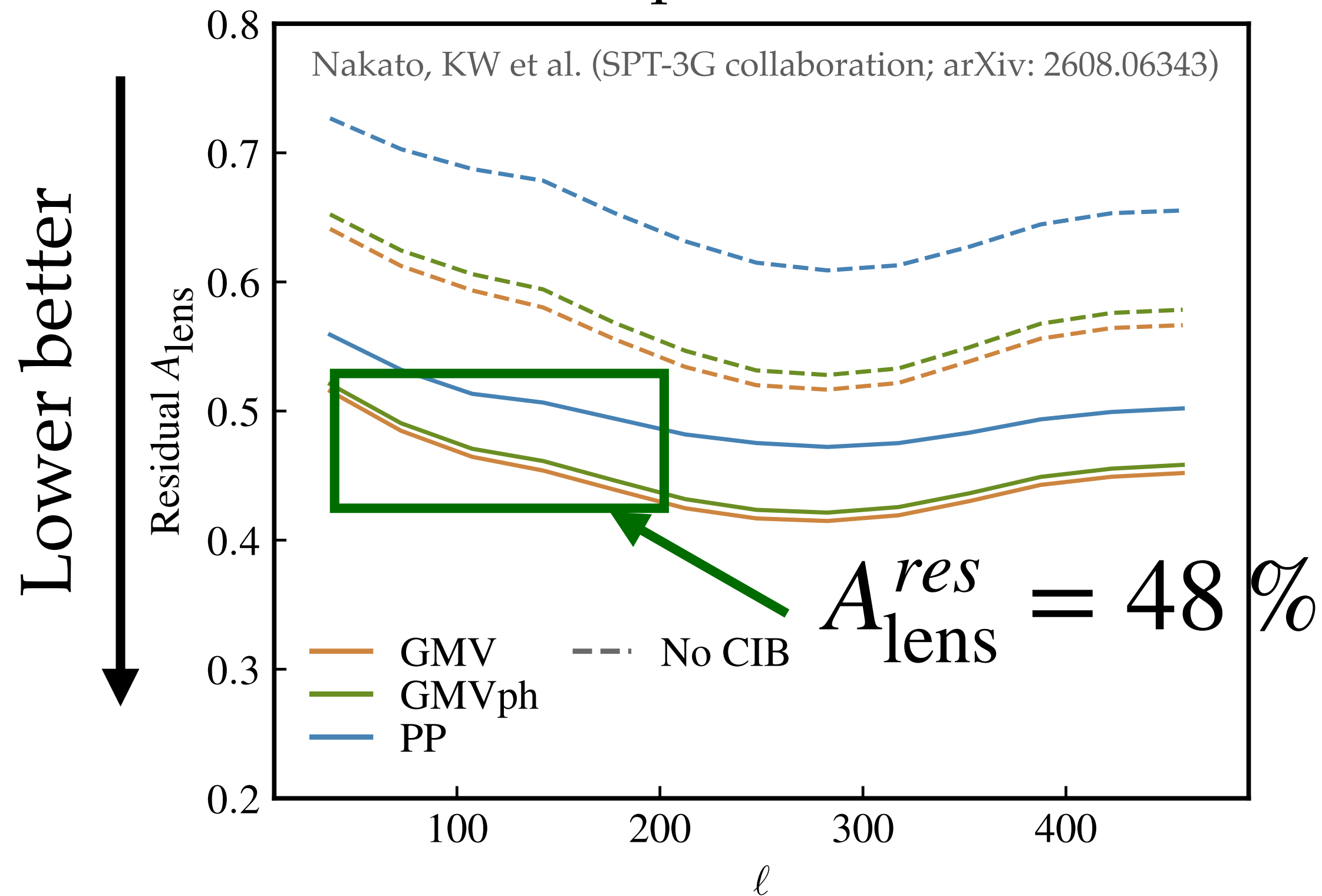
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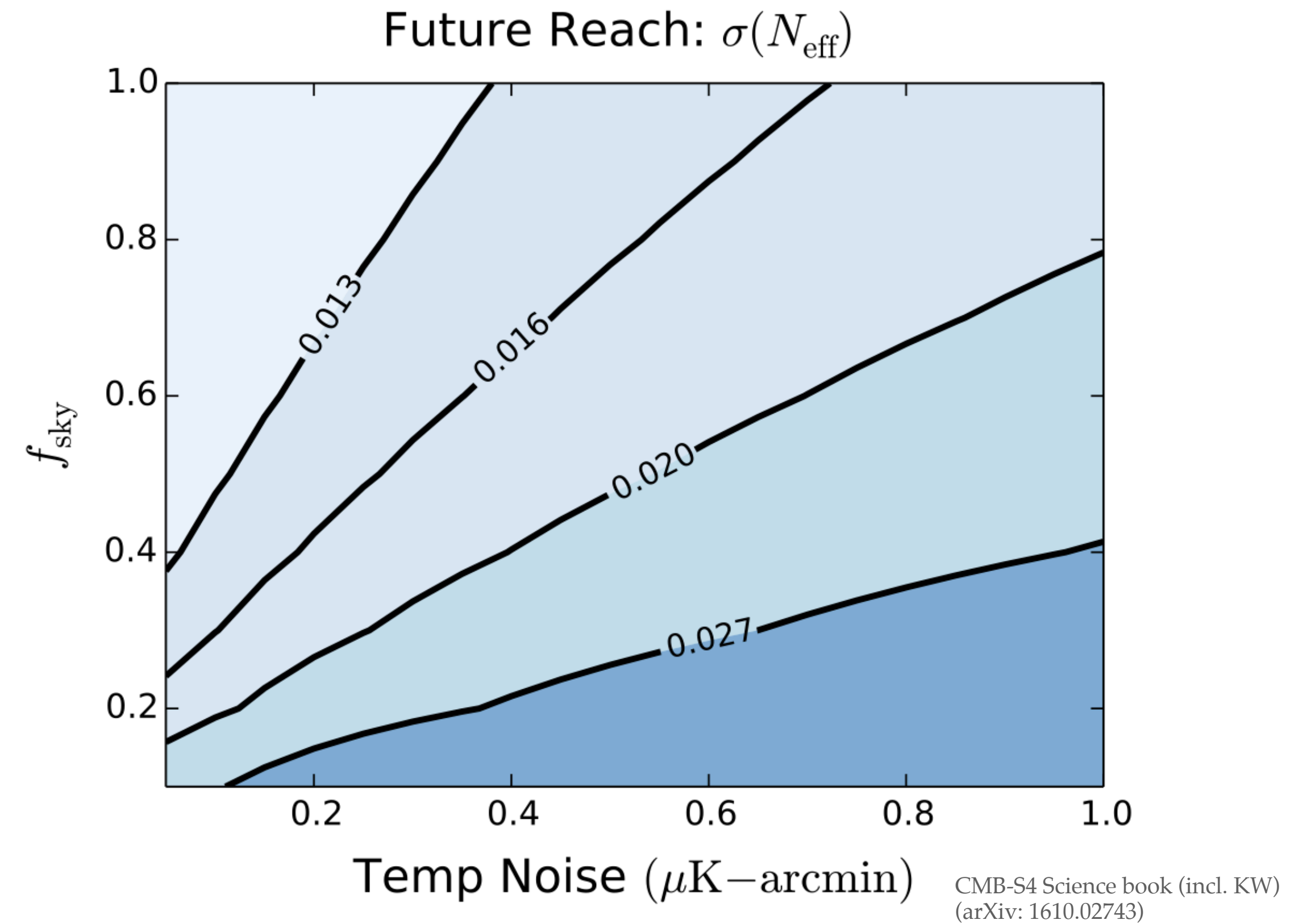
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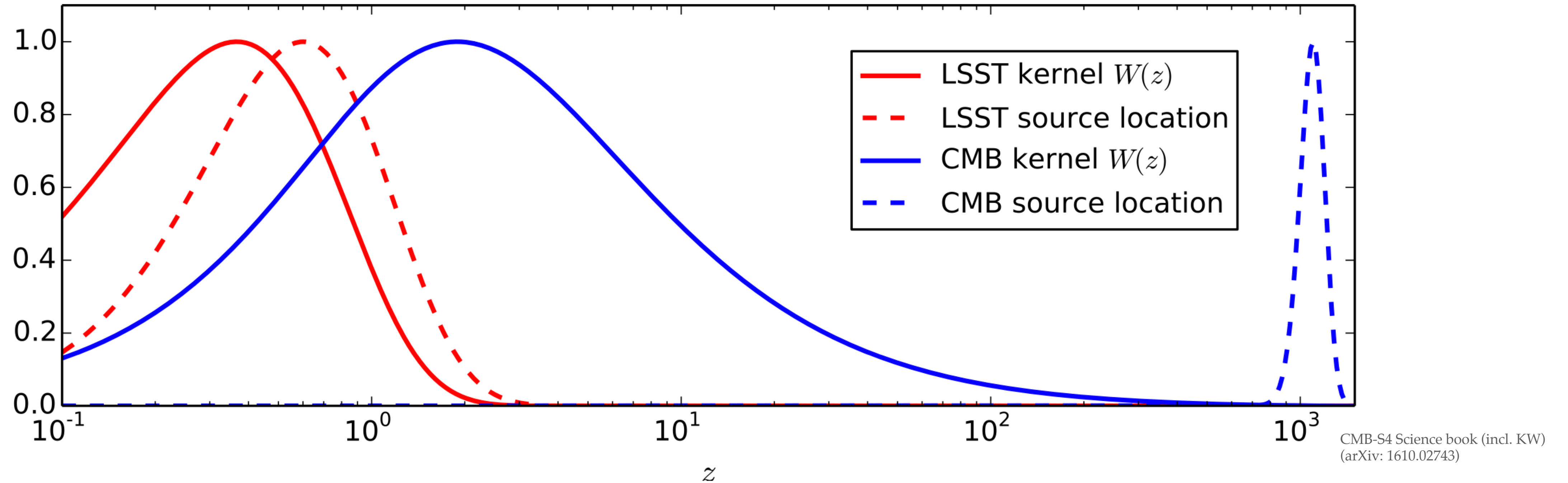
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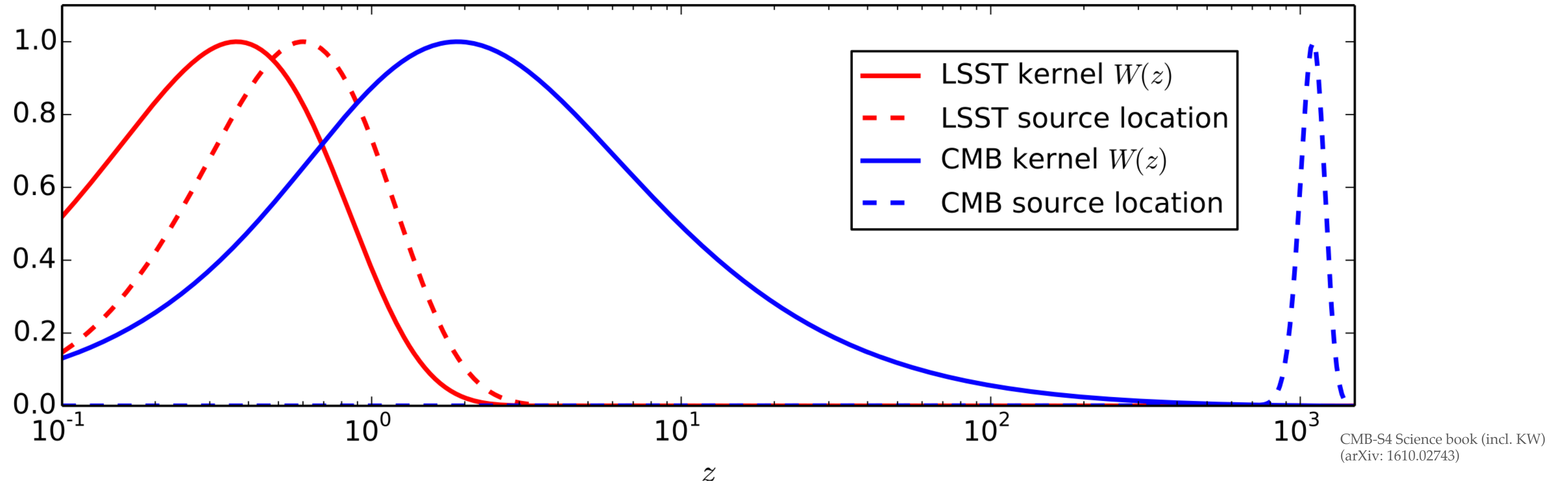
For relevant constraints on N_{eff} , we need large sky, deep maps, small beams.

Full-sky high SNR per-mode lensing map will enable plethora of science



- CMB lensing redshift kernel reaches reionization and beyond $\rightarrow$ a clean probe to anchor other biased tracer of LSS.
- Probe for f_{NL} , axions, neutrinos, modified gravity from auto-spectrum and/or cross-correlations.

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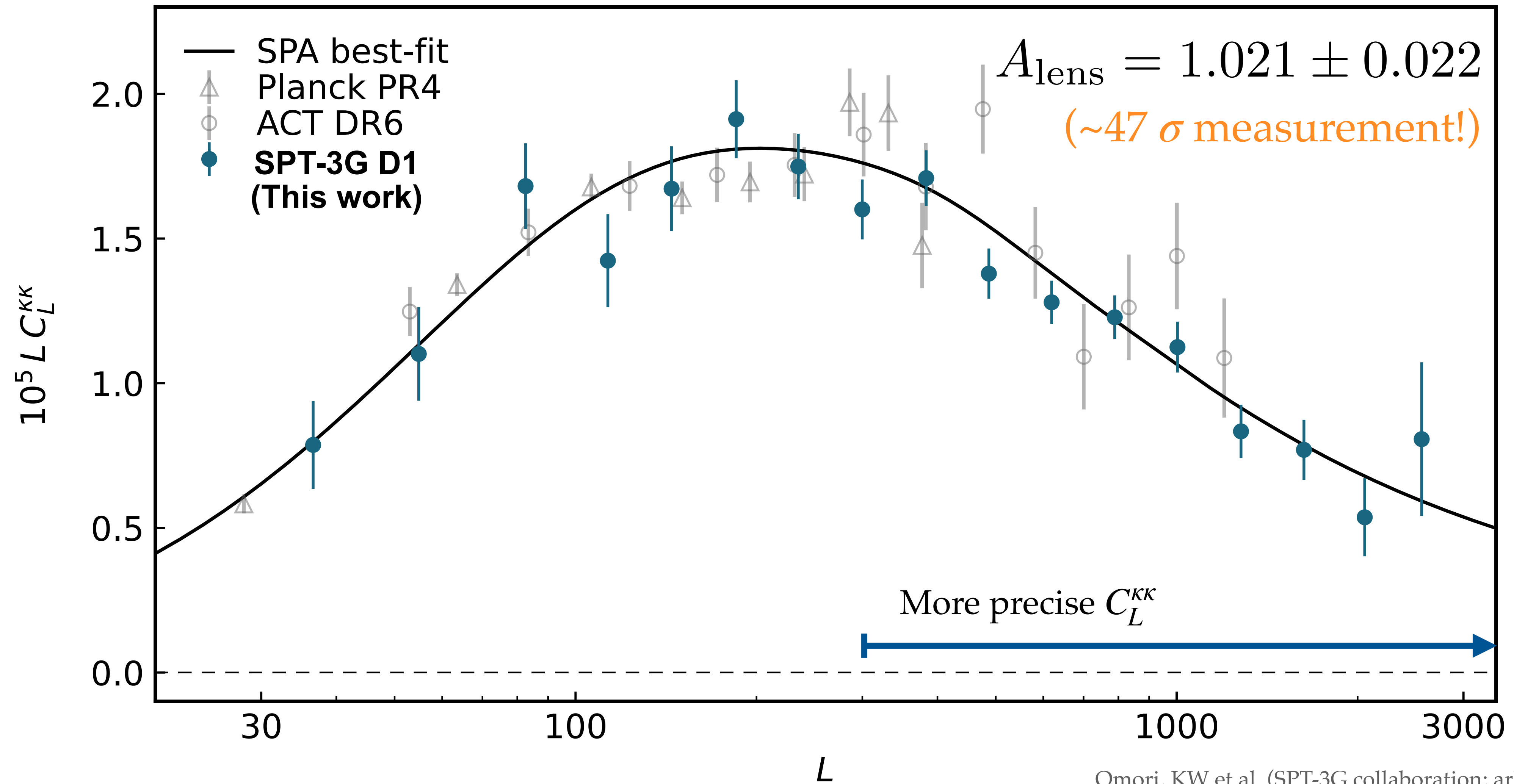
Summary

- CMB lensing went from first detection to a precision cosmology probe in the last ~ 15 years.
- At $\sim 60\sigma$, CMB lensing push/pull distance from DESI BAO when combined with primary CMB. Deep CMB lensing measurements is already enabling efficient delensing for r today.
- CMB Probe+ will provide lensing spectrum measurements at hundreds of σ , with high SNR per-mode, probing beyond mildly non-linear scales, and full-sky coverage.
- In addition to the new physics CMB lensing itself can probe, these future lensing measurements will enable exciting science across multiple scales and redshifts in cross-correlation with other tracers of LSS.

Background: new CMB lensing map using SPT-3G data
Omori, KW et al. (SPT-3G collaboration; arXiv: 2608.31136)

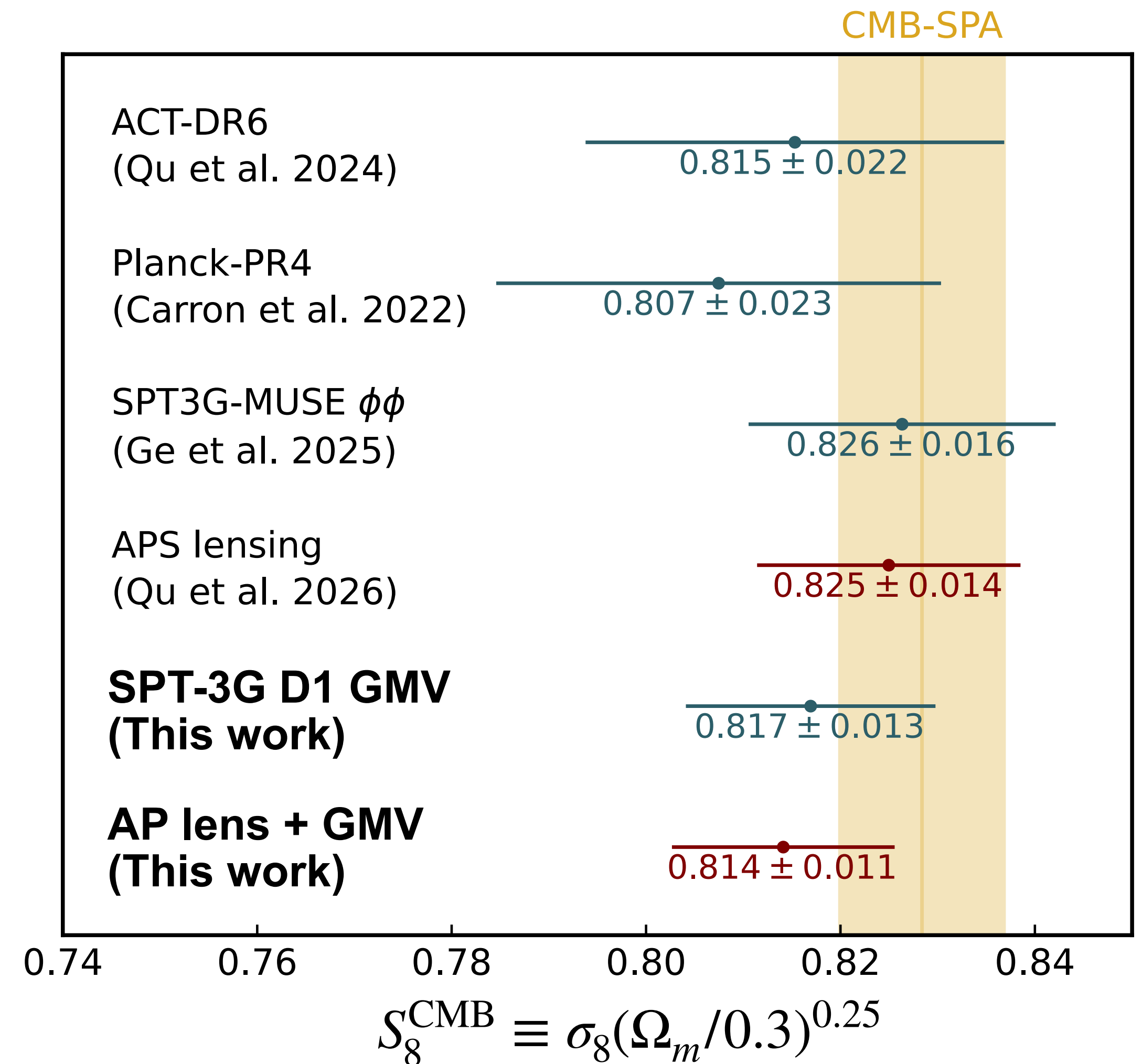
Extras

Like primary CMB measurements, SPT-3G lensing bandpowers complement those from Planck and ACT



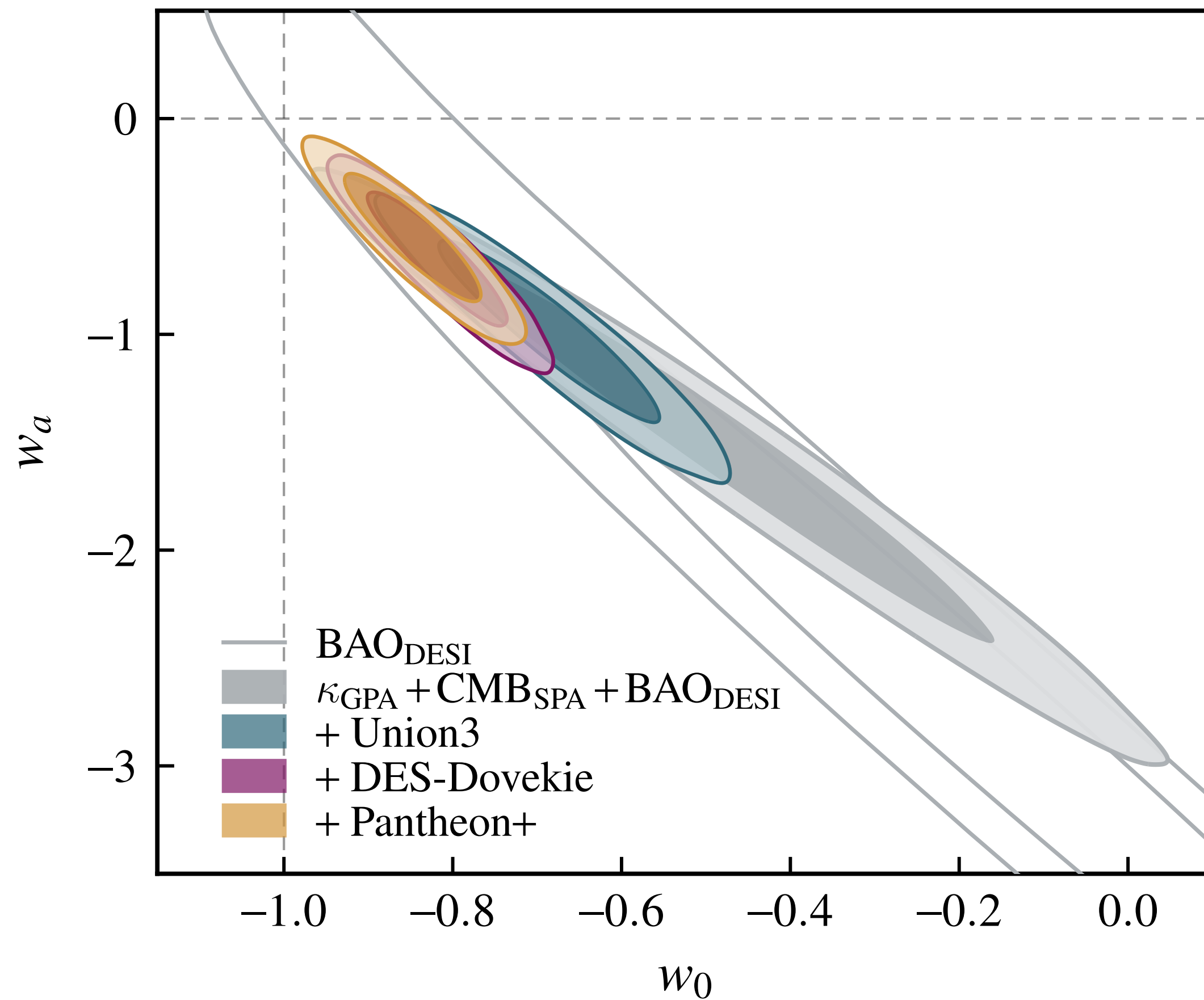
Results: 1.4% measurement of $\sigma_8 \Omega_m^{0.25}$

- CMB lensing best constrains the parameter combination $\sigma_8 \Omega_m^{0.25}$.
- SPT-3G D1 GMV provides tightest $\sigma_8 \Omega_m^{0.25}$ measurement from CMB lensing to date.
- Combining Planck, ACT, and SPT-3G GMV lensing, uncertainty on $\sigma_8 \Omega_m^{0.25}$ is on par with *Planck's* primary CMB ($\sim 1.4\%$)



Omori, KW et al. (SPT-3G collaboration; arXiv: 2608.31136)

$w_0 w_a$ CDM



Deviation of $(w_0, w_a) \neq (-1, 0)$:

CMB+BAO (2.1σ)

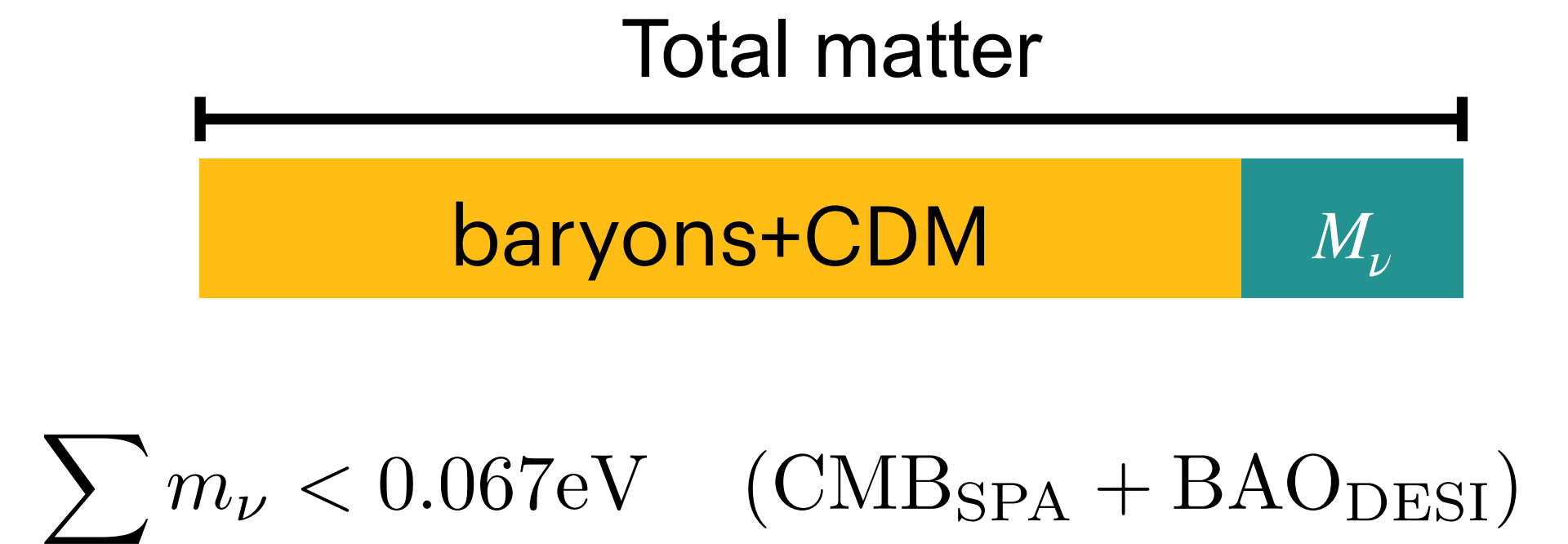
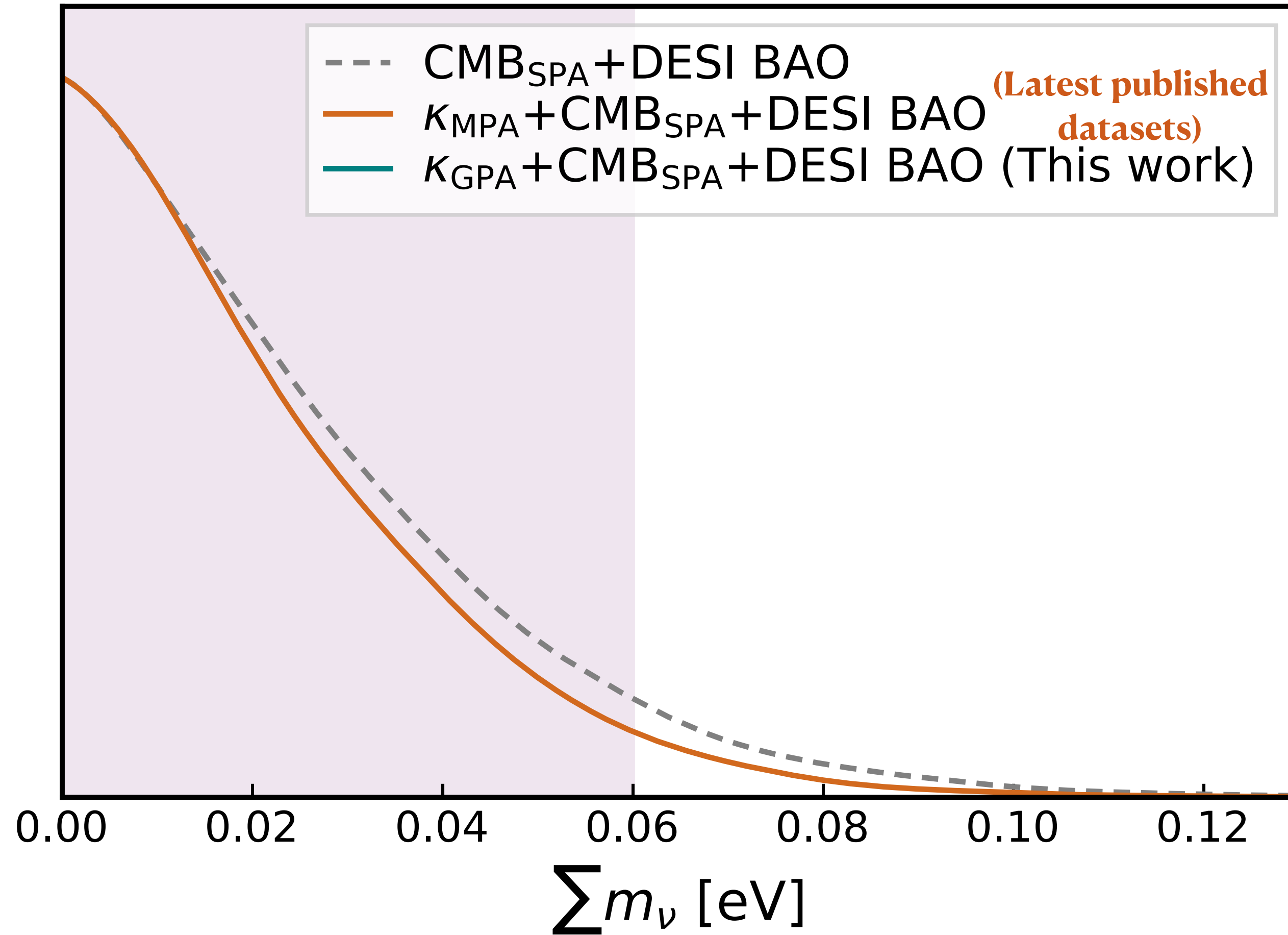
- + Pantheon+ (2.5σ)

- + DES-Dovekie (2.9σ)

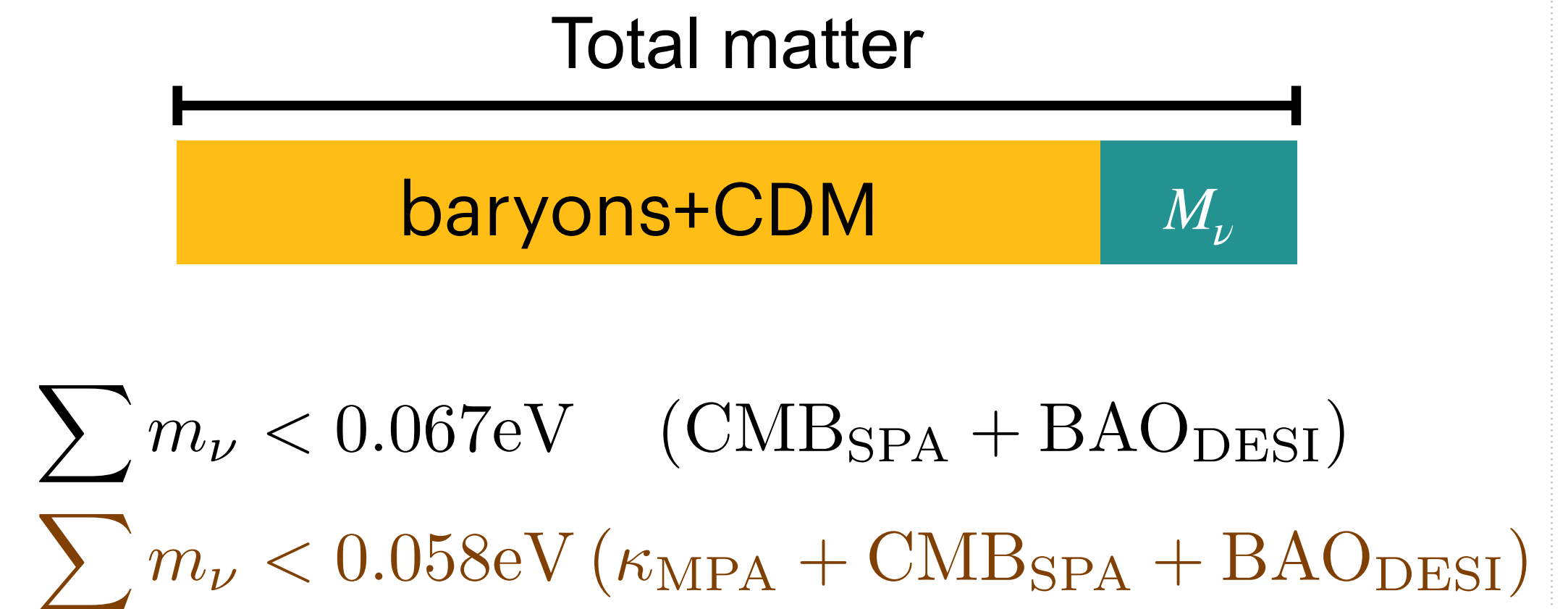
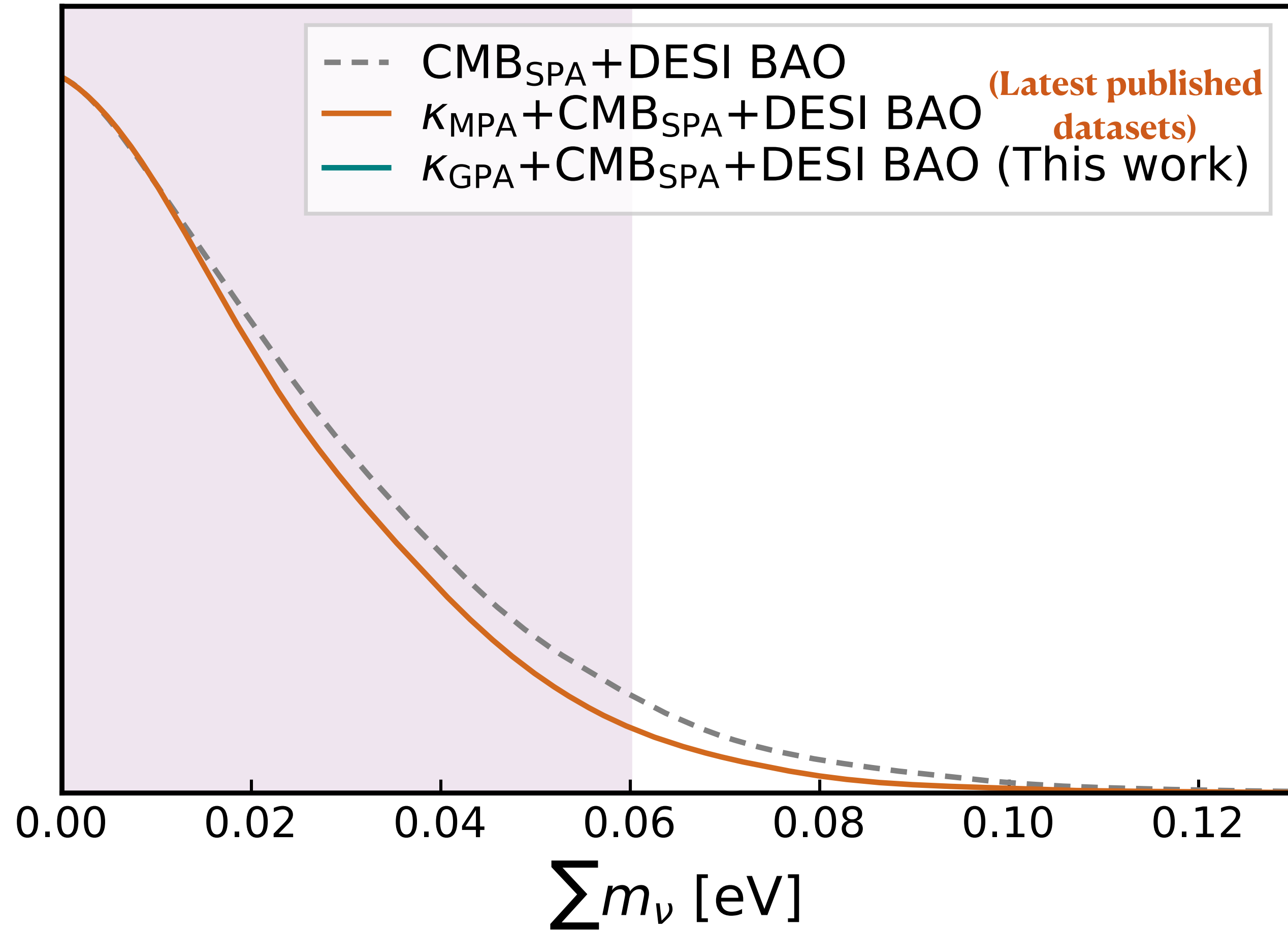
- + Union3 (3.3σ)

Omori, KW et al. (SPT-3G collaboration; arXiv: 2608.31136)

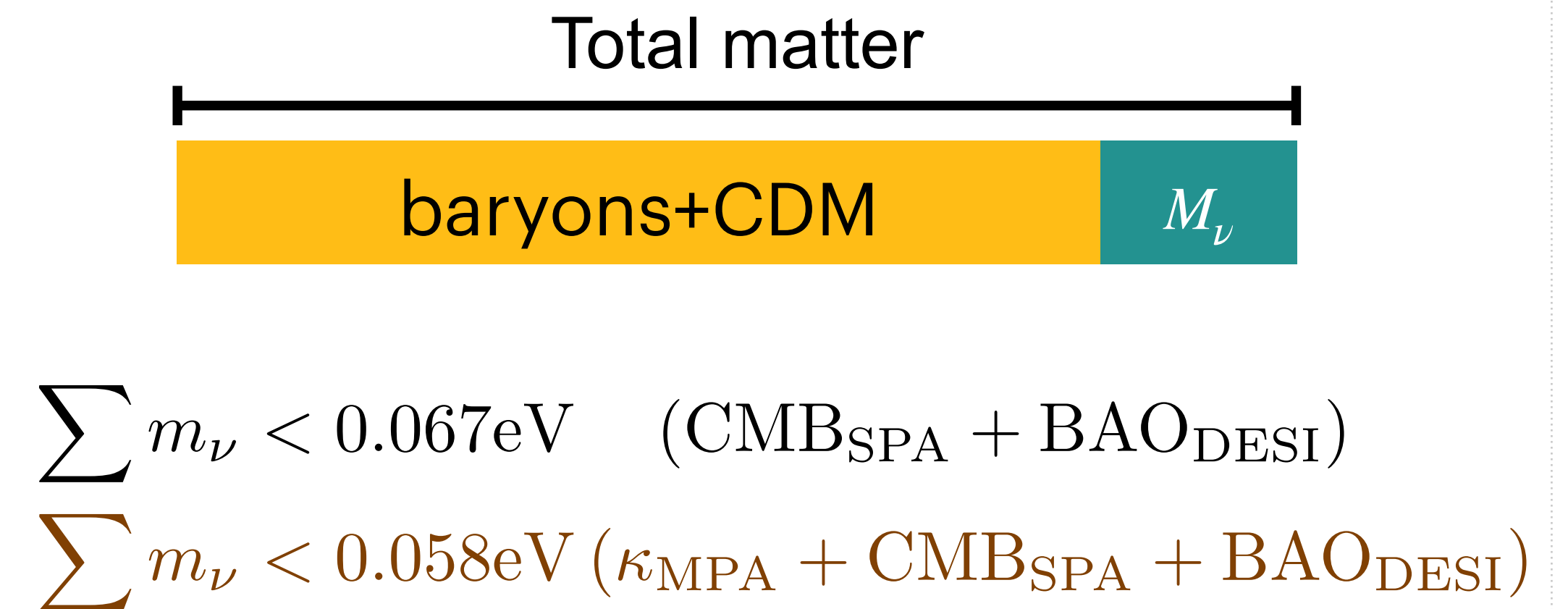
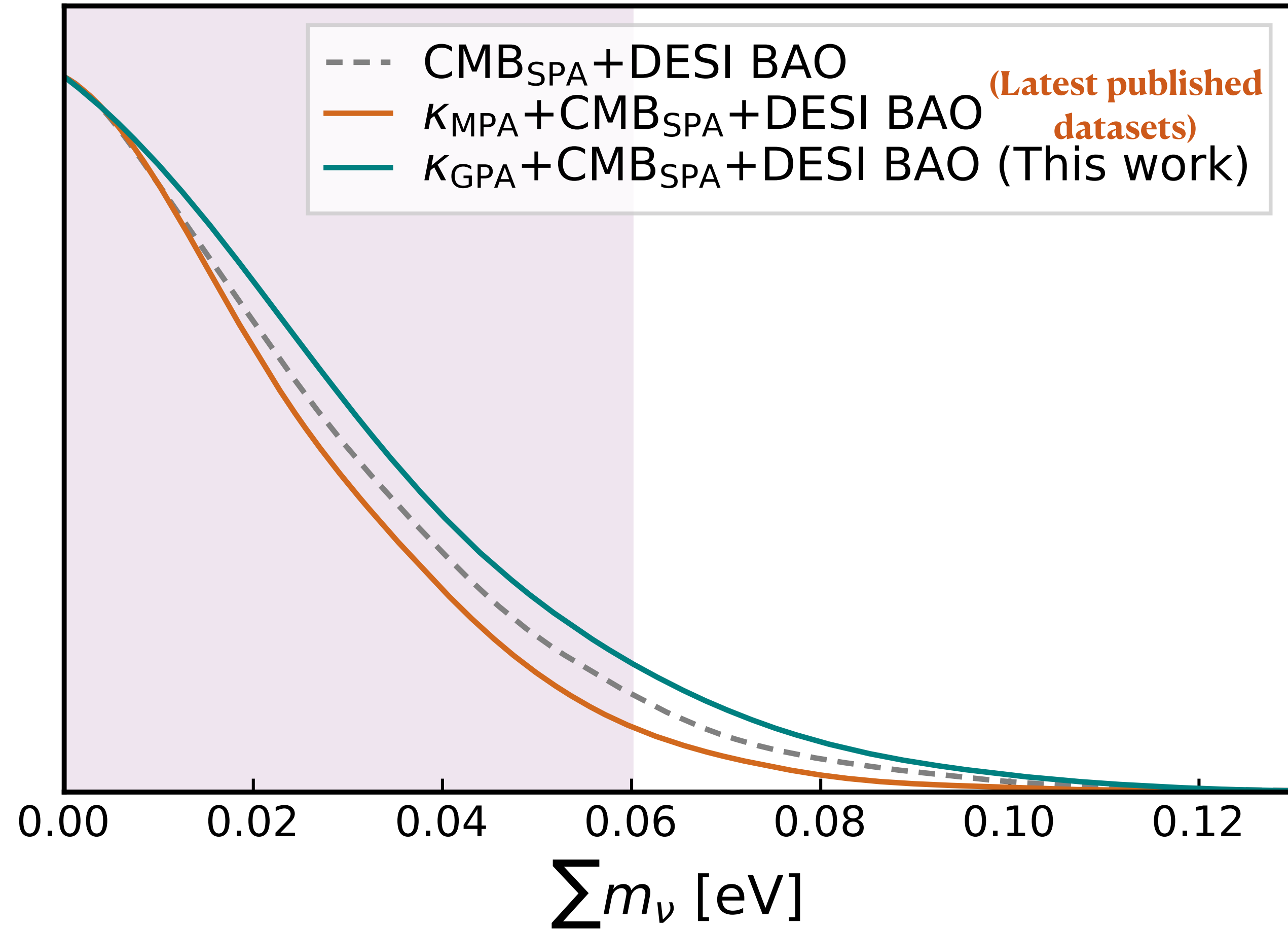
How does neutrino mass sum shift?



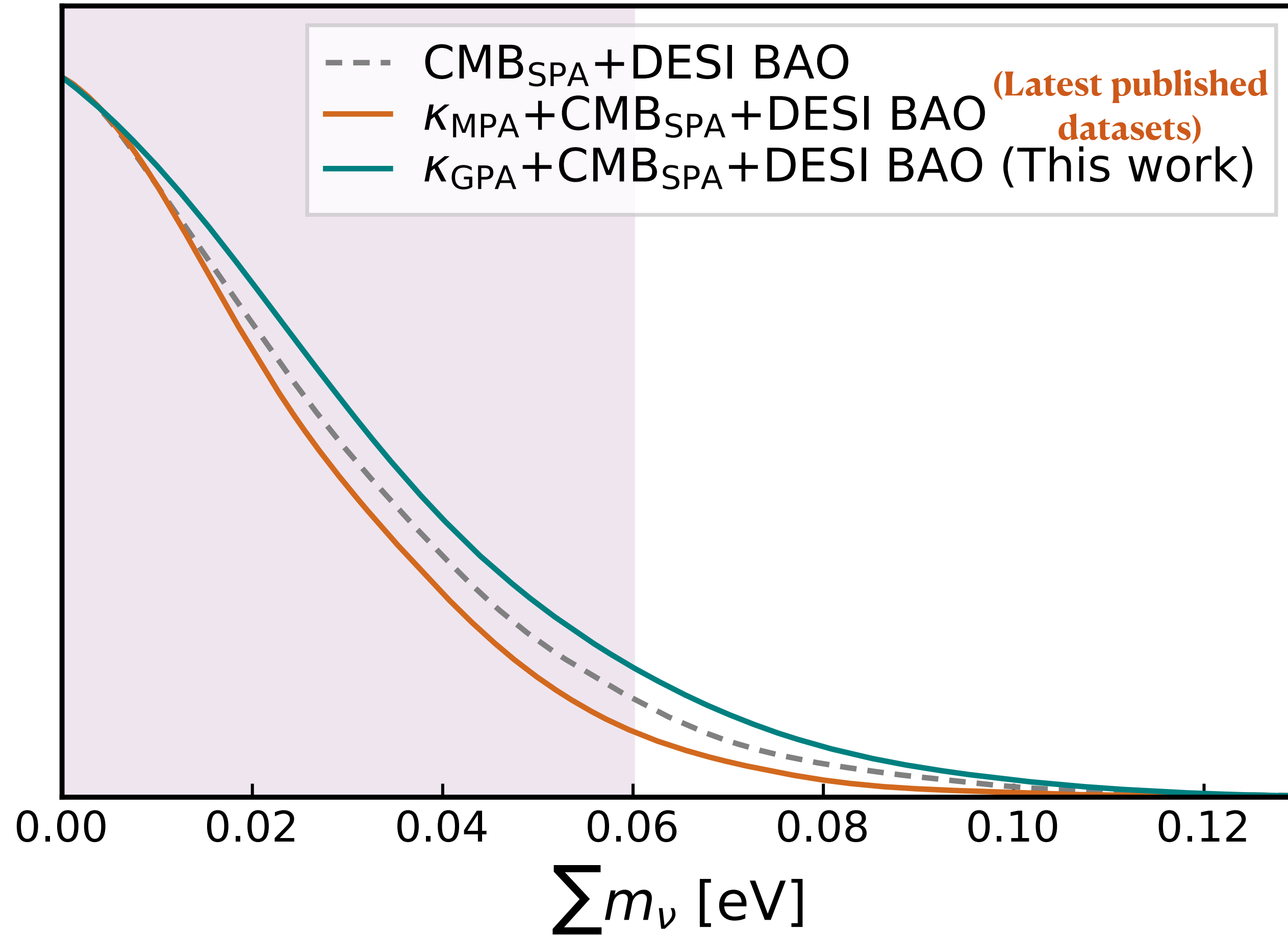
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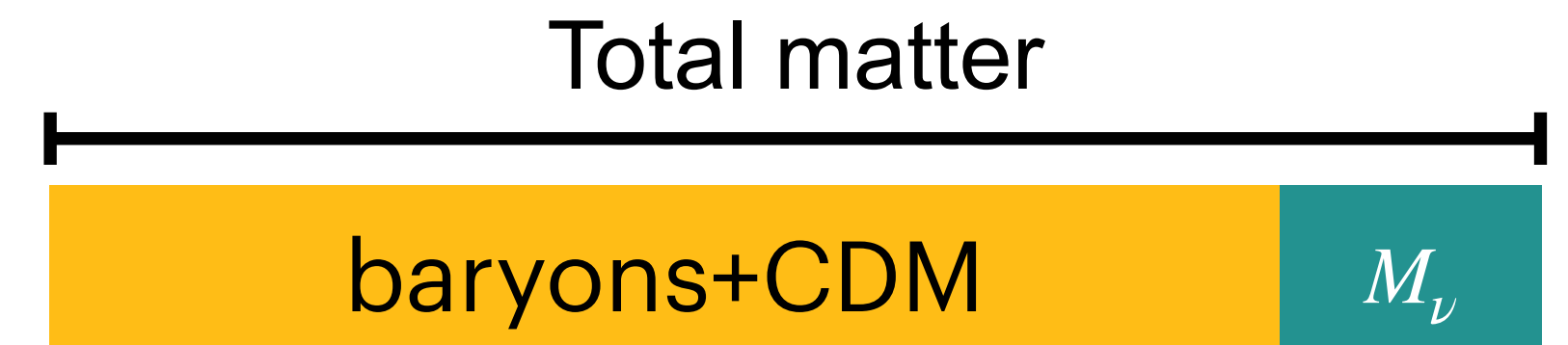
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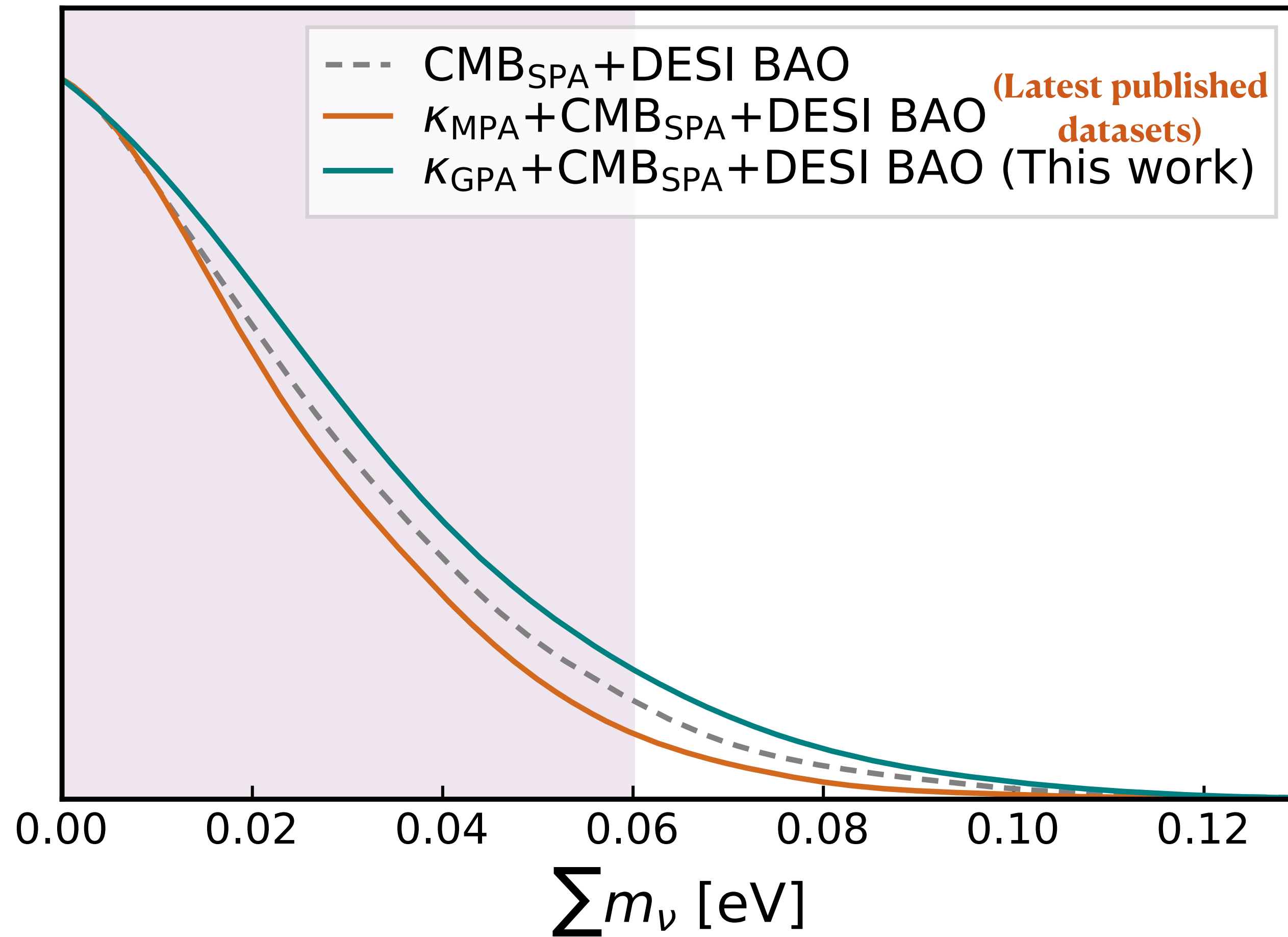


$$\sum m_\nu < 0.067\text{eV} \quad (\text{CMB}_{\text{SPA}} + \text{BAO}_{\text{DESI}})$$

$$\sum m_\nu < 0.058\text{eV} \quad (\kappa_{\text{MPA}} + \text{CMB}_{\text{SPA}} + \text{BAO}_{\text{DESI}})$$

$$\sum m_\nu < 0.072\text{eV} \quad (\kappa_{\text{GPA}} + \text{CMB}_{\text{SPA}} + \text{BAO}_{\text{DESI}})$$

How does neutrino mass sum shift?



Inverted hierarchy isn't as disfavored.



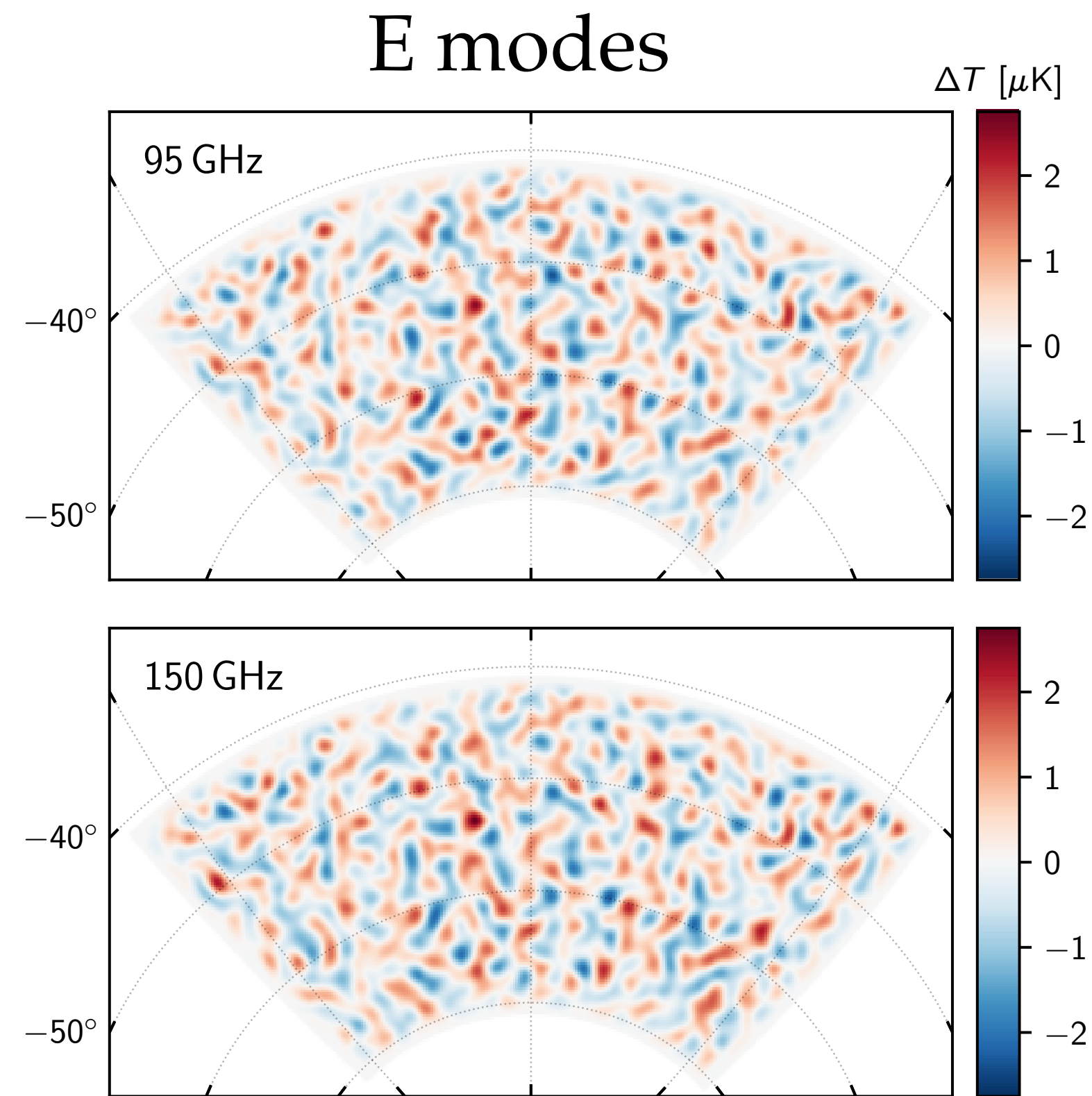
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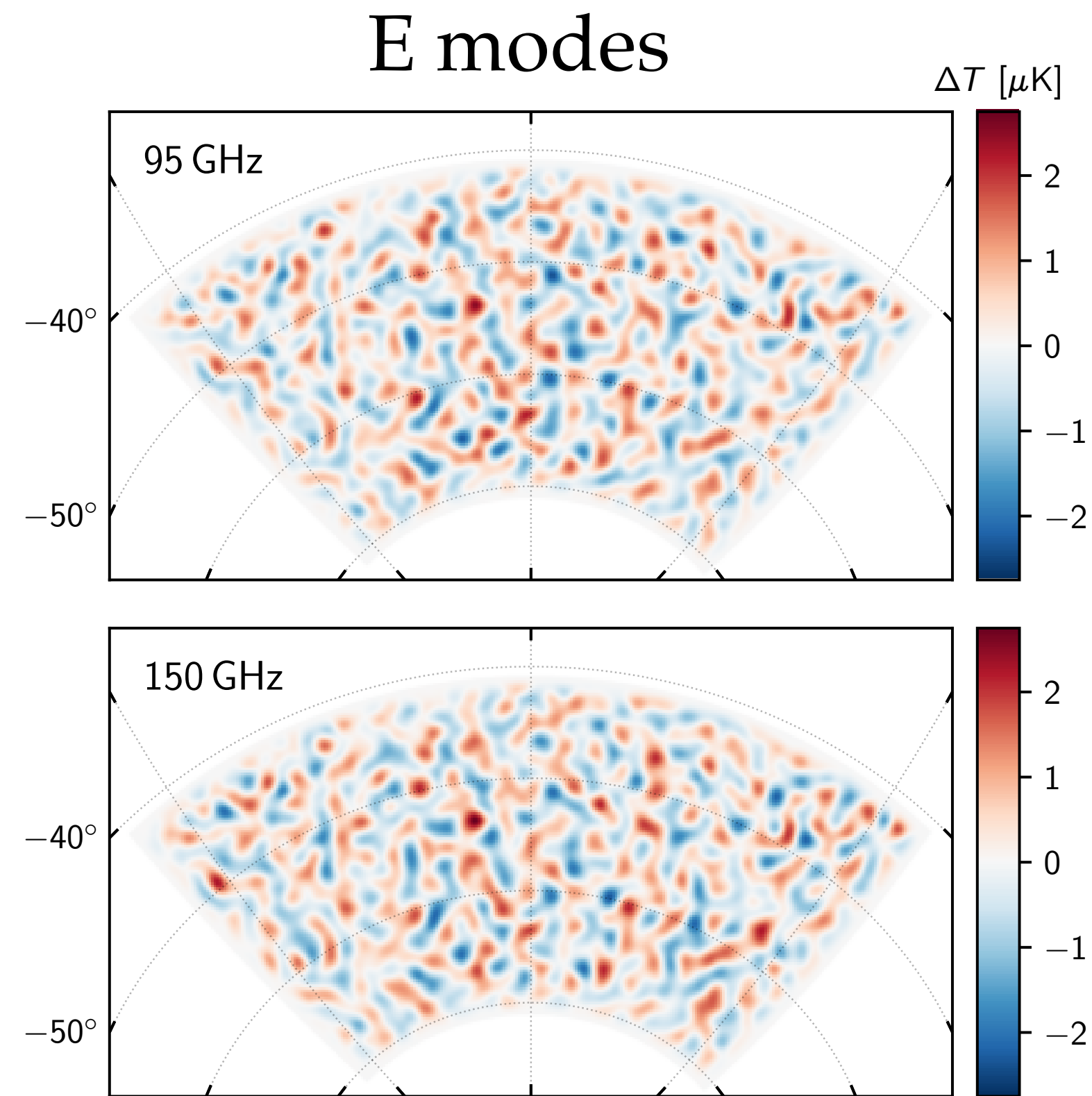
Lens the E modes to get the lensing B modes

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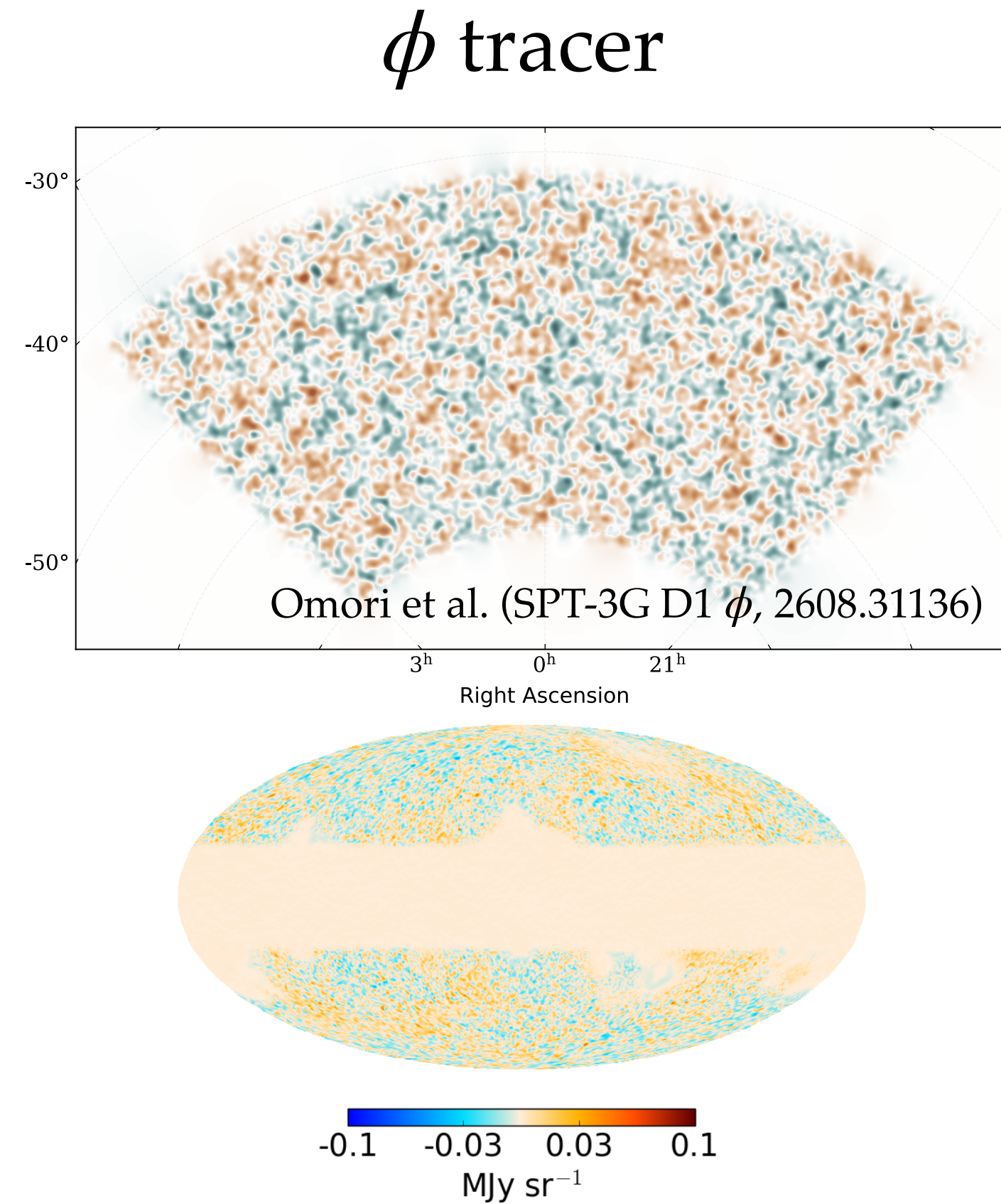


Zebrowski et al. (SPT-3G D1 BB arXiv: 2505.02827)

Lens the E modes to get the lensing B modes

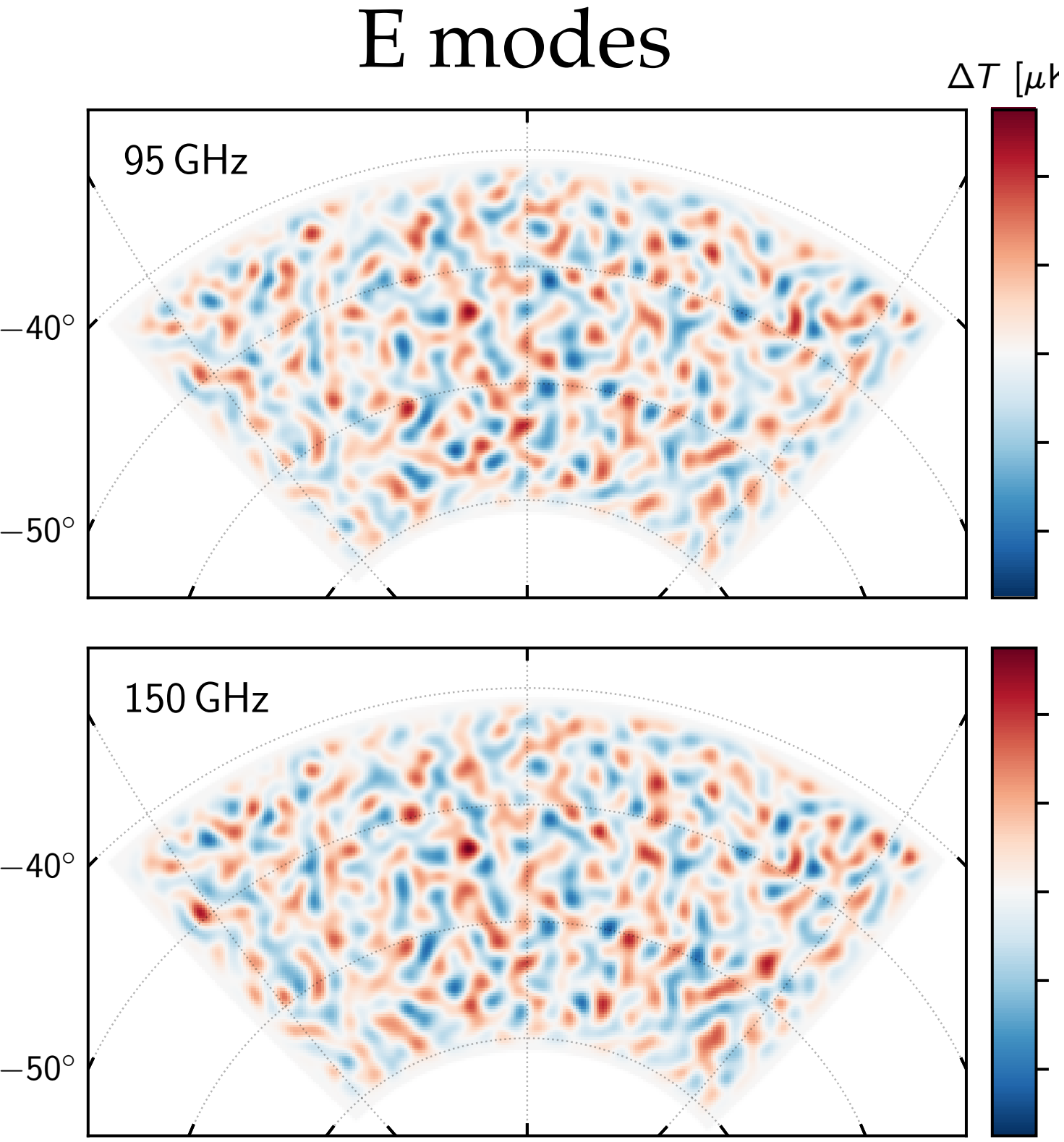


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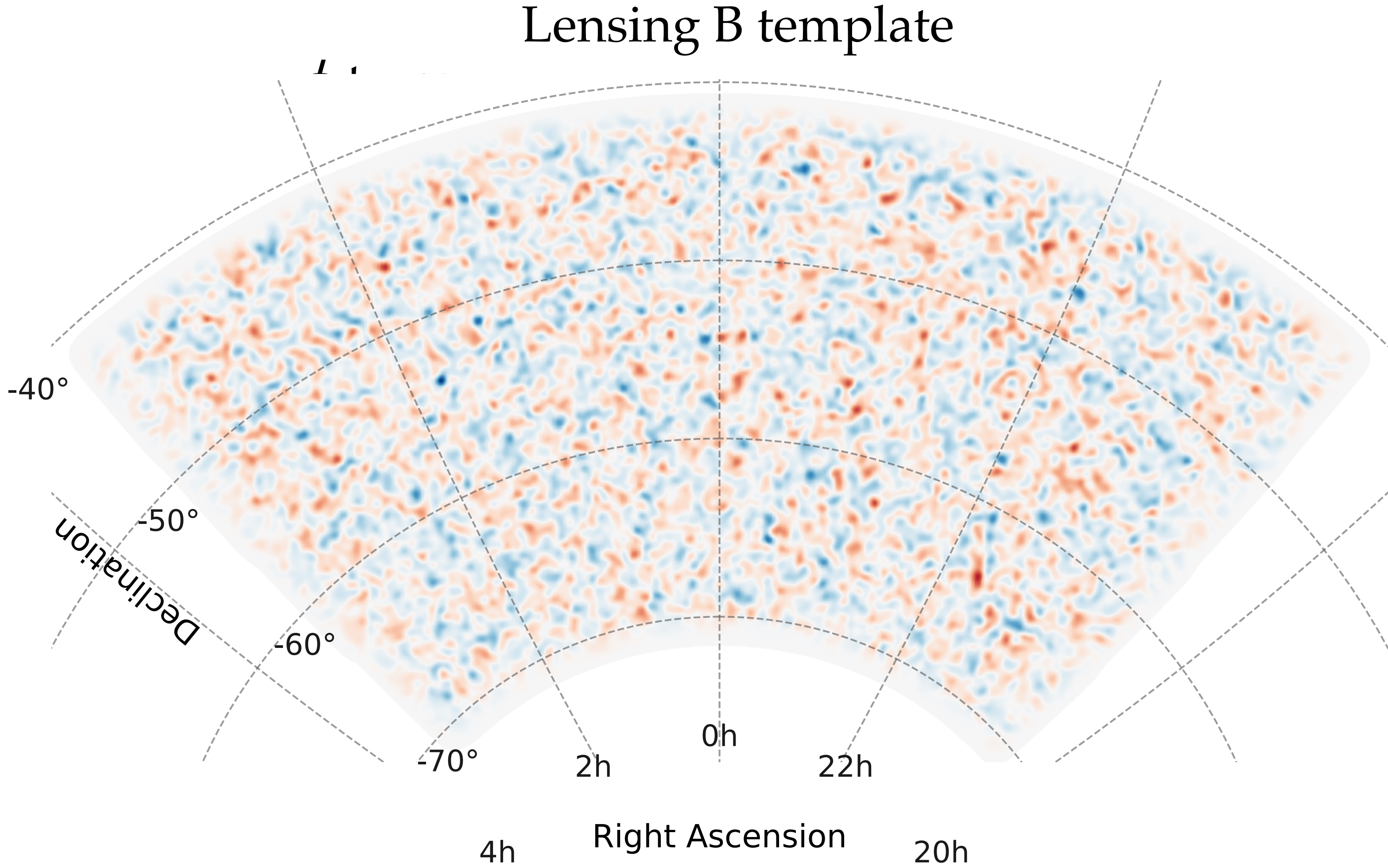


Planck PR2 GNILC CIB
(arXiv: 1605.09387)

Lens the E modes to get the lensing B modes



Zebrowski et al. (SPT-3G D1 BB arXiv: 2505.02827)



(arXiv: 1808.07507)

Nakato et al. (SPT-3G D1: arXiv: 2608.06343)