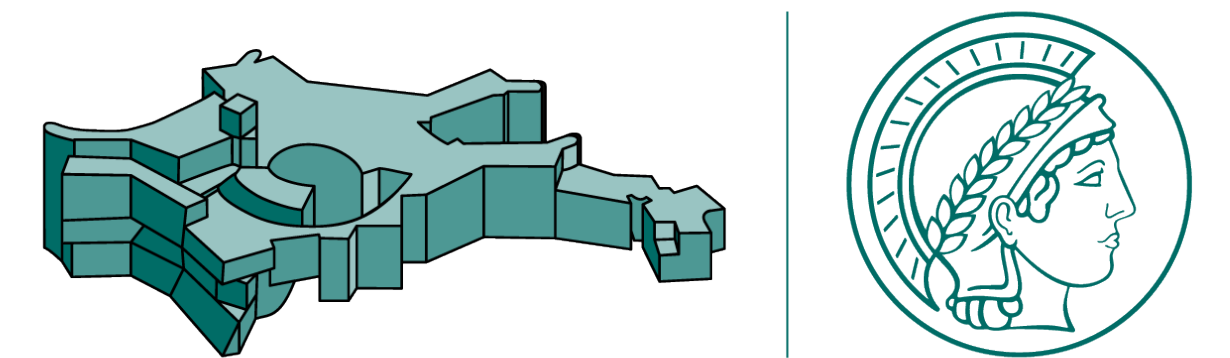


A new constraint on Early Dark Energy using the profile likelihood

based on LH, Ferreira, Komatsu (ApJ.L. 929 (2022) 1, L16)

Sep. 11, 2022 – “Tensions in Cosmology”, Corfu

Laura Herold (MPA, Munich)



MAX PLANCK INSTITUTE
FOR ASTROPHYSICS

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EDE and LSS

Prior volume effects in the EDE model?

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Early Dark Energy (EDE)

Kamionkowski et al. 2014, Karwal & Kamionkowski 2016, Caldwell & Devulder 2018, Poulin et al. 2019

Canonical EDE model: scalar field ϕ with potential

$$V(\phi) = V_0 [1 - \cos(\phi/f)]^n, \quad n = 3 \text{ fixed}$$

Free parameters:

f_{EDE} : max. fraction of EDE,

$\log(z_c)$: critical redshift at which EDE is max.,

$\theta_i \equiv \phi_i/f$: initial value of the field.

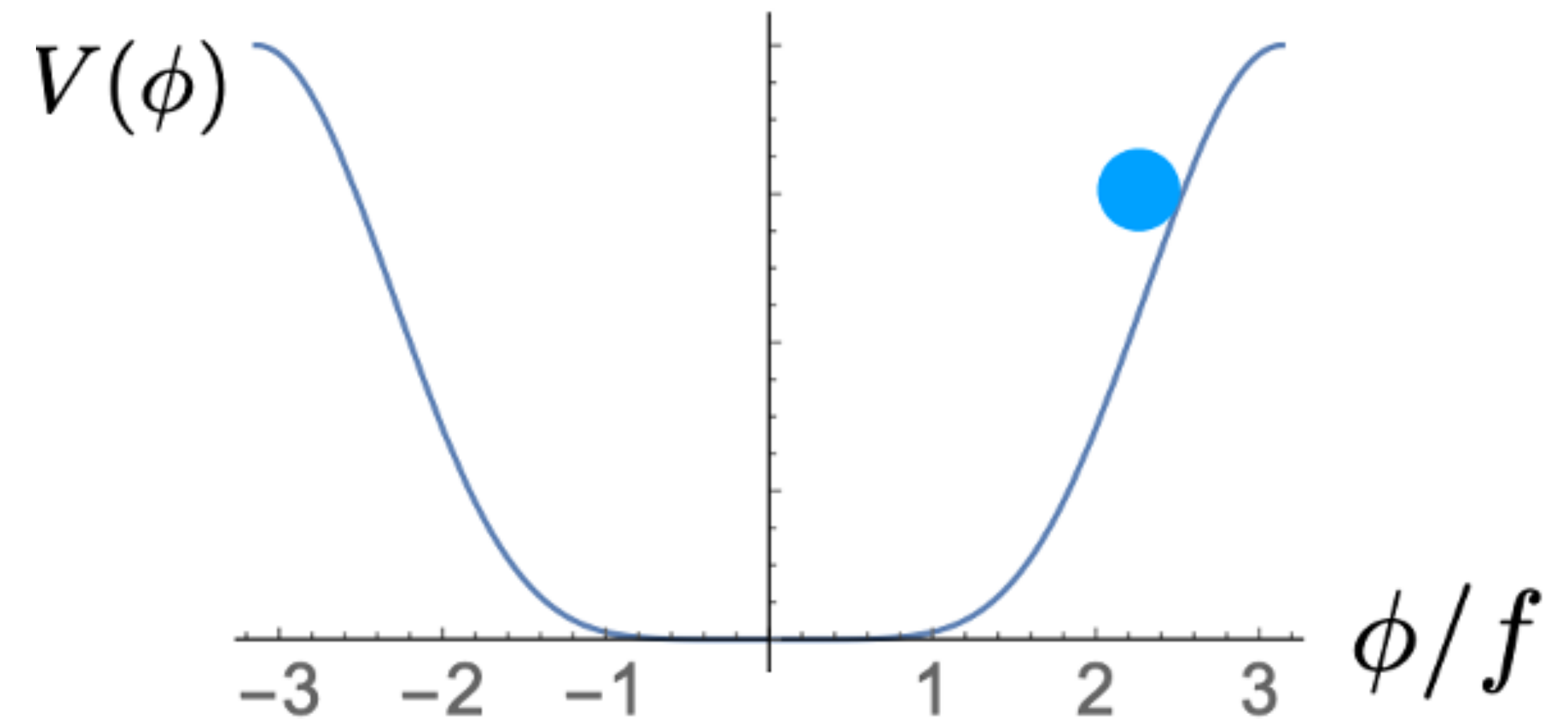


Image credit: Tristan Smith

“Solve” H_0 tension: $f_{\text{EDE}} \approx 10\%$

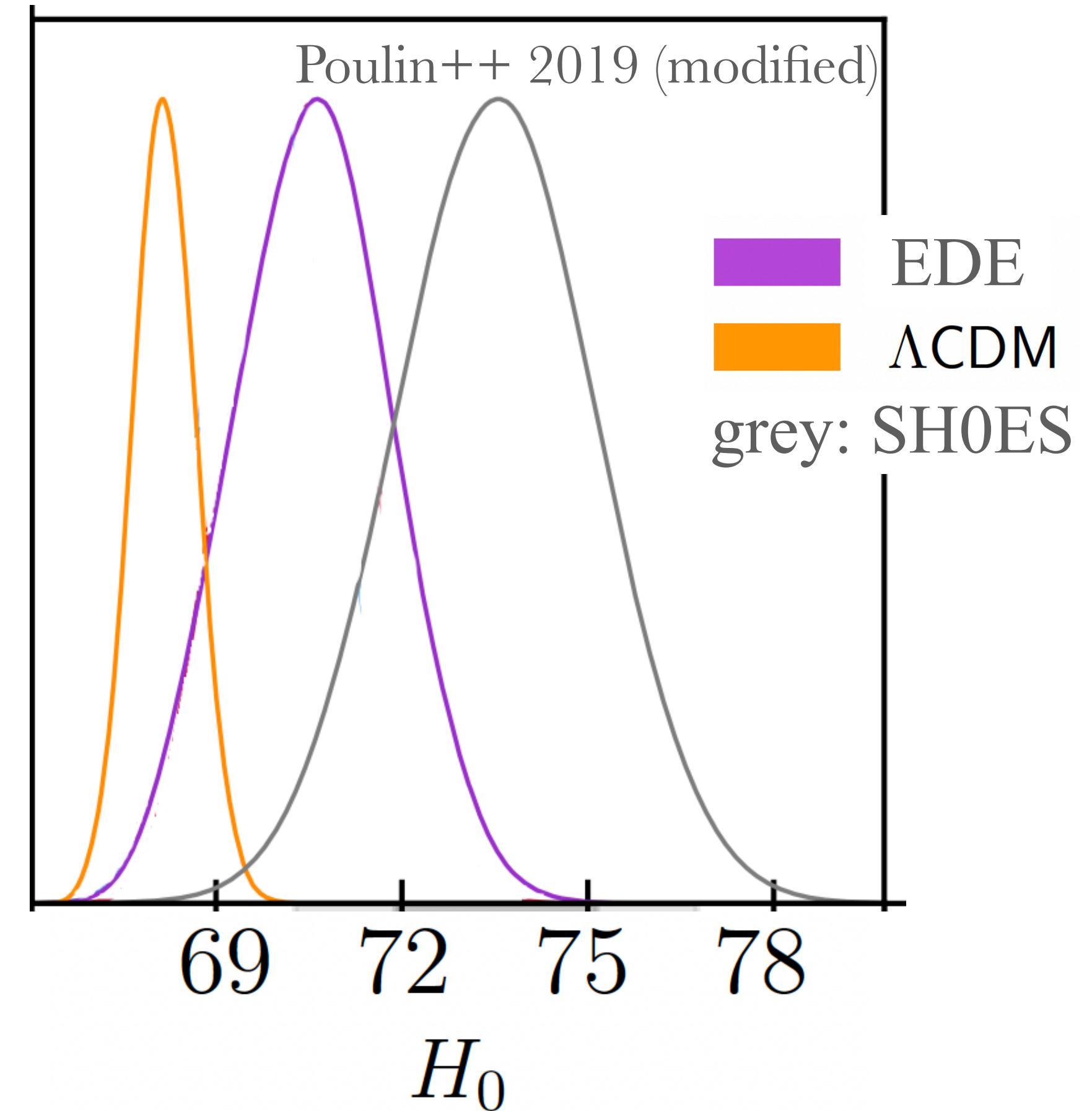


EDE can solve the H_0 tension

Poulin++ 2019

Data sets: Planck + BOSS BAO+ Pantheon + SH0ES

- $f_{\text{EDE}} = 0.107^{+0.035}_{-0.030}$ (mean $\pm 1\sigma$)
- $H_0 = 71.49 \pm 1.20$ km/s/Mpc

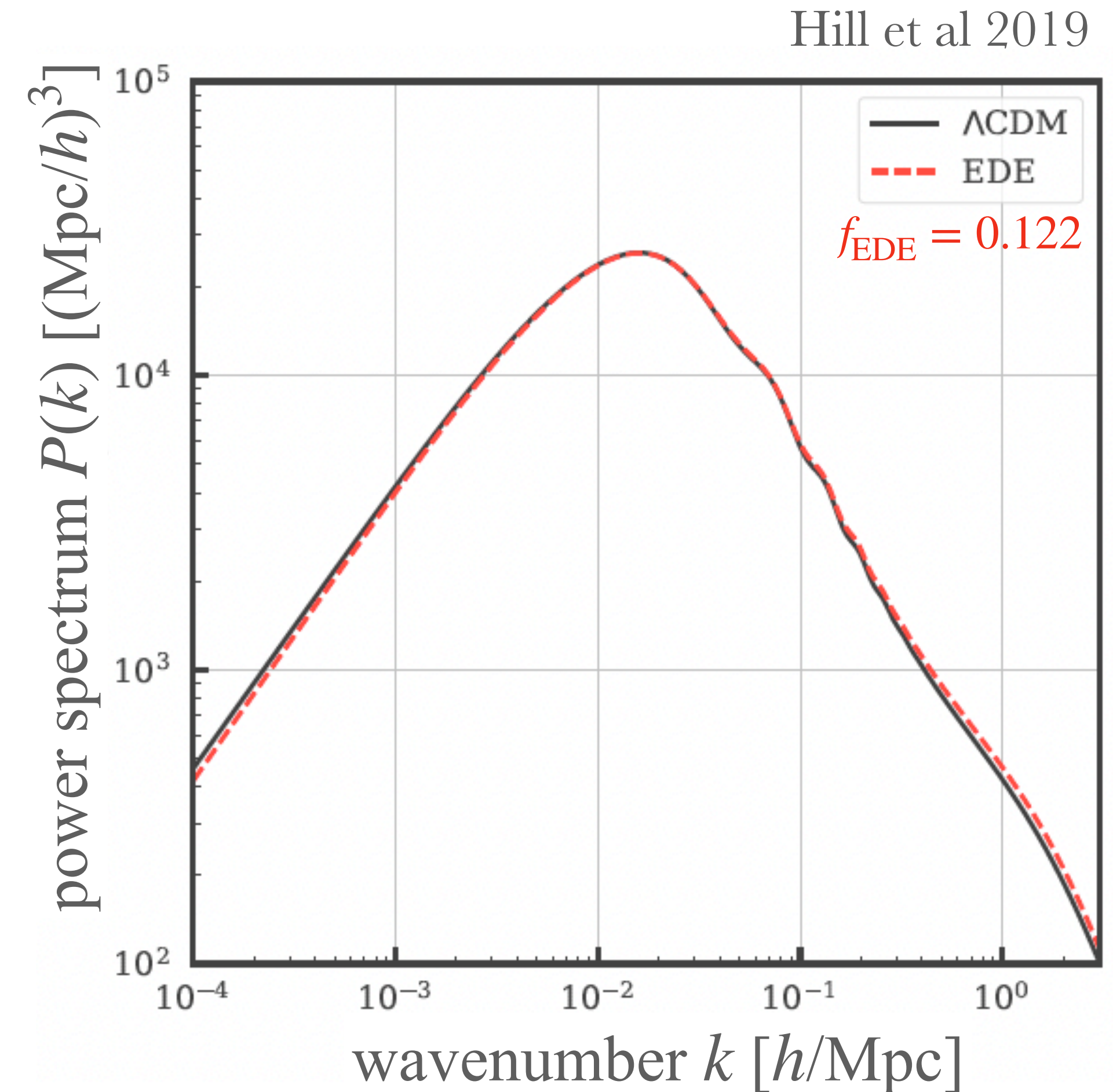


EDE can solve the H_0 tension

Poulin++ 2019, Hill++ 2019

Data sets: Planck + BOSS BAO+ Pantheon + SH0ES

- $f_{\text{EDE}} = 0.107^{+0.035}_{-0.030}$ (mean $\pm 1\sigma$)
- $H_0 = 71.49 \pm 1.20$ km/s/Mpc
- **But this comes at a cost:**
EDE suppresses growth of perturbations at early times
 - ω_{CDM} and n_s increase
 - small scale clustering increases



Adding galaxy clustering data: EDE is ruled out?

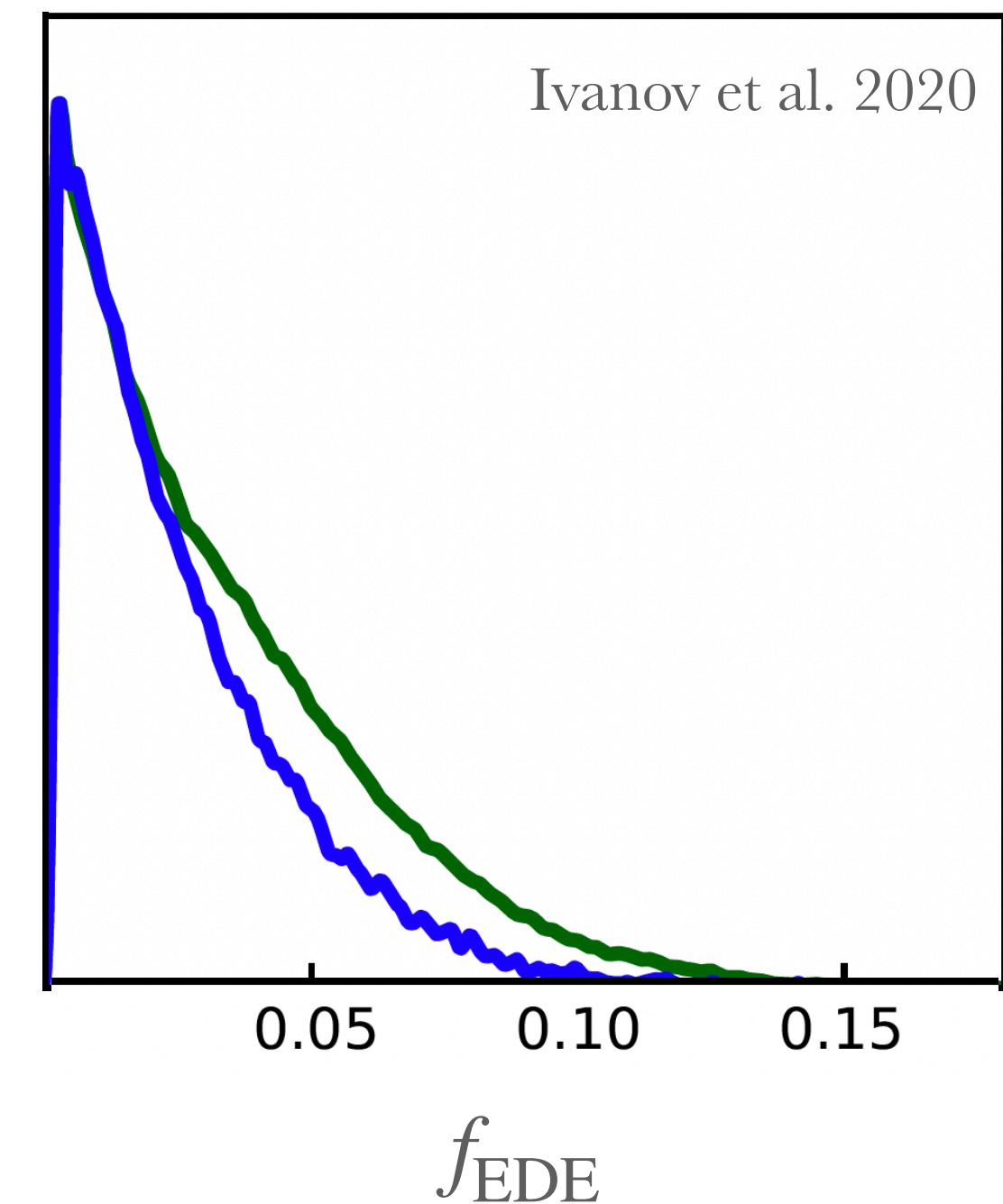
Ivanov++ 2020; D'Amico++ 2020

Data sets: Planck + BOSS DR12 BAO + full-shape analysis

- $f_{\text{EDE}} < 0.072$ (95% CL)
- $H_0 = 68.54^{+0.52}_{-0.95}$ km/s/Mpc

→ EDE does not solve H_0 tension

■ EDE, Planck TT+TE+EE
■ EDE, Planck + BOSS



EDE is not ruled out by LSS?

Smith++ 2020

Data sets: Planck + BOSS DR12 BAO + full-shape analysis + Pantheon

- fixing z_c , θ_i to bestfit to *Planck* — “1-parameter model”
- $f_{\text{EDE}} = 0.072 \pm 0.034$ (mean $\pm 1\sigma$)

Could **prior volume effects** bias the results?

■ SNe+CMB/1pEDE
■ EFT+BAO+SNe+CMB/1pEDE

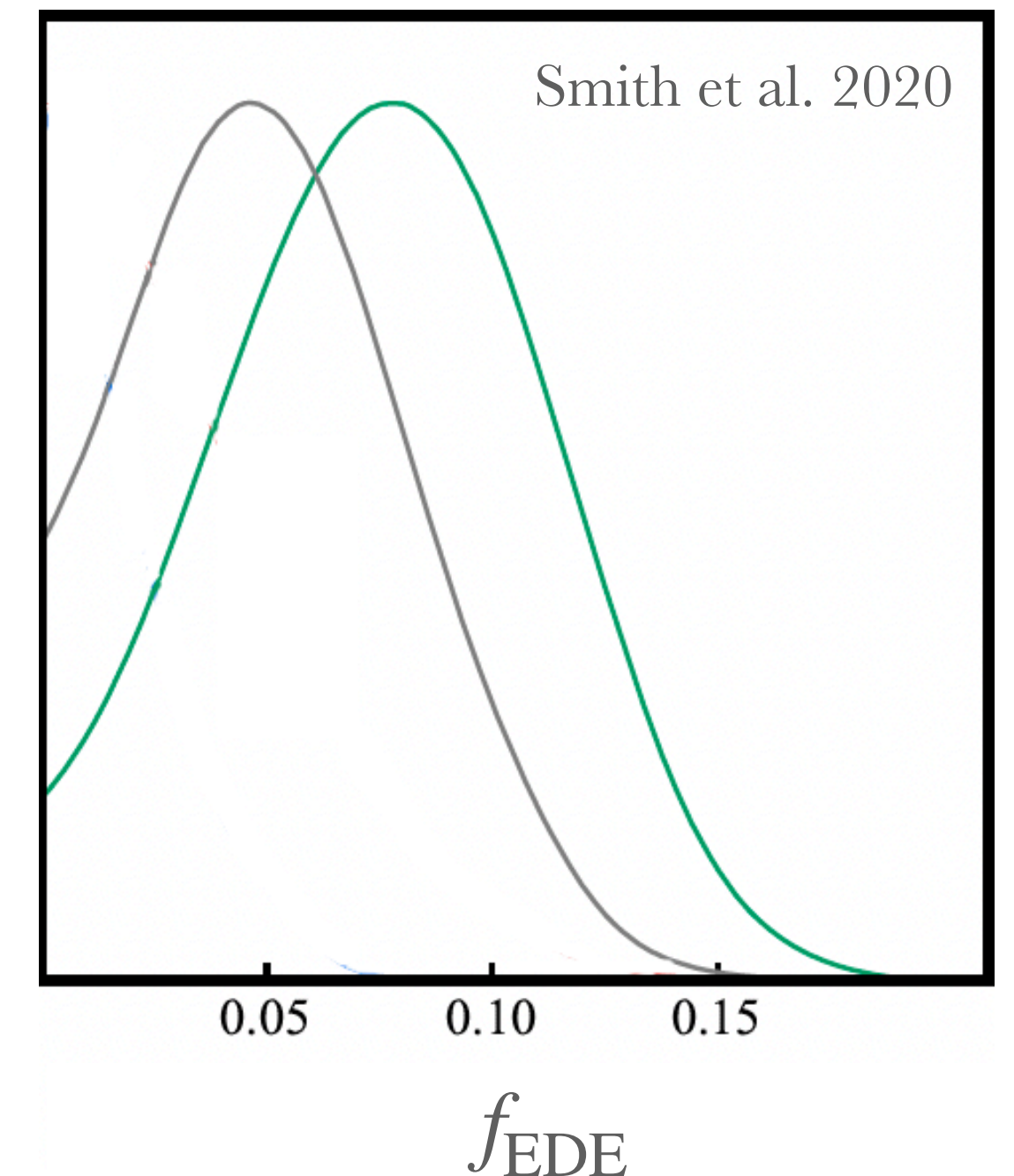


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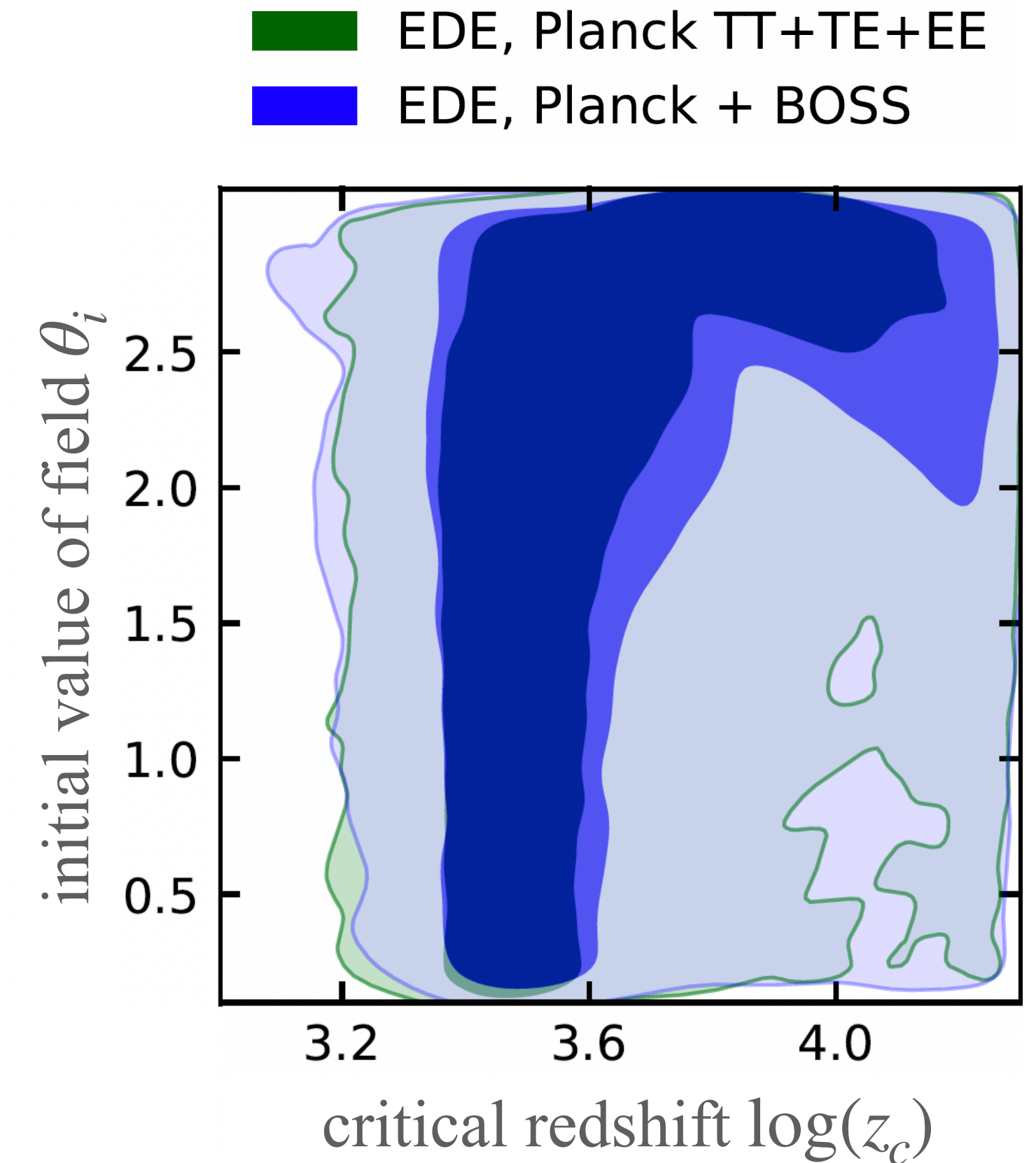
Prior volume effects

Ivanov et al. 2020

...appear if the posterior is influenced by the prior volume.

Reasons:

- Model has too many parameters / data is not constraining.
- Posterior is very non-Gaussian.
- Parameter structure of the model generates large volume differences.



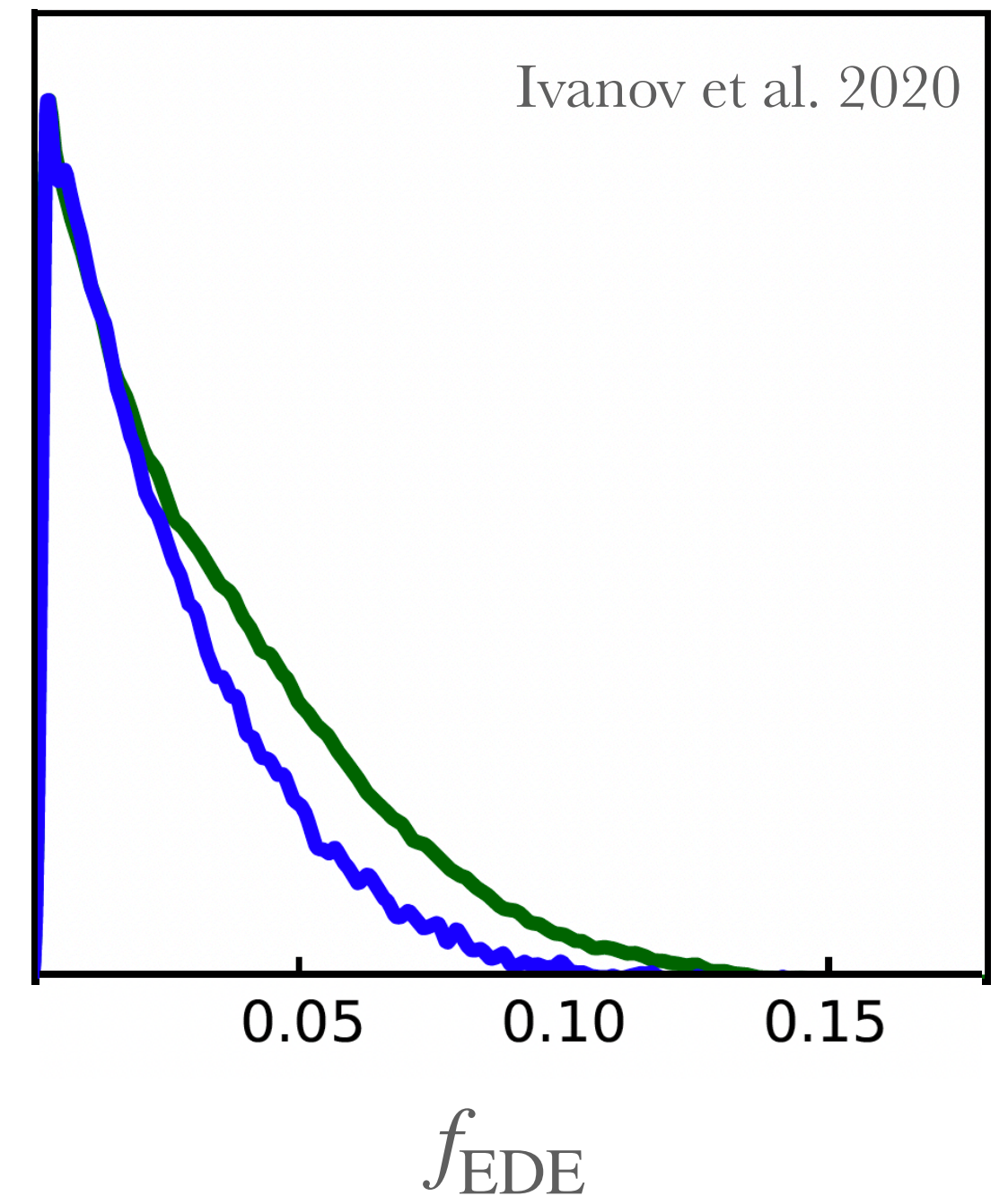
Prior volume effects

...appear if the posterior is influenced by the prior volume.

Reasons:

- Model has too many parameters / data is not constraining.
- Posterior is very non-Gaussian.
- Parameter structure of the model generates large volume differences.

■ EDE, Planck TT+TE+EE
■ EDE, Planck + BOSS



$f_{\text{EDE}} \approx 0$: all values of z_c, θ_i
degenerate with ΛCDM



Prior volume effects

...appear if the posterior is influenced by the prior volume.

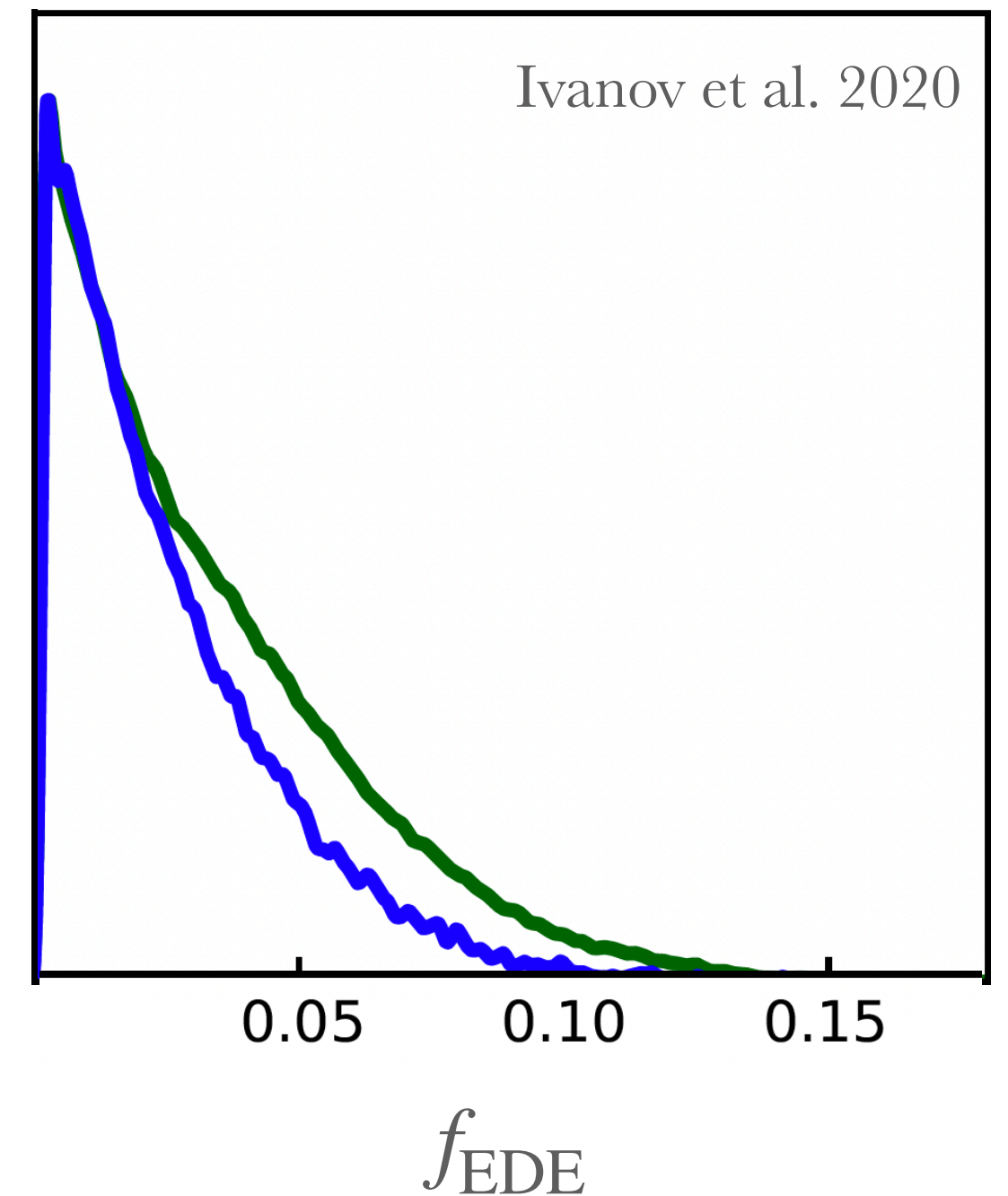
Reasons:

- Model has too many parameters / data is not constraining.
- Posterior is very non-Gaussian.
- Parameter structure of the model generates large volume differences.

→ Bias in the marginalised posterior.

Idea: **Profile likelihood** is not subject to volume effects

■ EDE, Planck TT+TE+EE
■ EDE, Planck + BOSS



$f_{\text{EDE}} \approx 0$: all values of z_c, θ_i
degenerate with ΛCDM



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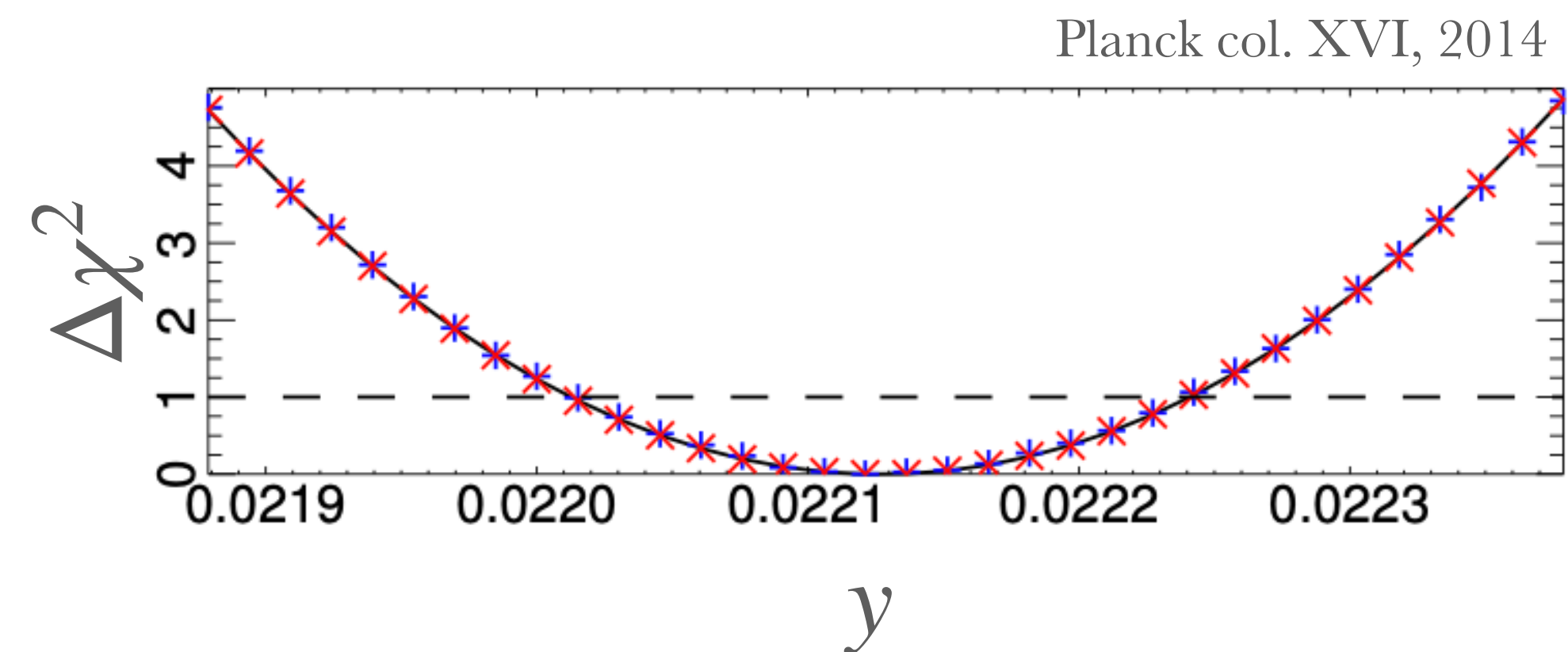
Profile likelihood

Profile likelihood:

- Fix parameter y of interest to different values, minimize χ^2 w.r.t. all other parameters
- for Gaussian distribution this gives parabola in $\Delta\chi^2$

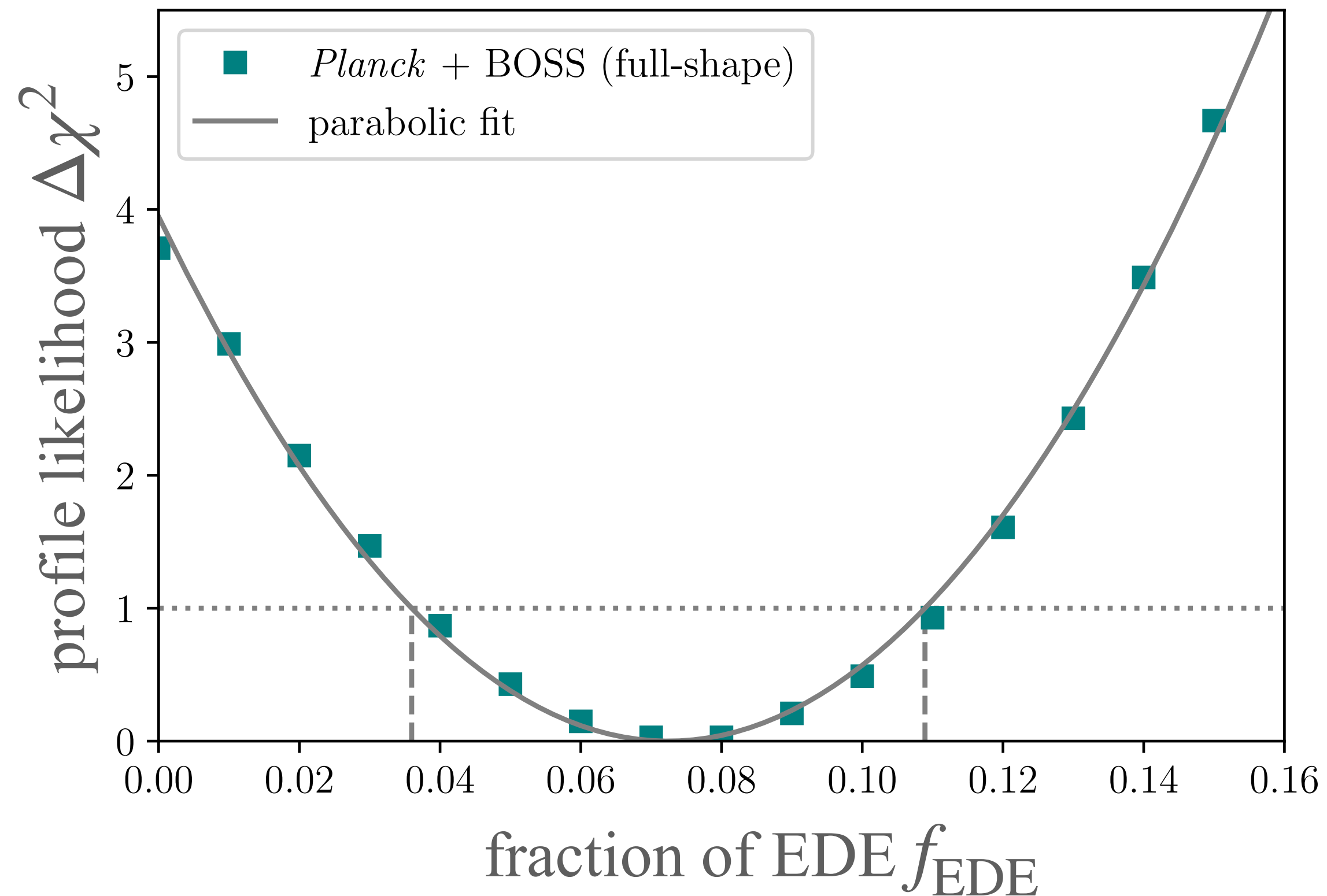
Confidence interval:

- Read off 1σ at the intersection with $\Delta\chi^2 = 1$
(*Neyman construction*)



Profile likelihood — results

LH, Ferreira, Komatsu (*ApJ.L.* 929 (2022) 1, L16)



Data sets: *Planck* 2018 + BOSS DR12 full-shape analysis (*Ivanov++ 2020*)

MCMC: Monte Python (*Brinckmann & Lesgourgues 2018*)

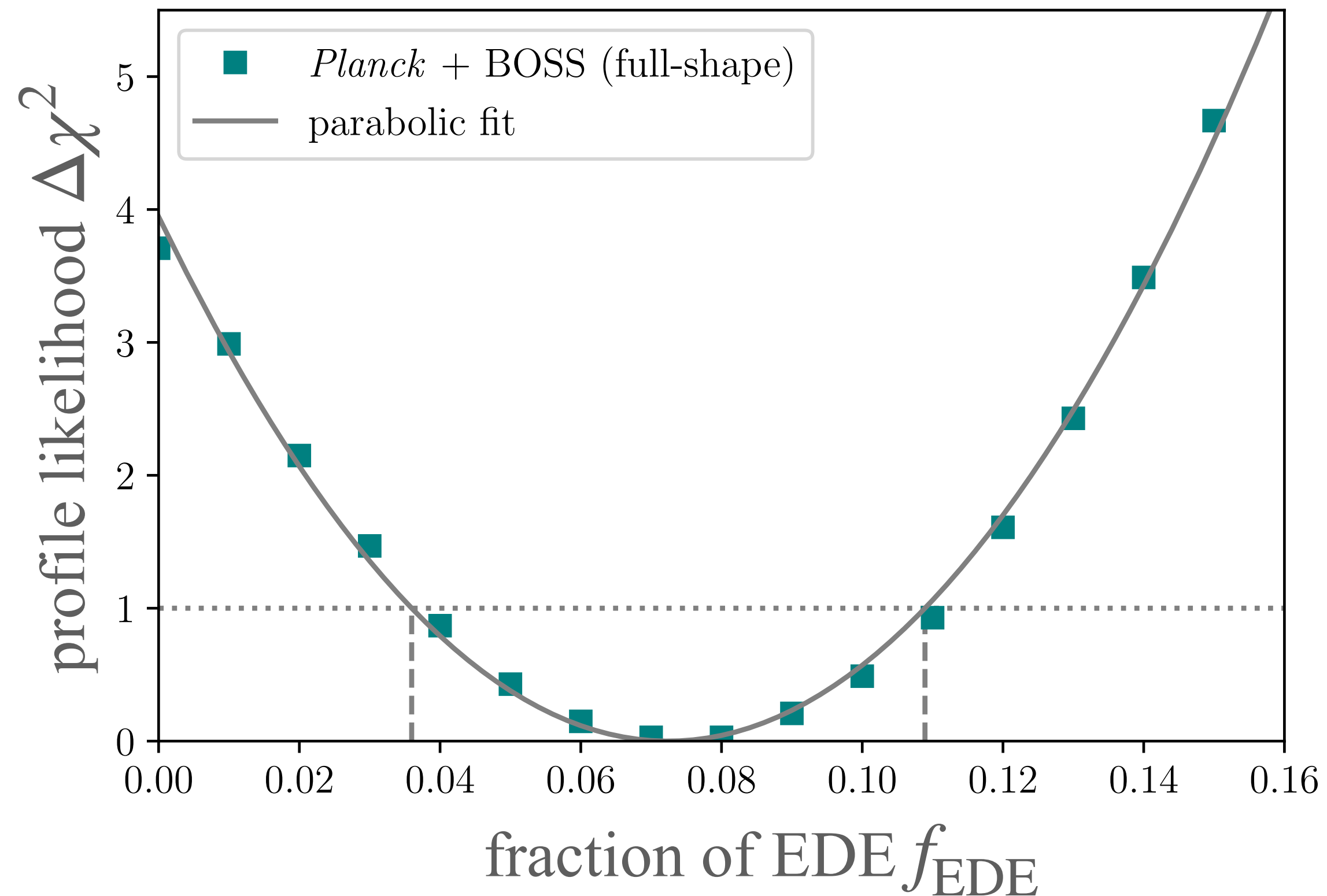
Model: EDE_CLASS-PT (*Hill++ 2020, Chudaykin++ 2020*)

We find $f_{\text{EDE}} = 0.072 \pm 0.036$ (68% C.L.)



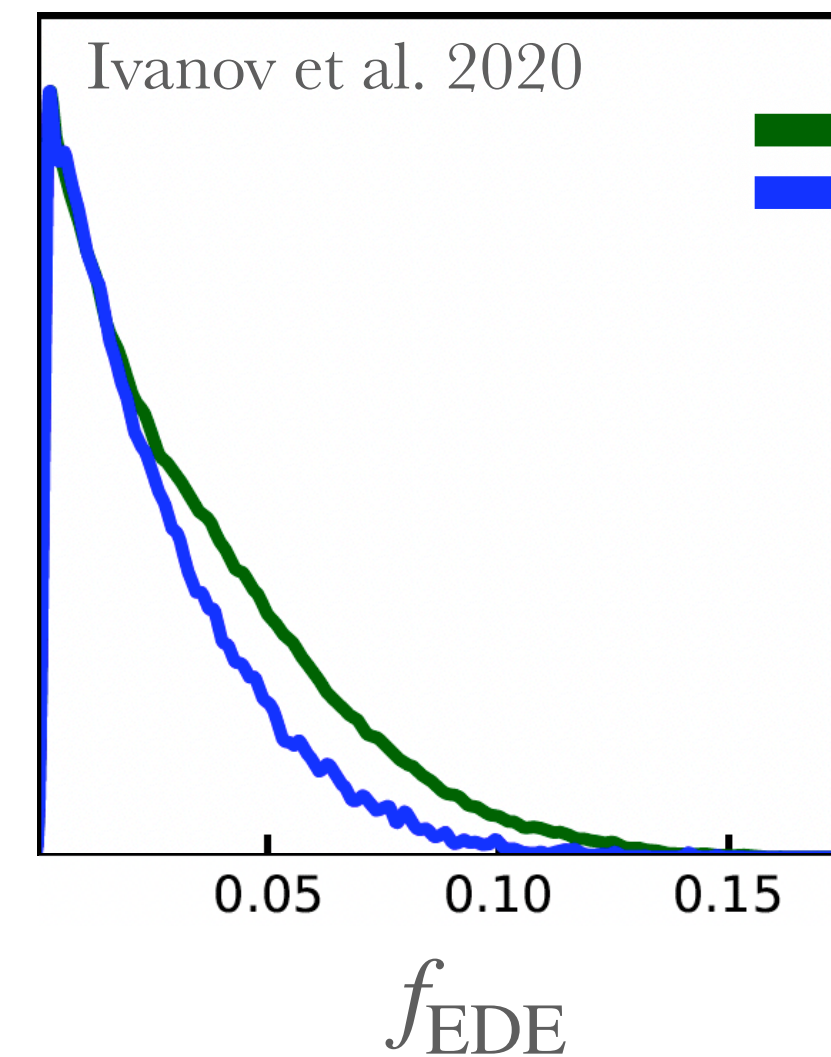
Profile likelihood – results

LH, Ferreira, Komatsu (ApJ.L. 929 (2022) 1, L16)



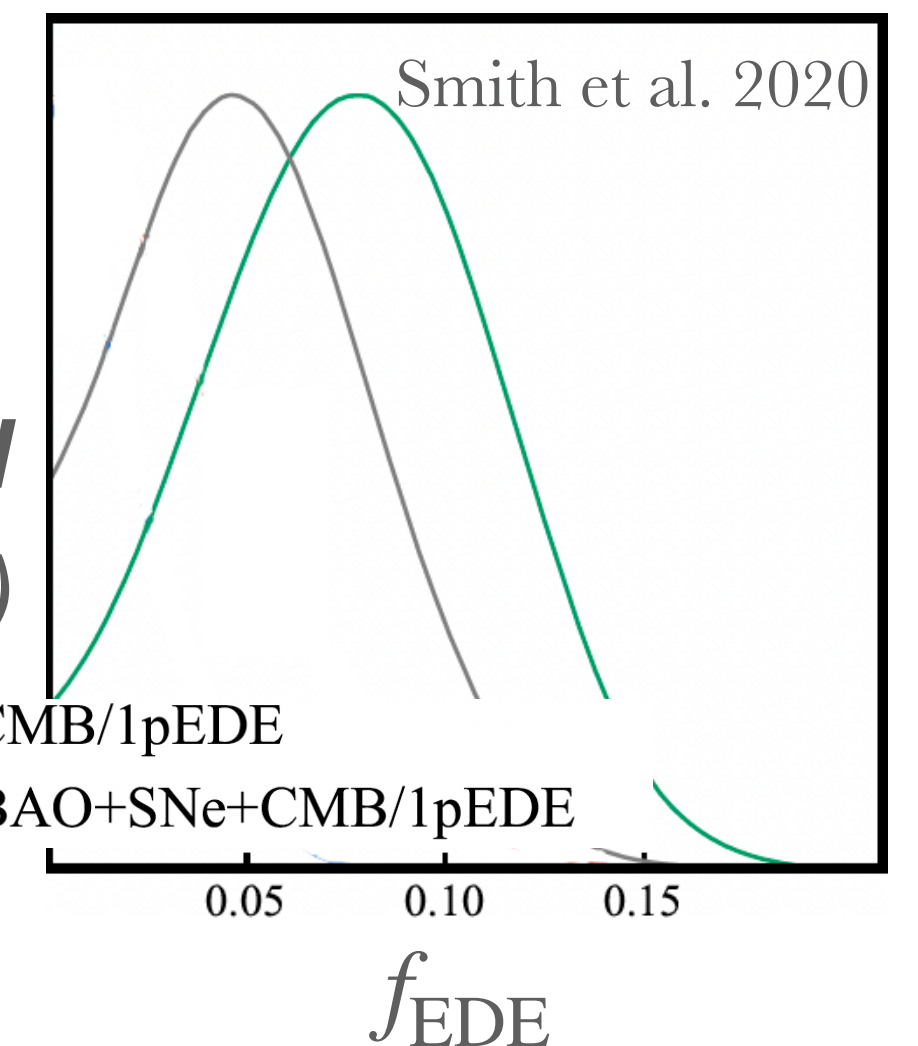
We find $f_{\text{EDE}} = 0.072 \pm 0.036$ (68% C.L.)

Comparison to previous results



■ EDE, Planck TT+TE+EE
■ EDE, Planck + BOSS
3-parameter model
 $f_{\text{EDE}} < 0.072$ (95% CL)

1-parameter model
 $f_{\text{EDE}} = 0.072 \pm 0.034$ (68% CL)



■ SNe+CMB/1pEDE
■ EFT+BAO+SNe+CMB/1pEDE



Summary

Prior volume effects

Important in the EDE model and possibly other beyond- Λ CDM models with extra parameters

Profile likelihood

Constraints on f_{EDE} and H_0 differ from full MCMC result
— EDE is not ruled out by galaxy clustering

To appear soon

EDE with more data sets (esp. weak lensing/ S_8 data)

