

The H_0 and σ_8 tensions: Implications for the dark energy equation of state

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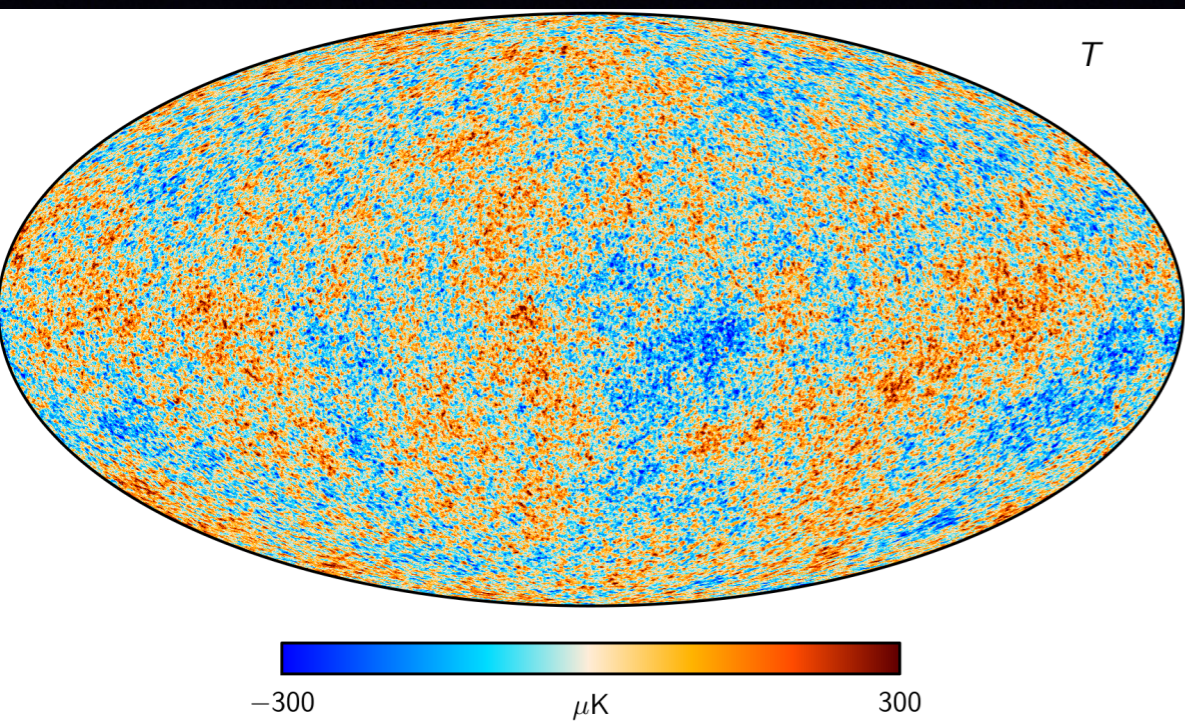
CosKASI 2019 Conference



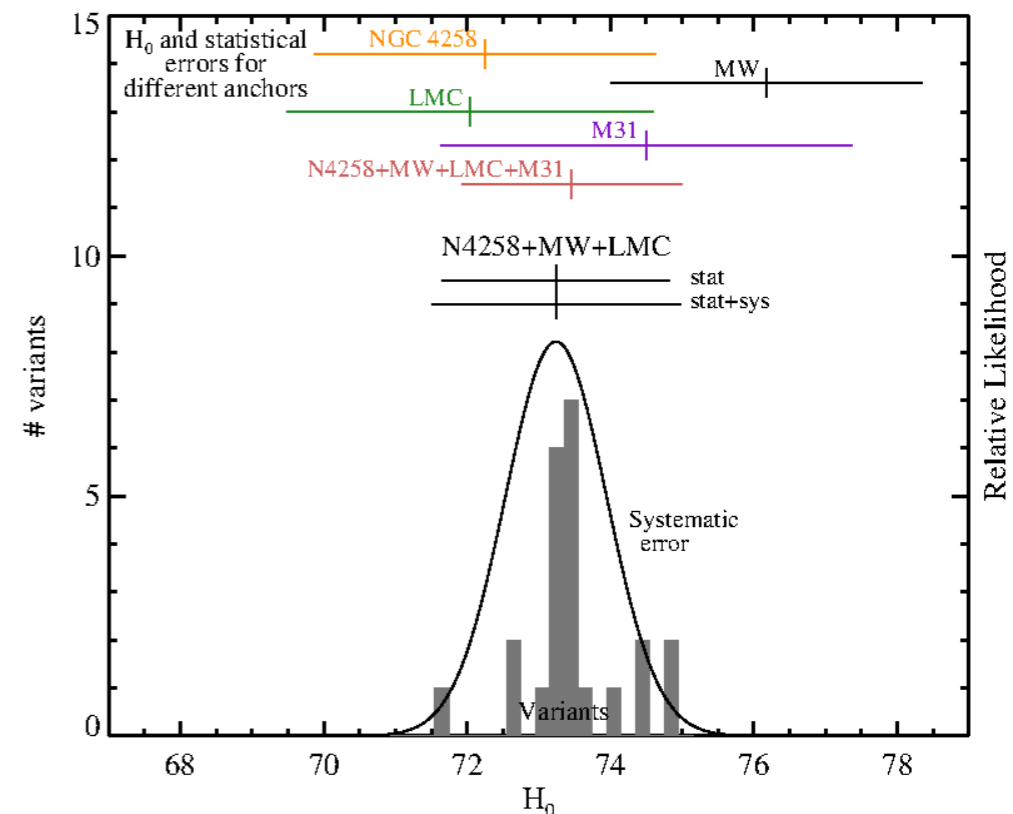
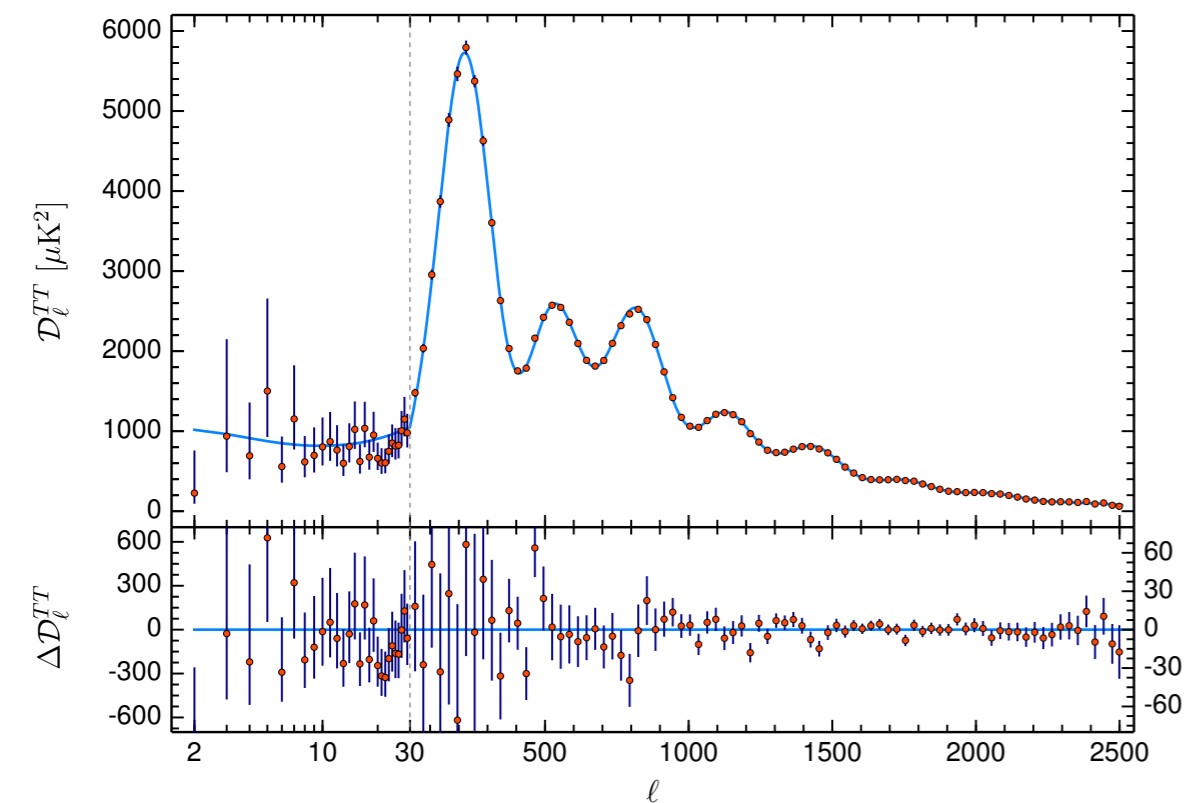
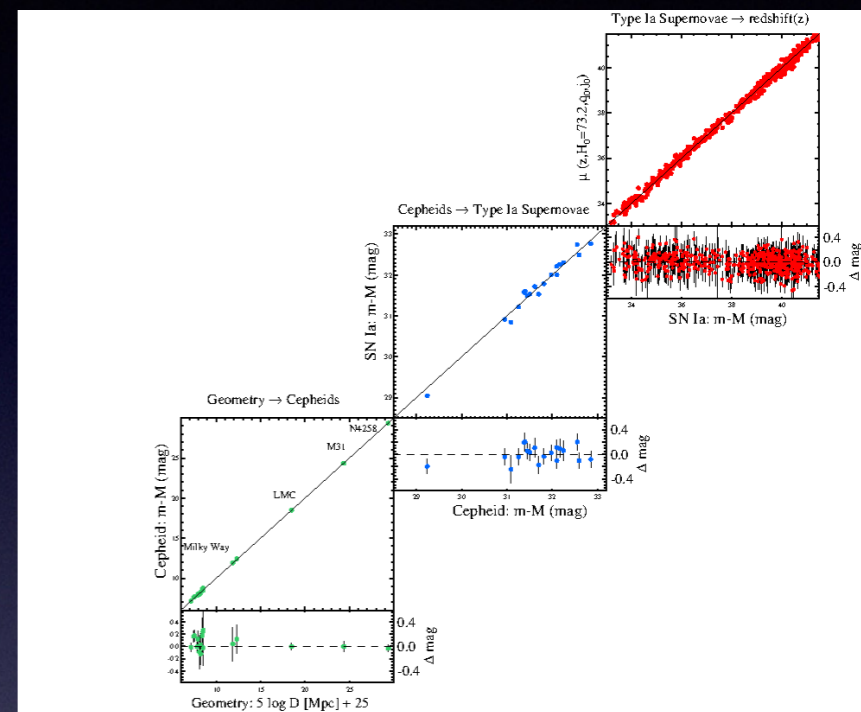
Collaborators: Manoj Kaplinghat,
David Kirkby, Shahab Joudaki

LCDM

High-z



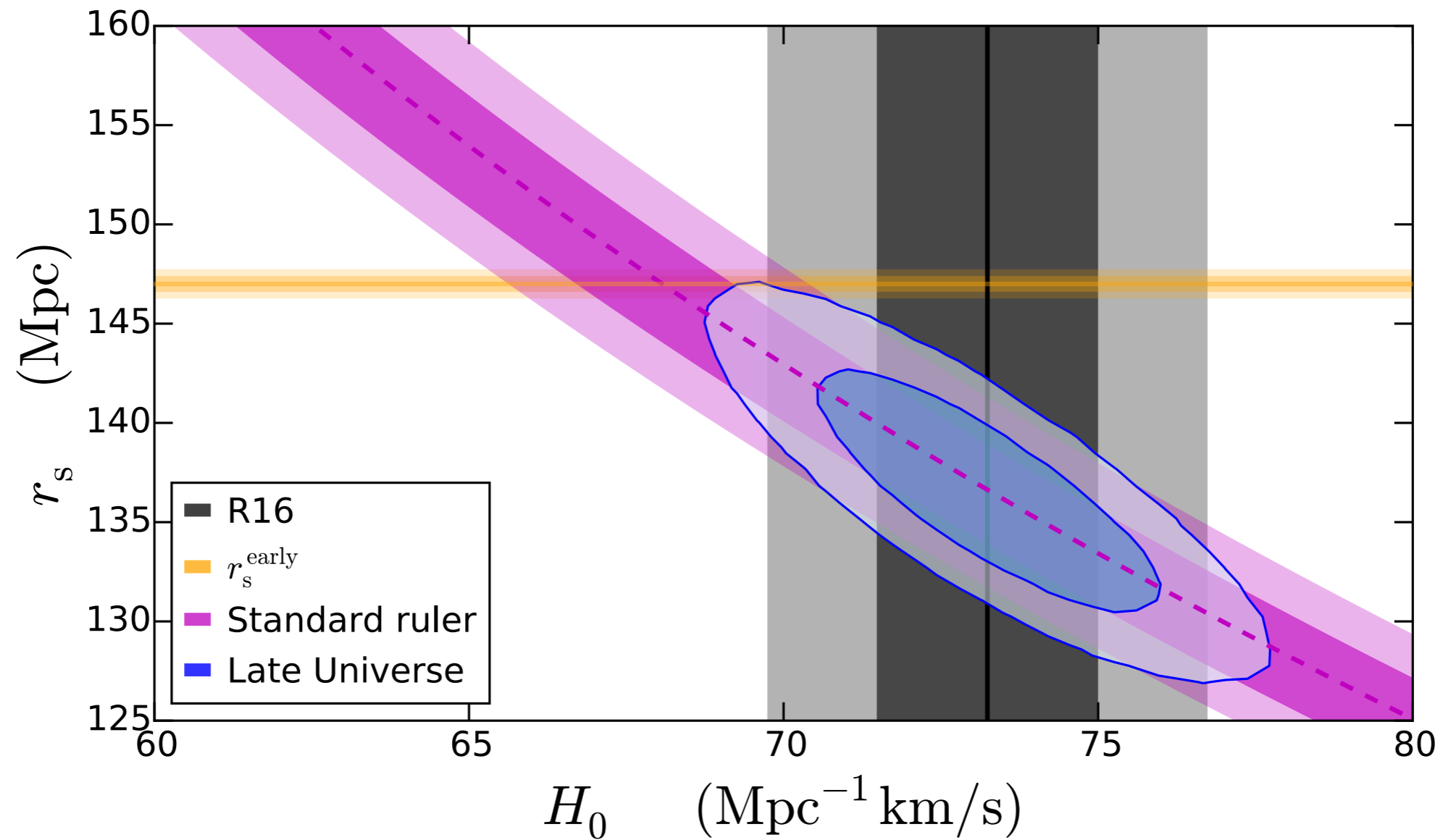
Low-z



Tensions

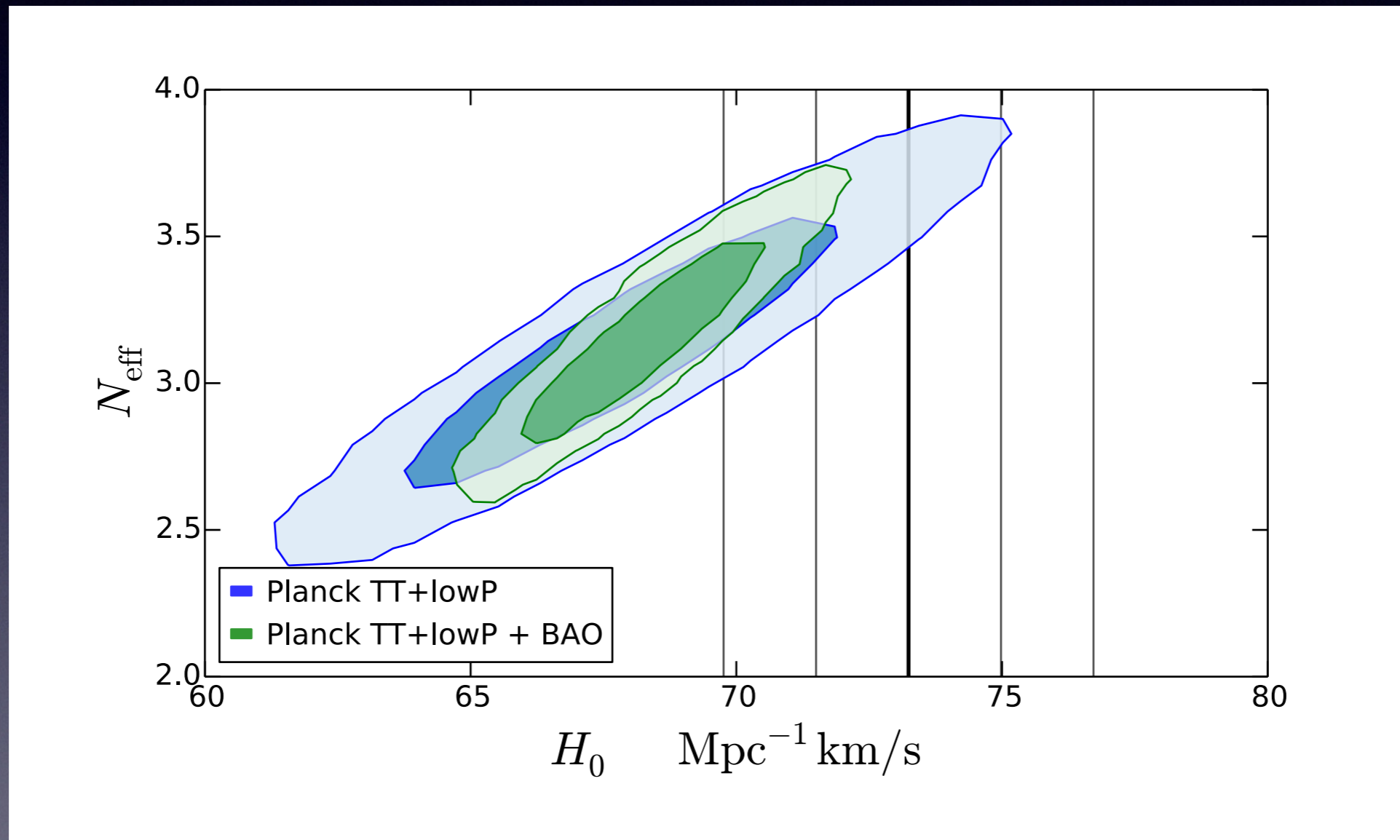
- Inferences from the CMB predict $H(z=0) = 67.36 \pm 0.54$ km/s/Mpc
- Measuring H_0 directly gives 74.03 ± 1.42 km/s/Mpc
- Difference is now at $4.4\text{-}\sigma$.
- No obvious systematics
- New Physics - Neff, Early Dark Energy (high redshift)
- New Physics - Evolving dark energy (low redshift)

Distance Scales



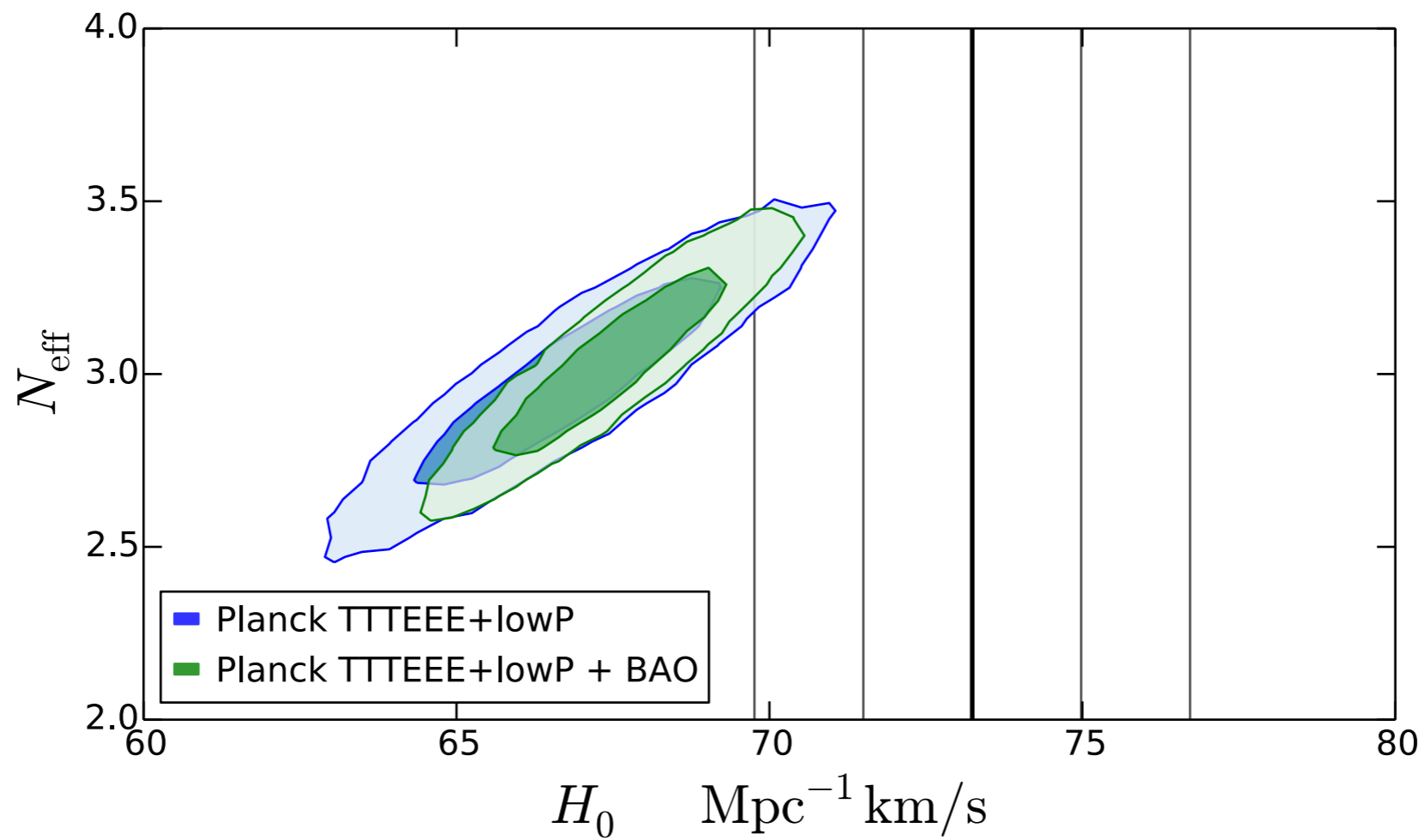
- Arxiv: 1607.05617 Bernal et al

High-z Physics

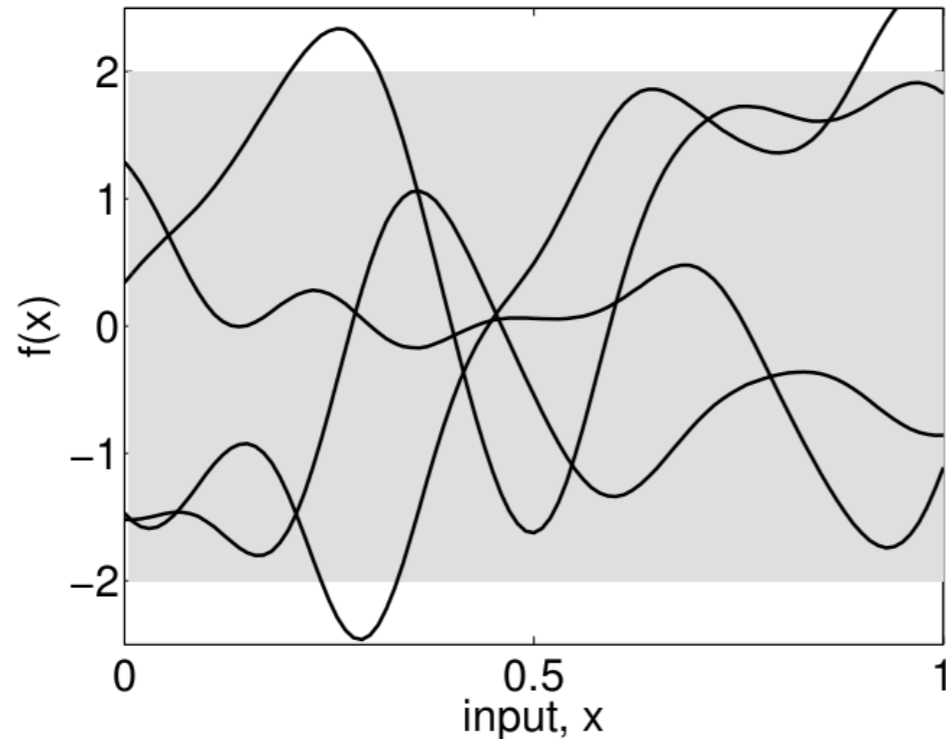


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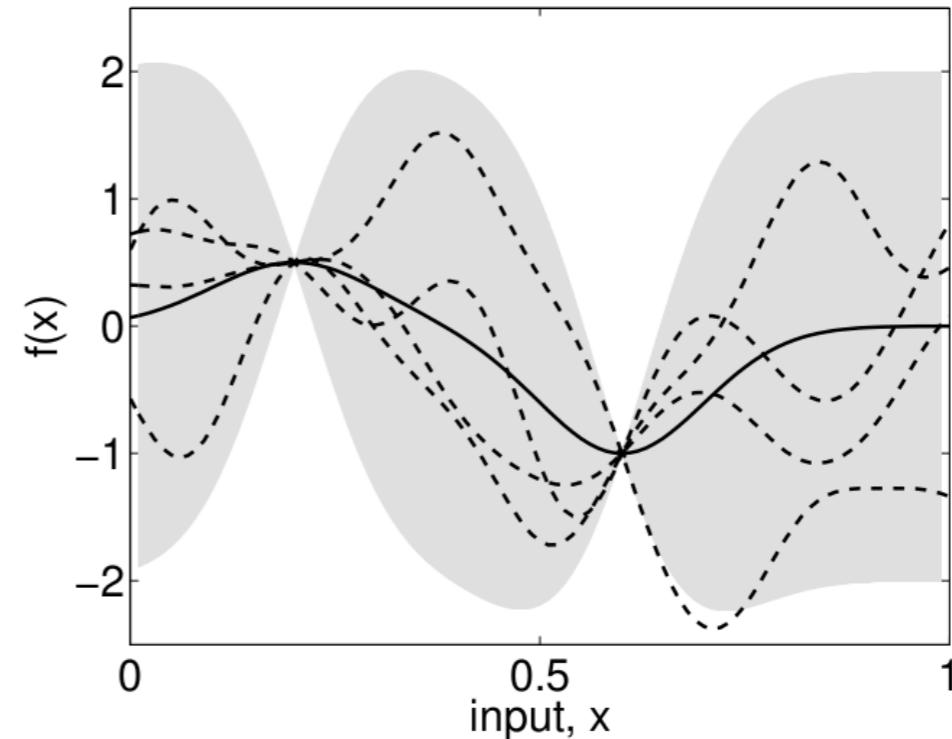
High-z Physics



Gaussian Process



(a), prior



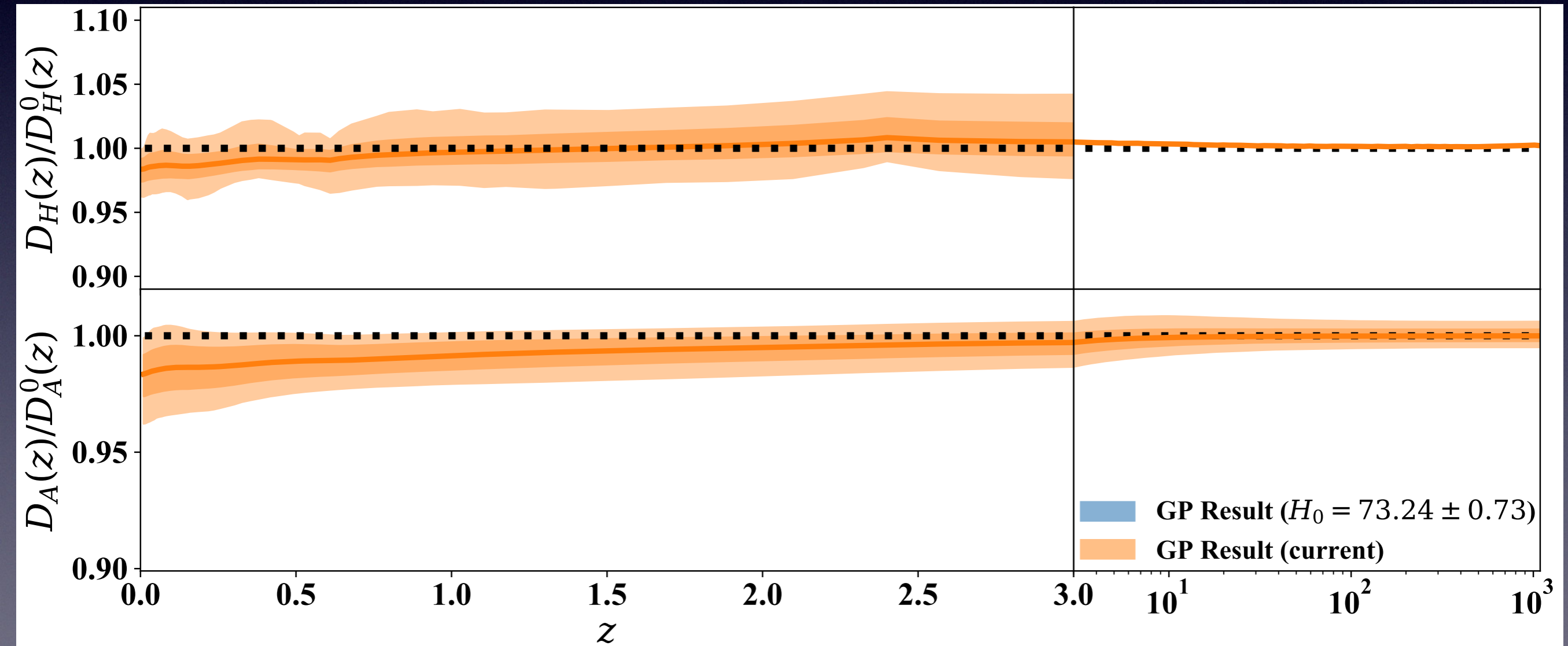
(b), posterior

$$\langle \gamma(s_1)\gamma(s_2) \rangle = h^2 \exp(- (s_1 - s_2)^2 / 2\sigma^2)$$

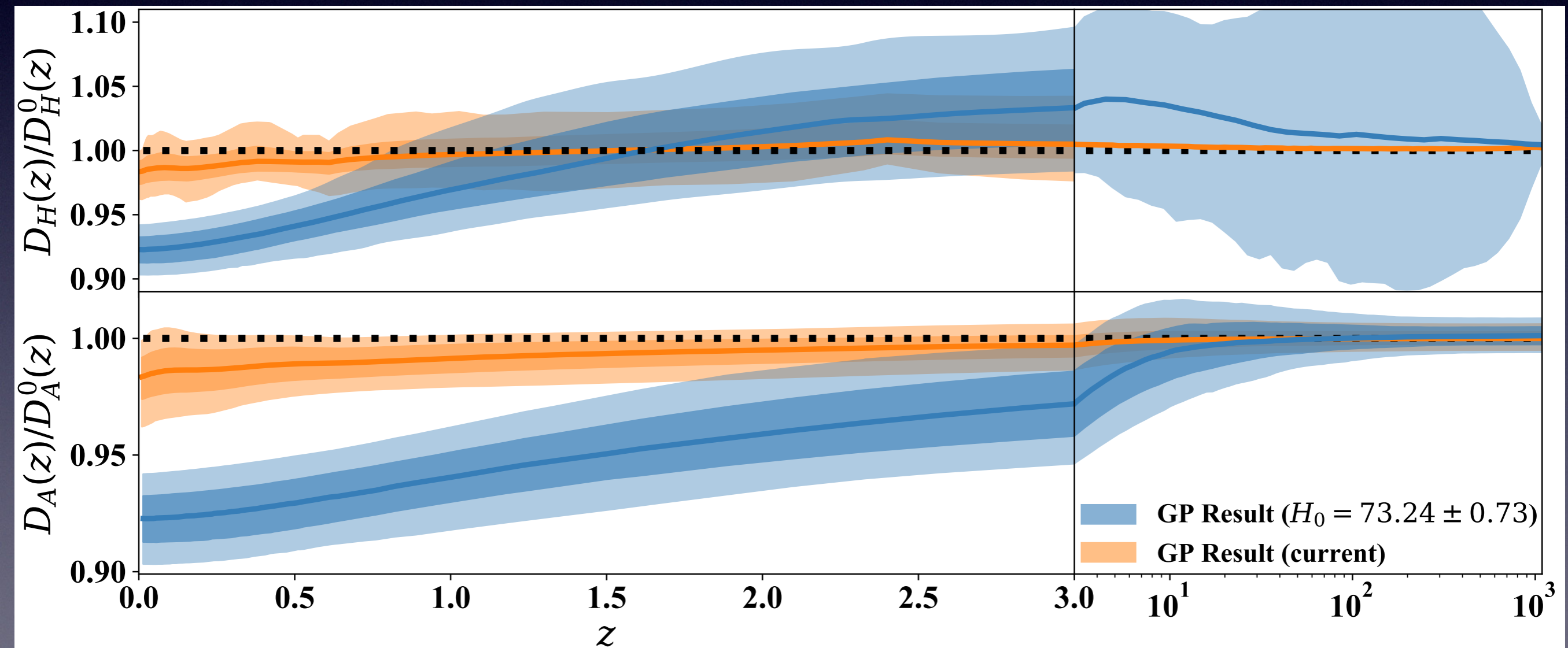
$$s(z) = \log(1 + z) / \log(1 + z_*)$$

$$\gamma = \log(D_H / D_H^0)$$

GP Inferences



GP Inferences



Dark Energy

- Infer dark energy evolution model independently
- Calculate the total energy density at all redshifts from the inferred GP expansion history
- Subtract off a fiducial radiation density
- Define the matter density to make up the rest of the energy density at the CMB
- The dark energy density is the remainder after subtracting off the radiation and matter densities

$$\rho_{\text{DE}}/\rho_{\text{crit},0} = \left(\frac{3H^2(z)}{8\pi G} - \rho_{\text{m}}(z) - \rho_{\text{r, fid}}(z) \right) \frac{8\pi G}{3H_0^2}$$

Growth

ϕ : gravitational potential

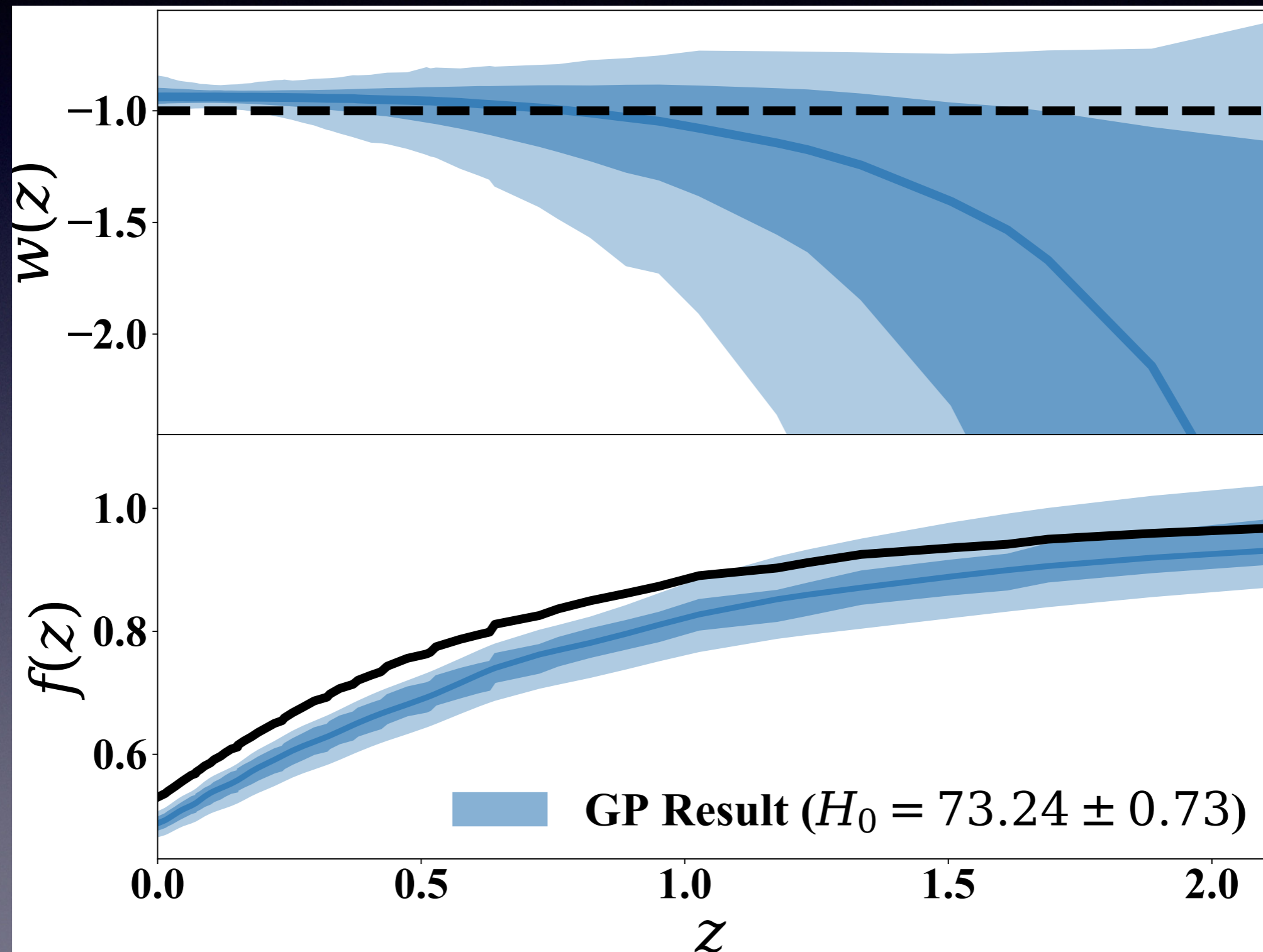
$$\delta\rho/\rho \propto \phi a$$

- Growth related to expansion via

$$\phi'' + (4 + H'/H)\phi' + (3 + 2H'/H)\phi = 0$$

$$f = \frac{d \log \phi a}{d \log a} \sim \Omega_m(z)^{0.55}$$

DE & Growth



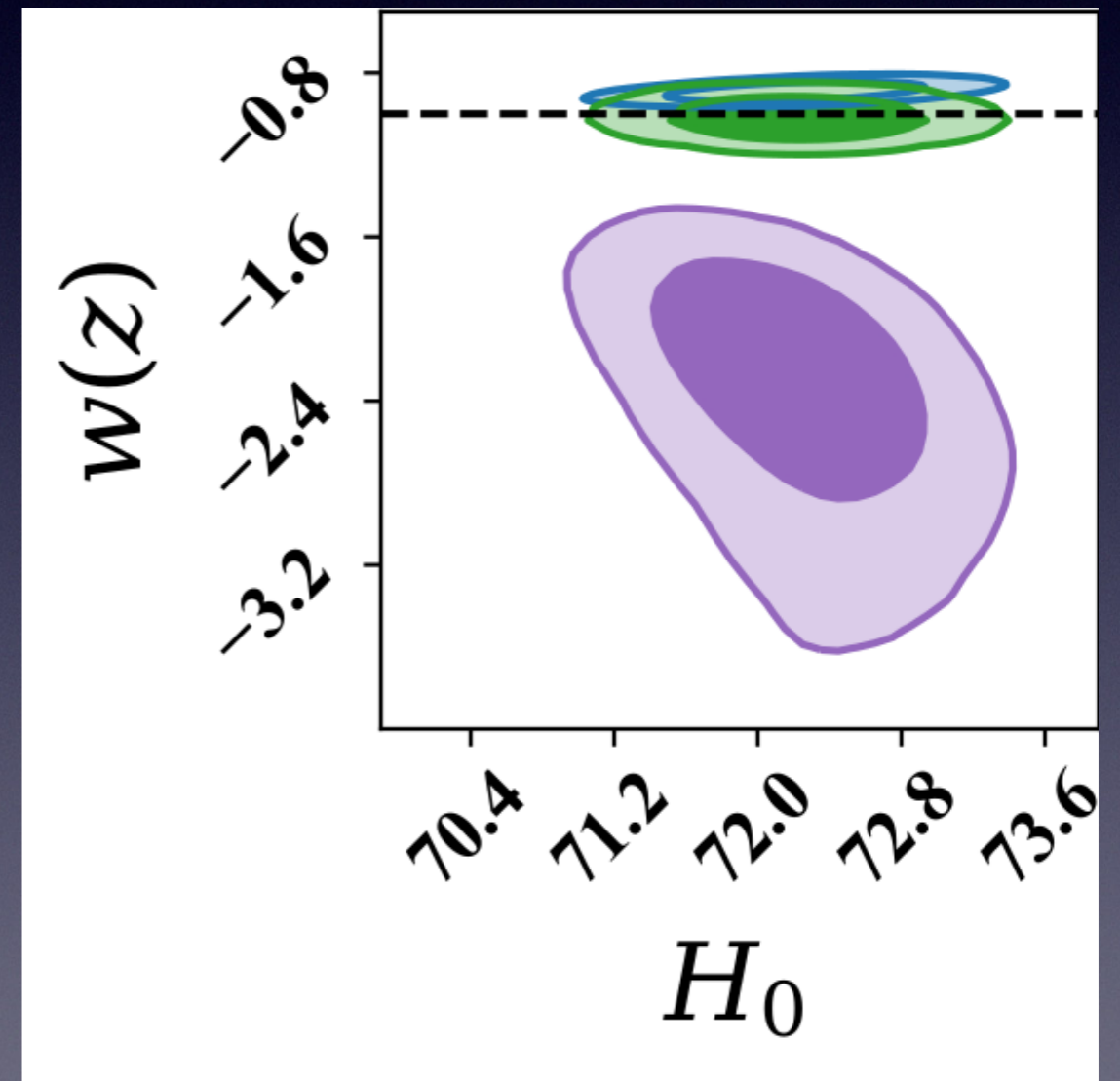
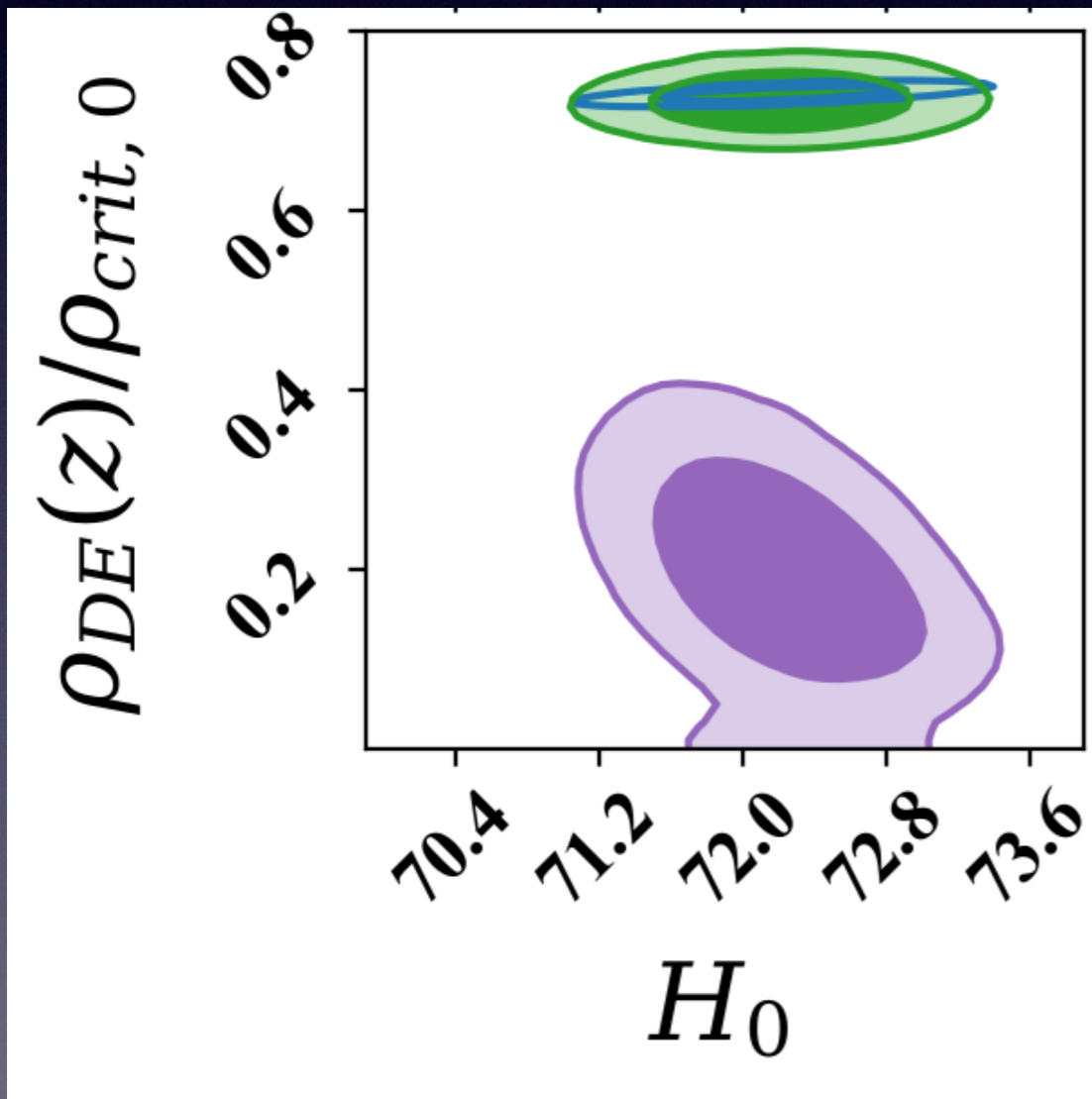
Transitional Dark Energy

$$\rho_{\text{DE}}(z) = \rho_{\text{DE},0}(1+z)^{3(1+W(z))}$$

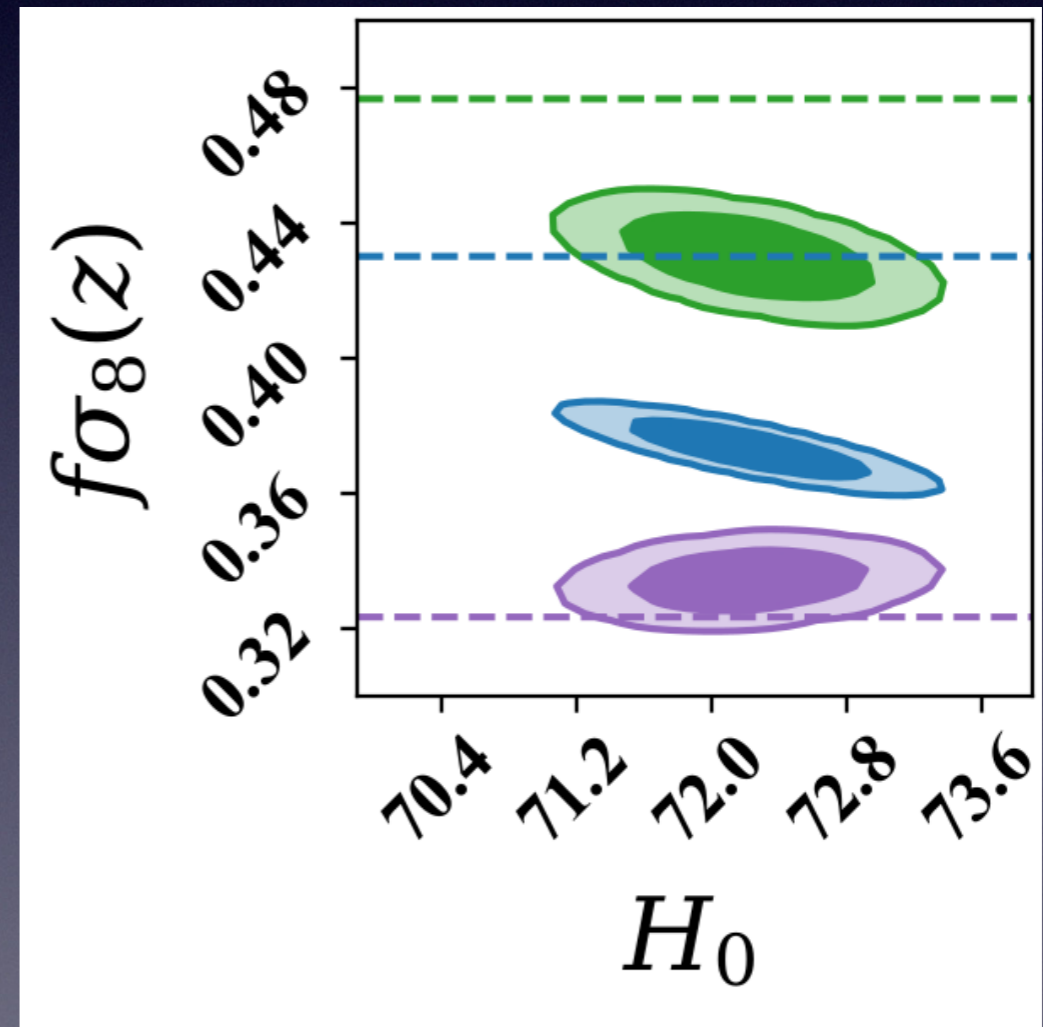
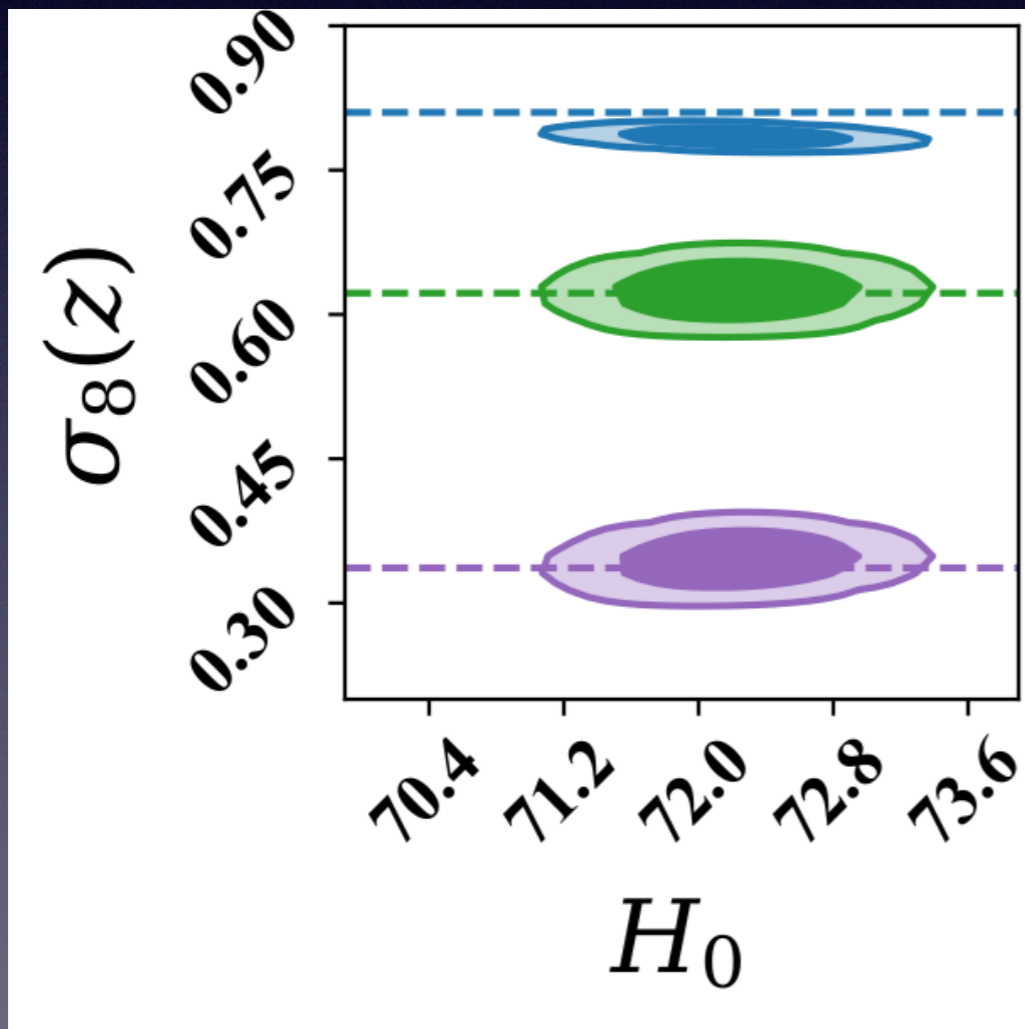
$$W(z) = ((w_0 + w_1) + (w_1 - w_0)\tanh((z - z_t)/\Delta_z))/2$$

- The values that fit the median GP inference are $w_0 = -0.95$, $w_1 = -1.95$, $z_t = 2.5$, and $\Delta z = 0.9$

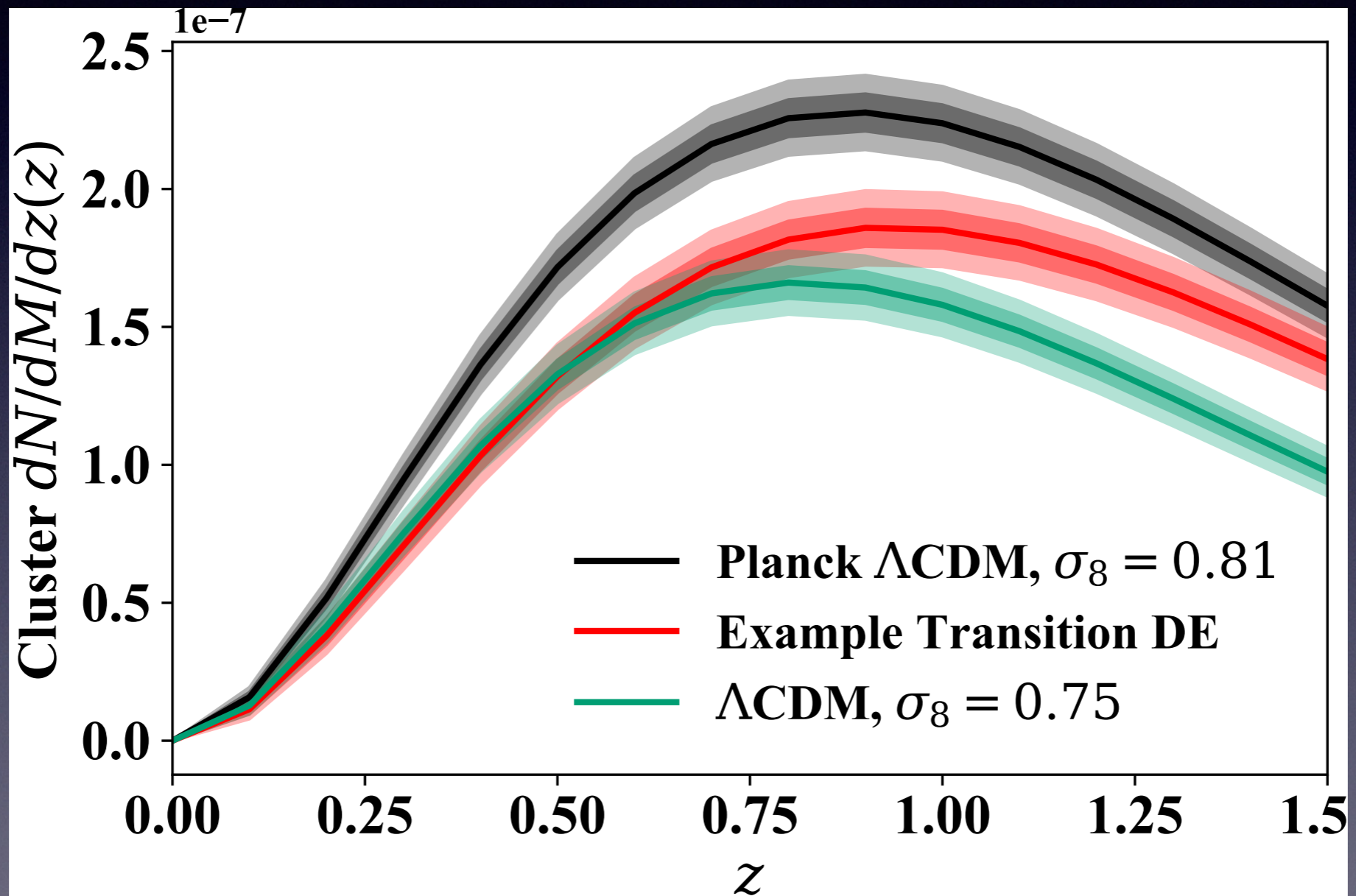
Dark Energy



Growth



Cluster counts



Conclusions

- If the central value of the H_0 measurement does not change and reaches the level of 1% precision, then a transitional DE equation of state is the preferred explanation to the H_0 tension
- This TDE dark energy can be tested via measurements of the growth rate and future BAO observations.