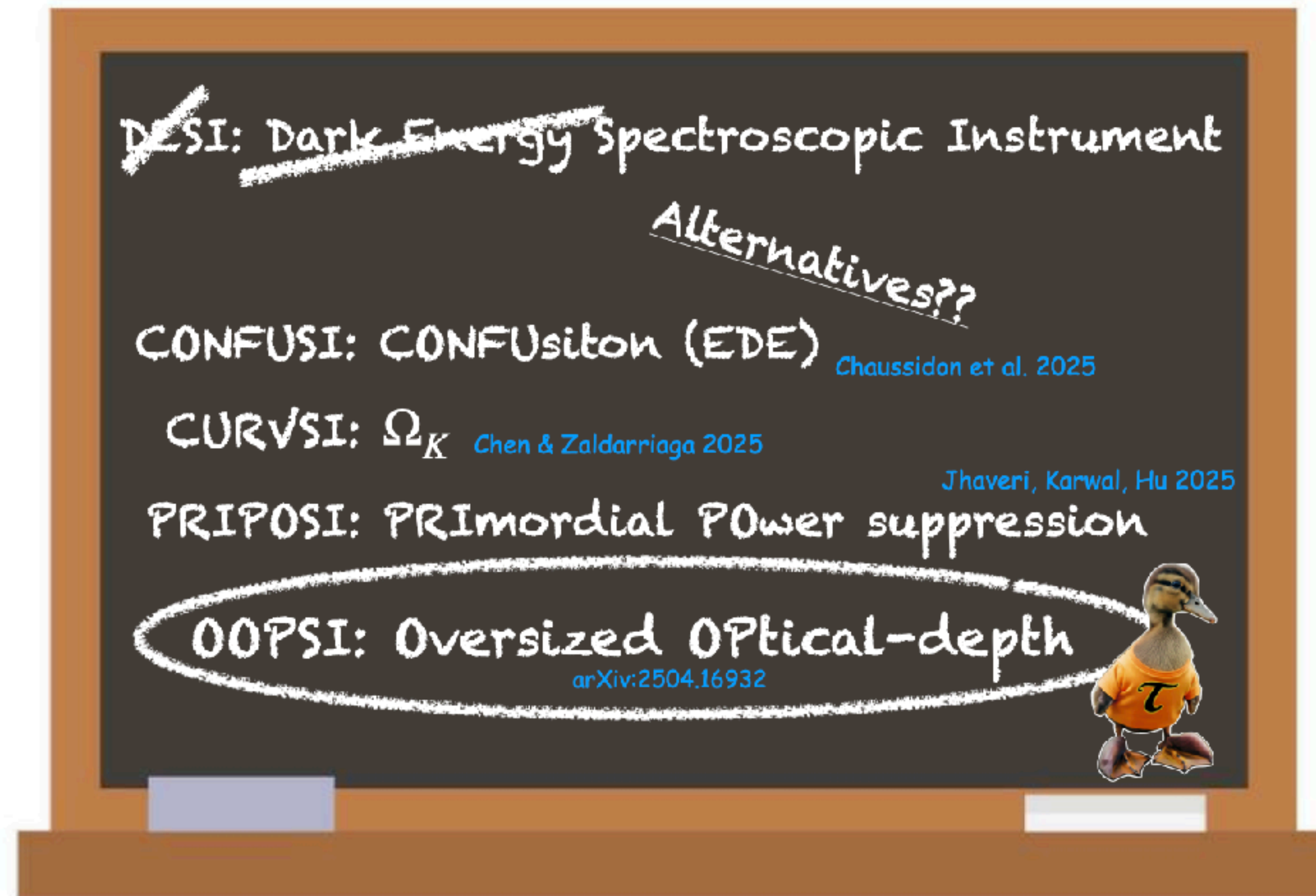# Dispuτable

the high cost of a low optical depth
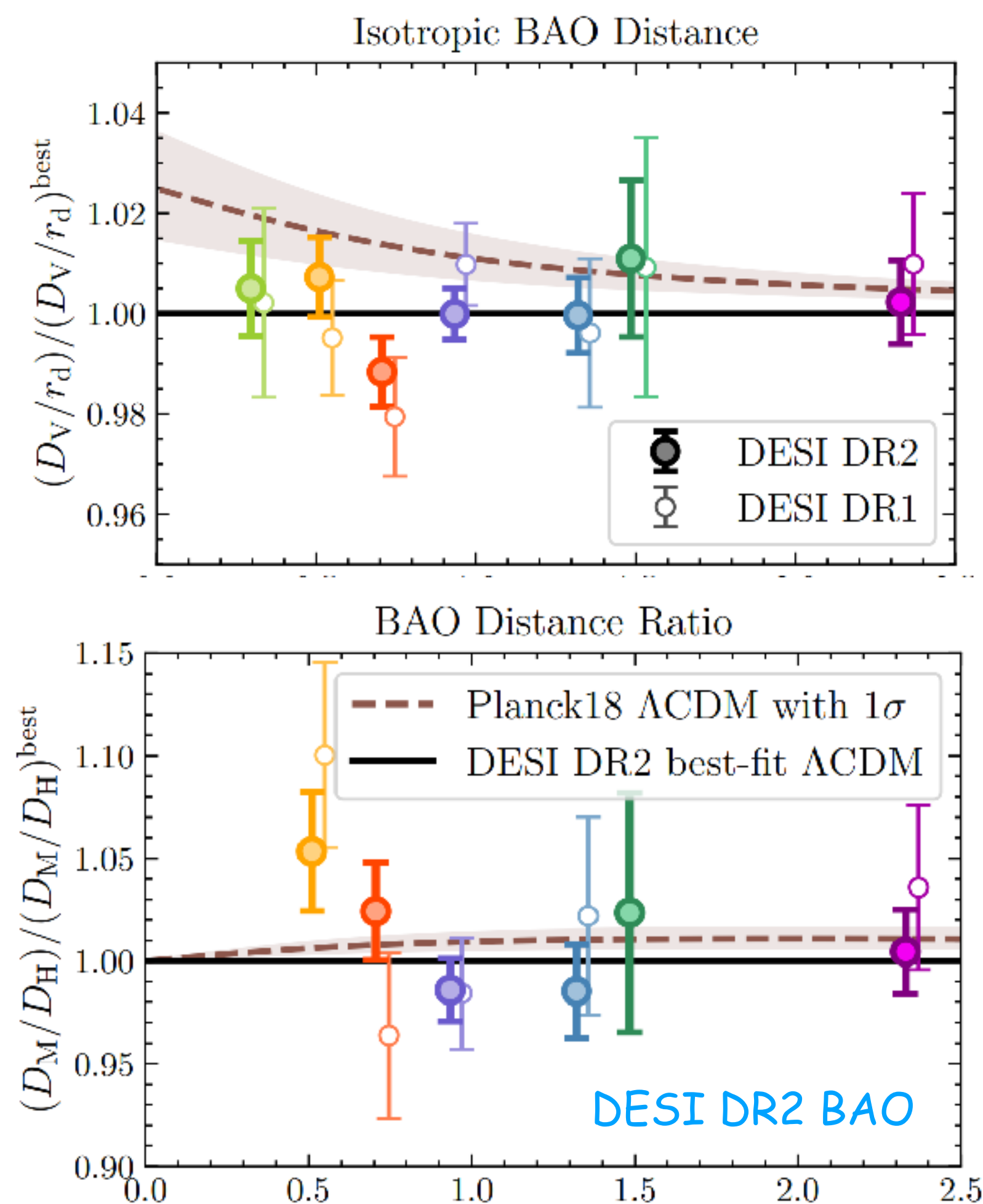
Noah Sailer

with Gerrit Farren, Simone Ferraro & Martin White

New Physics from Galaxy Clustering @ GGI
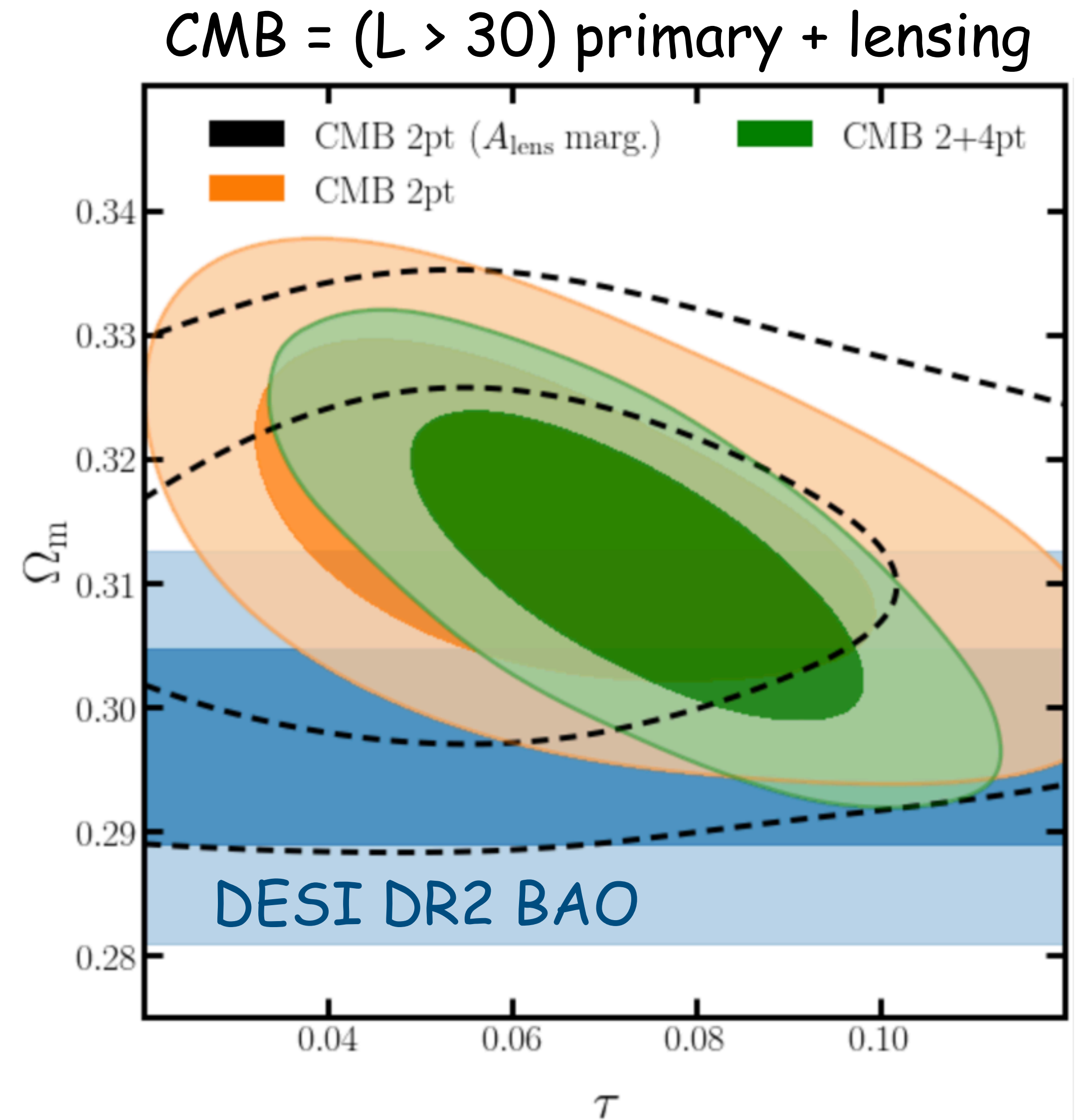
September 29th 2025

Stanford University

UNIVERSITY OF CAMBRIDGE

DESI: ~~Dark Energy~~ Spectroscopic Instrument

Alternatives??

CONFUSI: CONFUsiton (EDE) *Chaussidon et al. 2025*

CURVSI: Ω_K *Chen & Zaldarriaga 2025*

Jhaveri, Karwal, Hu 2025

PRIPOSI: PRImordial POwer suppression

OOPSI: Oversized OPtical-depth

arXiv:2504.16932

DESI → OOPSI

- Perfectly good fit to ΛCDM...

  ...but Ω_m is low (0.297 vs 0.317)

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CMB = (L > 30) primary + lensing

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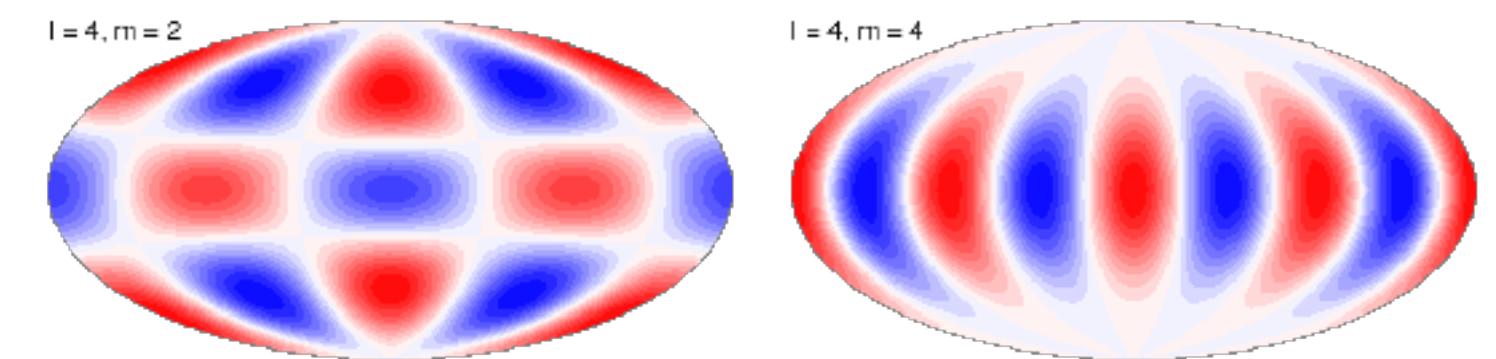 - largely insensitive to reionization model

de Belsunce et al. 2021

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- Extremely challenging measurement
  - 100x smaller than temp.
  - galactic foregrounds, instrumental effects (e.g. ADC non-linearities)

Polarized galactic emission (Q and U)


143 GHz

Spherical harmonics (L = 4)

l = 4, m = 2

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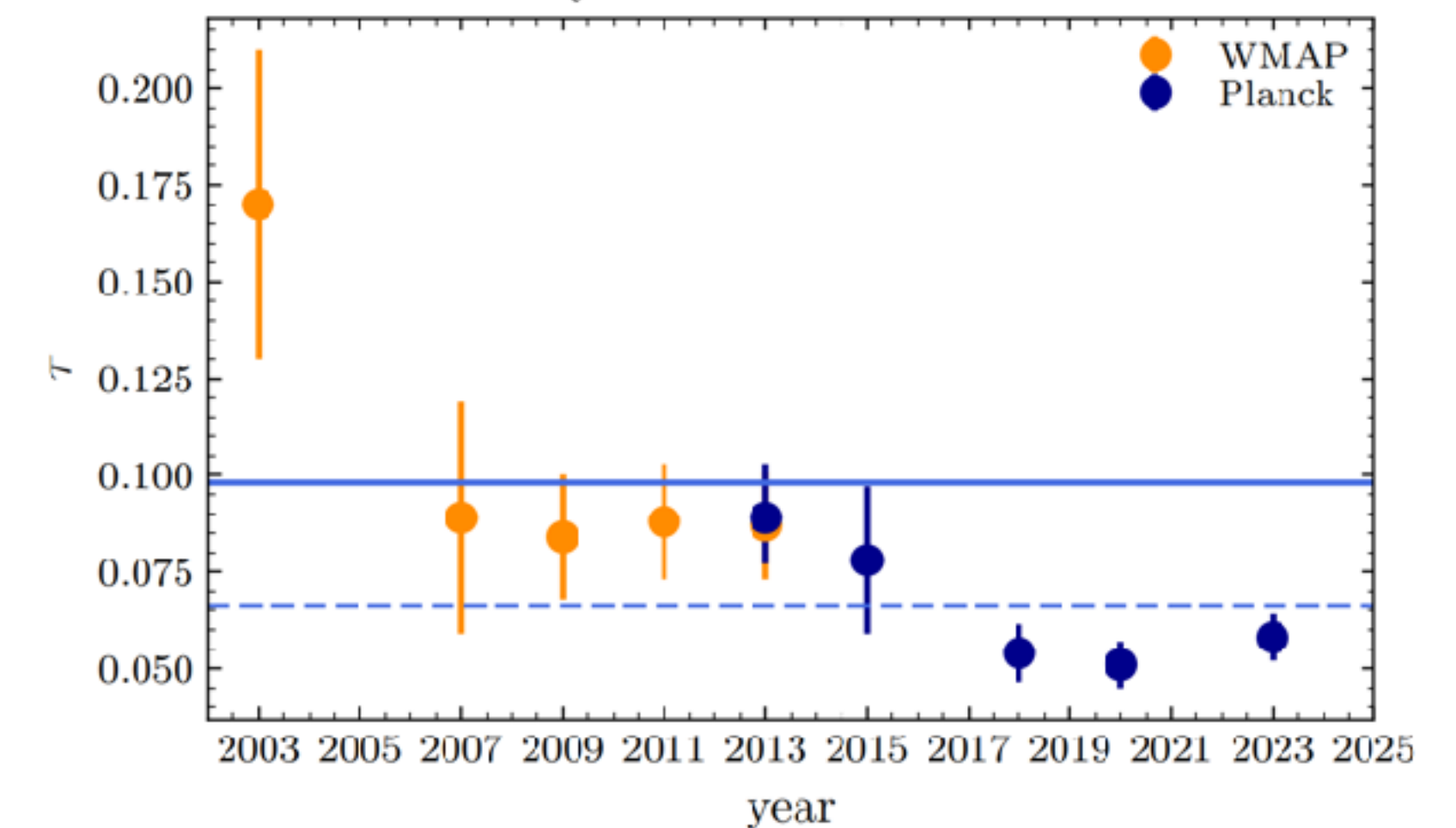 - only 2 independent measurements

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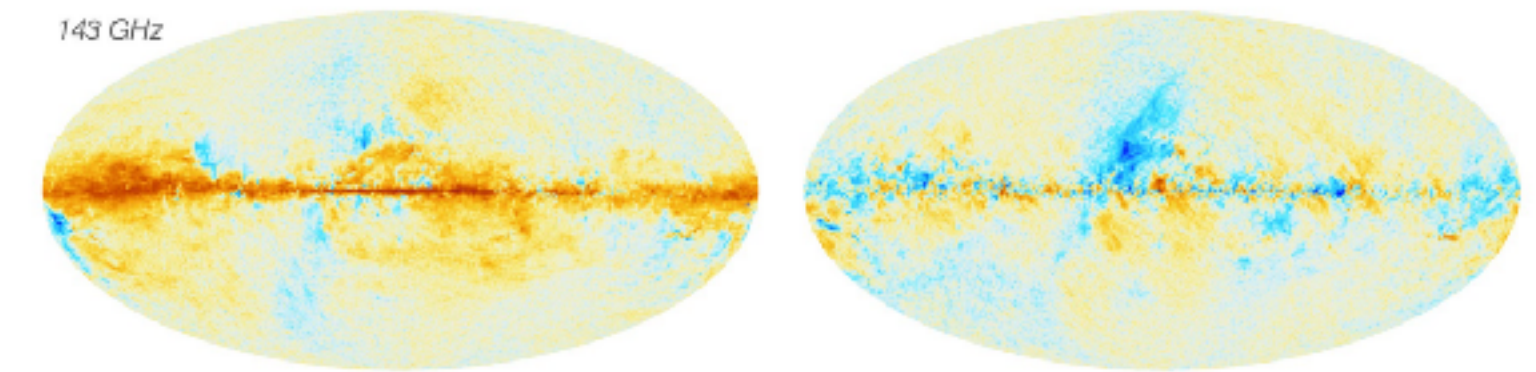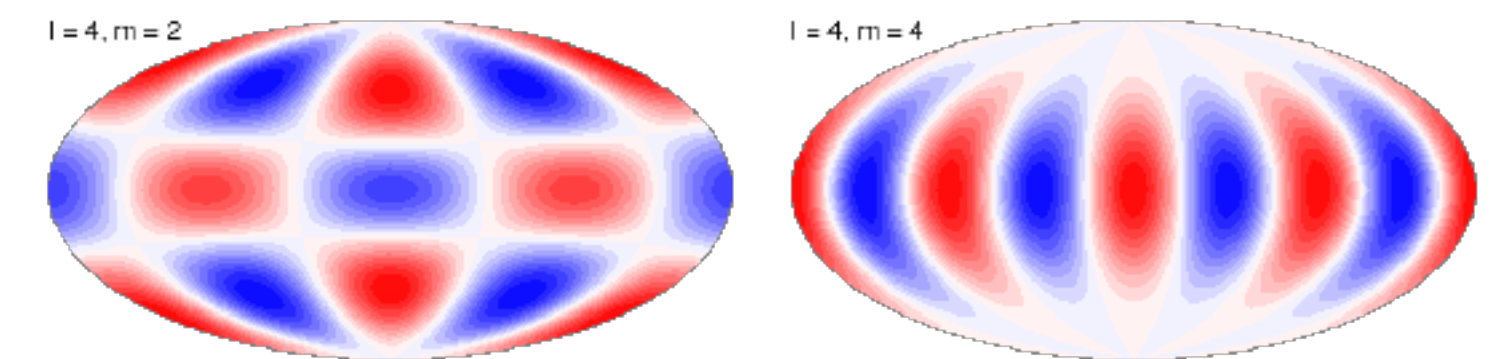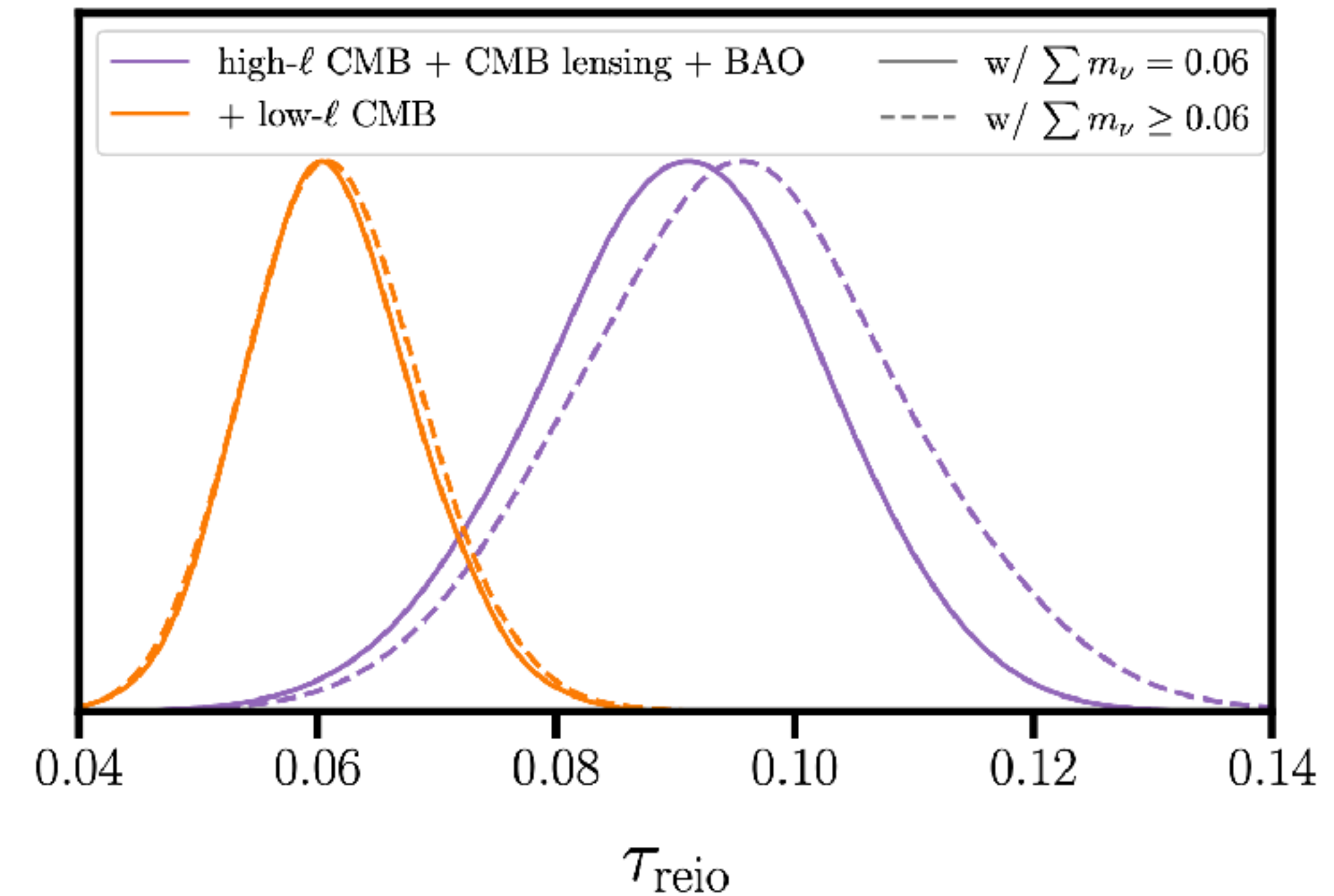

History of the τ Measurement

What "should" τ be? (in ΛCDM)

• Focus on statistics-limited, "linear theory" observables (small-scale CMB, CMB lensing, BAO)
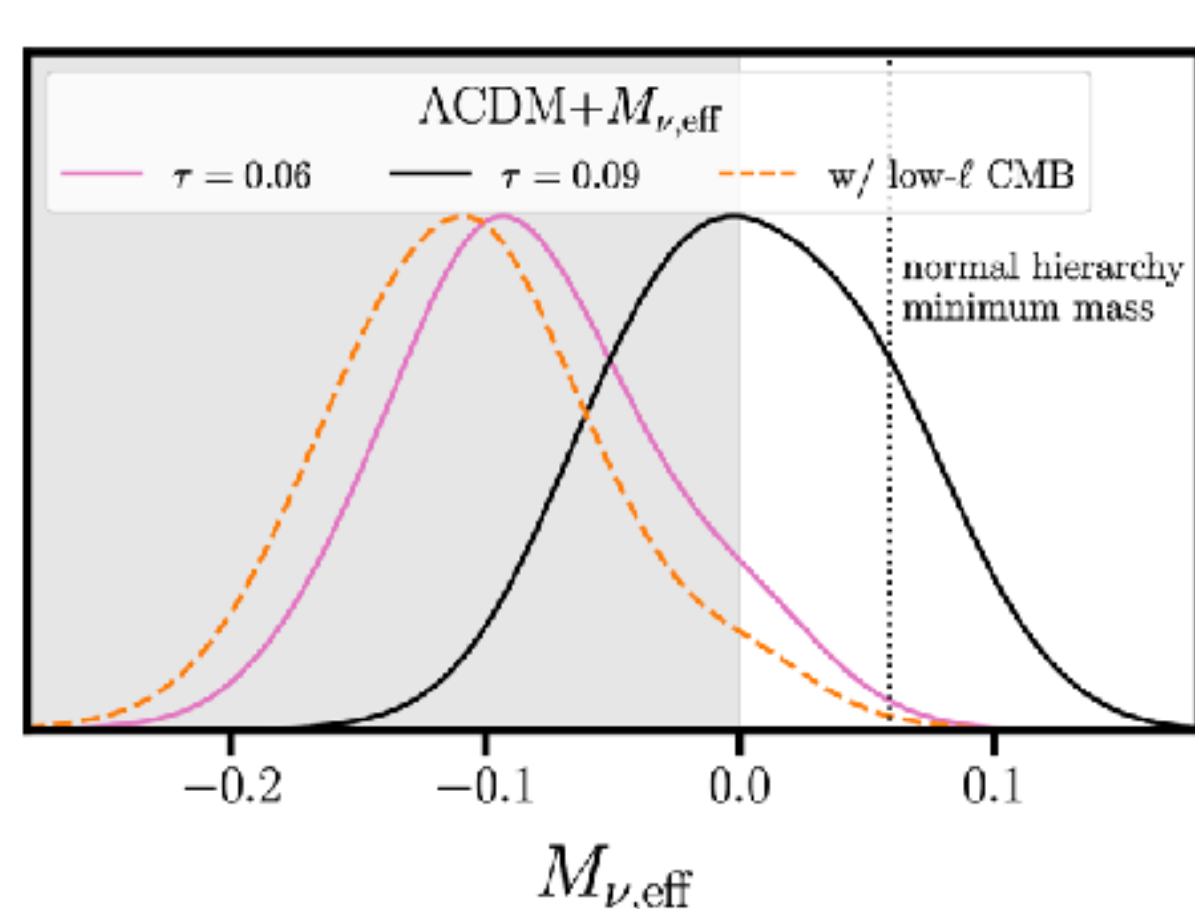
$$\tau = 0.090 \pm 0.012$$

• ~3σ tension with Planck low-ℓ polarization

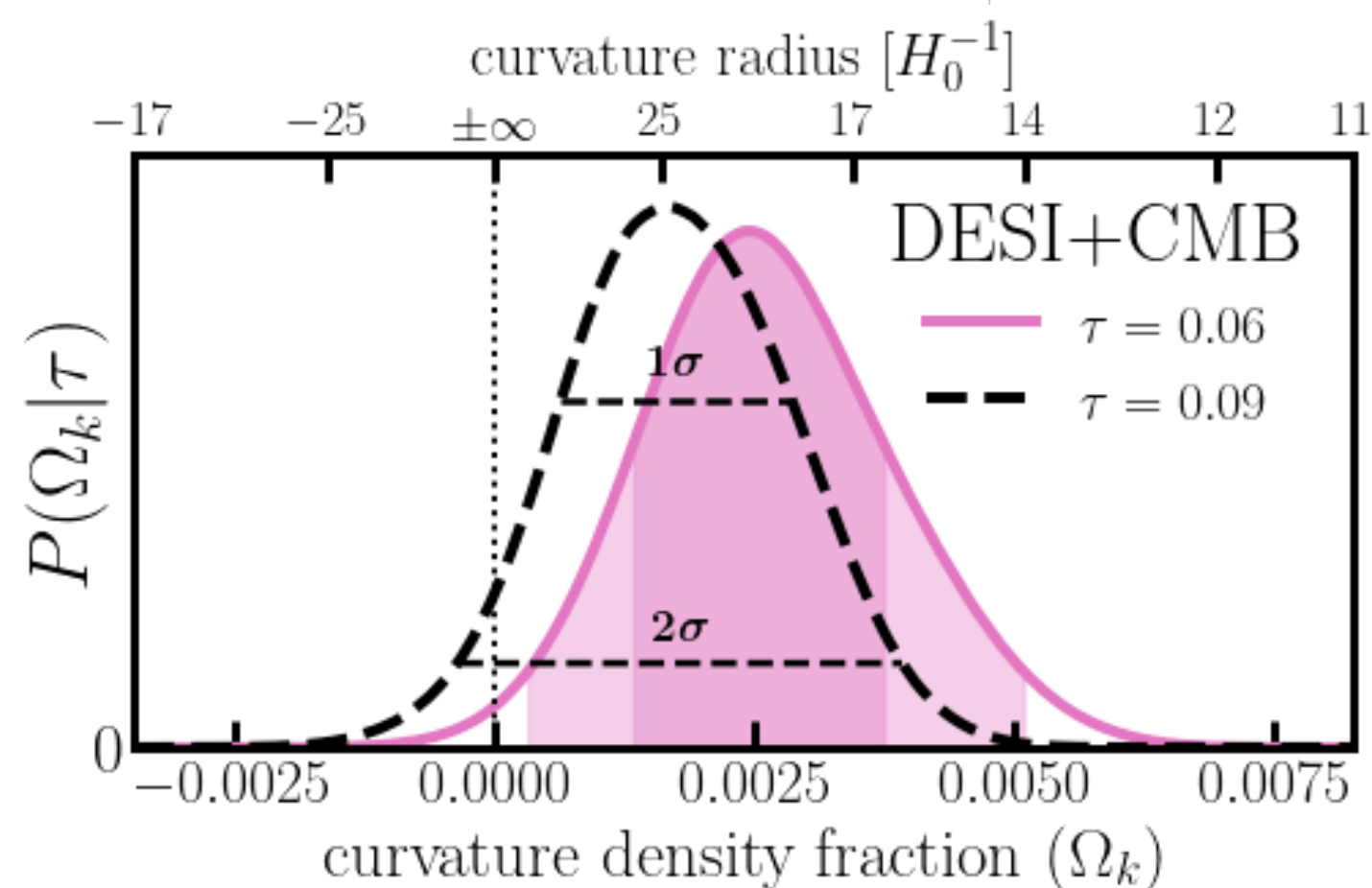• coincidentally (?) consistent with WMAP

If $\tau = 0.09^\star$

$^\star \tau = 0.08$ is "good enough"
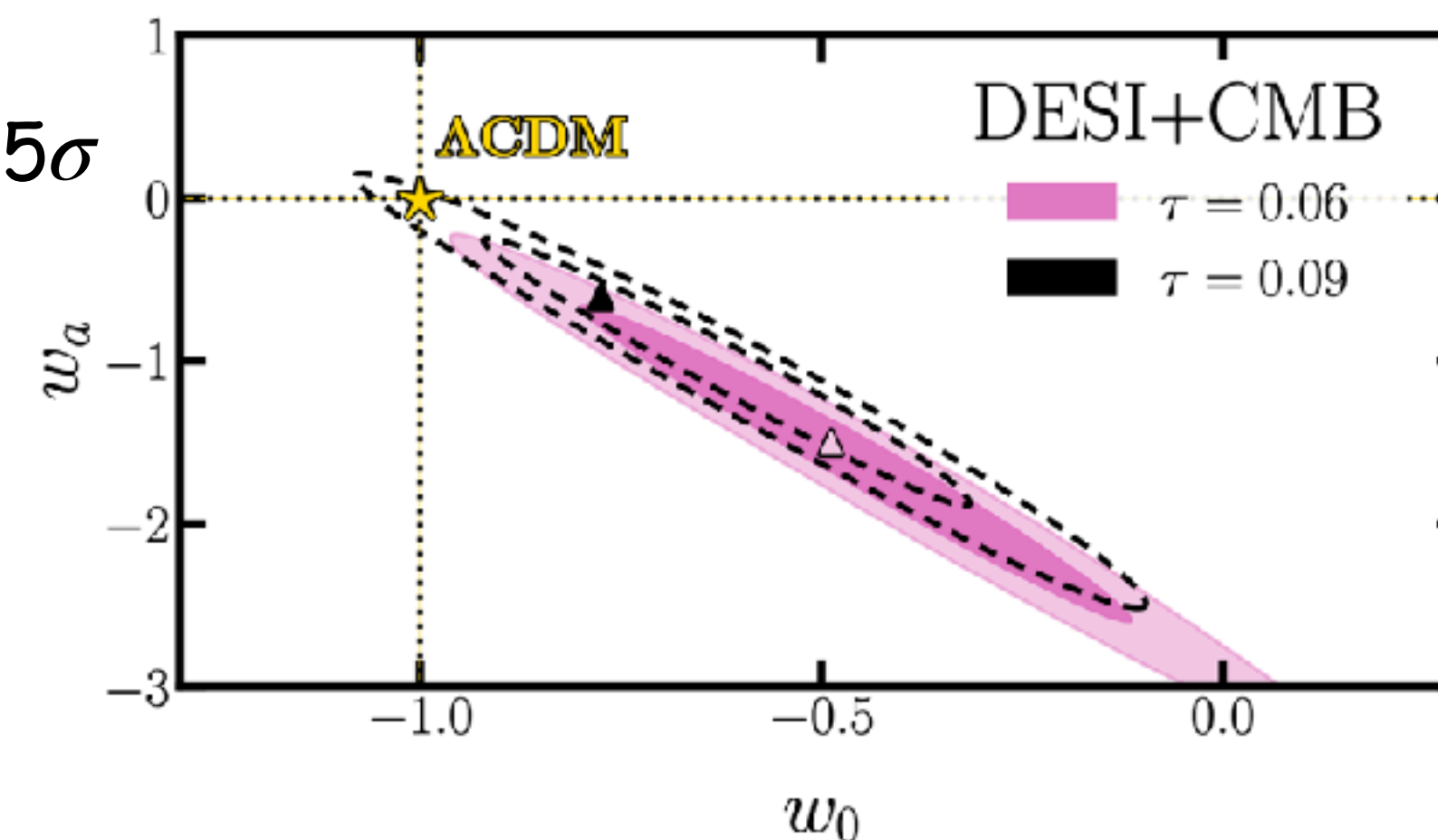
CMB and BAO are consistent within ΛCDM (0.9σ)

Neutrino mass consistent with oscillation experiments

Preference for evolving dark energy
$3\sigma \to 1.5\sigma$
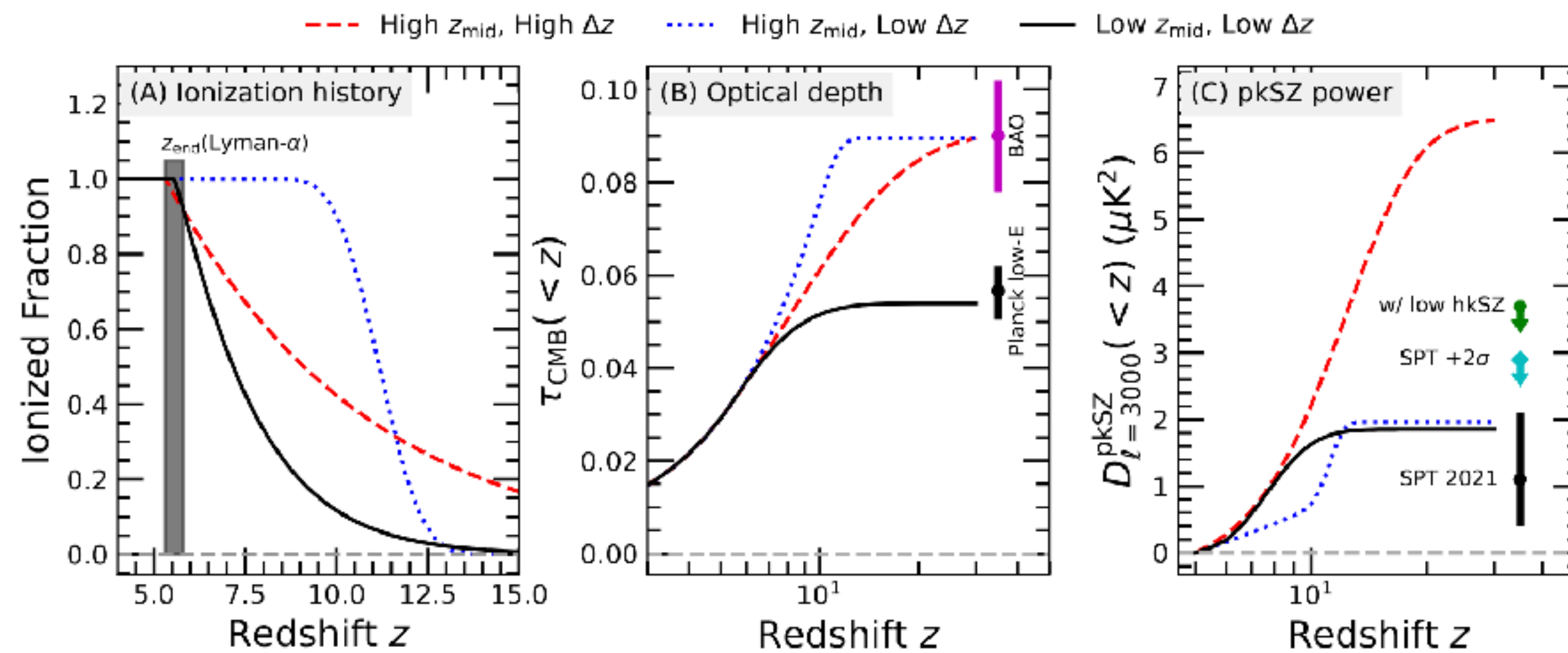
Preference for curvature
$2.4\sigma \to 1.7\sigma$

Could reionization be more extended?

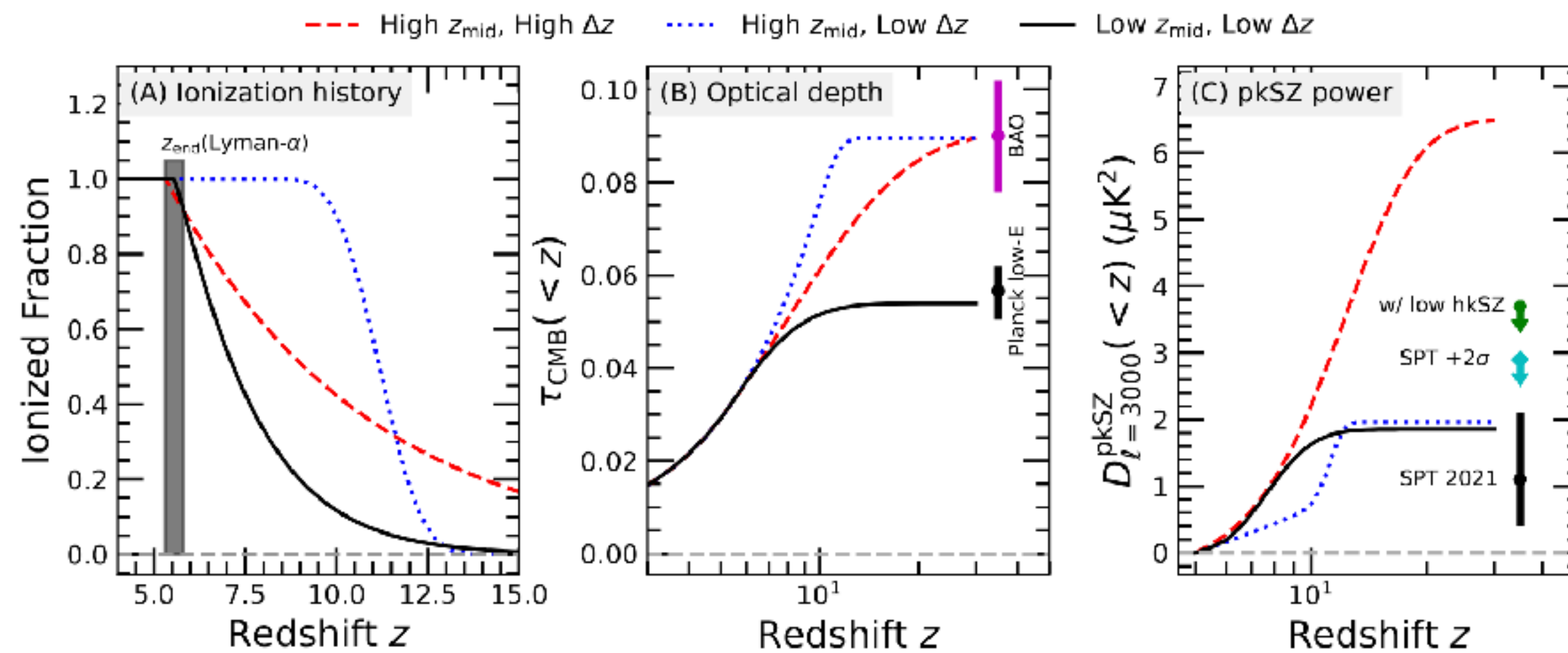- yields larger patchy kSZ effect
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Cain et al. 2025

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  - **highly model-dependent**
    fixed-shape templates, tSZ (feedback), tSZ x CIB,
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Reichardt et al. 2020

Cain et al. 2025

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    cluster lens model, galaxy-halo connection,
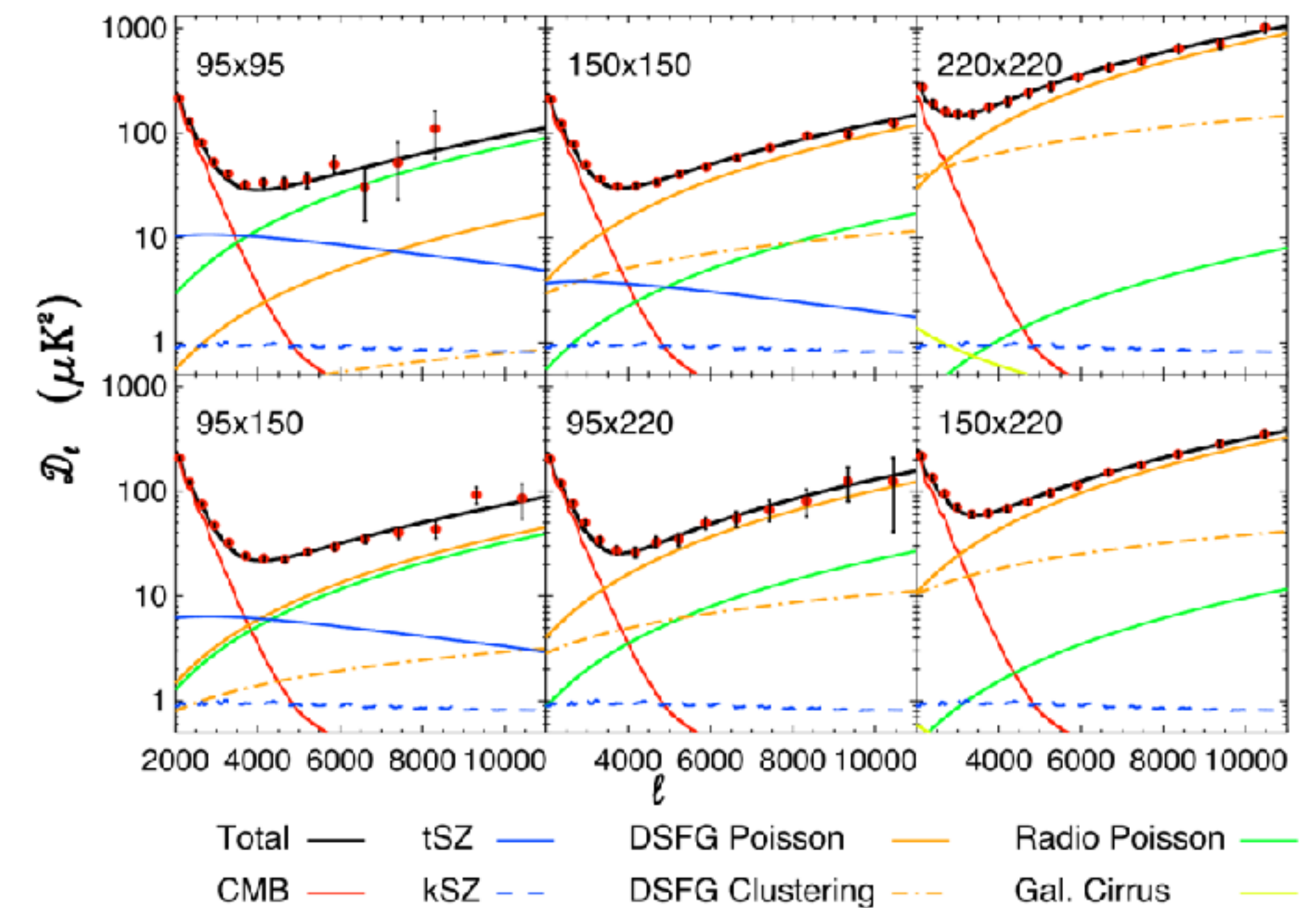   reionization morphology, …

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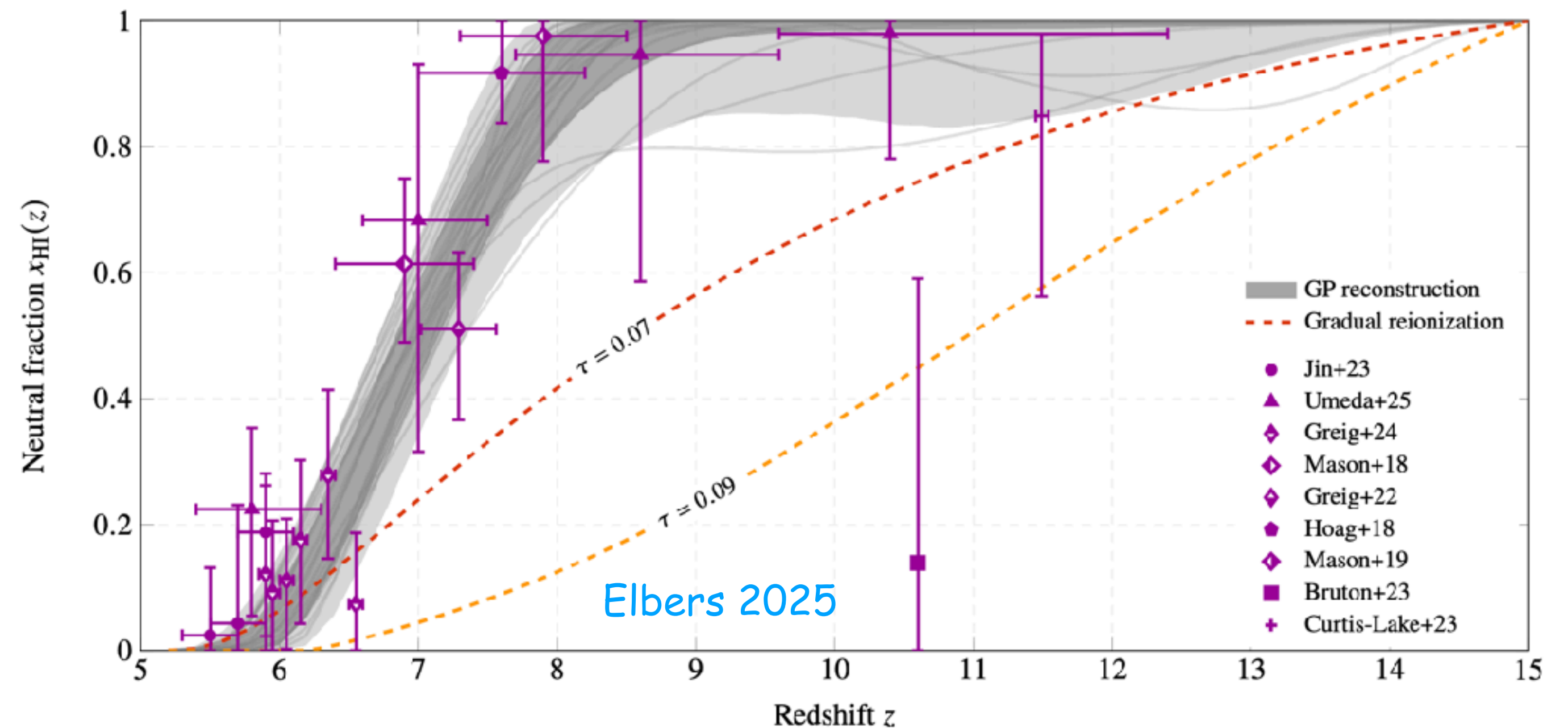   pkSZ vs hkSZ (reionization morphology), …

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Elbers 2025

$\tau = 0.09$

GP reconstruction + kSZ prior
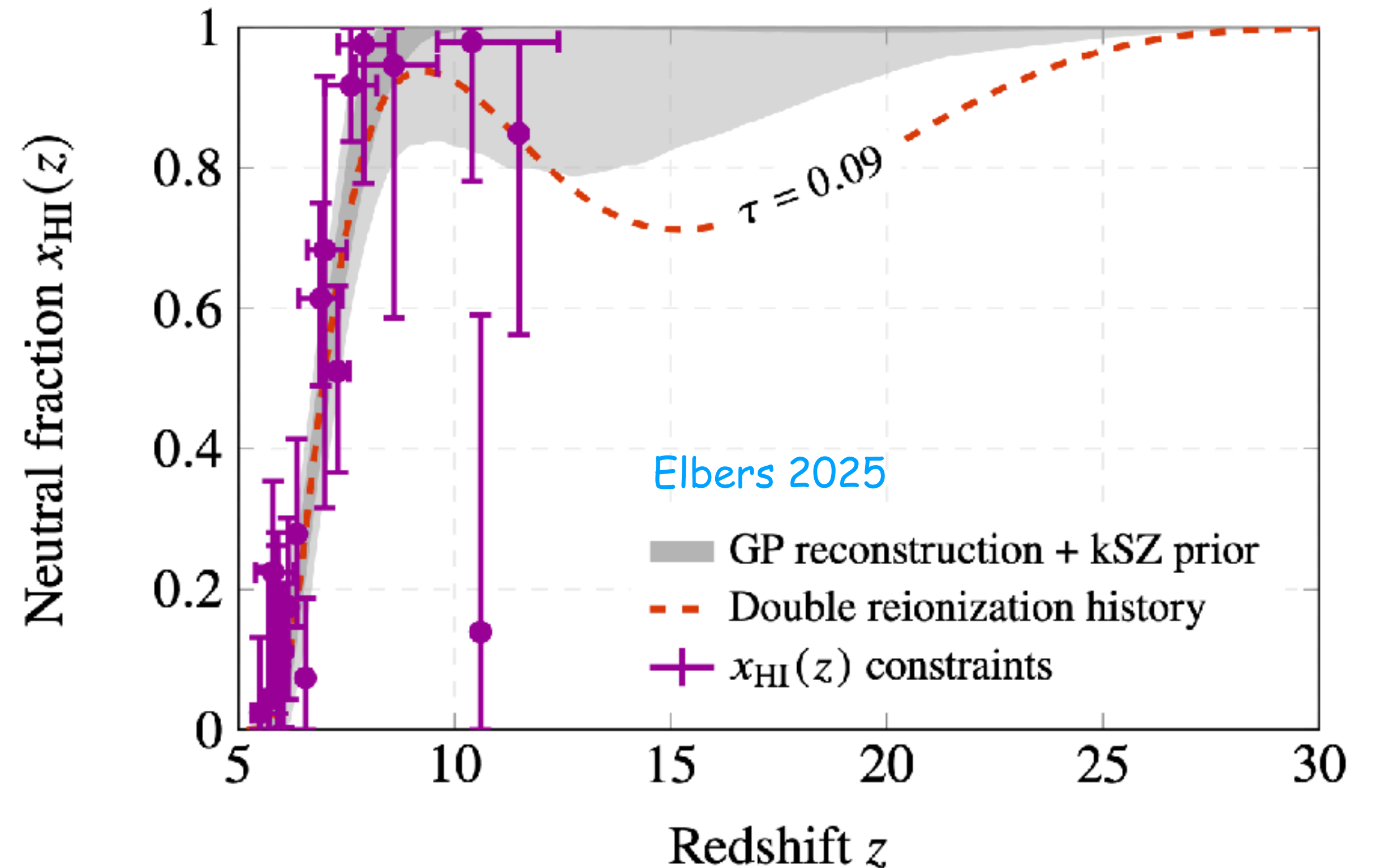Double reionization history
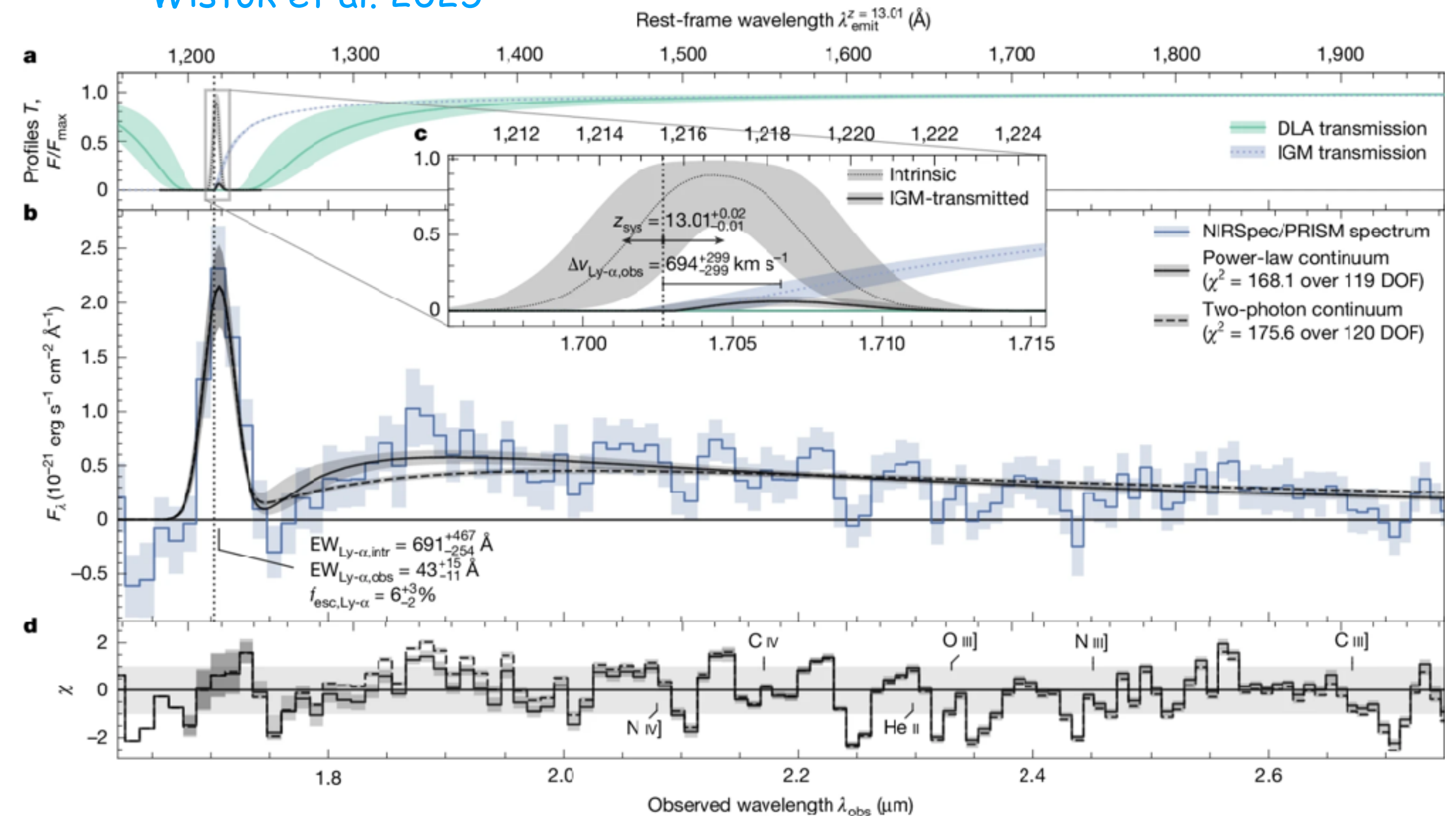$x_{HI}(z)$ constraints

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Wistok et al. 2025

see also Cohon et al. 2025

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- Looking to the future
  - kSZ 4-point
  - 21 cm fluctuations
  - future space-based CMB missions

Final thoughts

- within ΛCDM $\tau = 0.090 \pm 0.012$ from statistics-limited, "linear"-theory observables

- can rephrase DESI preference for $w_0 w_a$ as a "τ tension"

- τ is a single-point failure for CMB inference (e.g. σ_8 , Ω_m)
    - critical for determining significance of beyond-ΛCDM physics from BAO+CMB
    - **all modern CMB analyses rely on Planck** (not constrained by ACT, SPT, SO)

- larger τ softens additional tensions, unlike $w_0 w_a$ (e.g. $A_{\text{lens}} \simeq 1$, $H_0 \sim 68.5$ km/s/Mpc)

The End