

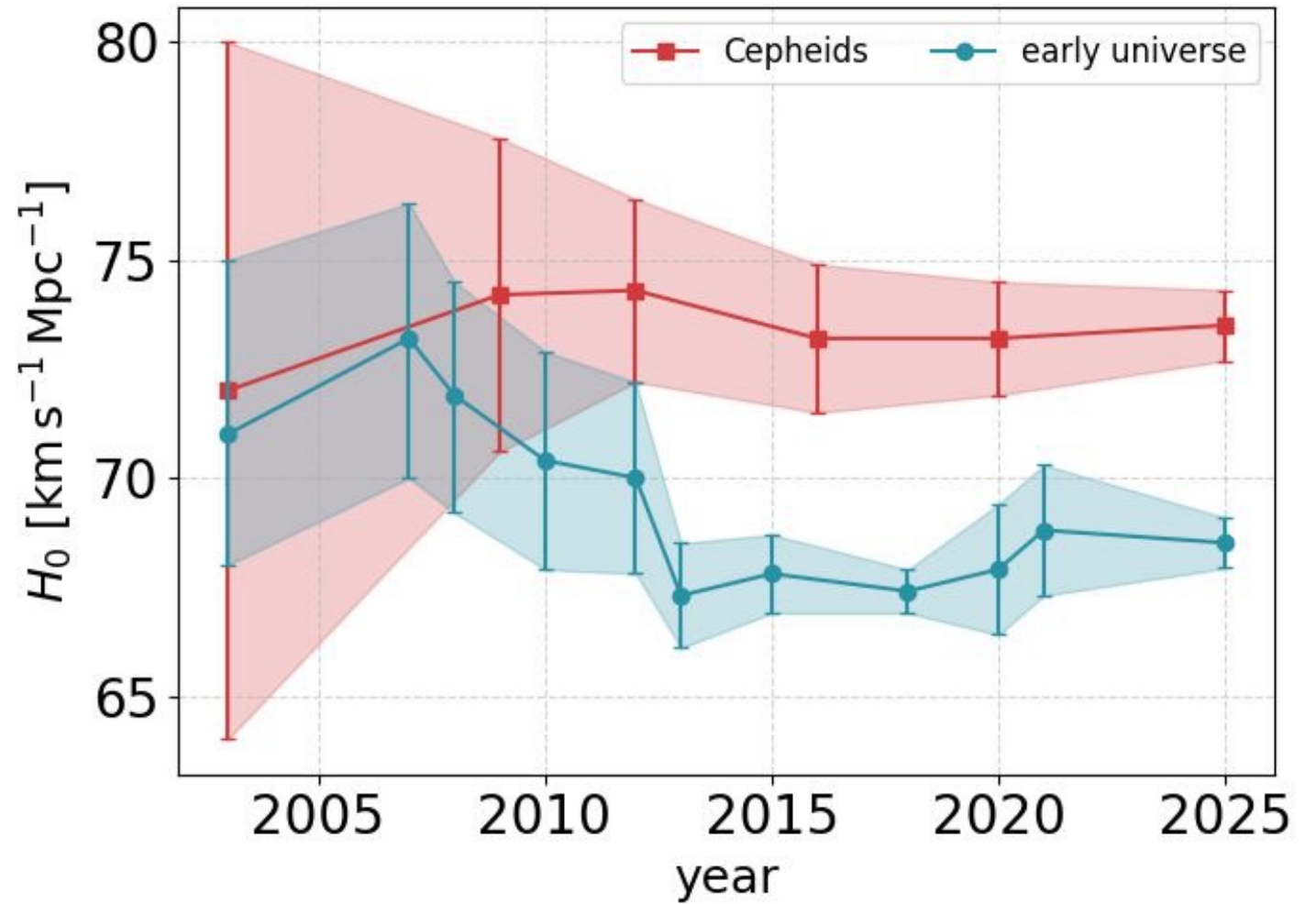
Multi-field EDE and the Hubble tension

marco bella

Univeristy of Trento -> UC Davis



hubble tension

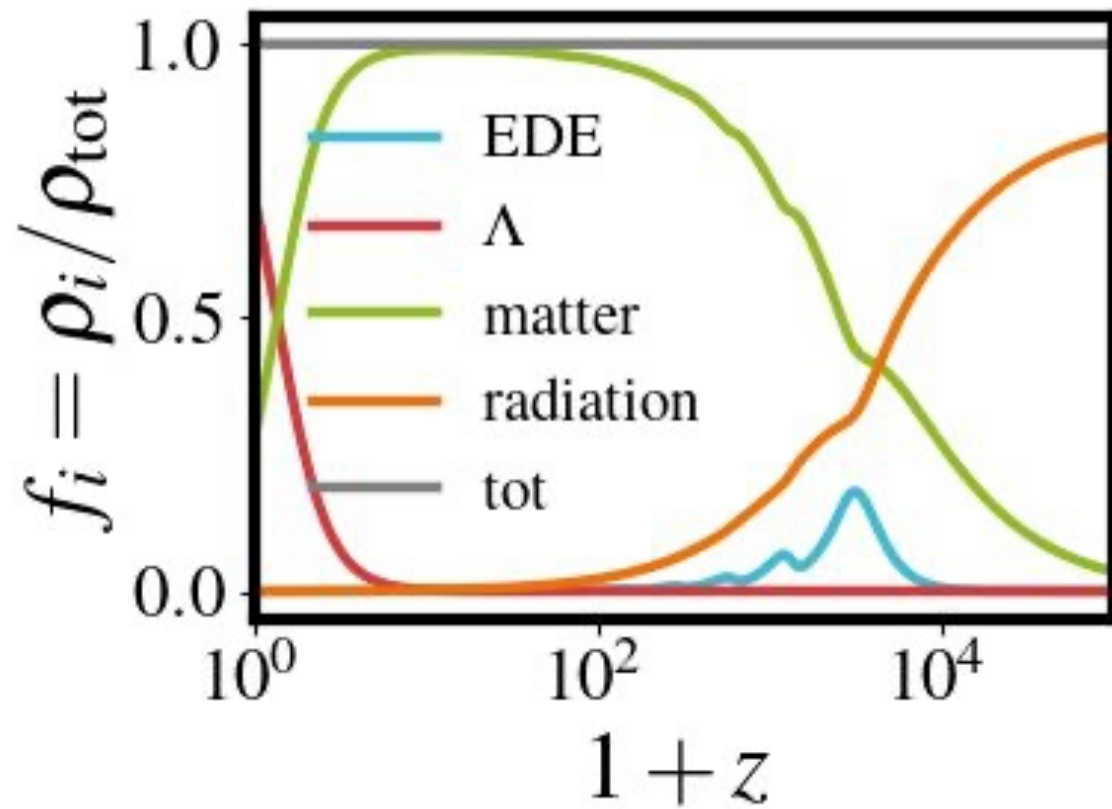
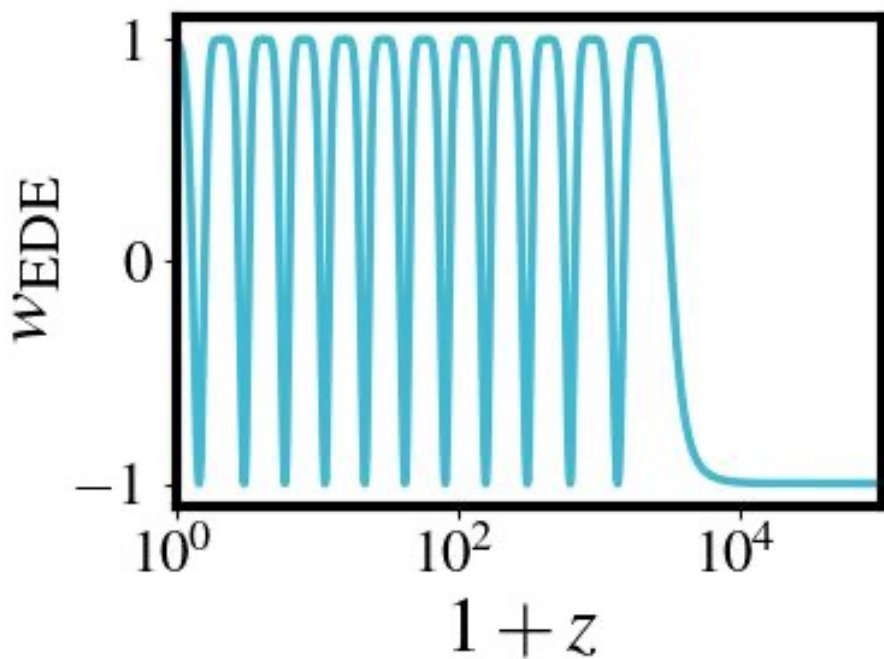




EDE: a popular solution

$$V(\phi) = m^2 f^2 \left(1 - \cos \frac{\phi}{f} \right)^n .$$

$$\phi(\tau, \mathbf{x}) \approx \phi^{(0)}(\tau) + \phi^{(1)}(\tau, \mathbf{x})$$

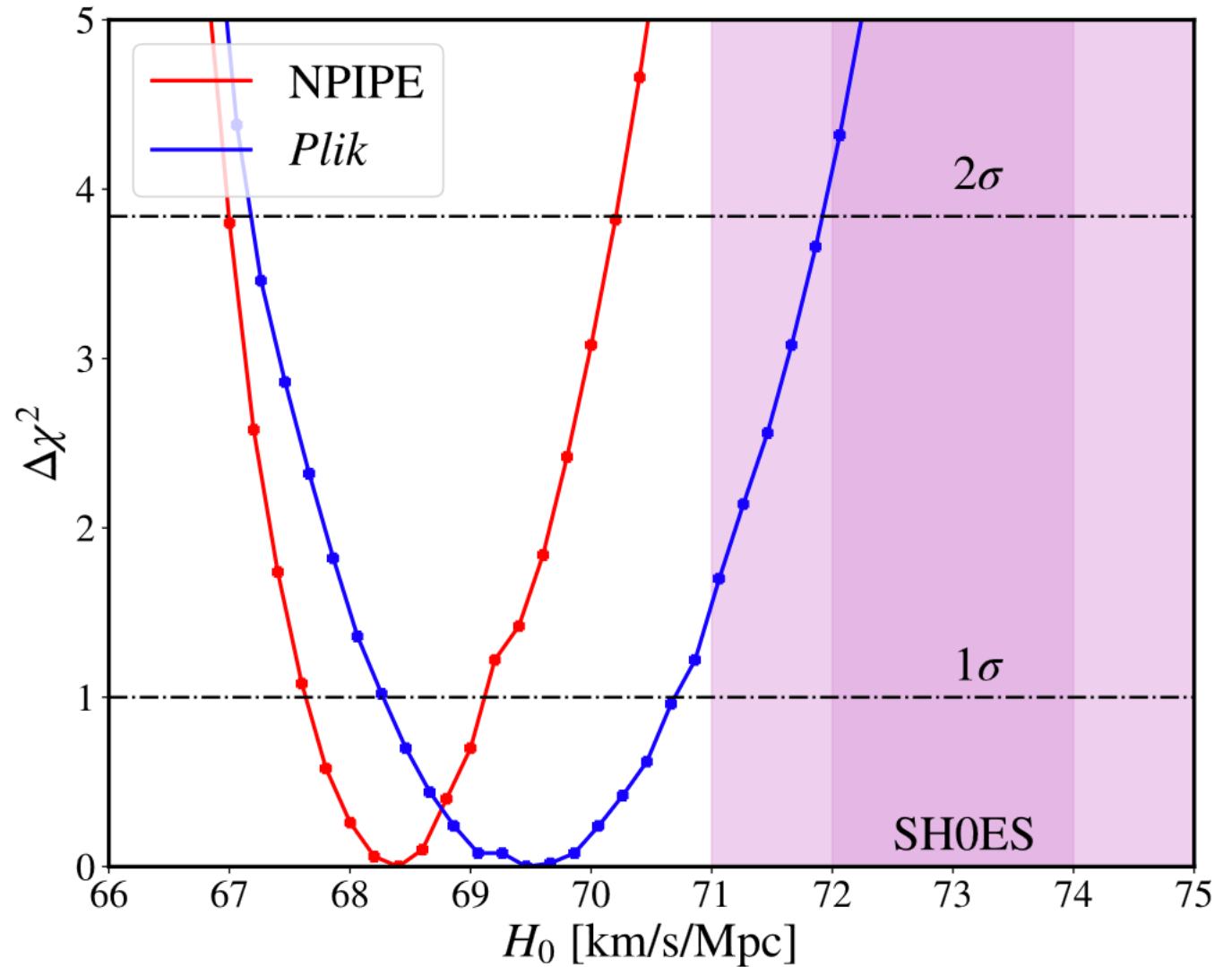


$$r_s^* \sim \int_{z^*}^{+\infty} \frac{dz}{H(z)} \quad r_s^* \downarrow \quad H_0 \uparrow$$

the NPIPE tragedy

Planck PR4: high- l reanalysis

EDE: H_0 at 3.7σ from SHoES

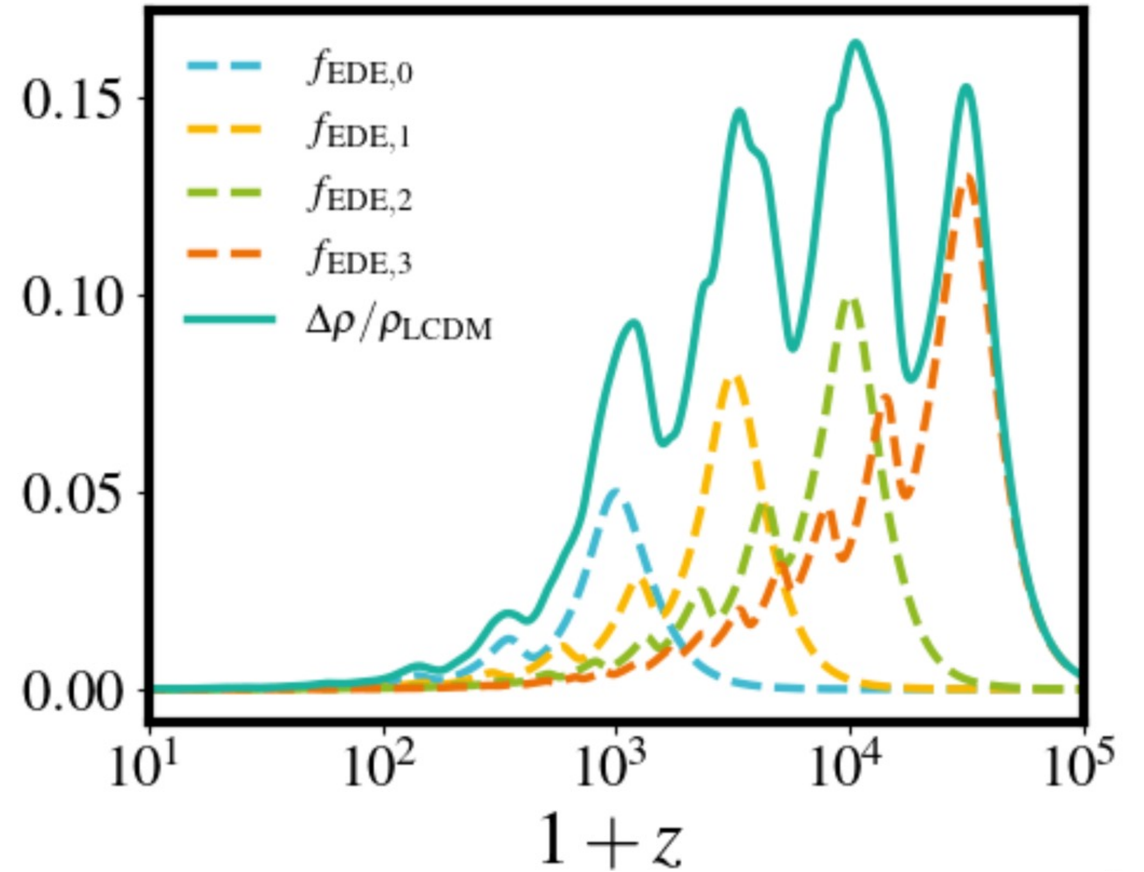


(Efsthathiou, Rosenberg, Poulin 2311.00524)

the model

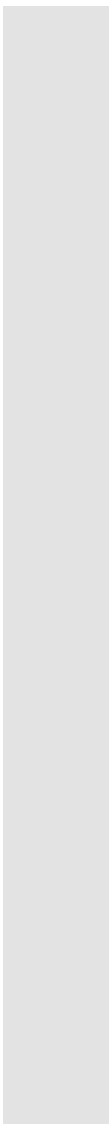


the (physical) model



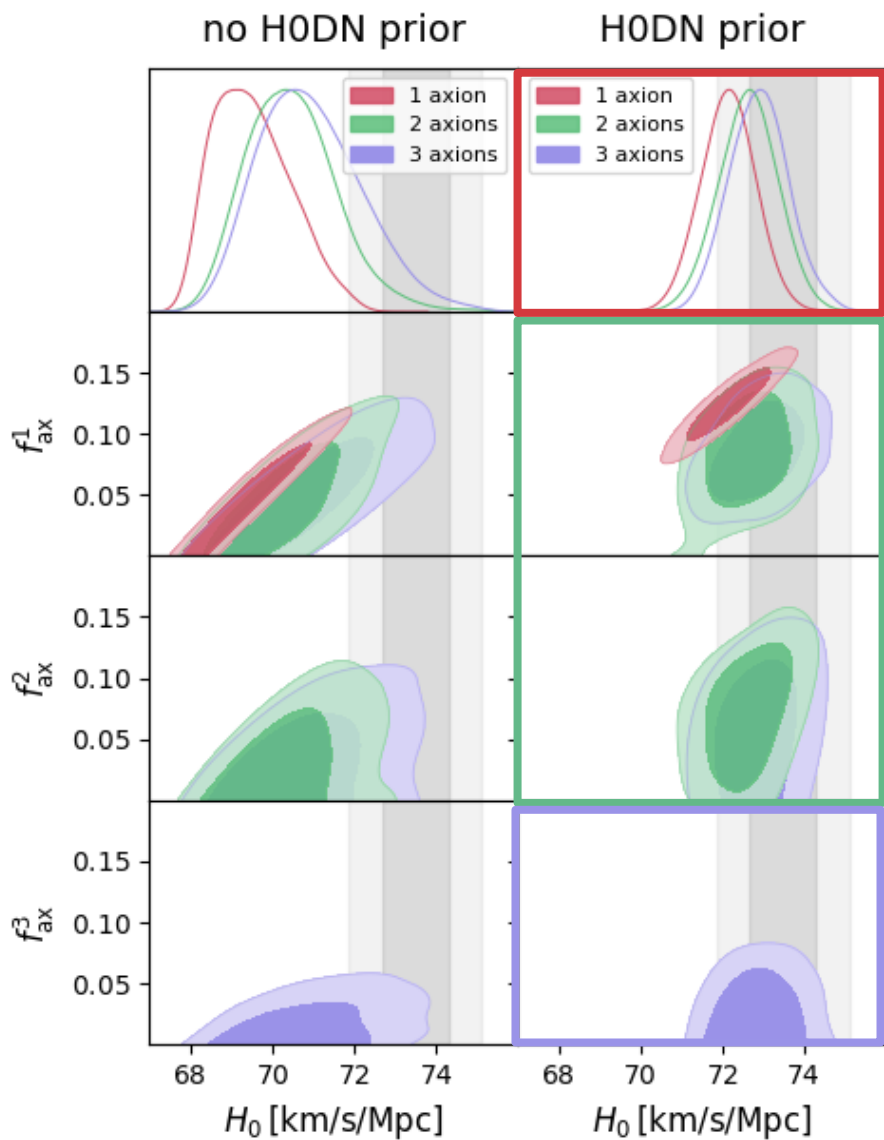
$$(f_{EDE,i} = \rho_{EDE,i}/\rho_{tot})$$

github.com/marcobeiia/mAxiCLASS



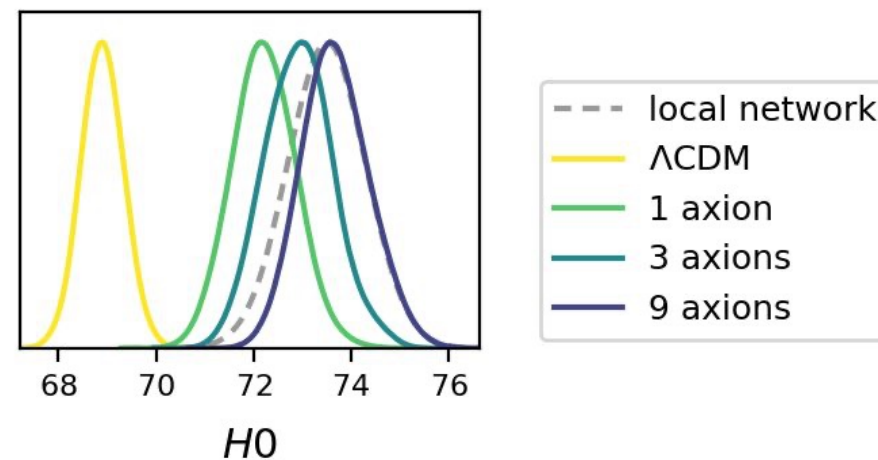
results

posteriors



more fields -> higher H_0

MORE FIELDS -> HIGHER H_0 !!!!

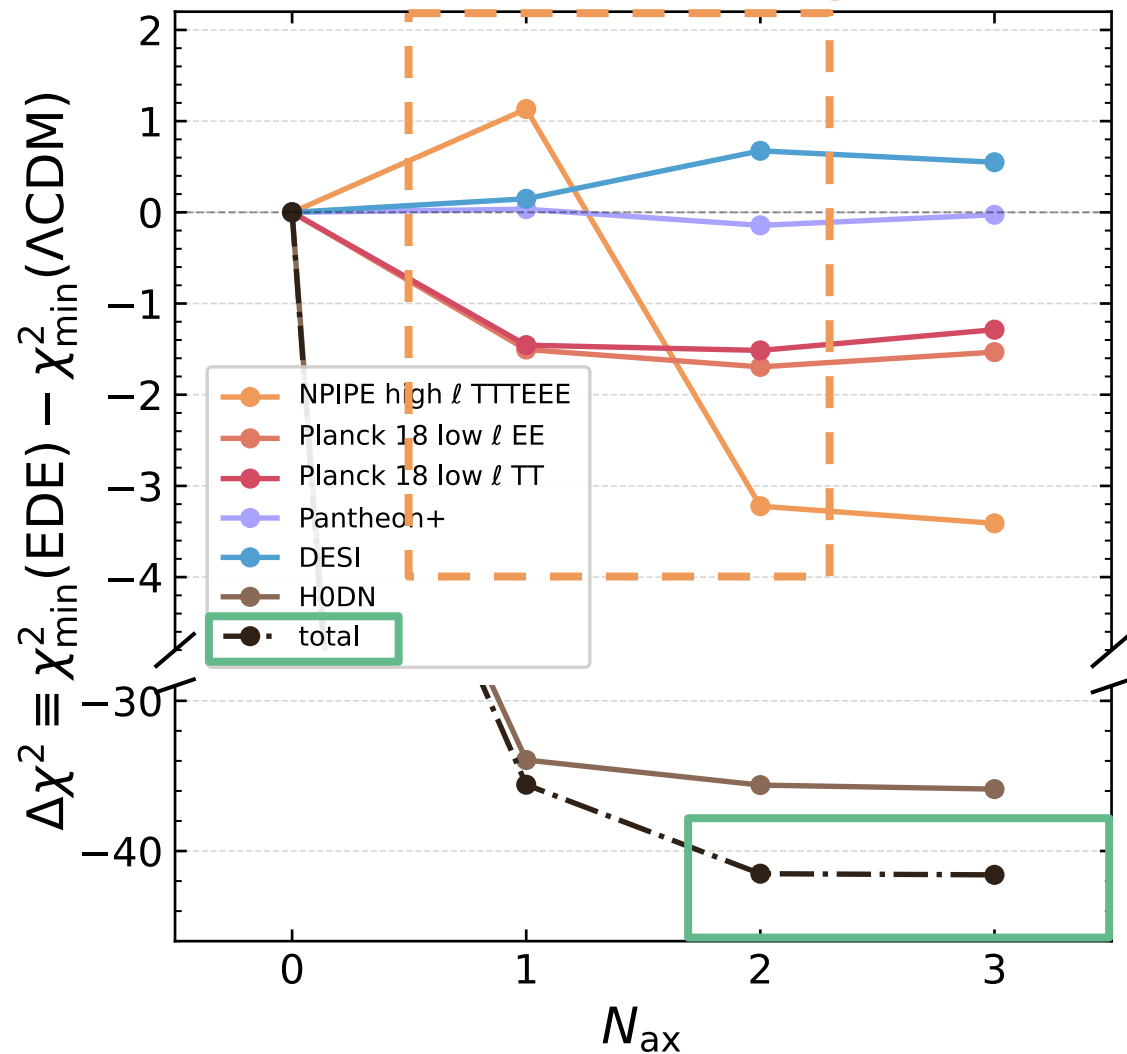


$f_{ax}^{1,2} \neq 0$ at 1σ !

no need for the third field?

chi2 per experiment

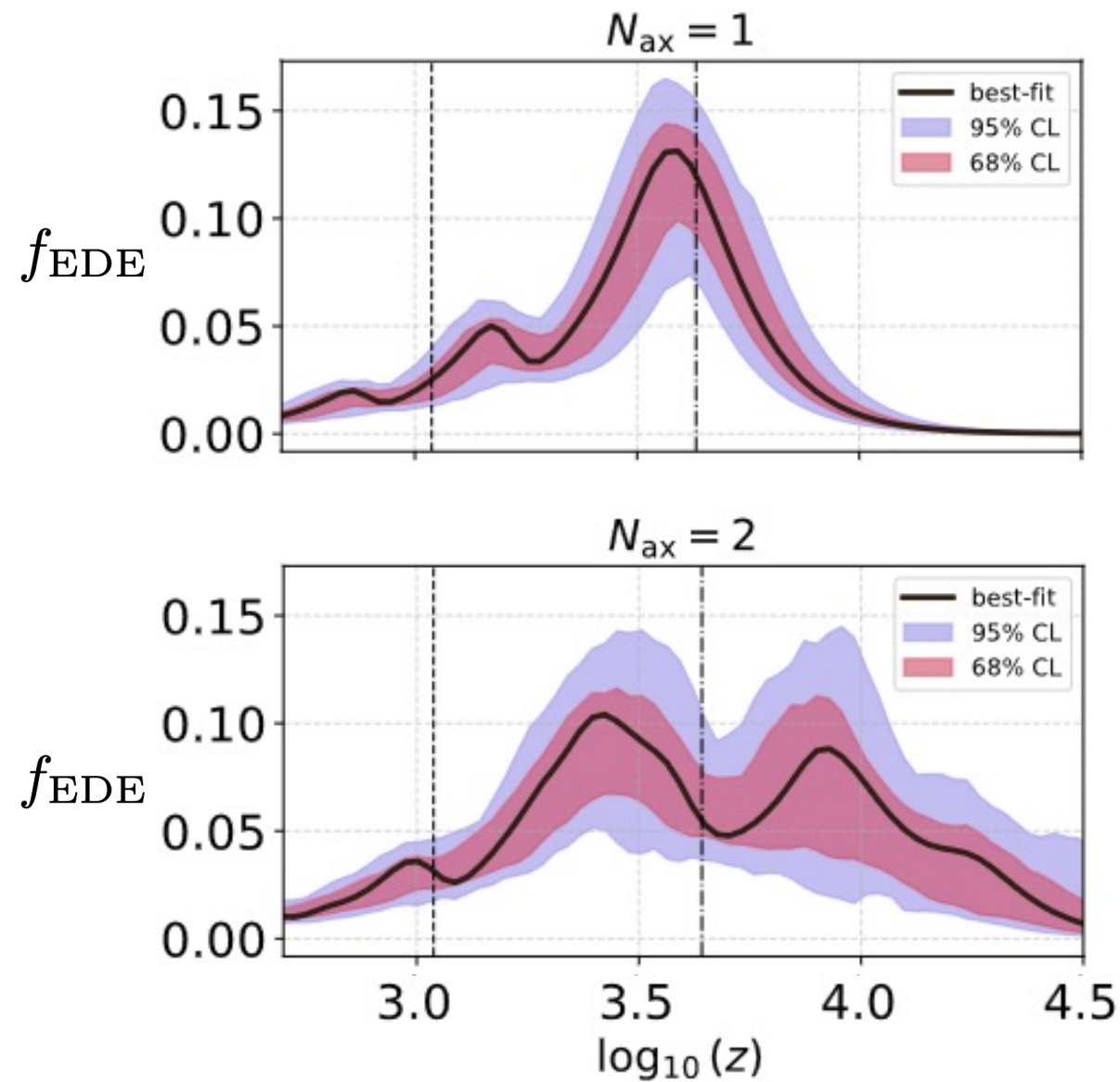
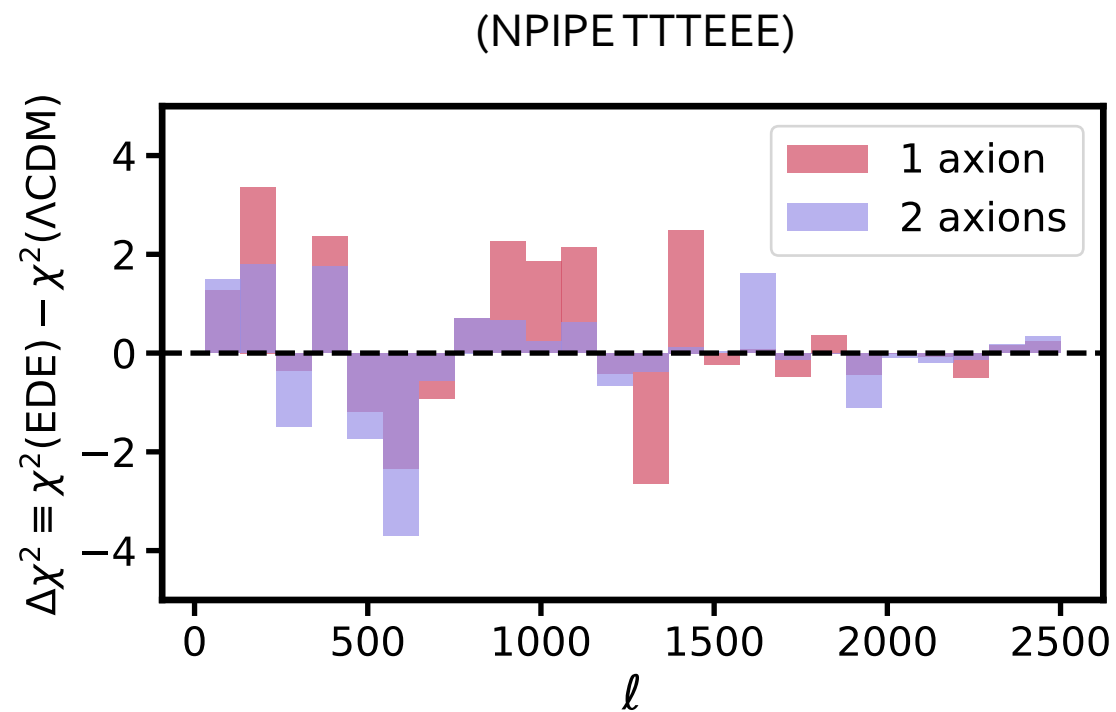
what's up with Planck?



third field doesn't improve the fit!

$$\Delta\text{AIC} = \chi^2_{\min}(\mathcal{M}) - \chi^2_{\min}(\Lambda\text{CDM}) + 2k$$

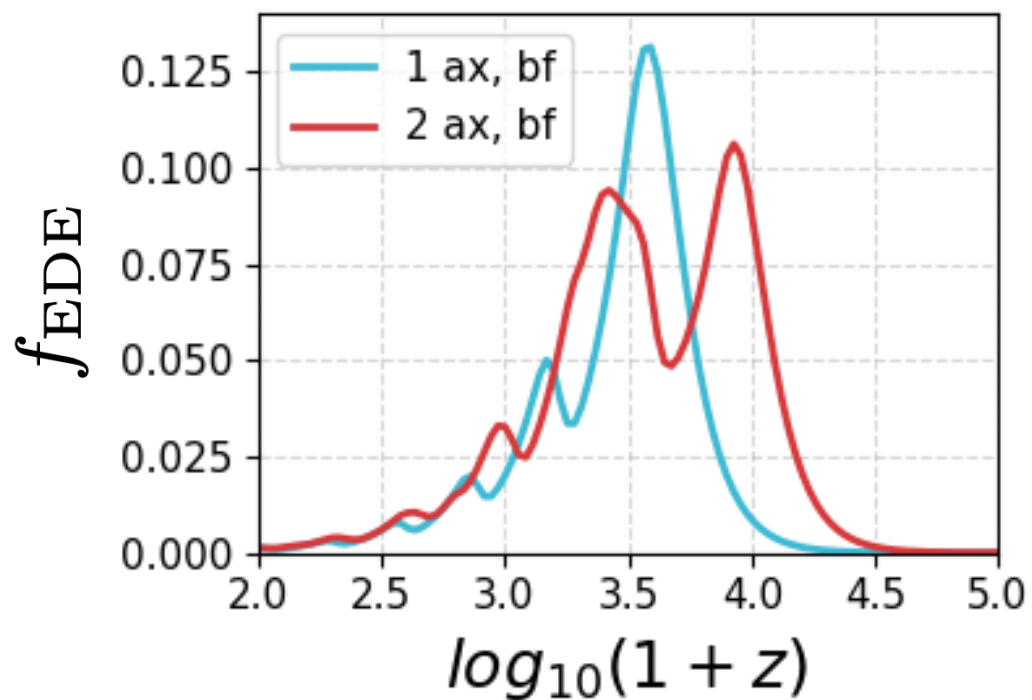
1 vs 2 axions



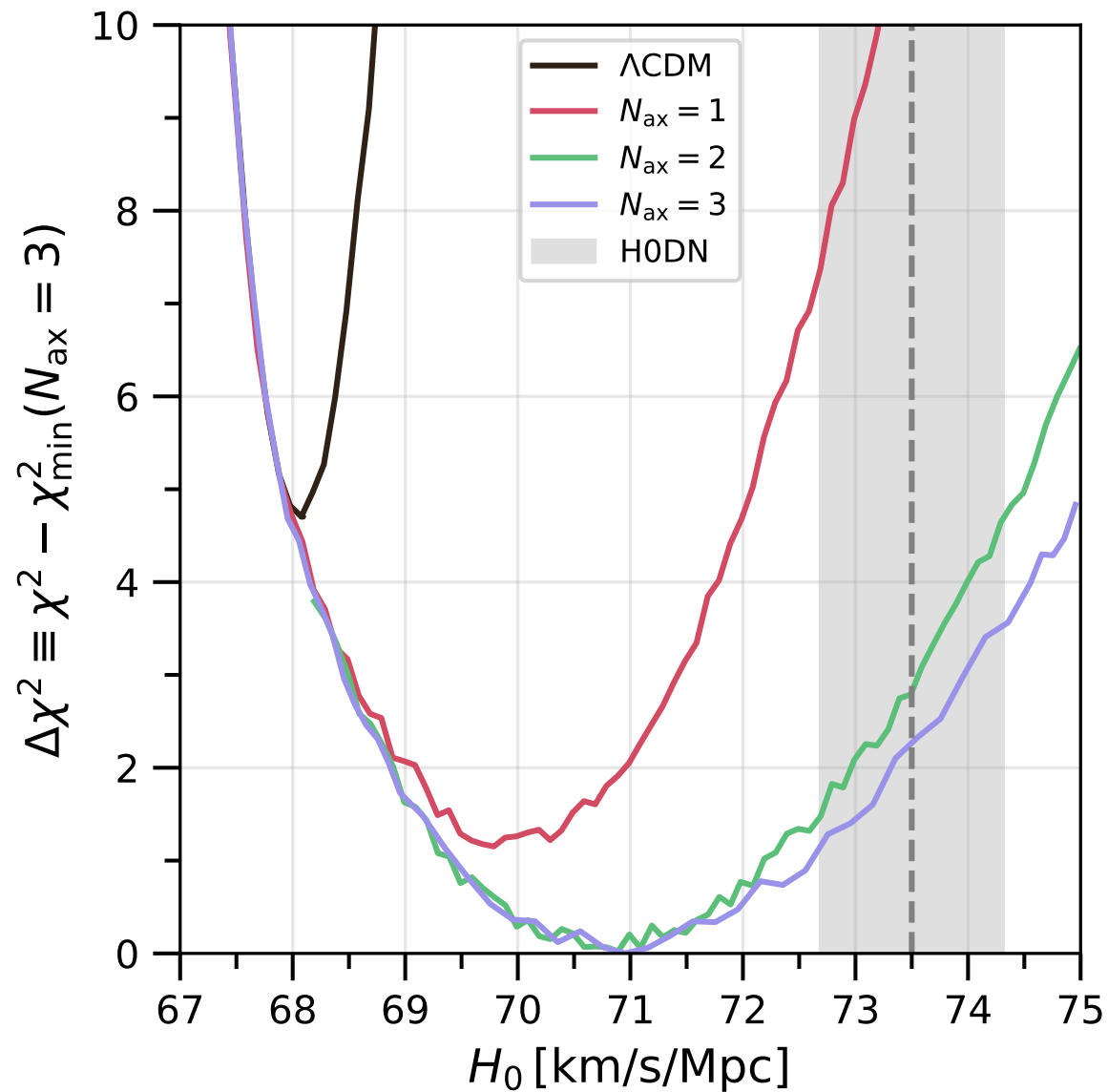
$$f_{\text{EDE}}(z) \equiv \sum_i \rho_{\text{ax}}^i(z) / \rho_{\text{tot}}(z)$$

wrapping up

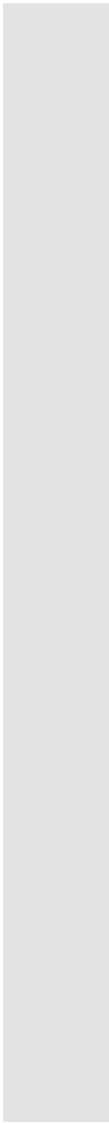
"what early expansion history solves the Hubble tension?"



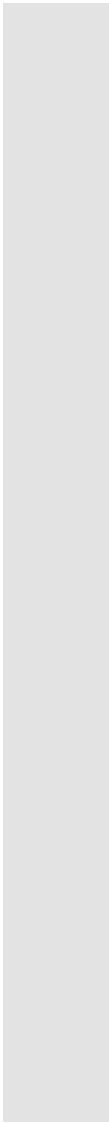
Planck likes it smooth :D



EDE not ded yet!



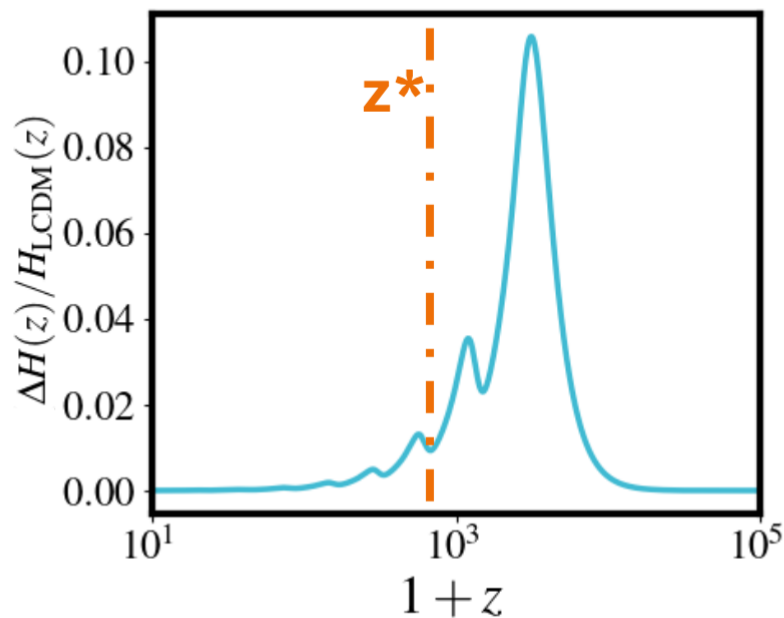
thank you!



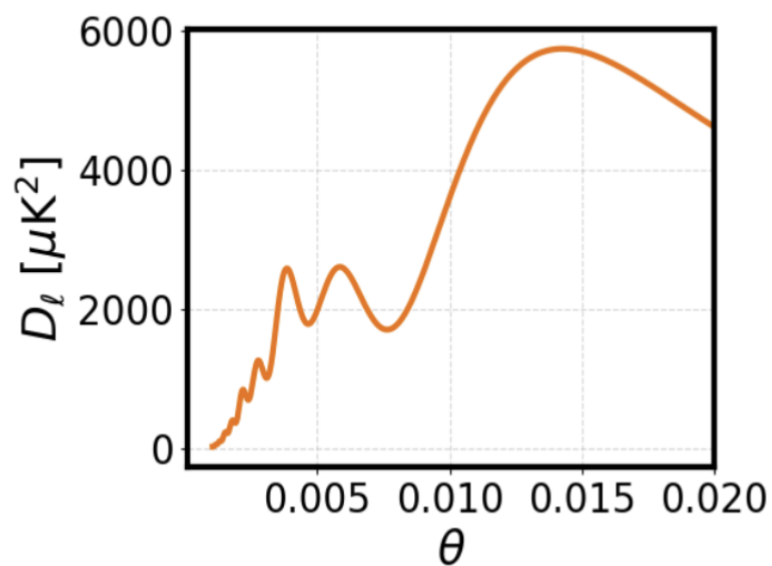
backup

EDE and Ho

boosts early hubble rate ($H \sim \rho^2$)



$$\theta_s^* = \frac{r_s^*}{d_A^*}$$



$$r_s^* \sim \int_{z^*}^{+\infty} \frac{dz}{H(z)}$$

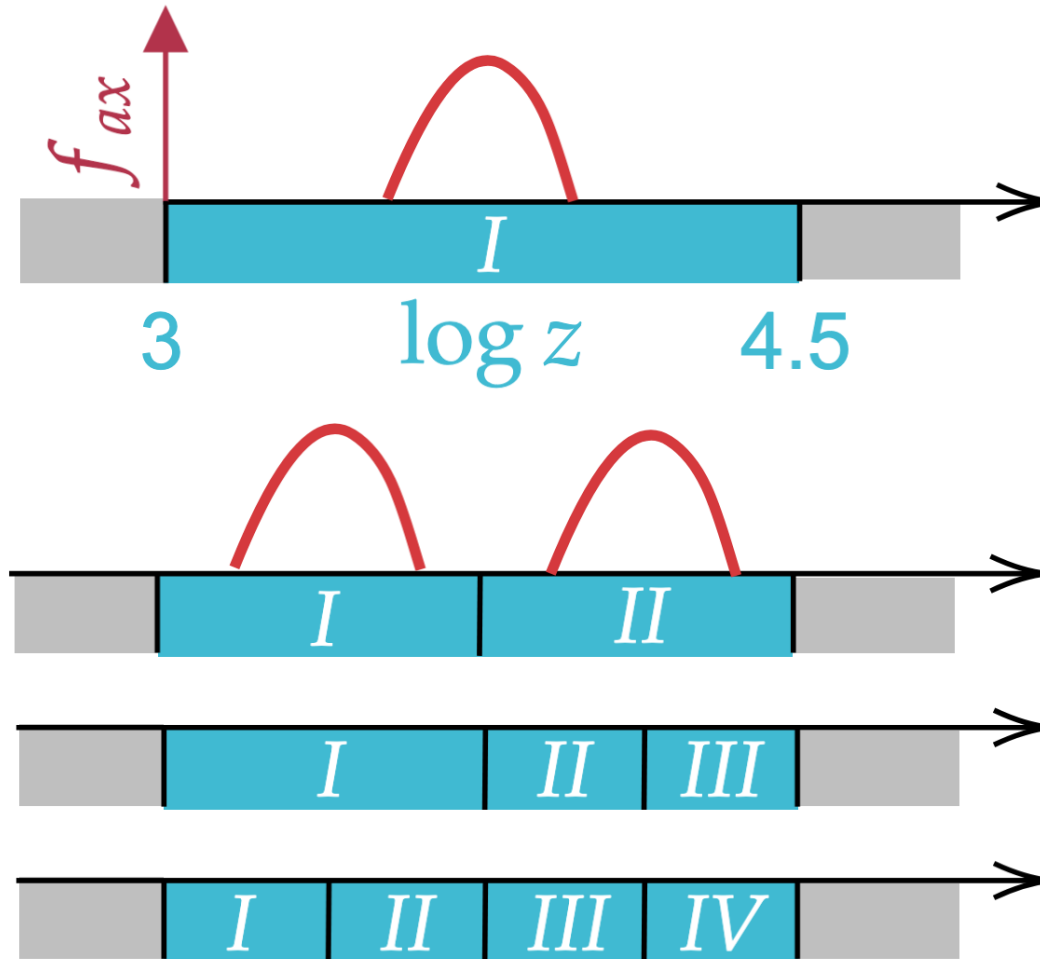
$$H(z > z^*) \uparrow$$

$$r_s^* \downarrow, d_A^* \downarrow$$

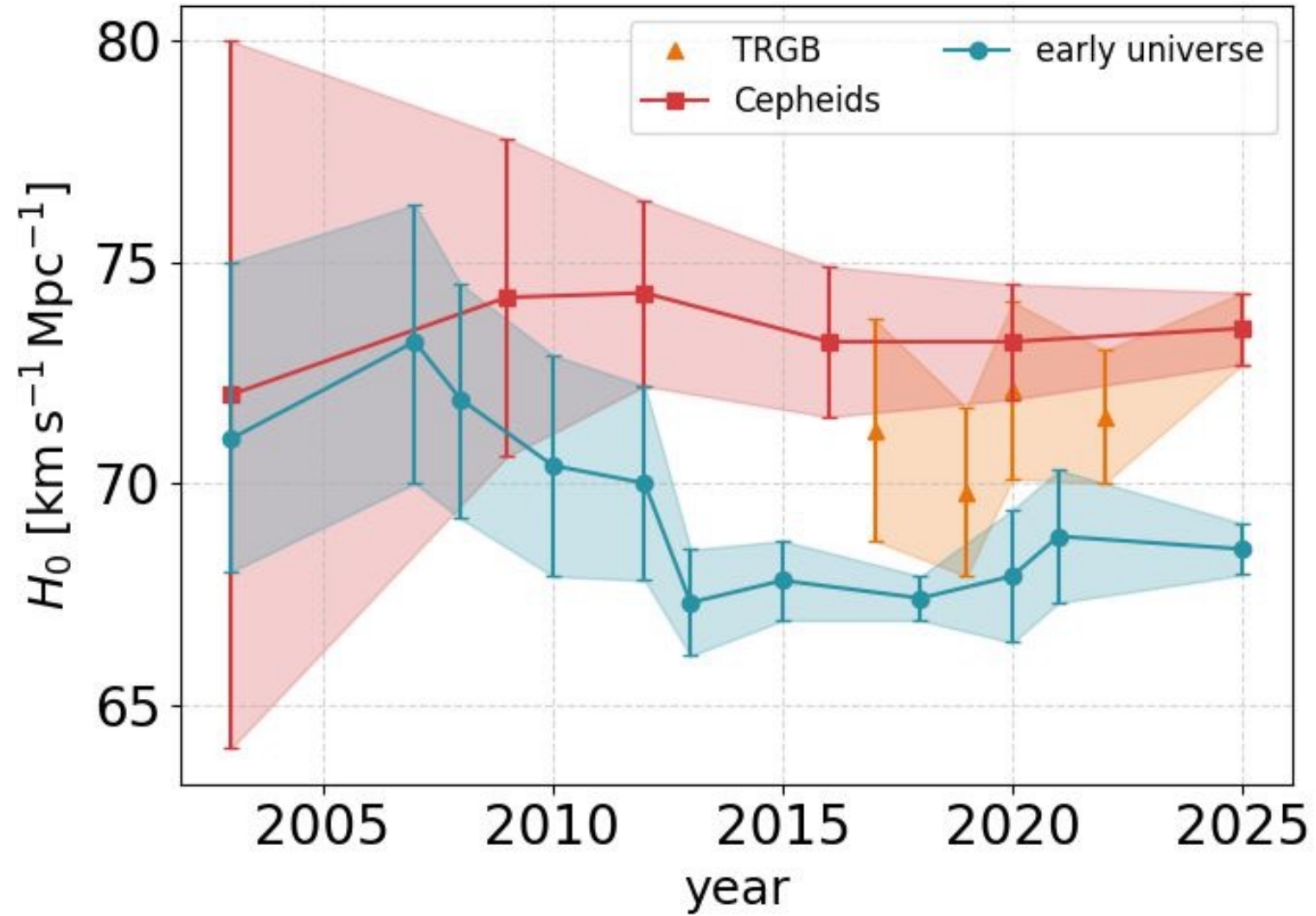
$$d_A^* \sim H_0^{-1}$$

$$H_0 \uparrow$$

multi-axion EDE: binning choice



more on H_0



Ho-rd plane

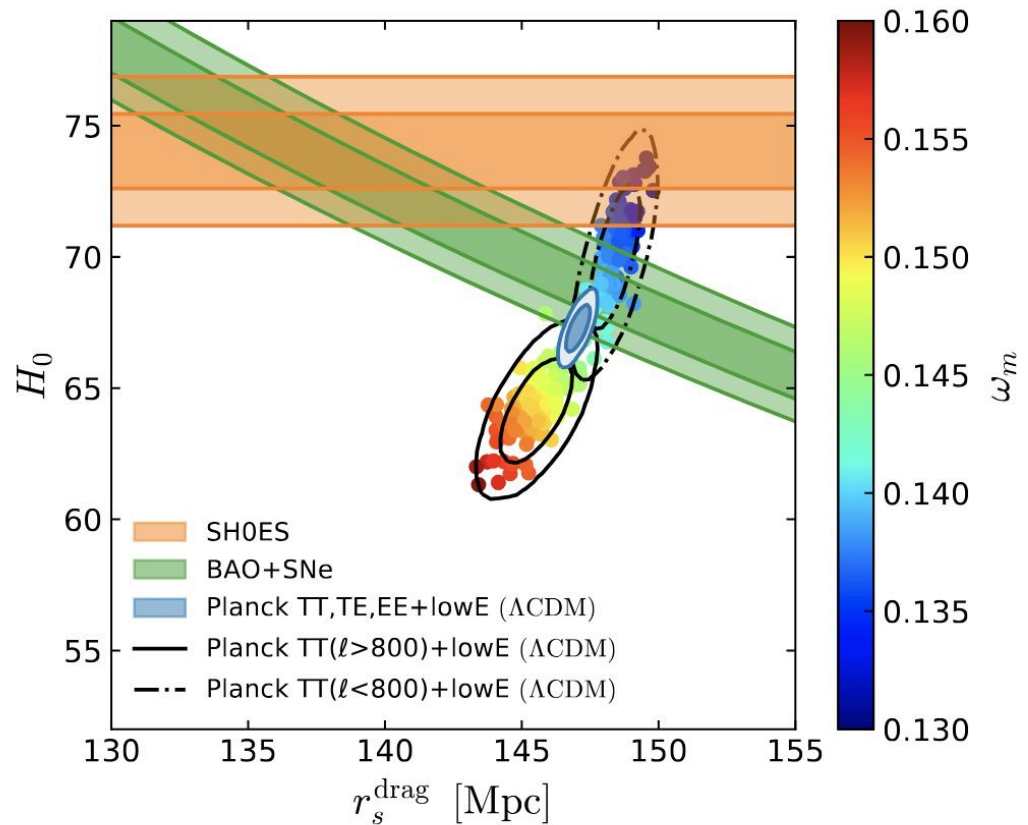
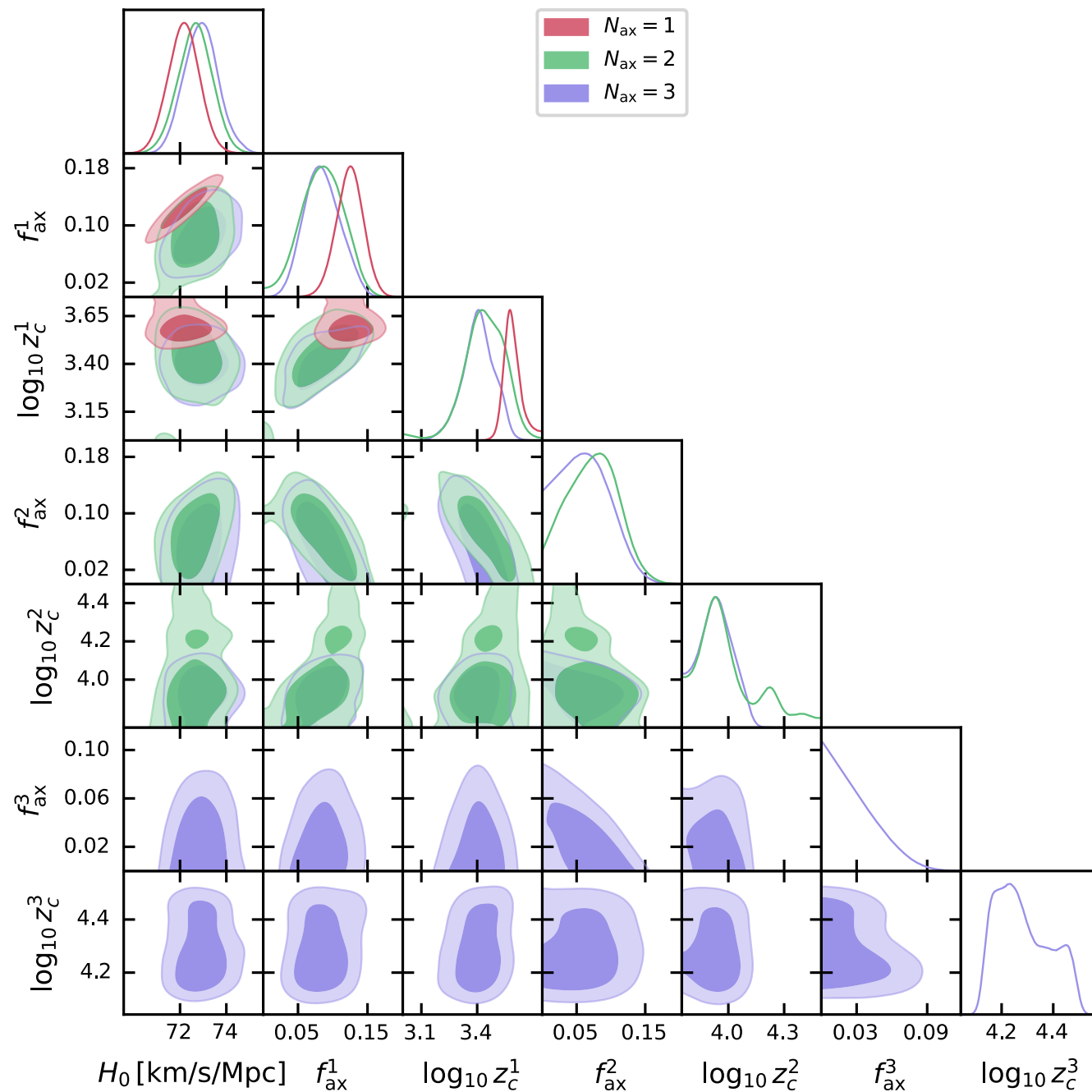
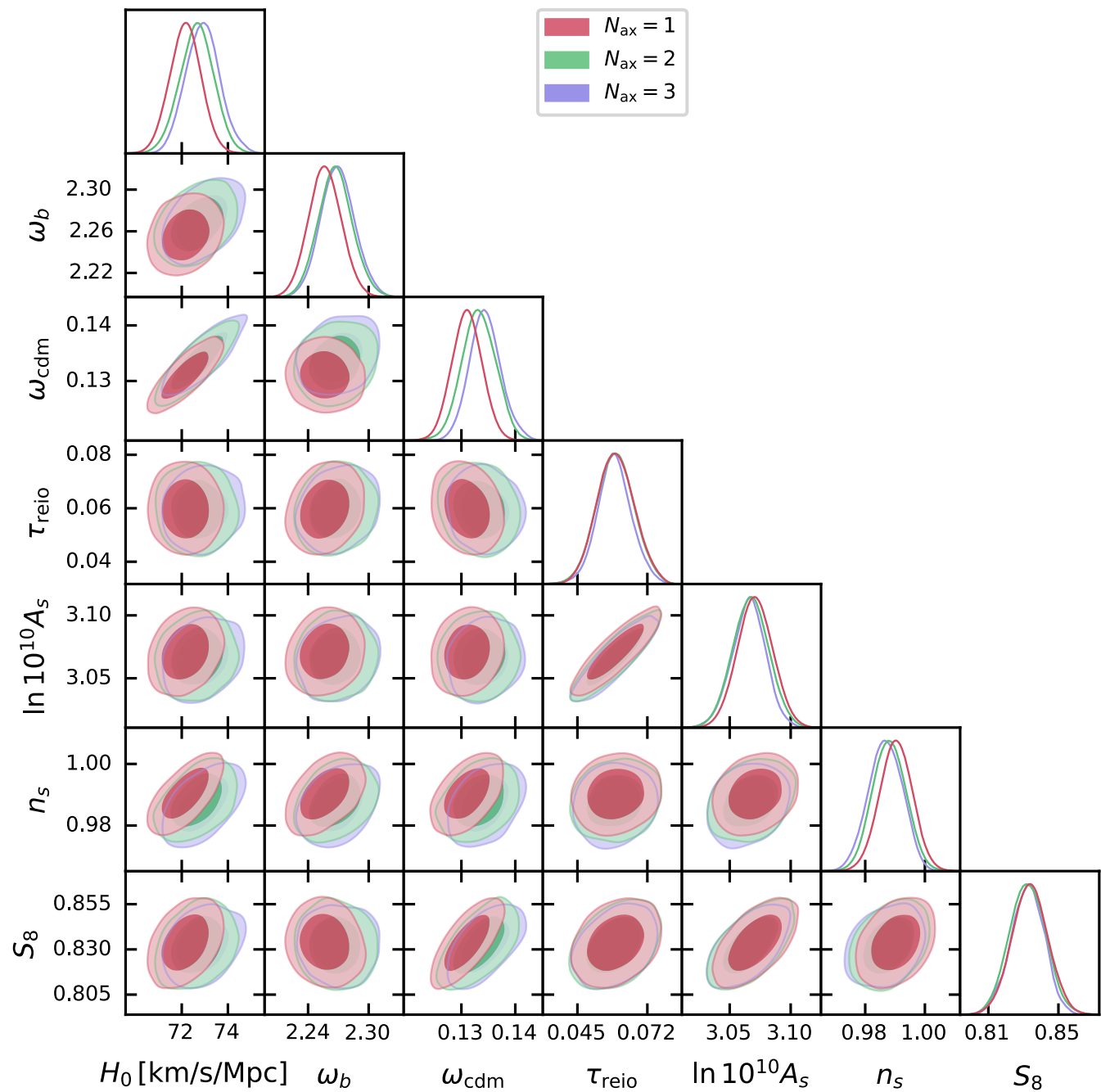


FIGURE 2.2: Degeneracy lines in the $H_0 - r_s$ plane. The shaded regions are 68% and 95% confidence regions. Different version of Planck data are used in this work, splitting the dataset at $\ell = 800$. The scatter is colour-coded with the value of $\omega_m = \Omega_m h^2$. The SHoES constraint is from [41], BAO data come from [31] and SNe from [35]. Reproduced from [51].

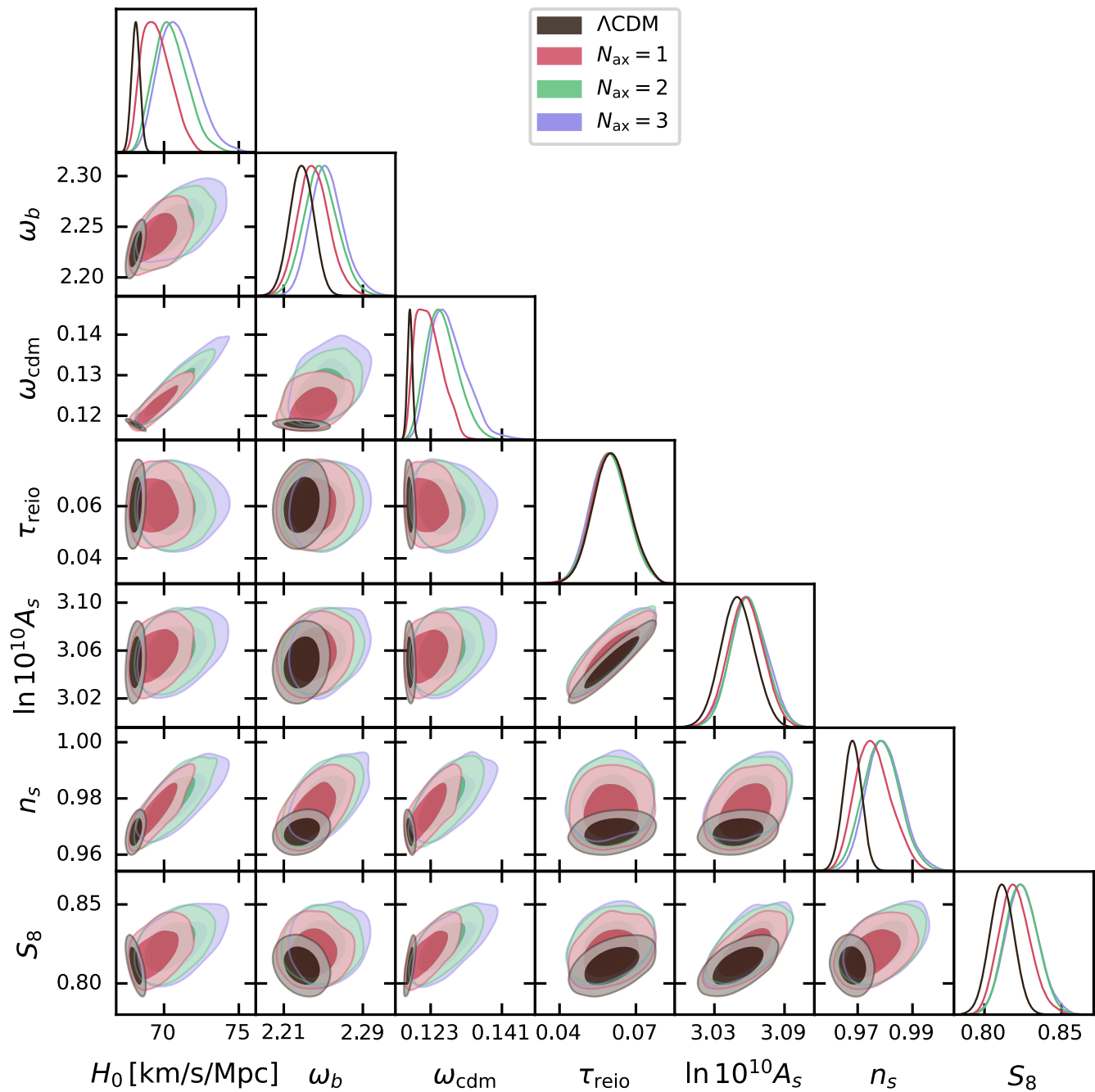
Pantheon+,
DESI,
HoDN
(axion sector)



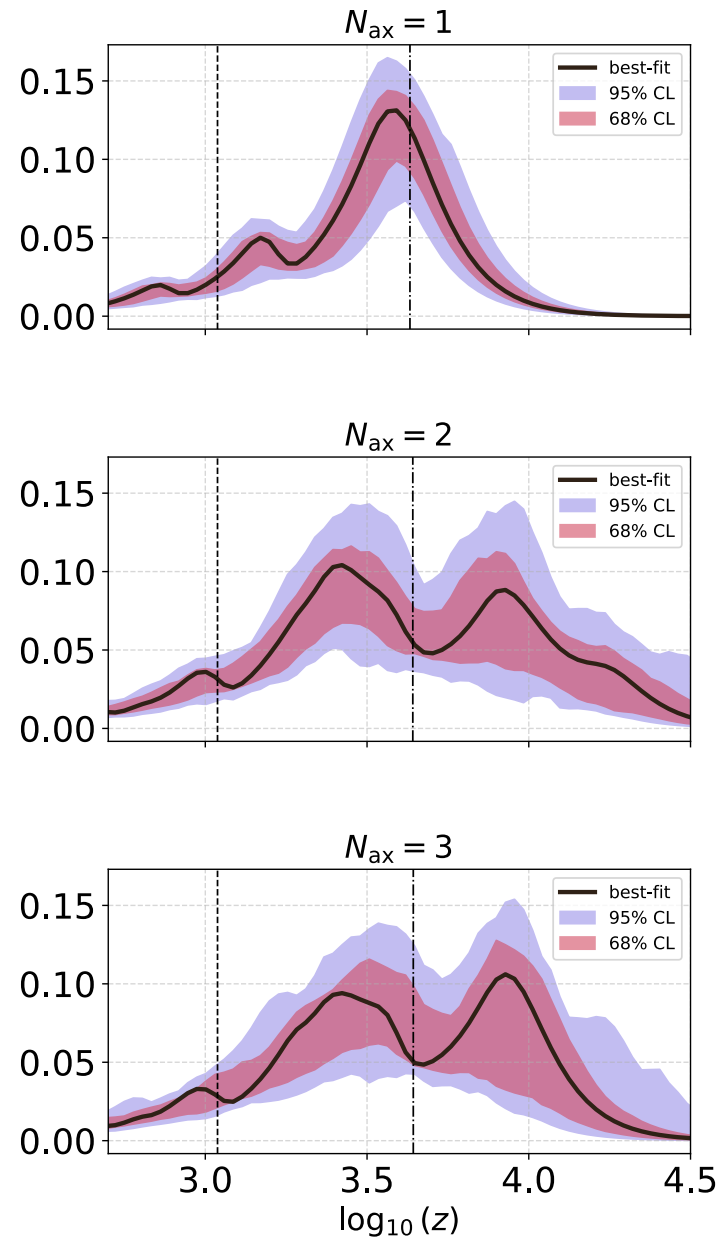
full posteriors
(Pantheon+,
DESI,
HoDN)



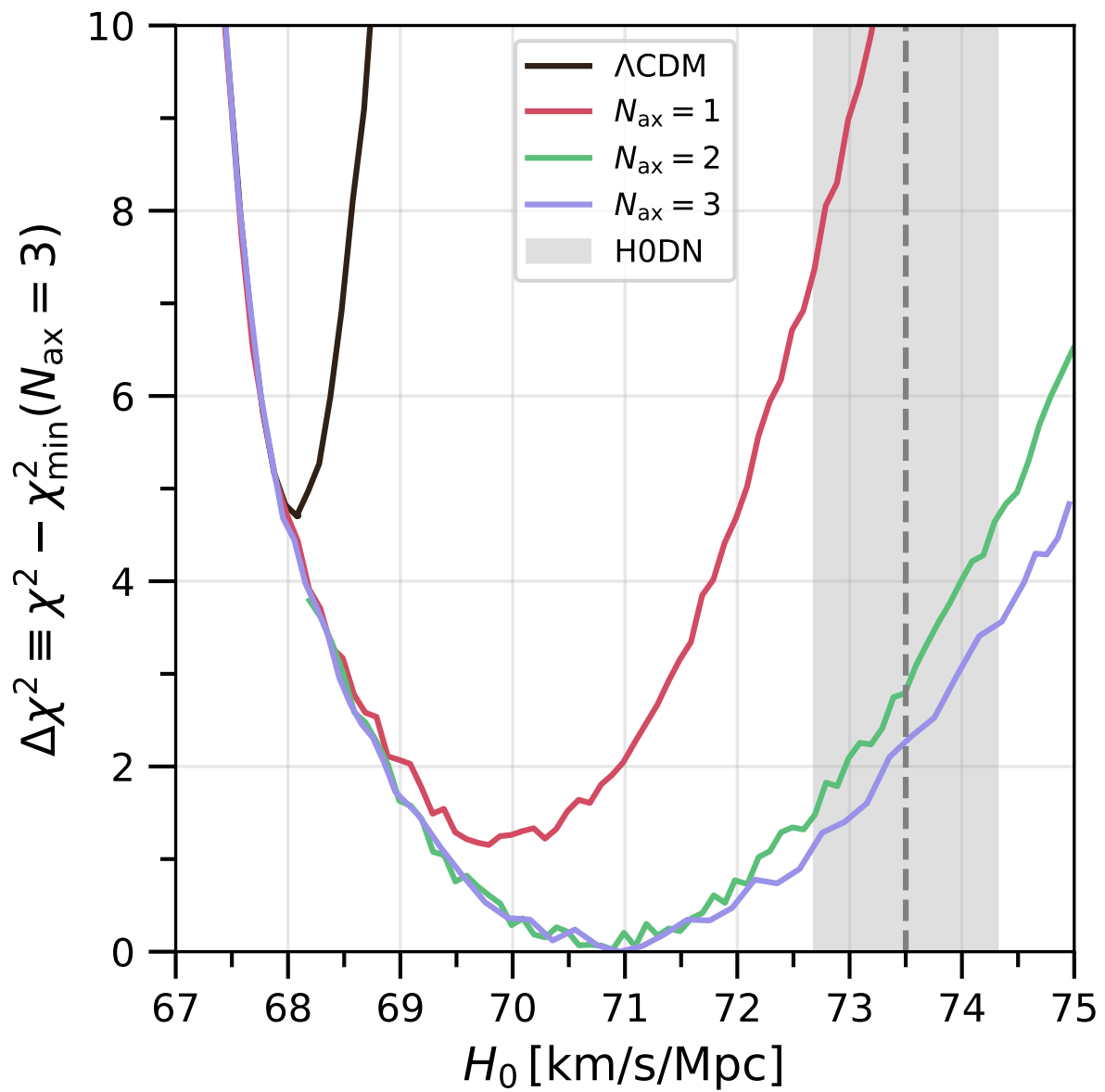
(Pantheon+,
DESI)



1 vs 2 vs 3 axions



profile
likelihoods!



tables

Model	Credible intervals		Confidence intervals
	with H0DN	no H0DN	Bestfit ${}^{+68\%}_{-68\%}$ (95%)
Λ CDM	—	68.10 ± 0.28	$68.10^{+0.40}_{-0.40}$ (${}^{+0.80}_{-0.80}$)
1 axion	$72.16^{+0.67}_{-0.68}$	$69.53^{+0.71}_{-1.20}$	$69.89^{+1.19}_{-1.03}$ (${}^{+2.21}_{-1.99}$)
2 axions	$72.65^{+0.73}_{-0.75}$	$70.46^{+0.96}_{-1.27}$	$70.59^{+1.66}_{-1.24}$ (${}^{+3.36}_{-2.42}$)
3 axions	$72.91^{+0.68}_{-0.73}$	$70.93^{+1.06}_{-1.47}$	$70.93^{+1.67}_{-1.49}$ (${}^{+3.55}_{-2.73}$)

TABLE I. H_0 constraints (in km/s/Mpc) from the PD and PDH0 combinations. The first two columns show means and 68% Bayesian credible intervals with and without the H0DN prior. The third column shows frequentist confidence intervals from profile likelihoods on PD at 68% (95%).

Model	Q_{DMAP}	$\Delta\text{AIC}(\text{PD})$	$\Delta\text{AIC}(\text{PDH0})$
Λ CDM	6.3σ	-0.86	$+32.52$
1 axion	2.6σ	ref. model	ref. model
2 axions	1.5σ	$+2.96$	-1.70
3 axions	1.3σ	$+6.92$	$+1.76$

TABLE II. Tension and model comparison metrics. Q_{DMAP} measures the residual tension with the H0DN determination. The ΔAIC values are computed with respect to the 1-axion model, so $\Delta\text{AIC} < 0$ indicates that the model in question is favored against the 1-axion model by the given combination.