

Model Independent Inferences - Relating Dark Energy and Growth

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Arxiv:1710.04236

Tensions

- Inferences from the CMB predict $H(z=0) = 67.31 \pm 0.96$ km/s/Mpc
- Measuring H_0 directly gives 73.52 ± 1.62 km/s/Mpc
- Difference is now at $3.8\text{-}\sigma$.
- Systematics - CMB?
- Systematics - Local Void? Calibration errors?
- New Physics - N_{eff} (high redshift)
- New Physics - Evolving dark energy (low redshift)
- Other discordant datasets - Boss Lya, Planck SZ cluster counts, CFHTLenS, KiDS

Model Independence Through Geometry

- Cosmological constant problem lacks a concrete way forward
- Ensure conclusions are robust and general, but come at the cost of interpretability
- More likely to give surprising results
- We achieve model independence by using only distances

$$D_H = c/H(z), D_c = \int_0^z dz' D_H(z')$$

Data

- HST measurement of H_0
- Pantheon compilation of SN
- BOSS measurement of BAO signal in LRGs
- BOSS measurement of BAO signal in Ly α
- Planck TT+TE+EE+lowP CMB datasets

Growth

ϕ : gravitational potential

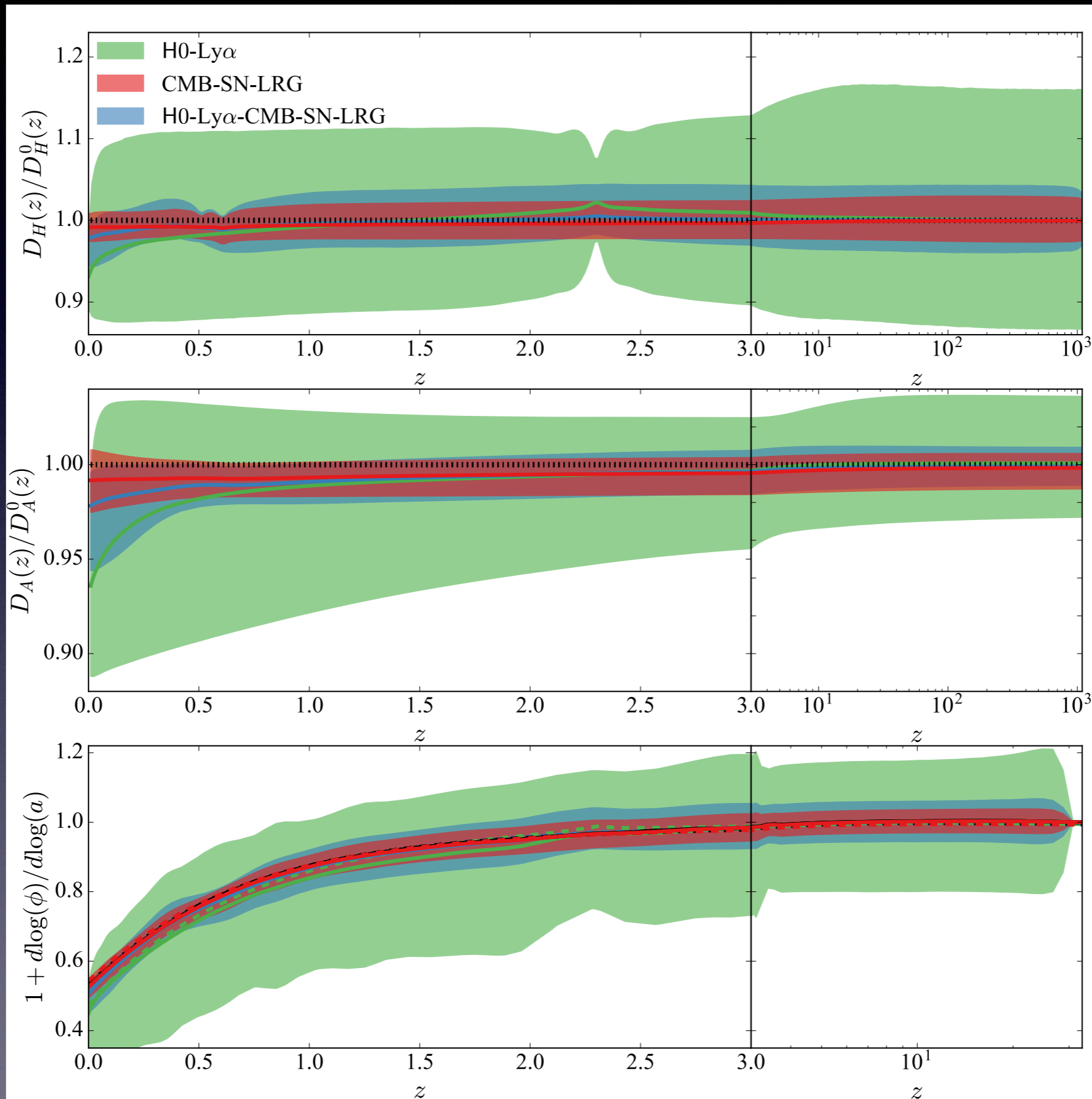
$$\delta\rho/\rho \propto \phi a$$

- Growth related to expansion via

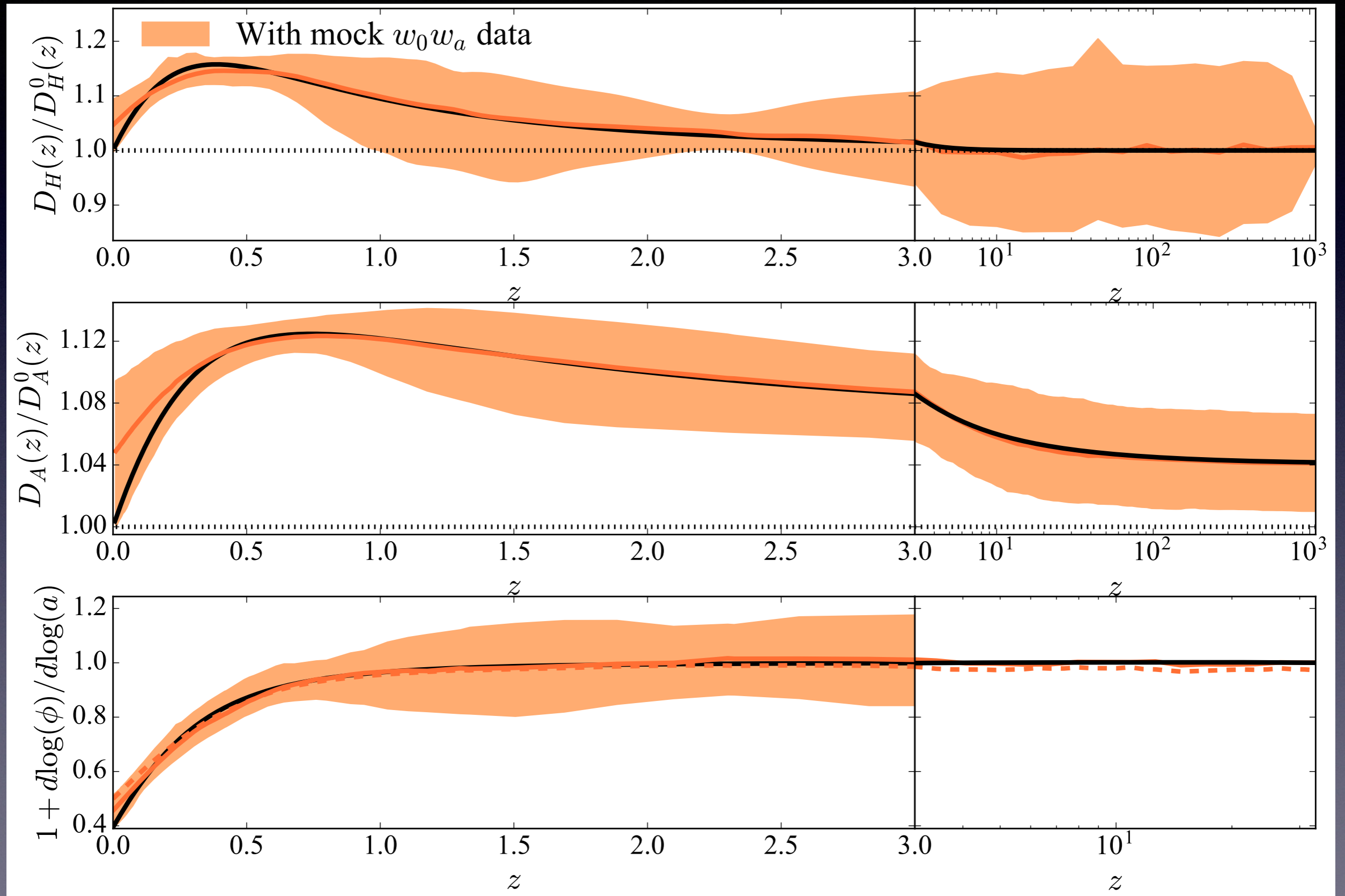
$$\phi'' + (4 + H'/H)\phi' + (3 + 2H'/H)\phi = 0$$

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

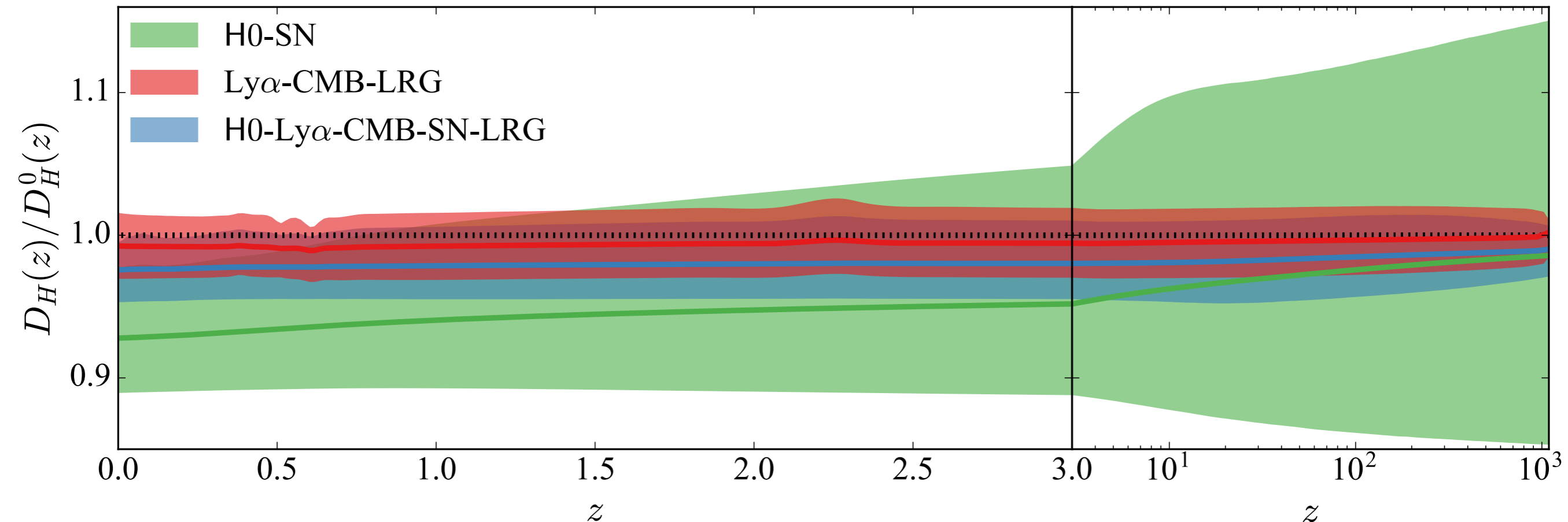
Results



Validation

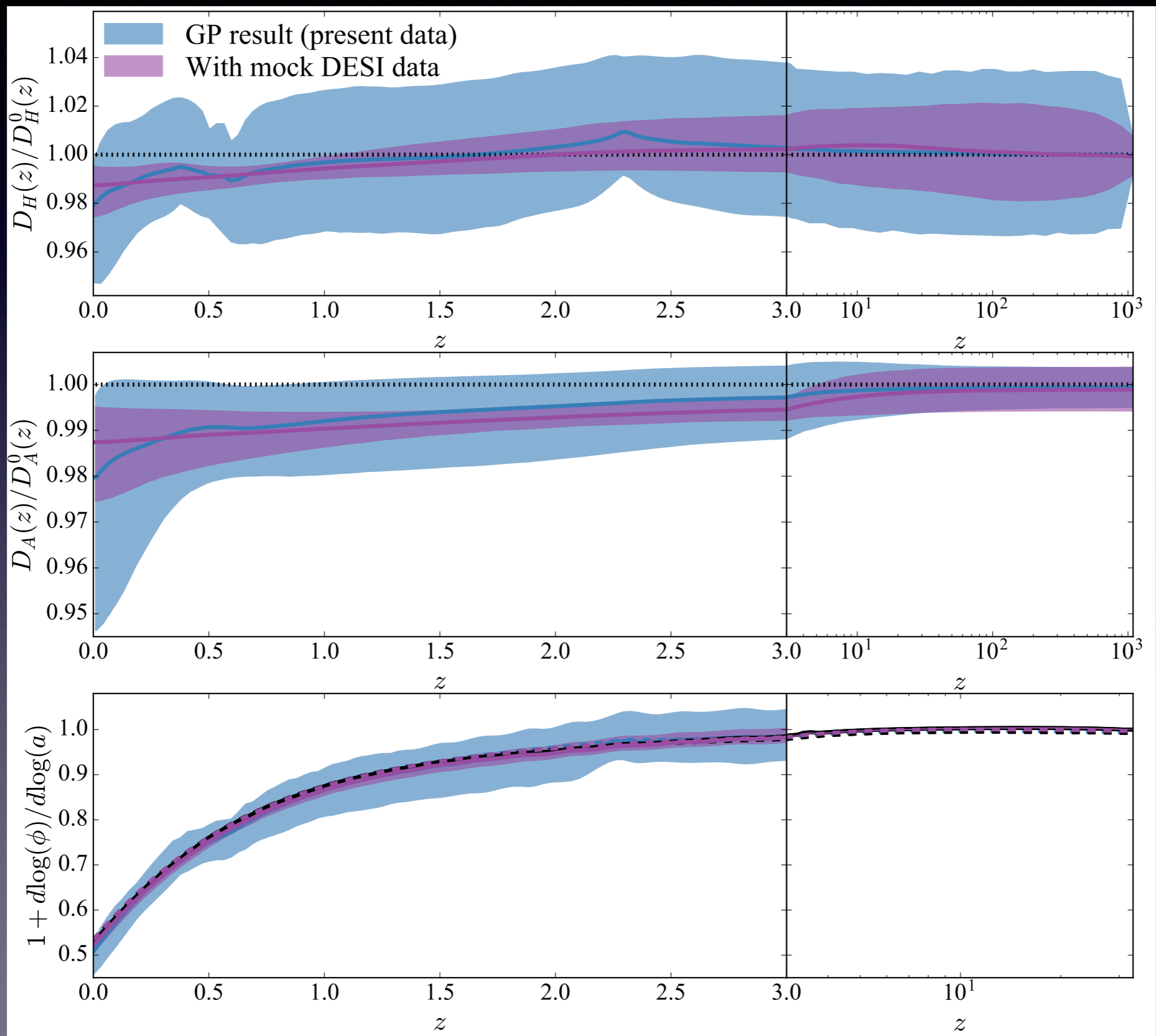


Dark Radiation



- Neff modifies drag sound horizon
- BAO features scale with r_{drag}
- Calculate scaling relation with $D_H(z^*)$ and r_{drag}

Forecasts

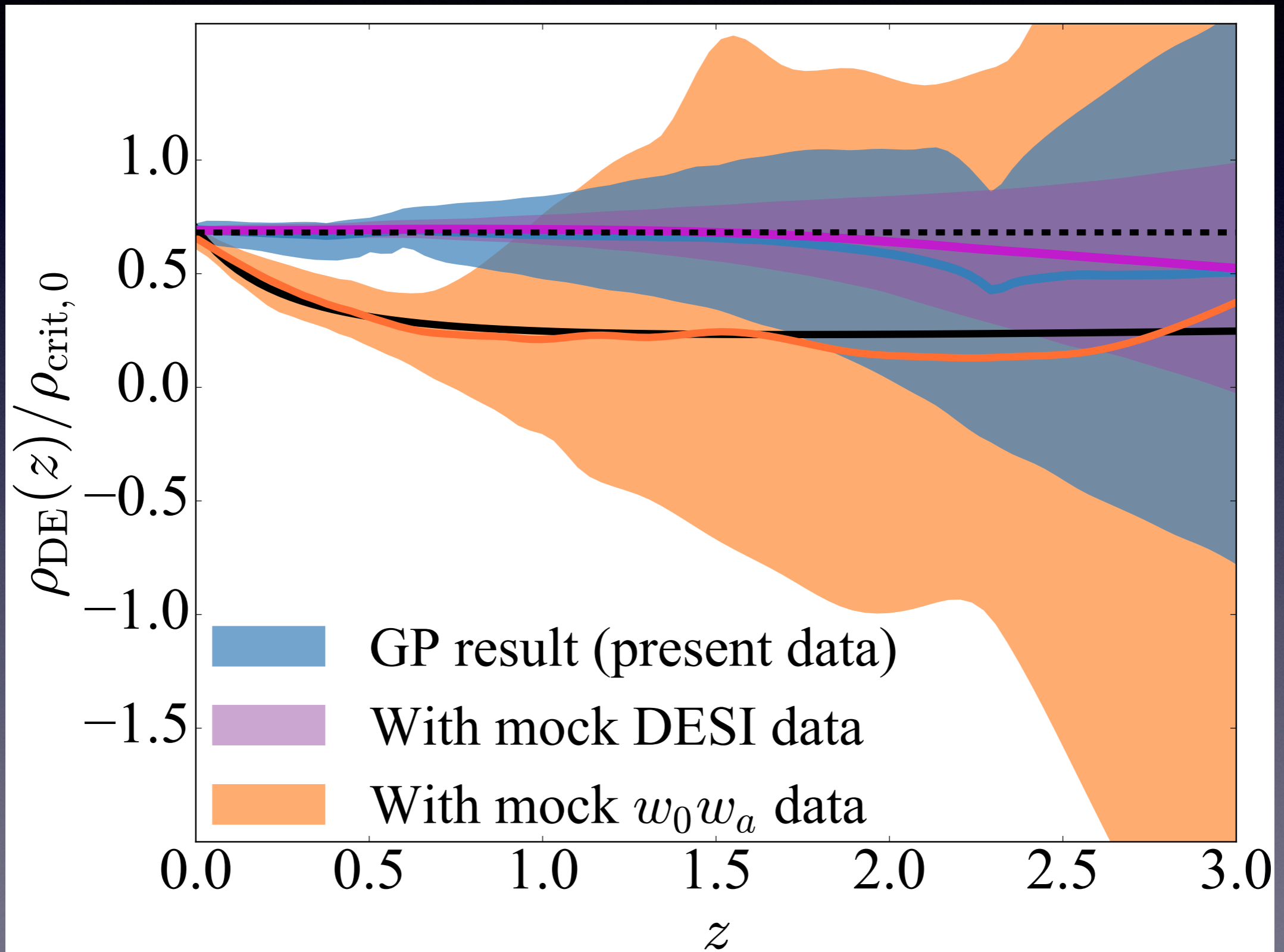


Dark Energy

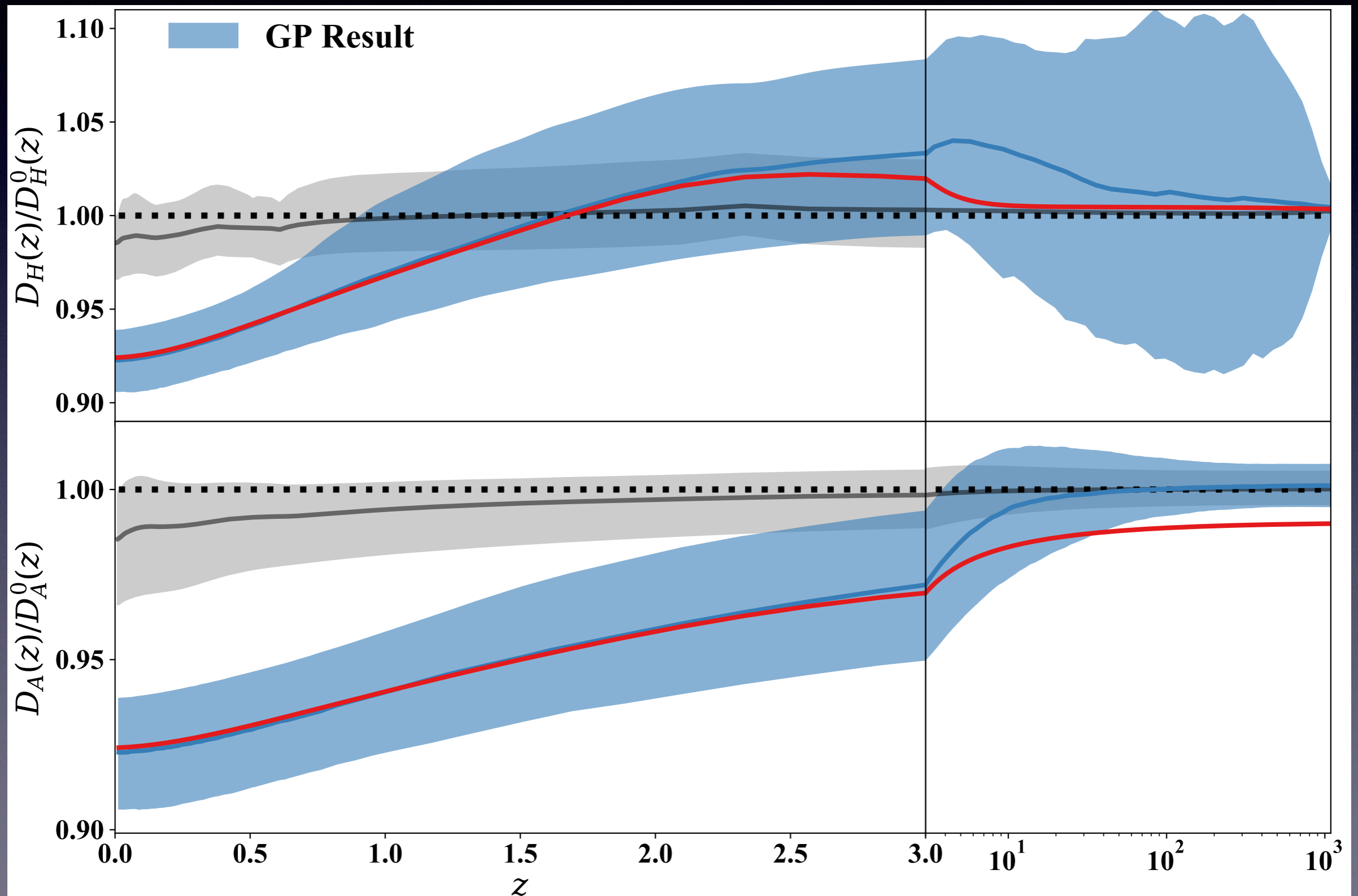
- Infer dark energy evolution model independently
- Calculate the total energy density at all redshifts from the inferred GP expansion history
- Subtract off a fiducial radiation density
- Define the matter density to make up the rest of the energy density at the CMB
- The dark energy density is the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

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

Dark Energy



1% H0 Measurement



Conclusions

- No deviations at current level of precision
- 2% errors on DH & DA from $z=0$ to z^*
- No evidence for dark radiation, late-time physics remains a possibility
- Growth rate is consistent with LCDM at $<4\%$
- DESI forecasts 1% errors on DH & DA
- Novel results if H_0 is measured to 1% precision