Universiteit Leiden

Instituut-Lorentz

Shape of CMB lensing in EDE

arXiv:2305.18873,

Gen Ye, Jun-Qian Jiang, Yun-Song Piao

Cosmological Tensions

Hubble tension

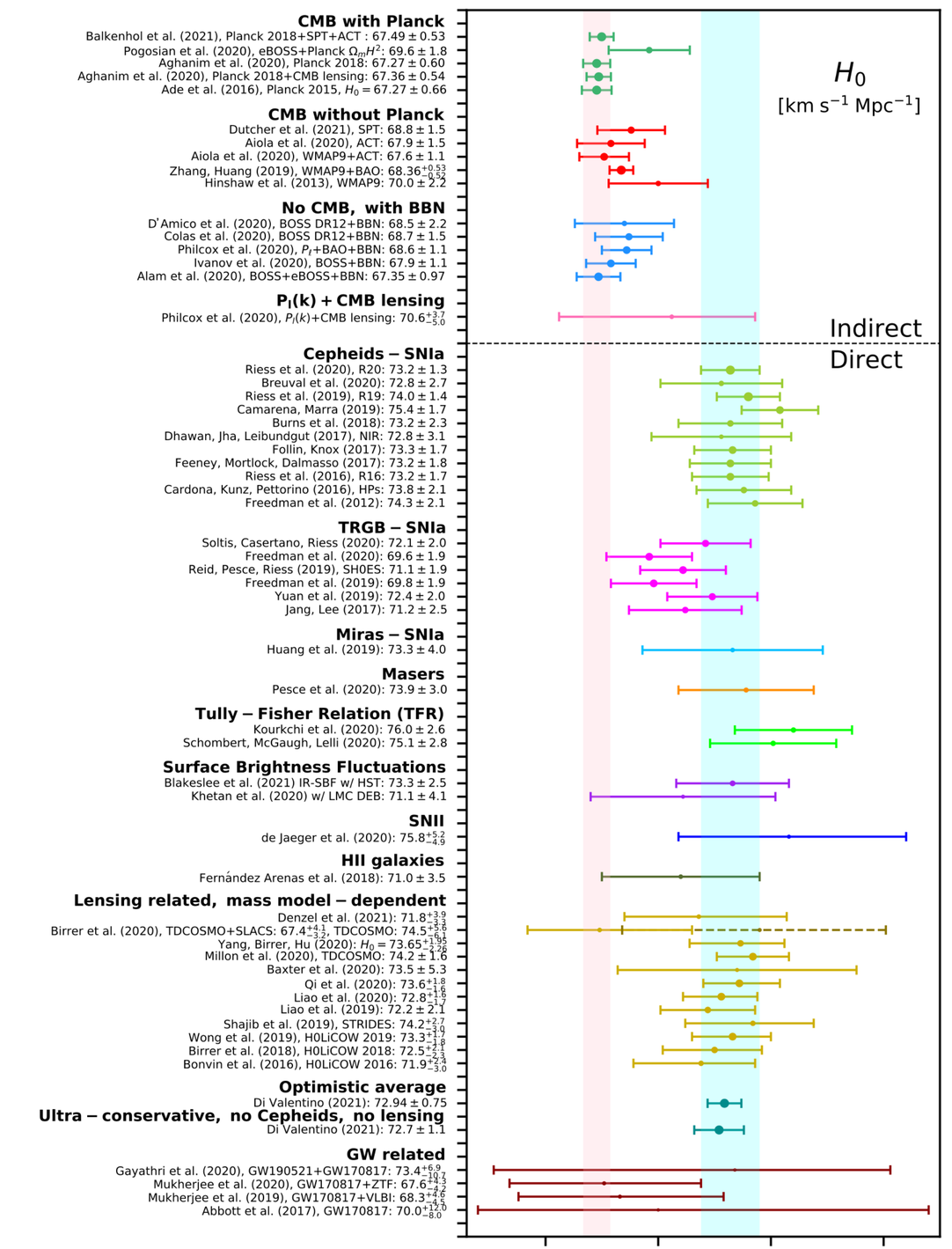
SH0ES

$$H_0 = 73.04 \pm 1.04 \text{ km/s/Mpc}$$

v.s.

CMB

$$H_0 = 67.49 \pm 0.52 \text{ km/s/Mpc}$$



Class.Quant.Grav. 38 (2021) 15, 153001

Early Dark Energy (EDE)

$$\theta_s = \frac{r_s}{D_A} \sim \frac{1}{\Delta l}$$

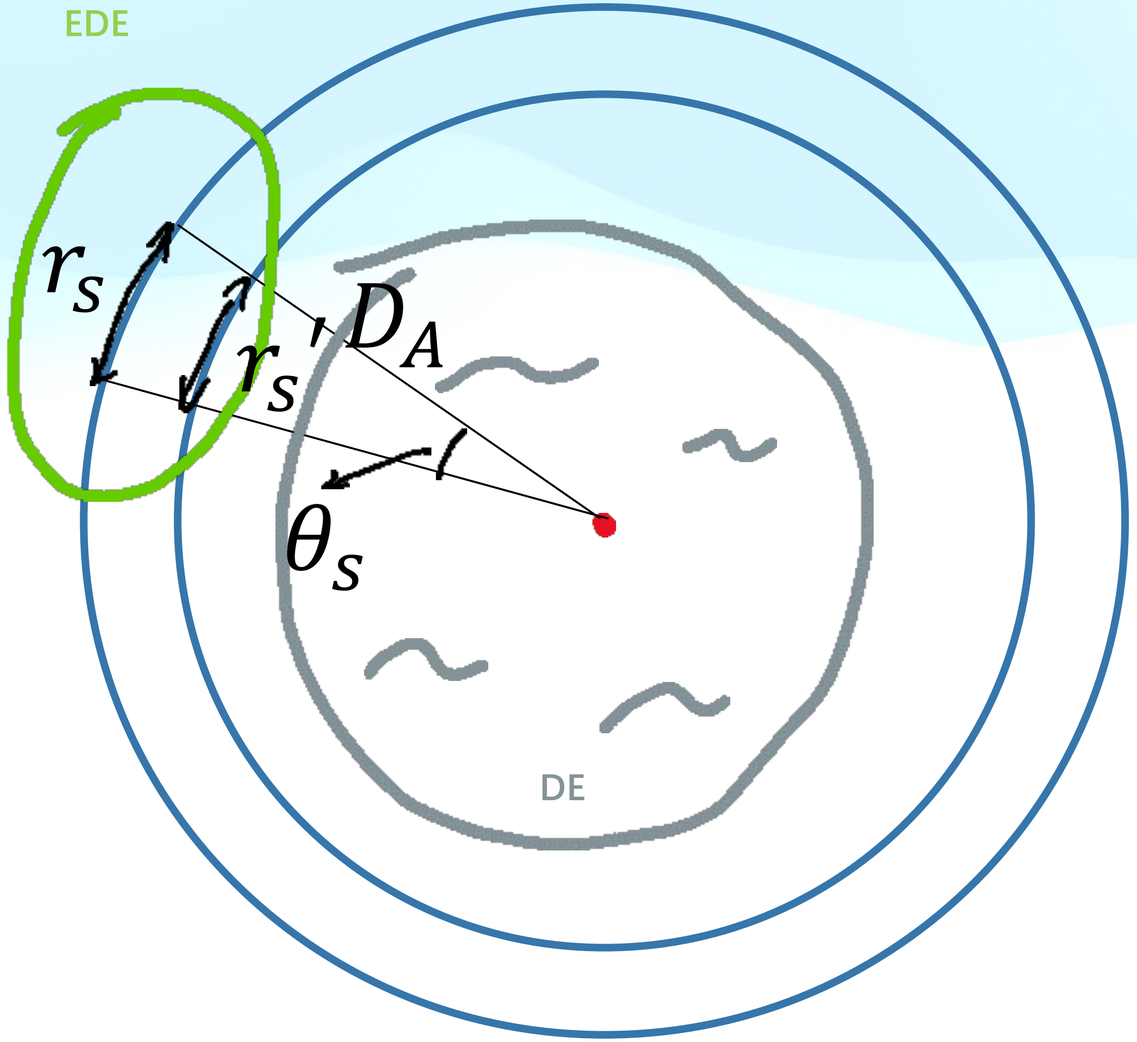
Tanvi Karwal, Marc Kamionkowski, PhysRevD.94.103523
Vivian Poulin, Tristan L. Smith, Tanvi Karwal, Marc Kamionkowski, PhysRevLett.122.221301

$$r_s = \int_{z_*}^{\infty} \frac{c_s}{H(z)} dz$$

Early Dark Energy

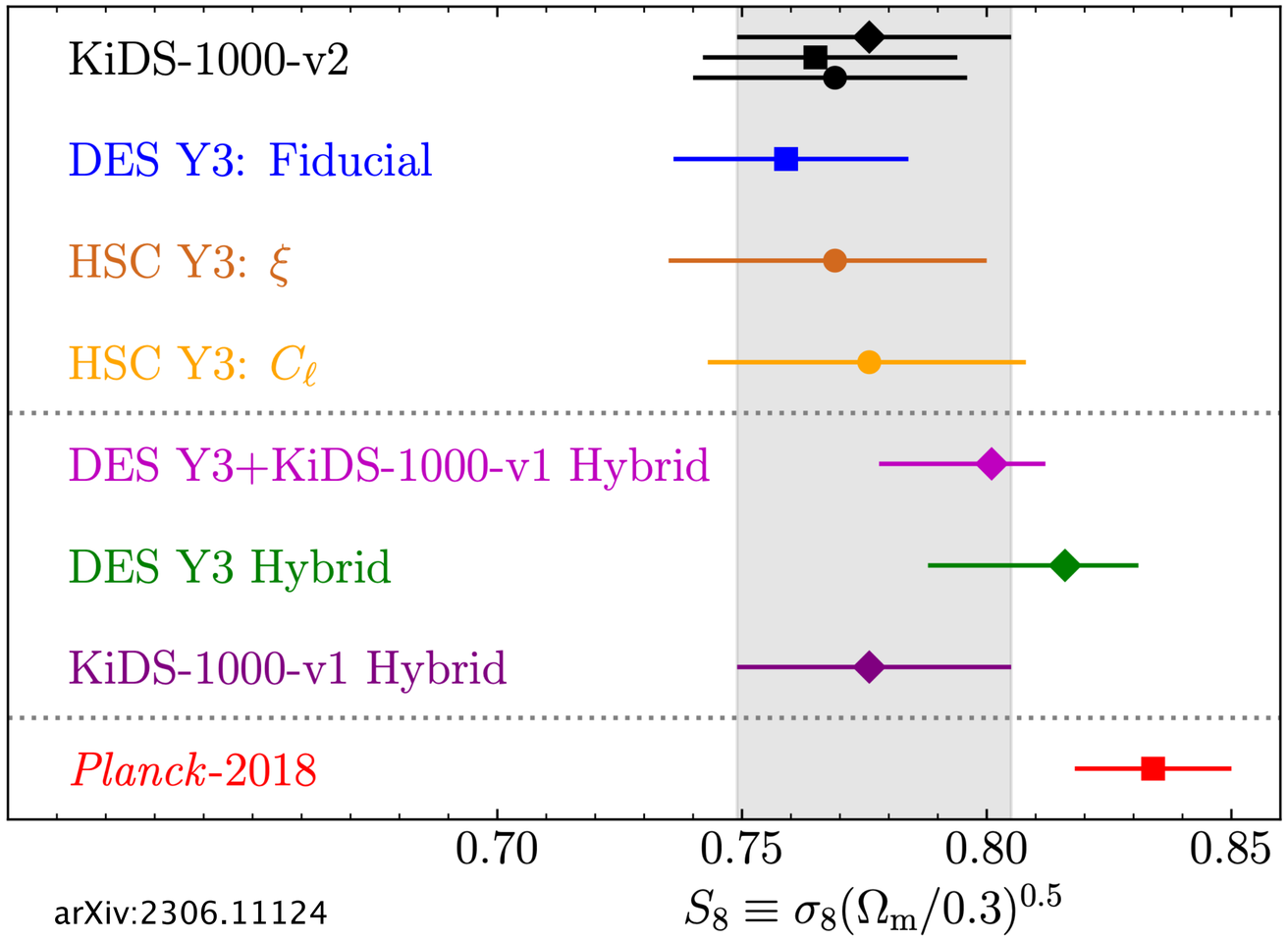
$$D_A = H_0^{-1} \int_0^{z_*} \frac{dz}{E(z)}$$

Dark Energy



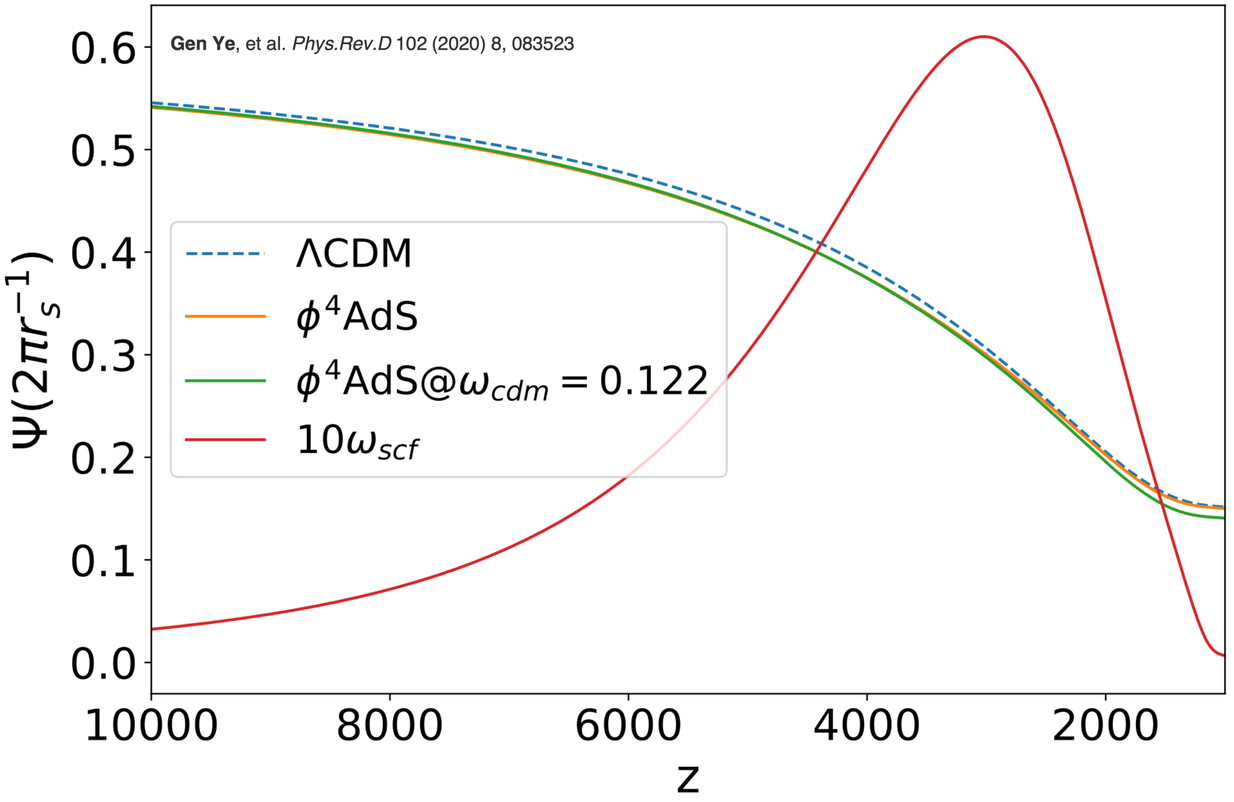
Tensions in the model?

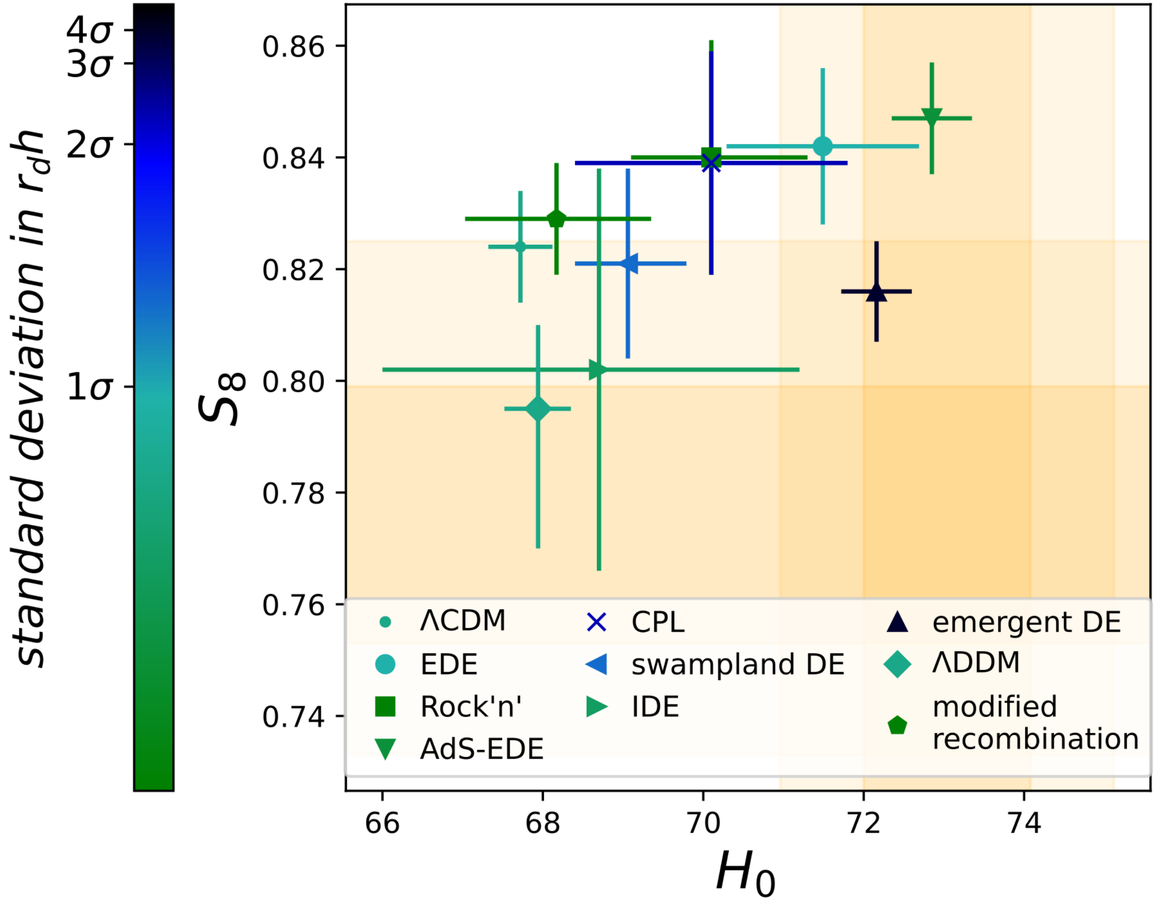
S_8 tension



arXiv:2306.11124

EDE and S_8



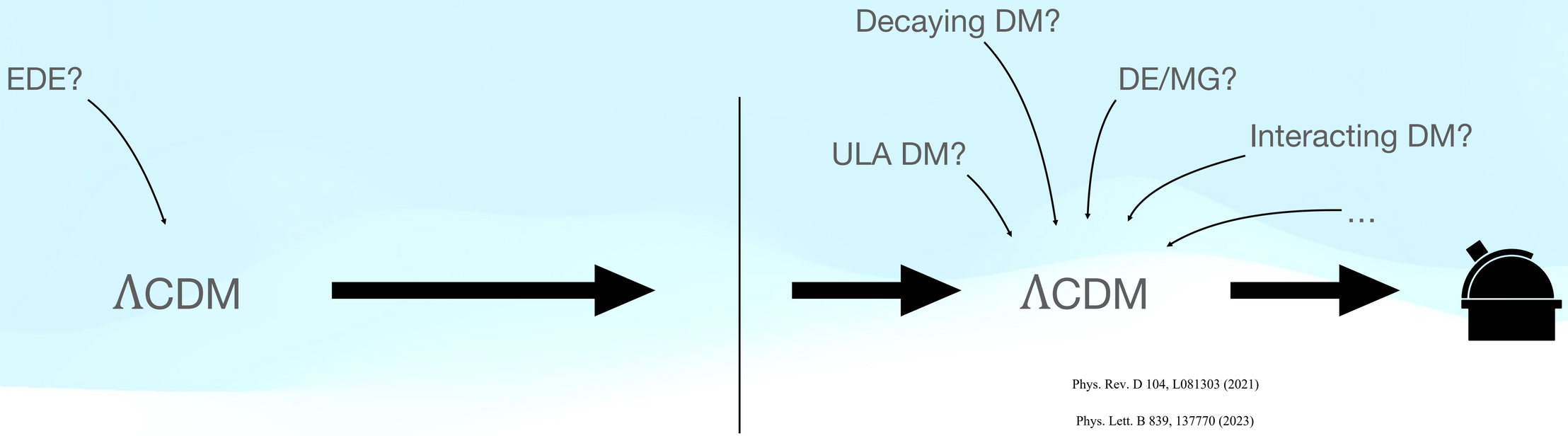


S_8 tension exacerbated by EDE

Phys. Rev. D 102, 043507 (2020)
Phys. Rev. D 102, 103502 (2020)
JCAP 05, 072 (2021)

ω_{cdm} is increased to compensate for EDE's effect on radiation driving and ISW

Gen Ye, et al. *Phys.Rev.D* 102 (2020) 8, 083523
Astrophys. J. Lett. 904, L17 (2020)
Phys. Rev. D 104, 063524 (2021)



Phys. Rev. D 104, L081303 (2021)

Phys. Lett. B 839, 137770 (2023)

Phys. Rev. D 107, 083527 (2023)

Mon. Not. Roy. Astron. Soc. 520, 3688 (2023)

Phys. Rev. D 104, 12533 (2021)

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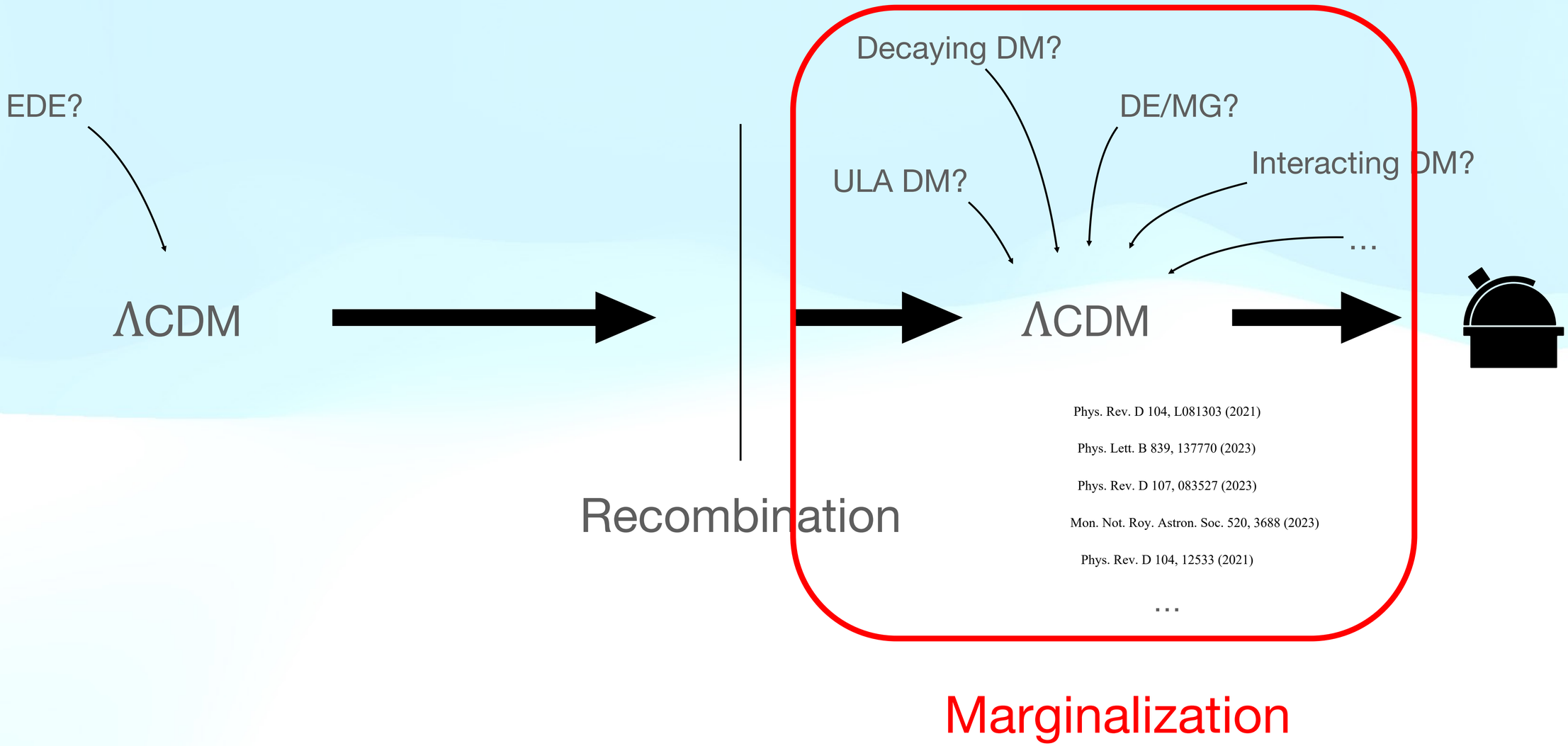
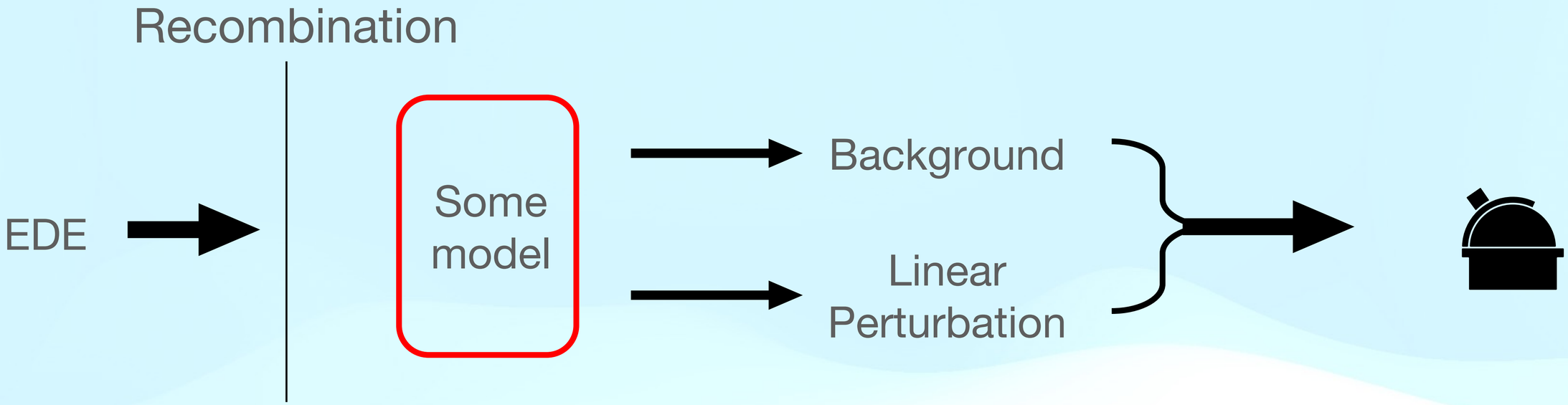


Marginalization



Background?

$$D_A(z) = H_0^{-1} \int_0^z \frac{dz'}{E(z')}$$

- Cosmological parameters: H_0, Ω_m
- Dark energy EoS $w(z)$

Phys. Lett. B 832, 137244 (2022)
arXiv:2302.07333
} $w \equiv -1$

Perturbation?

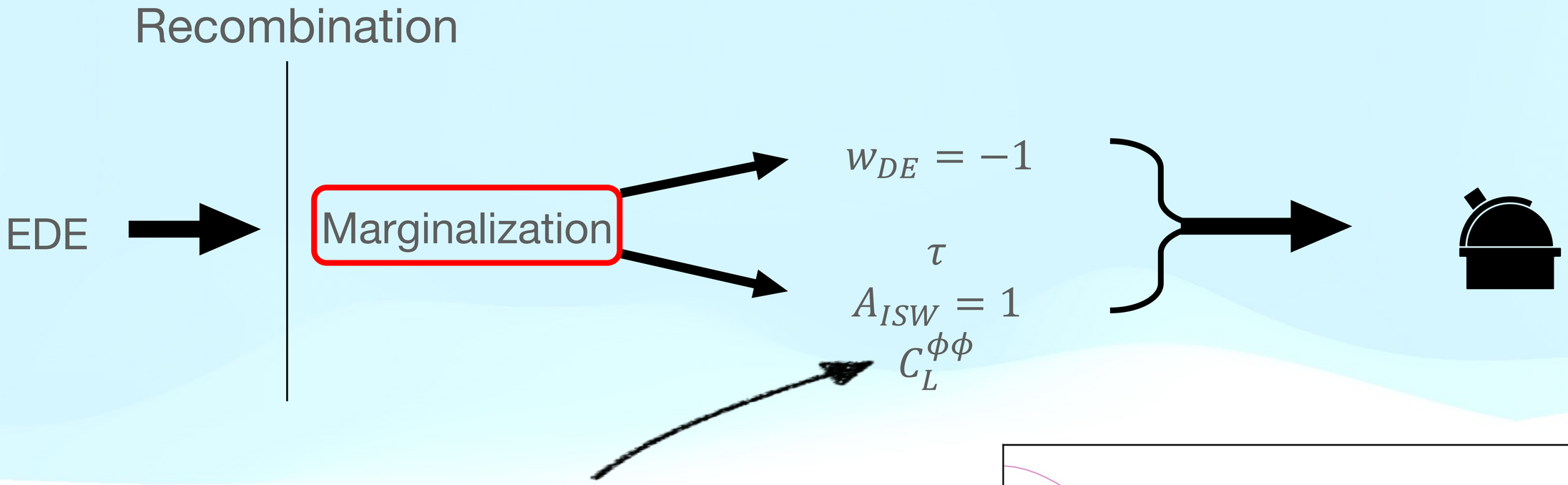
- Reionization

  High ℓ optical depth $A_s e^{-2\tau}$

  Low ℓ E polarization
- Integrated Sachs-Wolfe

  Phys. Rev. D, 107 103505
- Gravitational Lensing $P(k)$

  This work arXiv:2305.18873

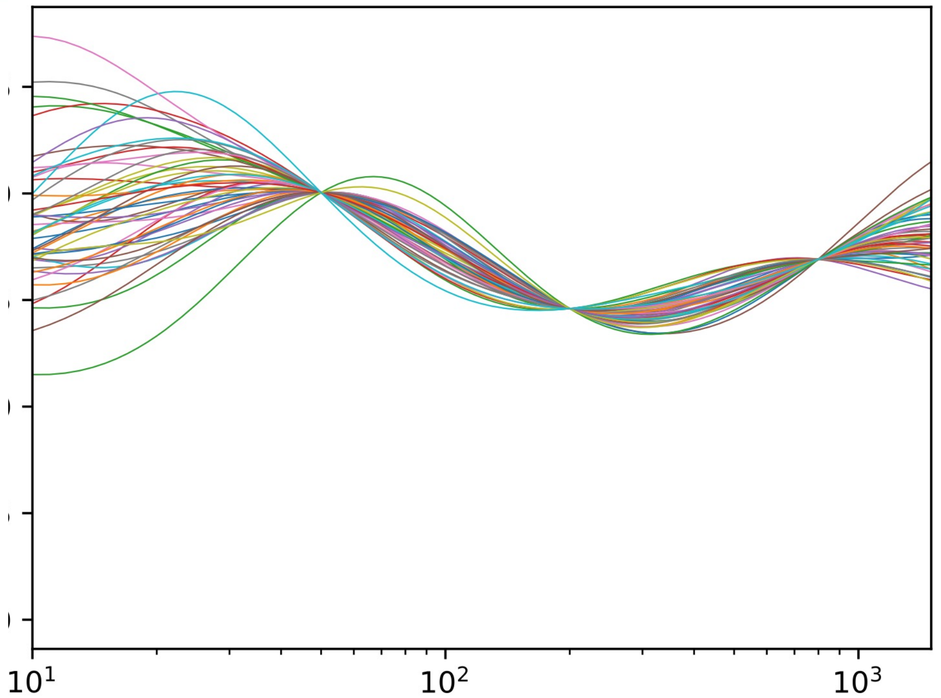


Gaussian Process (GP)

$$C_L^{\phi\phi} = A(L) C_{L,fid}^{\phi\phi}$$

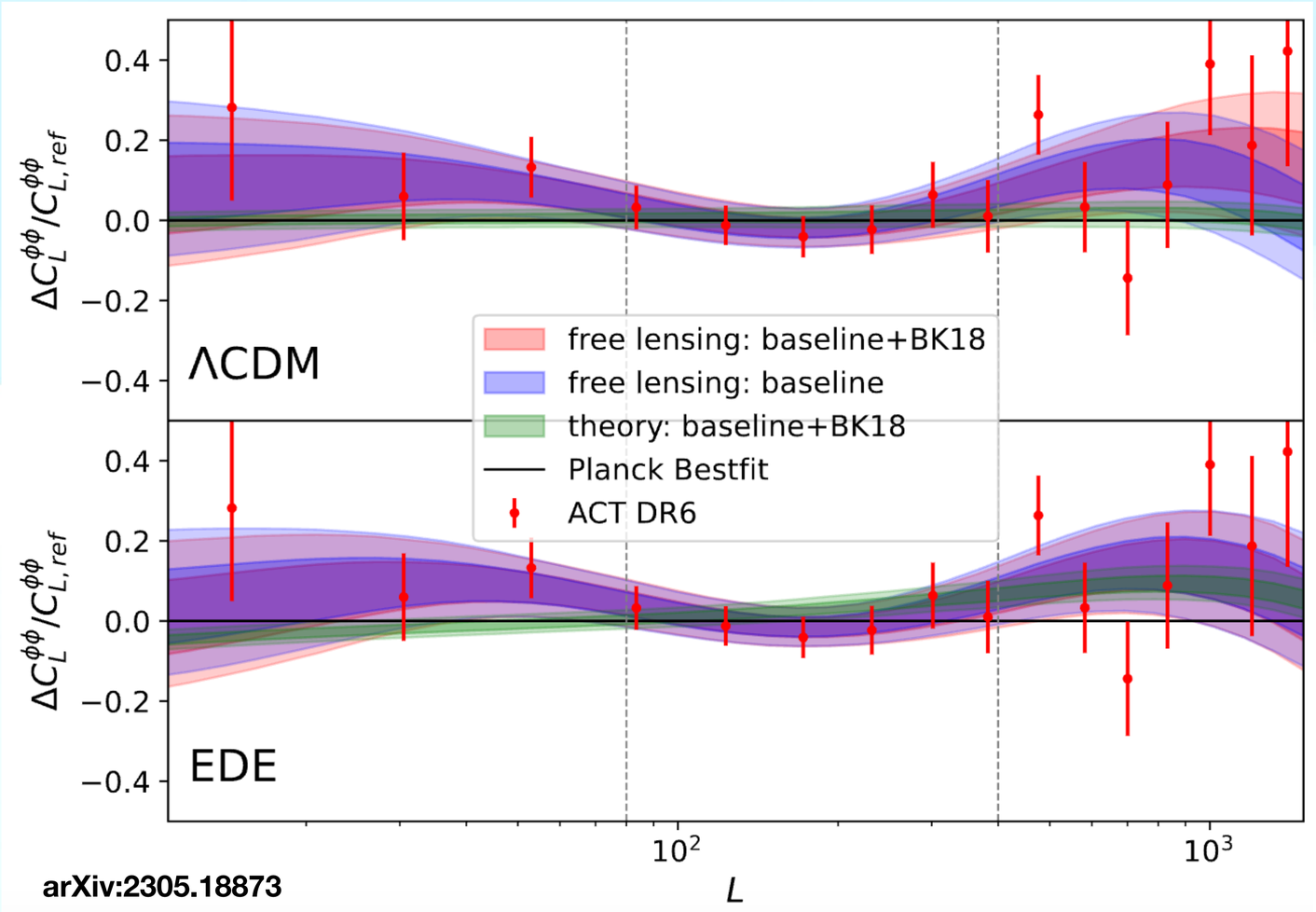
$$A(L) \sim GP[\bar{f}(L), K]$$

3 Nodes: $\{A_{L=50}, A_{L=200}, A_{L=800}\}$



Results

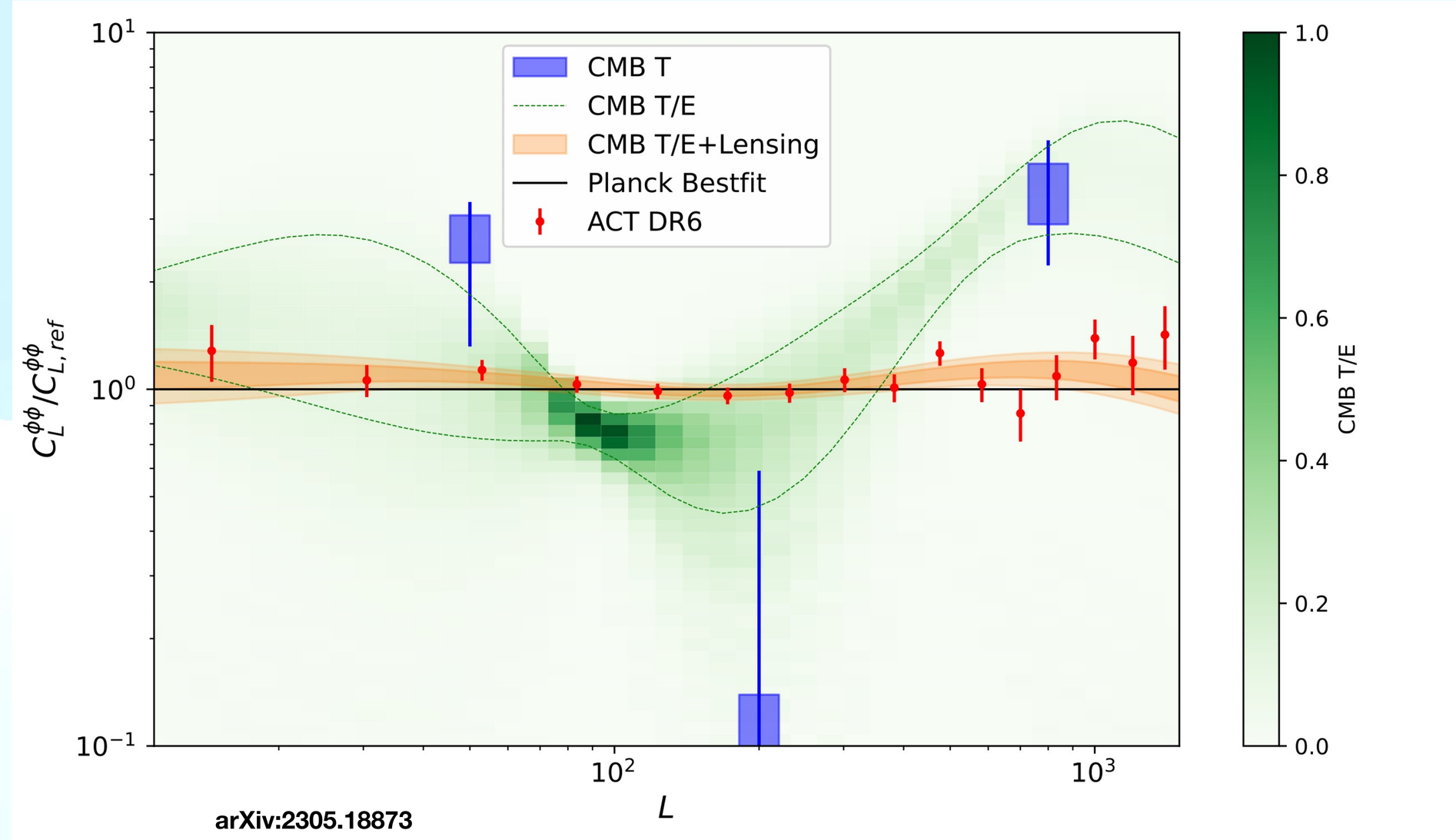
CMB TTTEEE + Lensing reconstruction (+ CMB B mode)



arXiv:2305.18873

- Similar constraints for different EDE
- Compatible with LCDM in (80,400)
- Enhanced amplitude at high and low L
- B mode constraint at high L

Results


CMB T
CMB T/E
CMB T/E+Lensing
Planck Bestfit
ACT DR6
$C_L^{\phi\phi}/C_{L,ref}^{\phi\phi}$
L
CMB T/E
arXiv:2305.18873

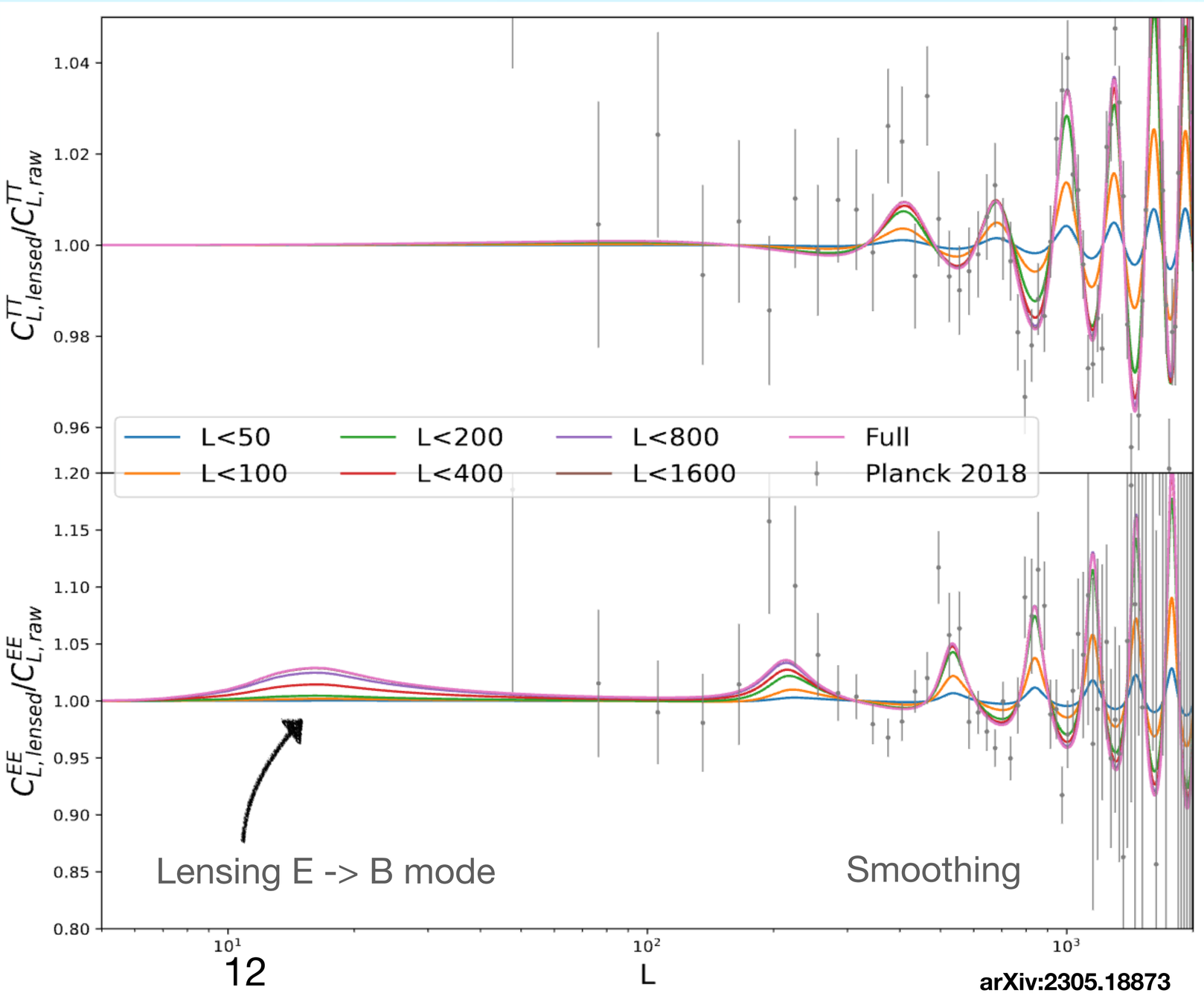
Results

$C_{L,raw}$

$C^{\phi\phi}_{L<\#}$

$C_{L,lensed}$

B mode constrains L>400



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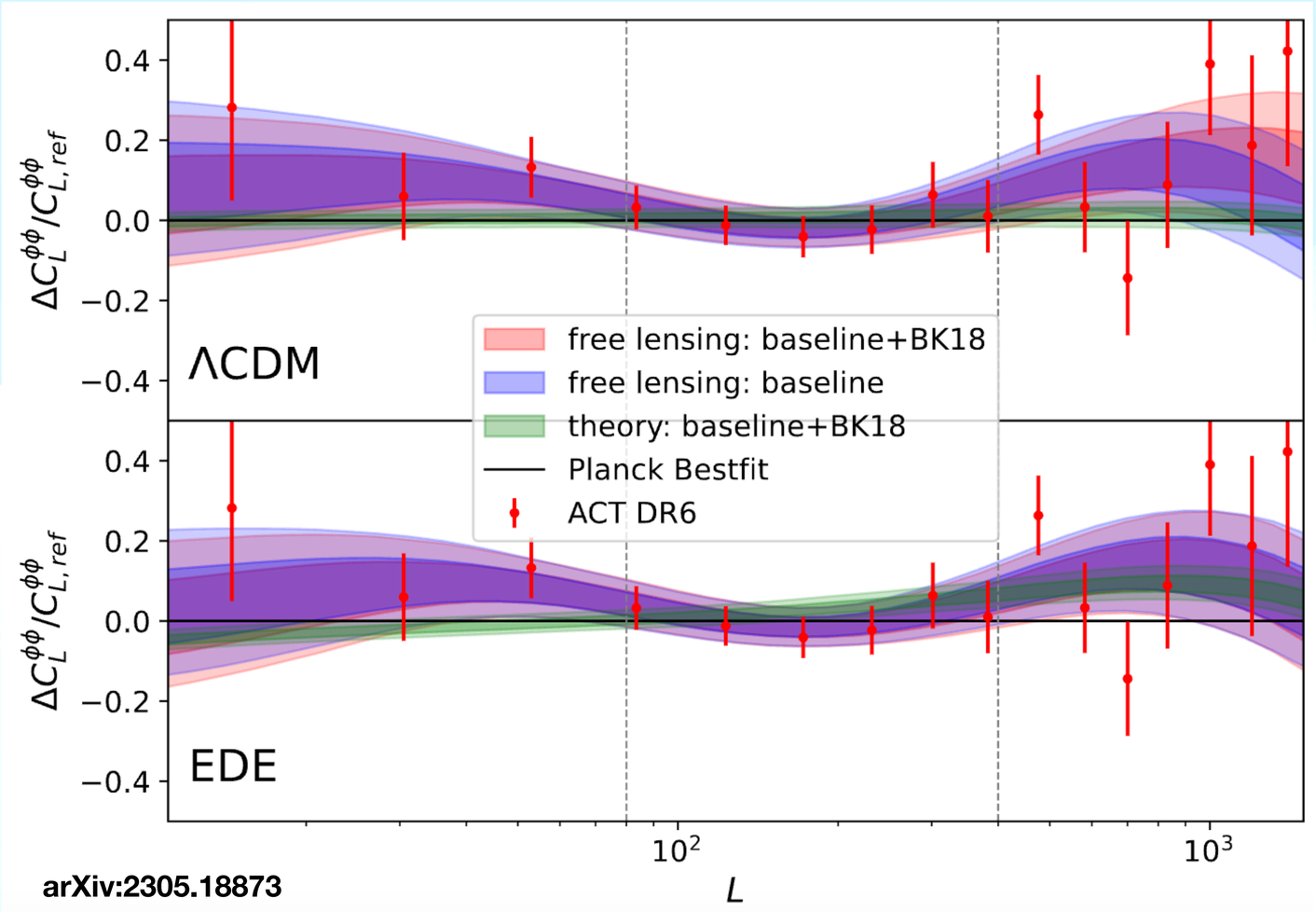

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Conclusion

- New GP sampling method, fewer nodes required
- Late universe marginalized over
  - Insensitive to early Universe model (ΛCDM vs EDE)
  - 80<l<400 dominated by lensing reconstruction
  - High and low l pushed up by lensed T/E
  - New constraint from B mode
- Work in progress: crossing with galaxy weak lensing

$$K(x_1, x_2) = \sigma^2 \exp\left(-\frac{|x_1 - x_2|^2}{2l^2}\right) \qquad l = 1.0, \sigma = 0.1$$

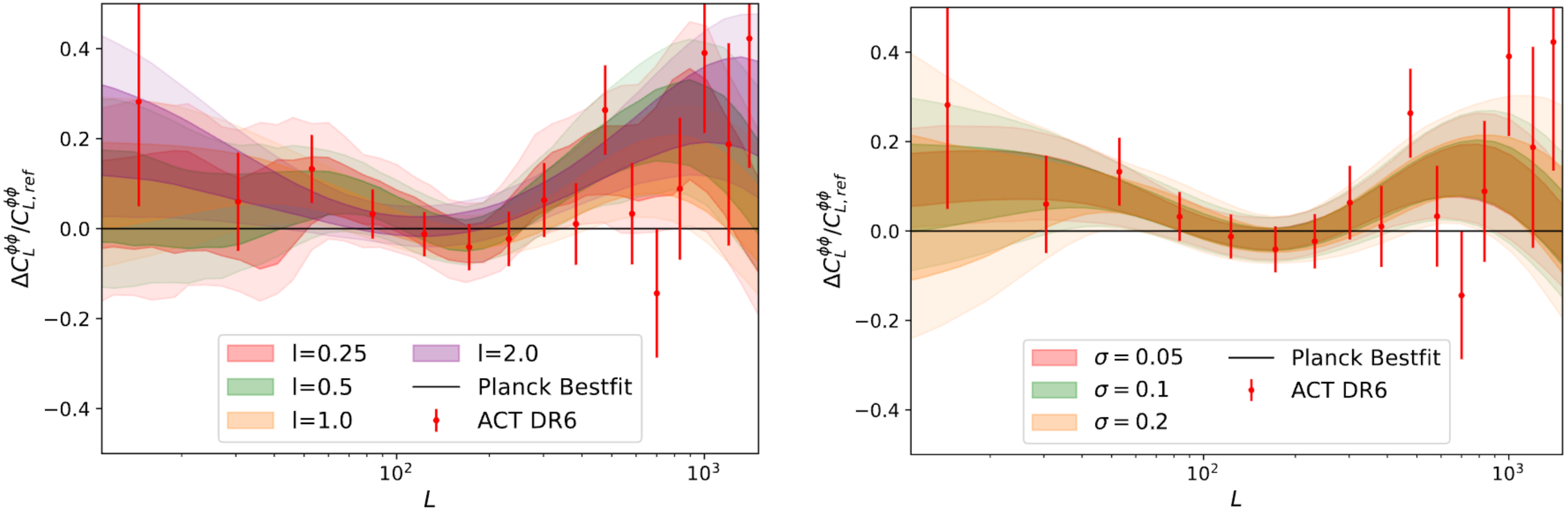
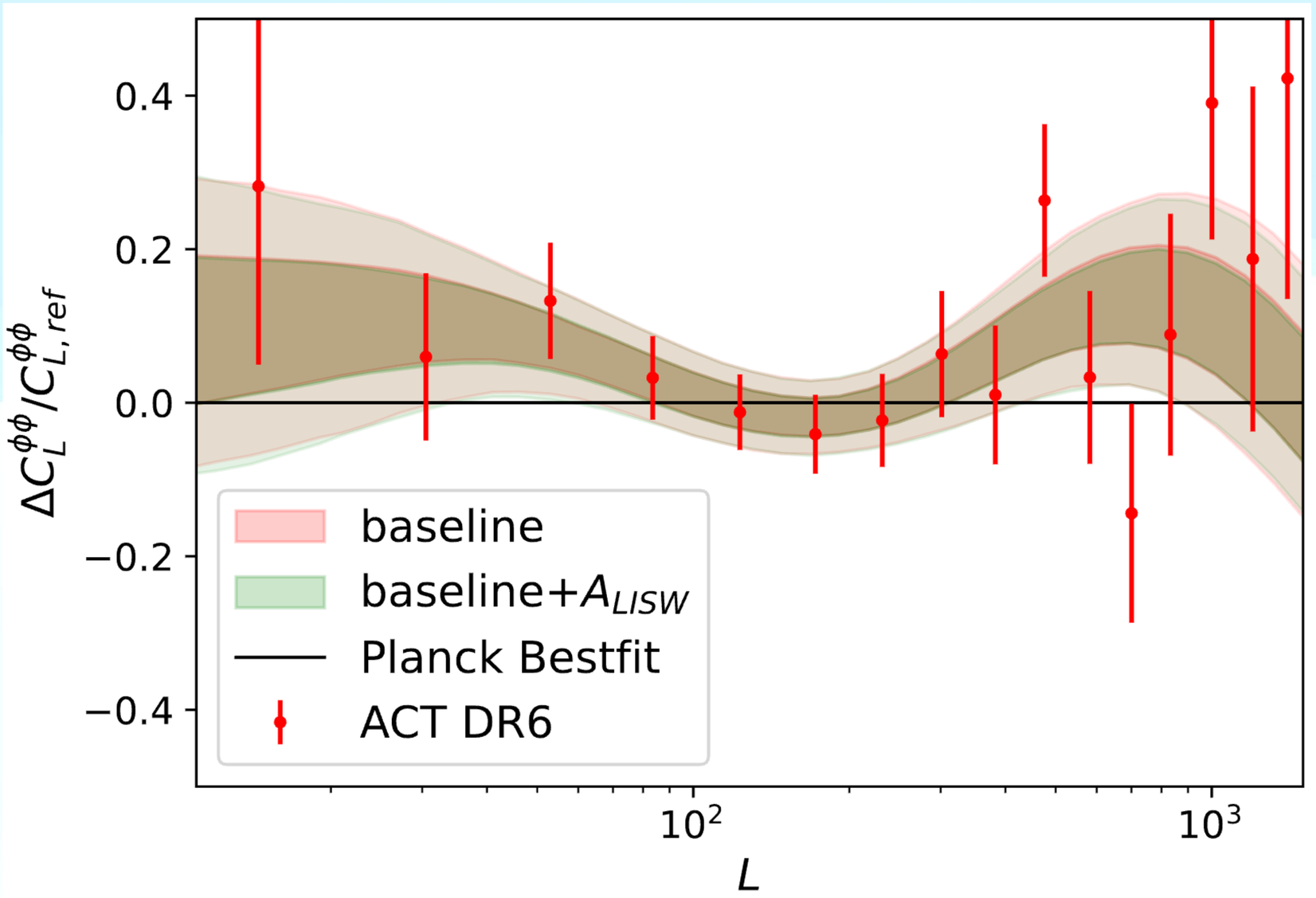


FIG. 10: Lensing shape constraints in ΛCDM with different GP parameters. *Left panel*: $l = \{0.25, 0.5, 1.0, 2.0\}$, $\sigma = 0.1$. *Right panel*: $l = 1.0$, $\sigma = \{0.05, 0.1, 0.2\}$.

$A_{ISW} = 1$


0.4
0.2
0.0
−0.2
−0.4
$\Delta C_L^{\phi\phi}/C_{L,ref}^{\phi\phi}$
baseline
baseline+A_{LISW}
Planck Bestfit
ACT DR6
10^2
10^3
L