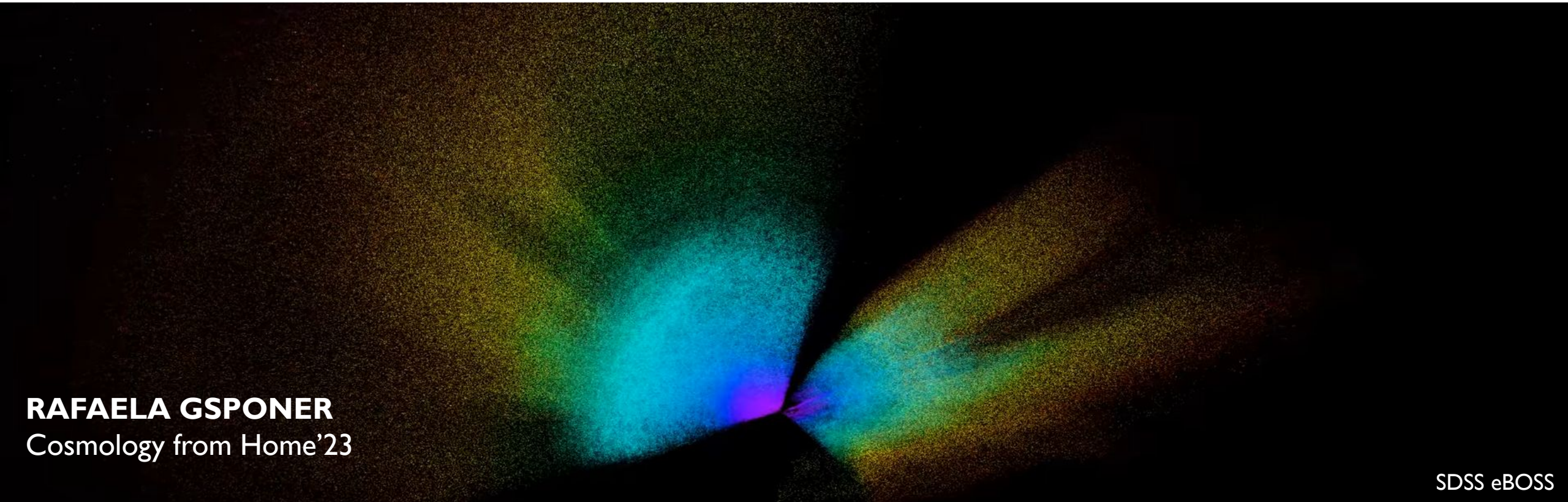
UNIVERSITY OF PORTSMOUTH

EARLY DARK ENERGY IN THE LIGHT OF LARGE SCALE STRUCTURE DATA



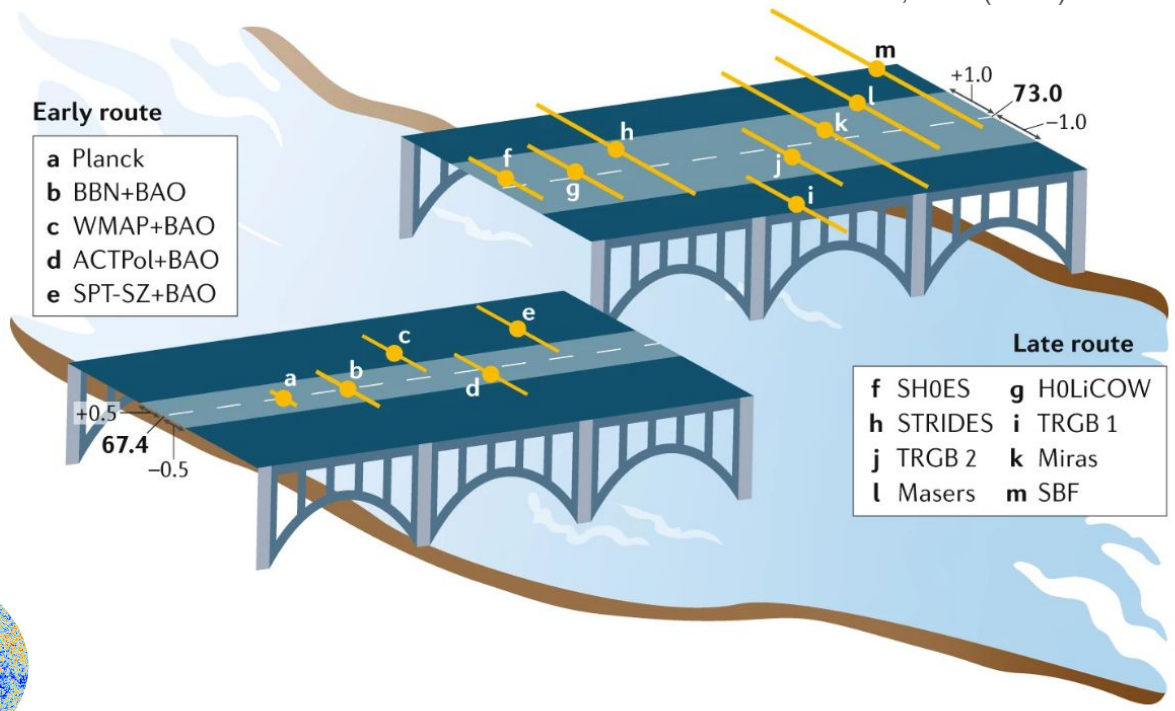
RAFAELA GSPONER

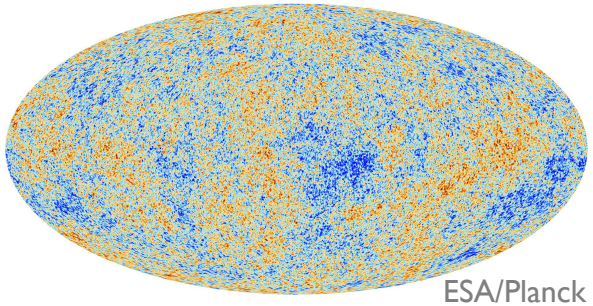
Cosmology from Home'23

SDSS eBOSS

Hubble Tension

Riess, A.G. (2020)





ESA/Planck

Early universe +
Cosmological assumptions
67.4 +/- 0.5 km/s/Mpc

NASA/CXC

Late universe +
Astrophysical assumptions
73.04 +/- 1.4 km/s/Mpc

Hubble Tension

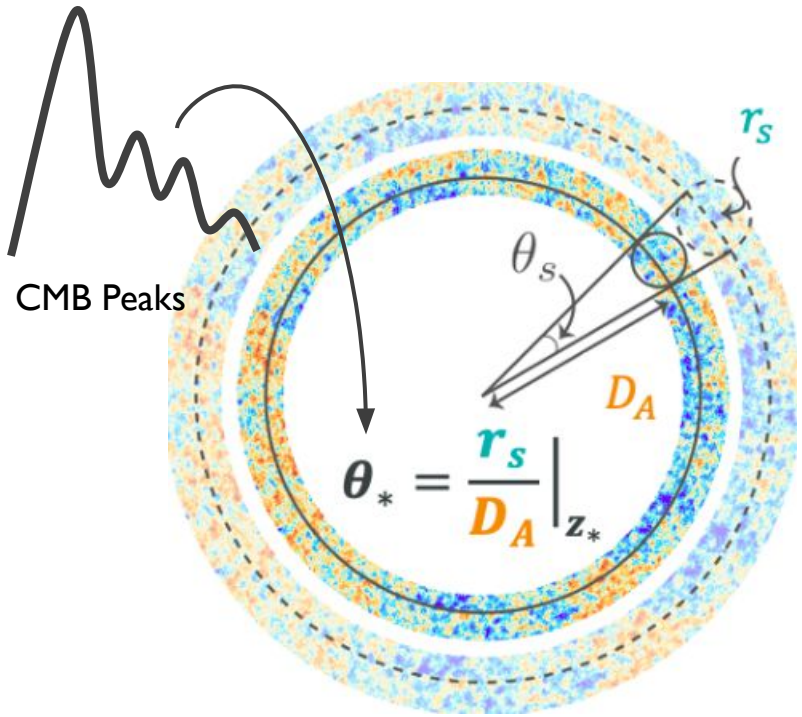
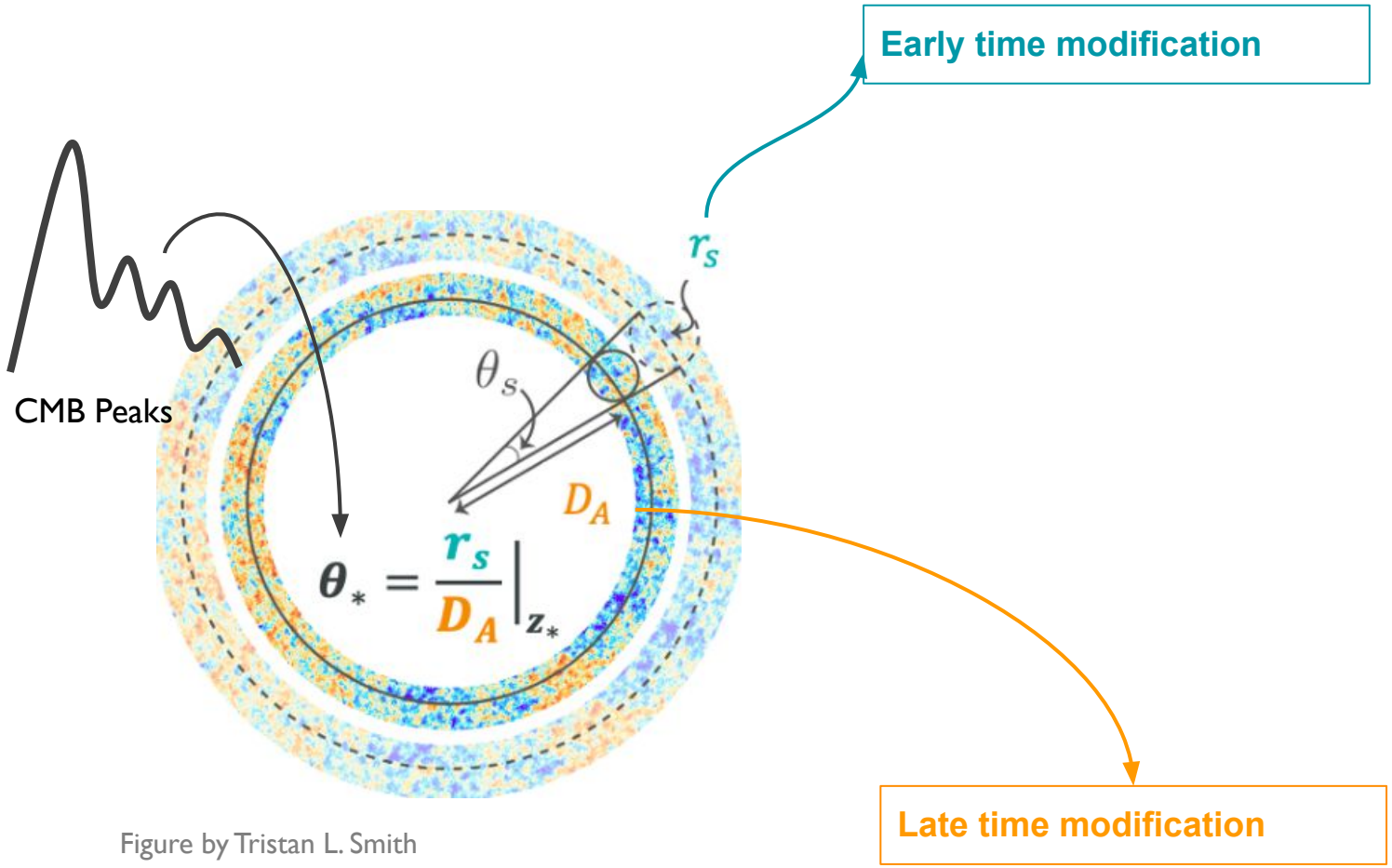


Figure by Tristan L. Smith

Hubble Tension



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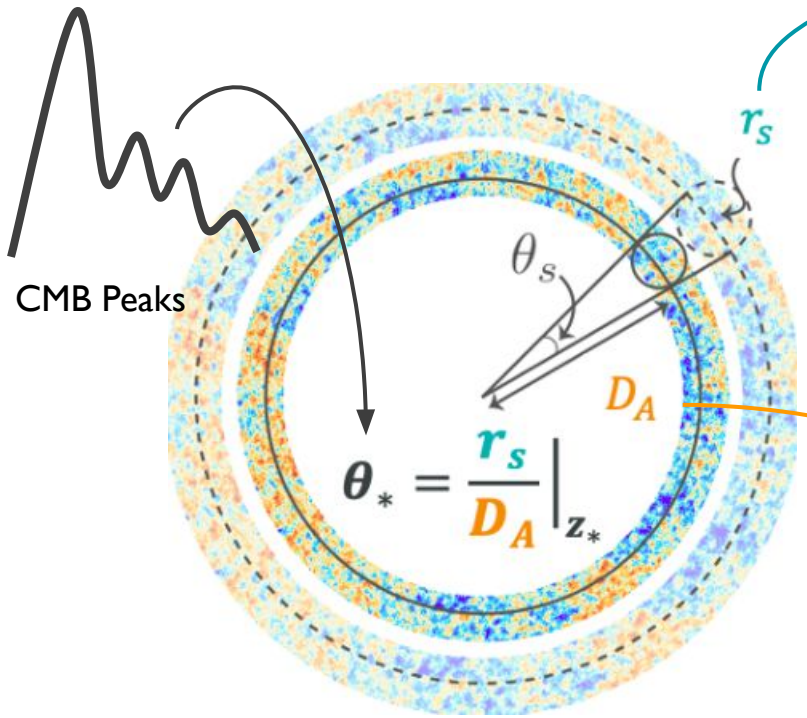
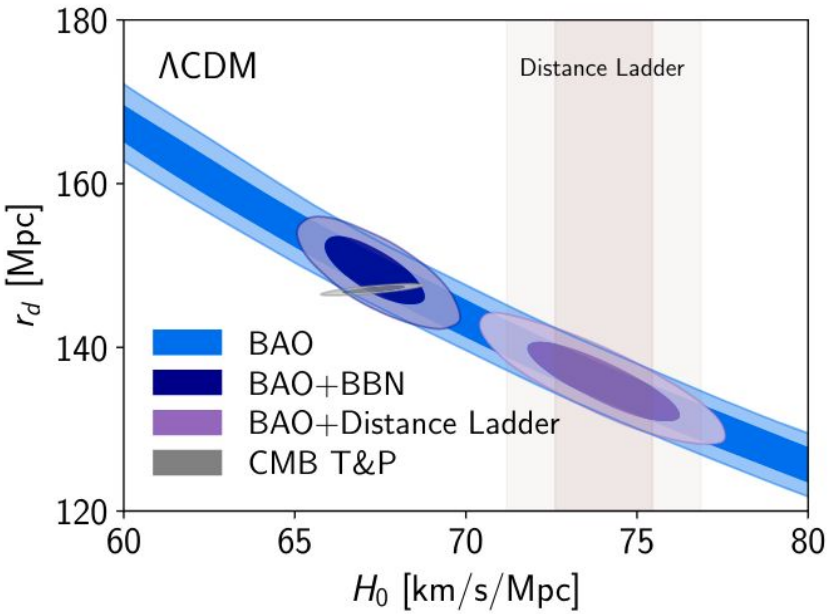


Figure by Tristan L. Smith

Early time modification

Late time modification

eBOSS collaboration



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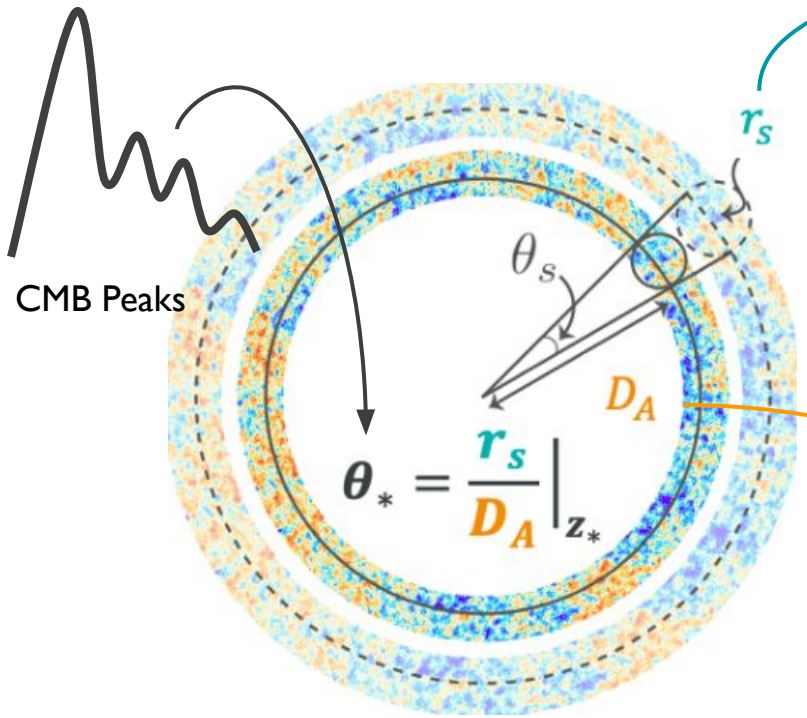


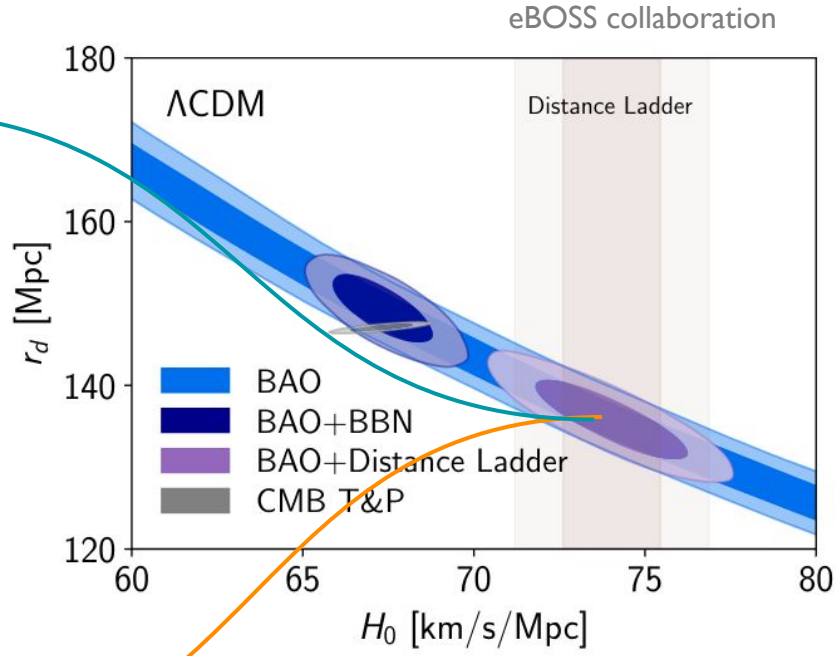
Figure by Tristan L. Smith

Early time modification

$$D_A \propto 1/H_{post}$$

$$r_s \propto 1/H_{pre}$$

$$\theta_s \sim \frac{r_s}{1/H_{post}} \sim r_s H_0$$



Late time modification

Very well tracked expansion history

Early Dark Energy

Including **new components prior to recombination** is one of the most likely categories of solutions to the H0 tension. (Hubble Hunter's Guide, 2019)

Early Dark Energy (V. Poulin et al., 2019)
axion-like particle with a periodic potential

$$V(\phi) = V_0(1 - \cos\theta)^3, \quad V_0 = m^2 f^2$$

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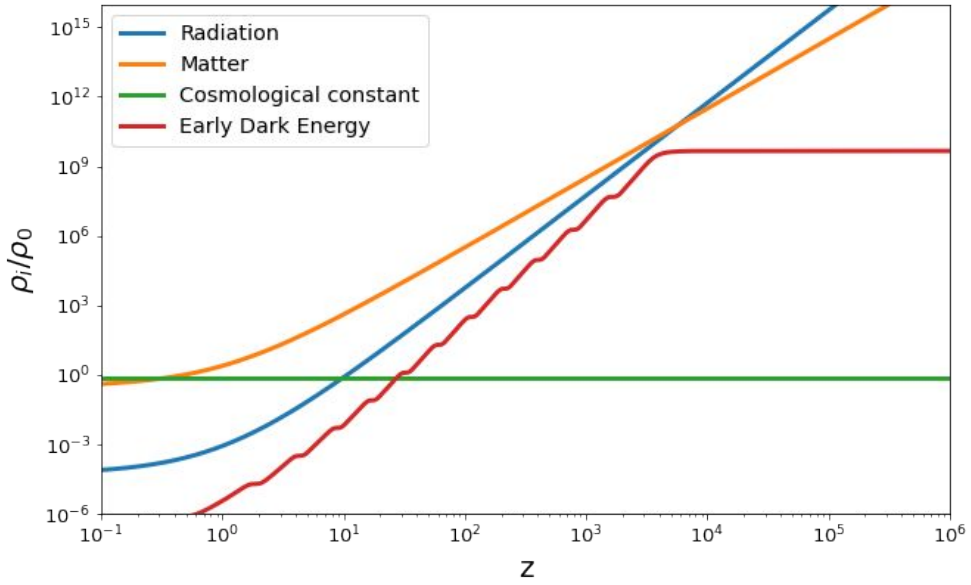
3 additional parameters to LCDM

Figure by Tanvi Karwal



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f_{EDE} How much EDE?

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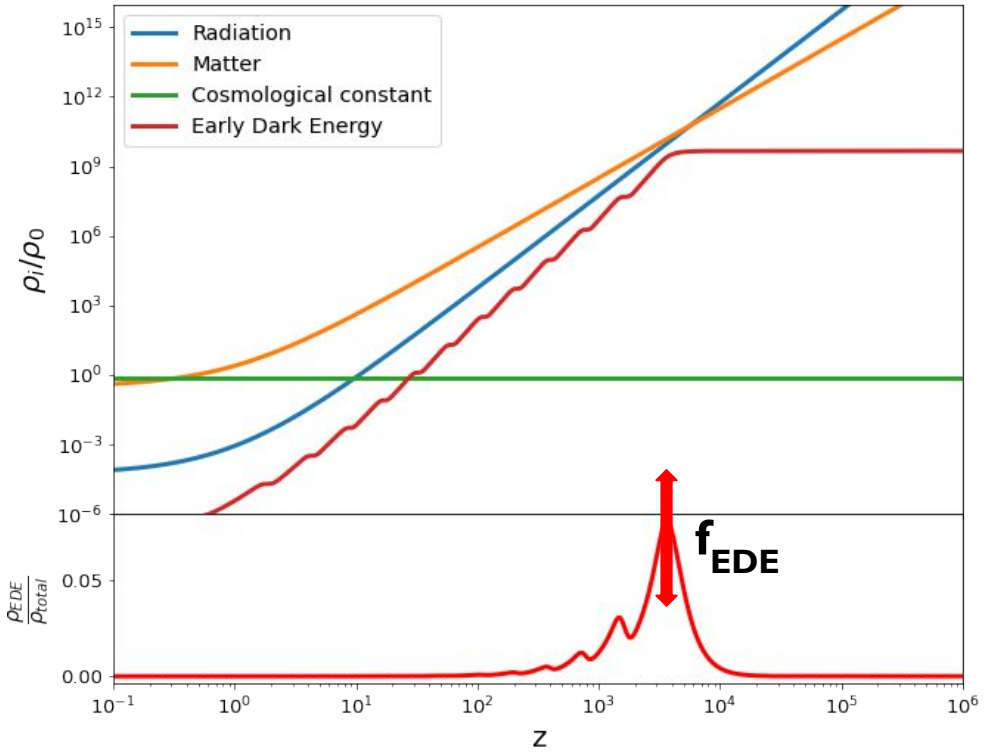

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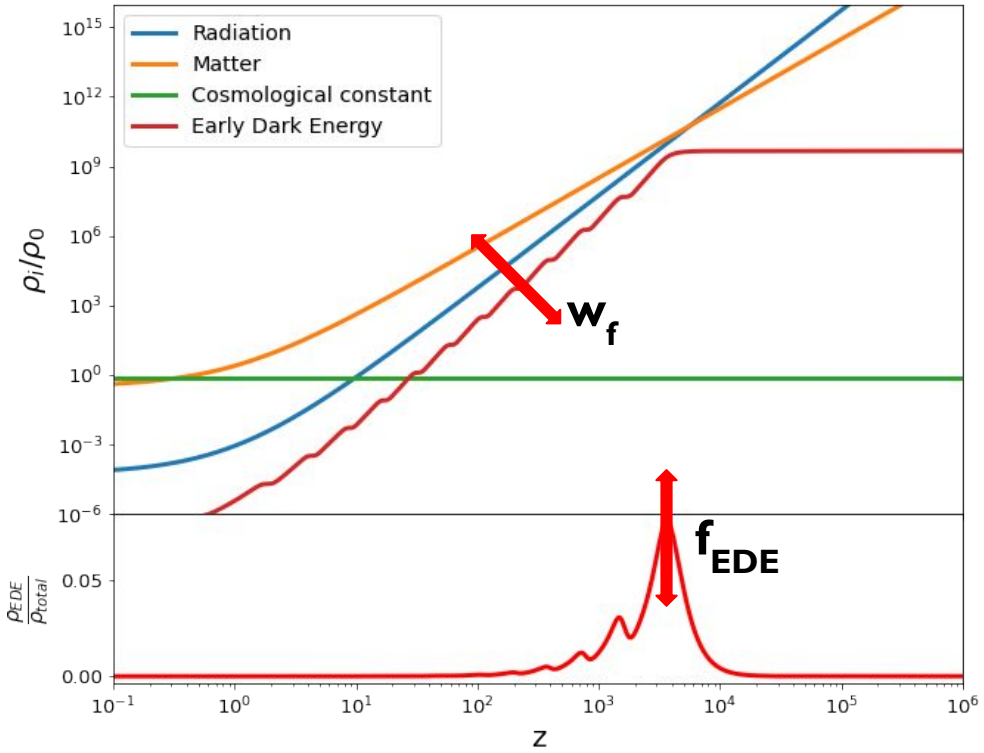

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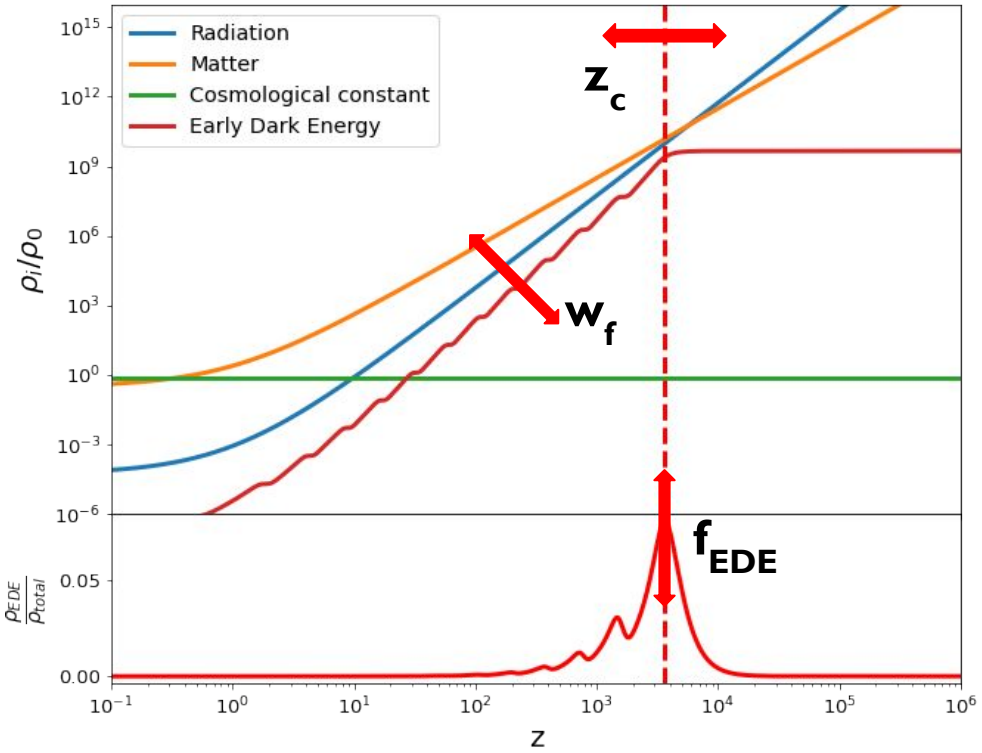
f_{EDE} How much EDE?

w_f How fast does it disappear?

z_c When does it disappear?

Figure by Tanvi Karwal



EDE vs Data Constraints

EDE & the question of tension trading

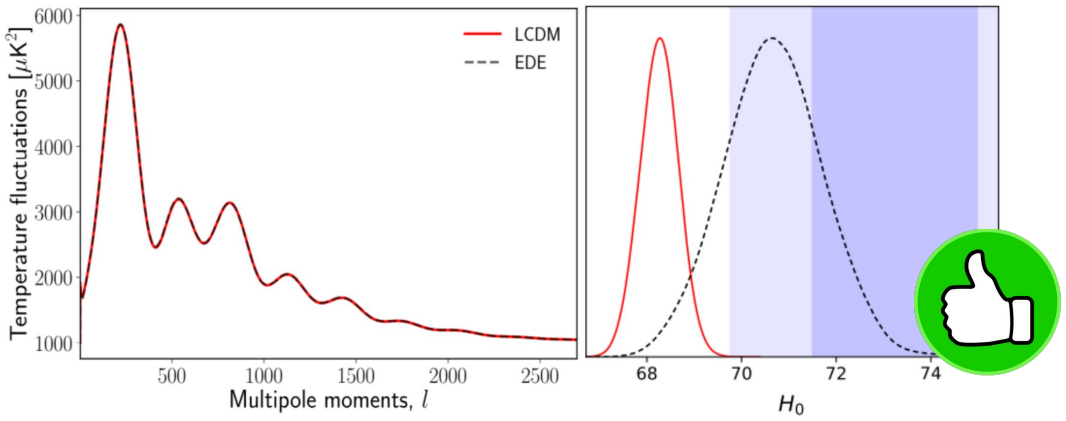
EDE vs Data Constraints

CMB + EDE

EDE & the question of tension trading

EDE vs Data Constraints

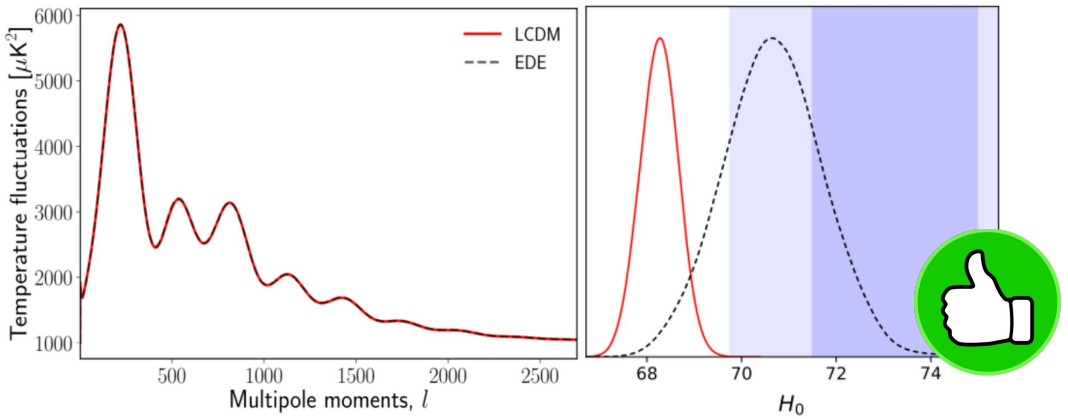
CMB + EDE



EDE & the question of tension trading

EDE vs Data Constraints

CMB + EDE

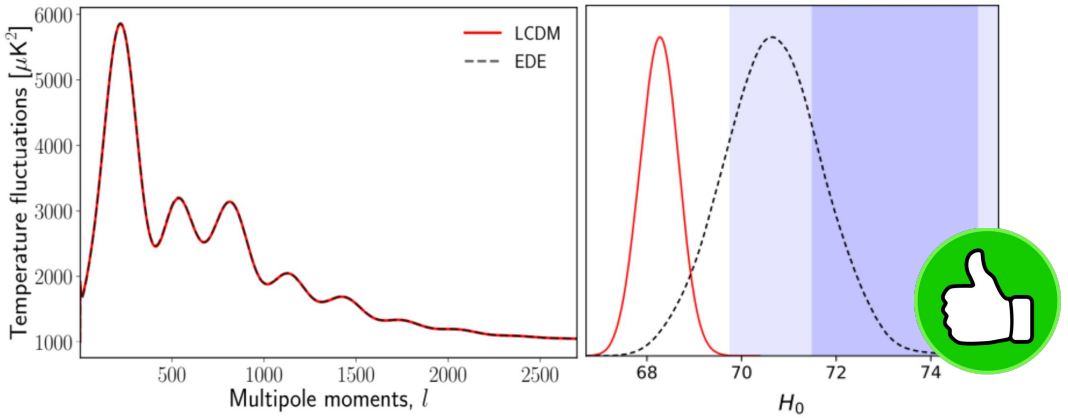


EDE & the question of tension trading

LSS + EDE

EDE vs Data Constraints

CMB + EDE



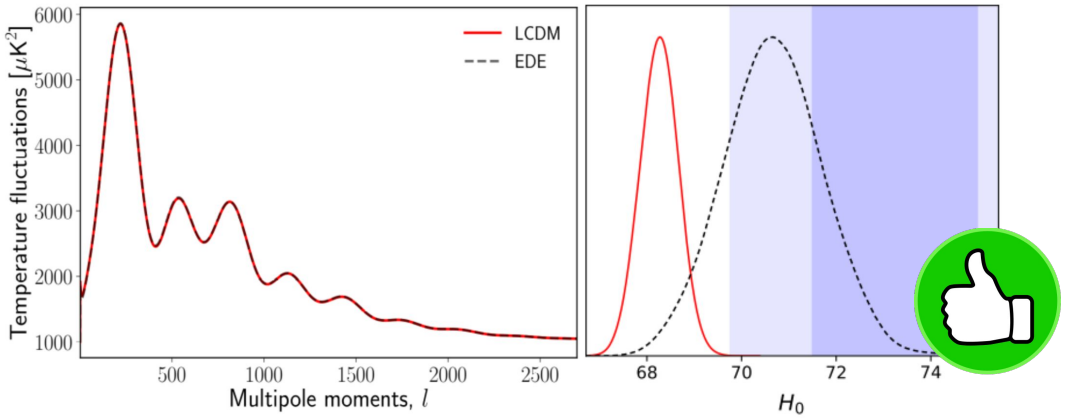
EDE & the question of tension trading

In order to fit CMB, cosmological parameters are shifted

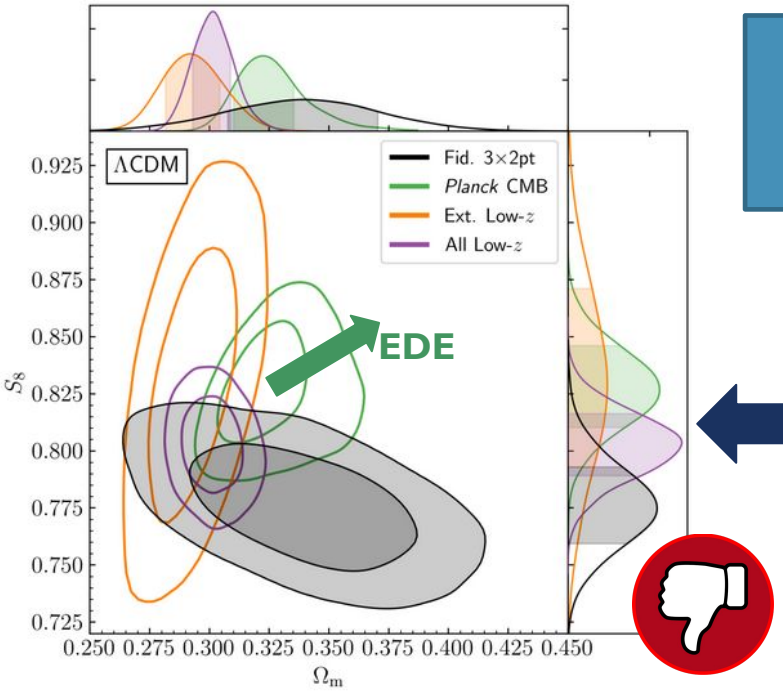
LSS + EDE

EDE vs Data Constraints

CMB + EDE



DES collaboration



EDE & the question of tension trading

In order to fit CMB, cosmological parameters are shifted

LSS + EDE

EDE meets eBOSS

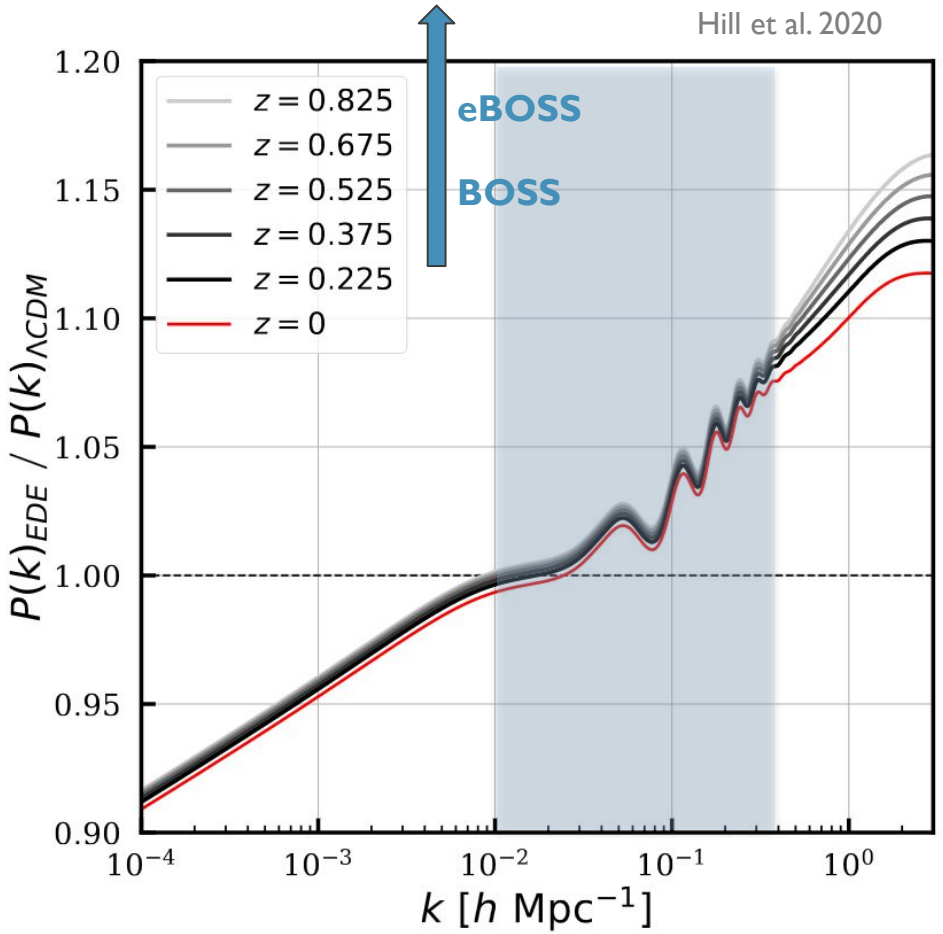
Goal of this Project:
Use eBOSS full shape analysis to put constraints on EDE

eBOSS:

- LRGpCMASS (z_{eff} = 0.698)
- ELG (z_{eff} = 0.86)
- QSO (z_{eff} = 1.48)

BOSS+eBOSS:

- BOSS z1 (z_{eff} = 0.38)
- LRGpCMASS (z_{eff} = 0.698)
- ELG (z_{eff} = 0.86)
- QSO (z_{eff} =1.48)



EDE meets eBOSS

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Use eBOSS full shape analysis to put constraints on EDE

Full shape analysis:

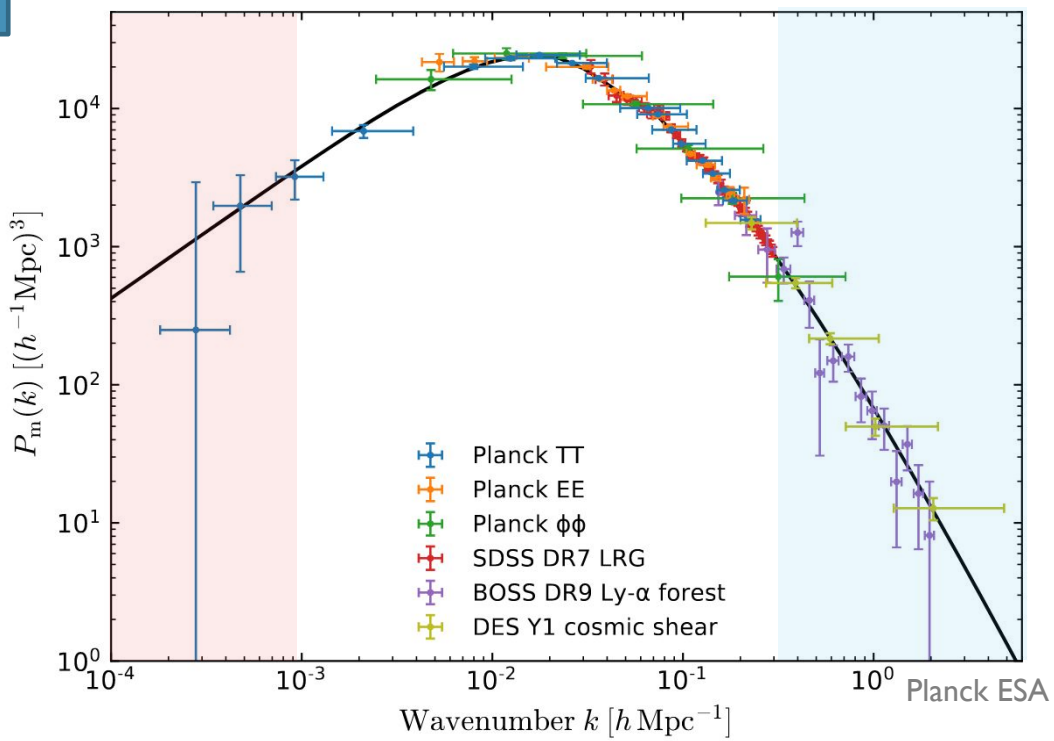
Modelling multipole moments of galaxy power spectrum in redshift space based on 1-loop perturbation theory

Effective Field Theory of Large Scale Structure

(Baumann et al. 2012, d'Amico et al. 2019, Ivanov et al. 2019)

SPT$^{(1\text{-loop})}$ + UV counterterms + IR resummation
Stochastic counterterms
Non – linear bias
Multipole expansion

$$P_{g,l}(k) = P^{lin}_{g,l}(k) + P^{1-loop}_{g,l}(k) + P^{ctr}_{g,l}(k) + P^{sto}_{g,l}(k)$$



Standard Perturbation Theory

IR	EFT:	UV
	$P(k) = P_{lin}(k) + P_{22,\Lambda}(k) + 2P_{13,\Lambda}$	$-\frac{c^2_{ctr}}{k^2_{NL}} k^2 P_{lin}(k)$

EDE meets eBOSS

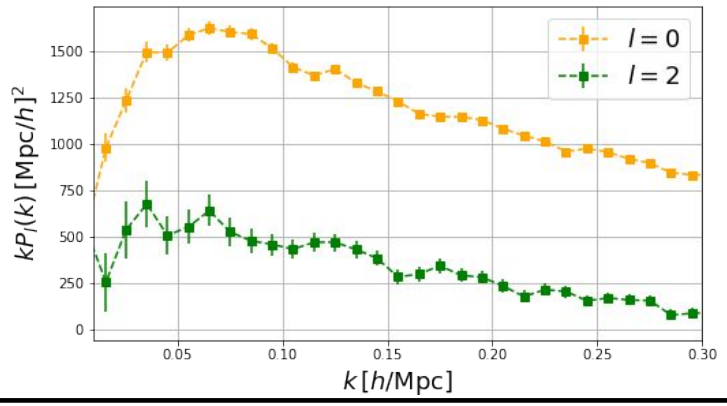
CLASS_EDE (Hill et al. 2020)

Gives P_{lin} including the evolution of EDE scalar field

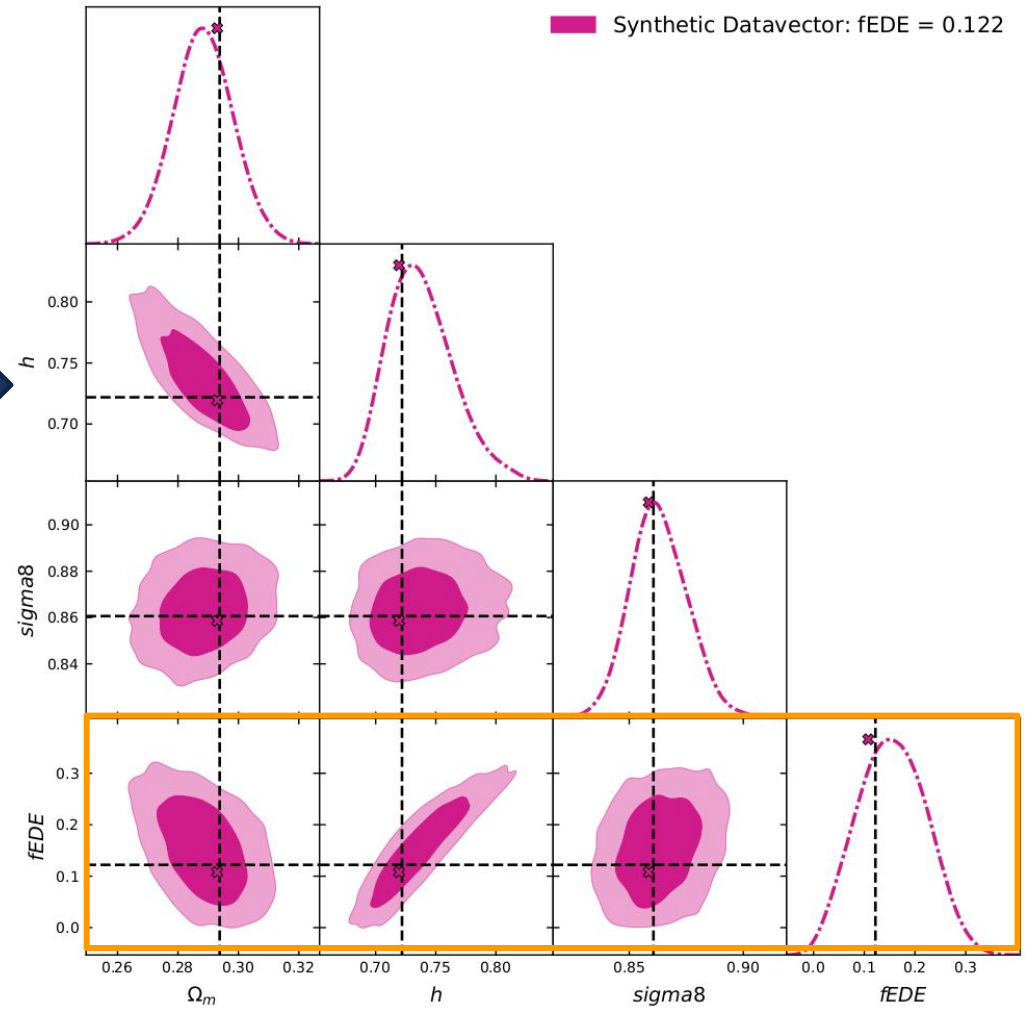
PyBird (D'Amico et al. 2020)

$$P_{g,l}(k) = P^{lin}_{g,l}(k) + P^{1-loop}_{g,l}(k) + P^{ctr}_{g,l}(k) + P^{sto}_{g,l}(k)$$

eBOSS DR16 Spectra (Dawson et al. 2016)



MCMC Sampler: Montepython
(Audren et al. 2012)



EDE meets eBOSS

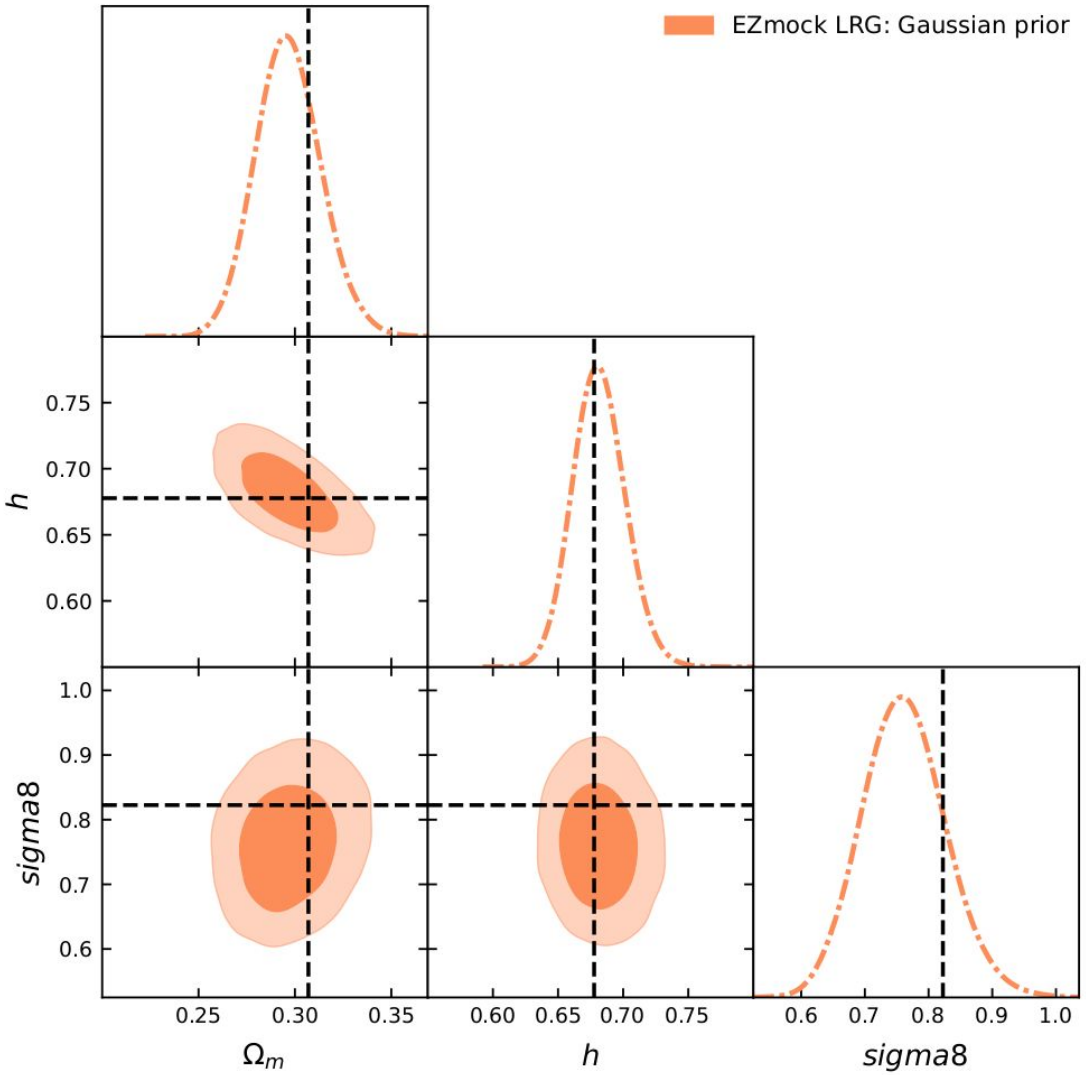
Currently investigating **prior choices:**
(Donald-McCann, Zhao, RG in prep.)

EFTofLSS has 7 nuisance parameters:

- 3 galaxy bias parameters
- 2 counterterms
- 2 stochastic parameters

Shift in posteriors, which depend on prior choices
(Simon et al. 2022, Carrilho et al. 2022)

Theoretical argument: size ~ $\mathcal{O}(1)$ → prior: $\mathcal{N}(0, 2)$



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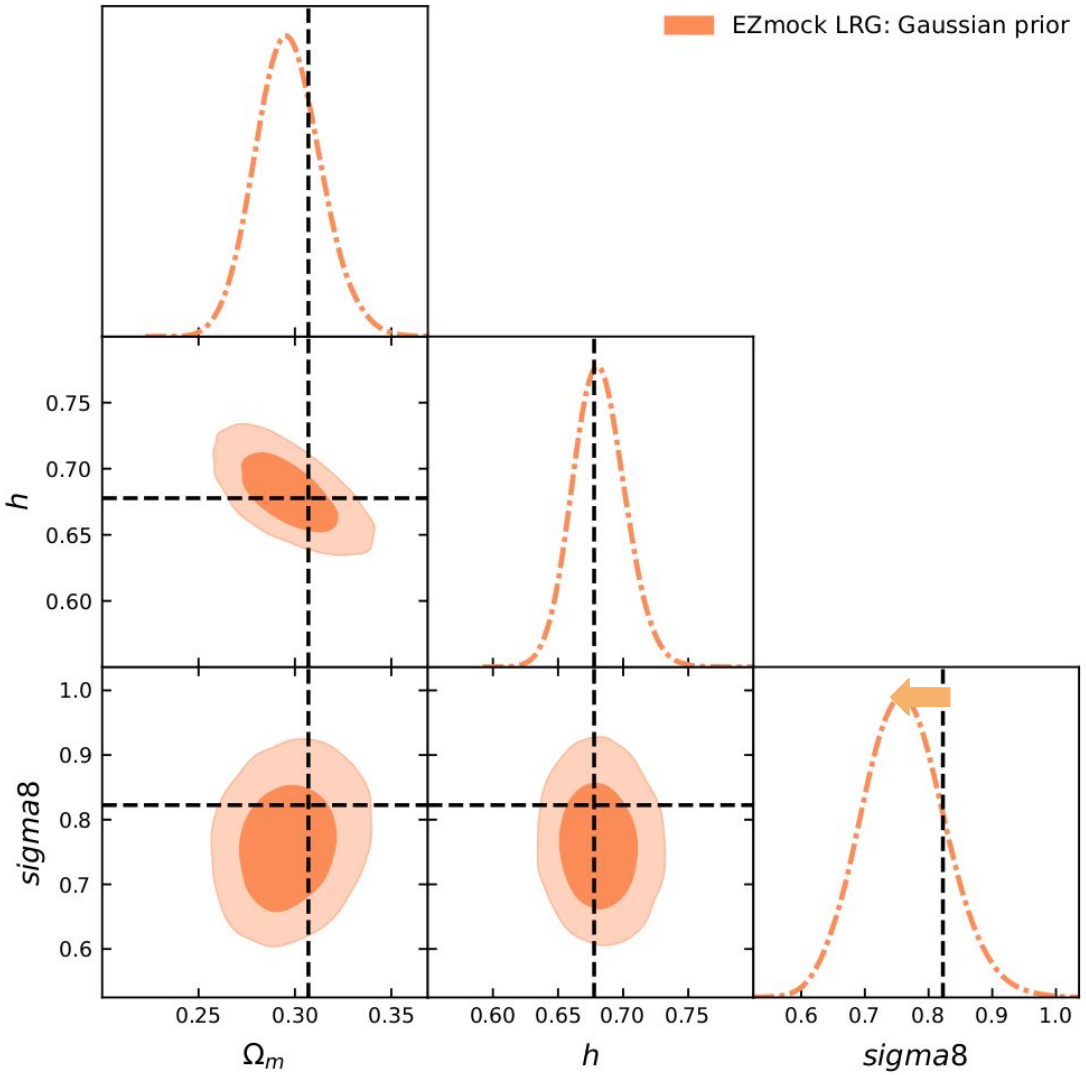
Shift in sigma8 becomes important in EDE analysis



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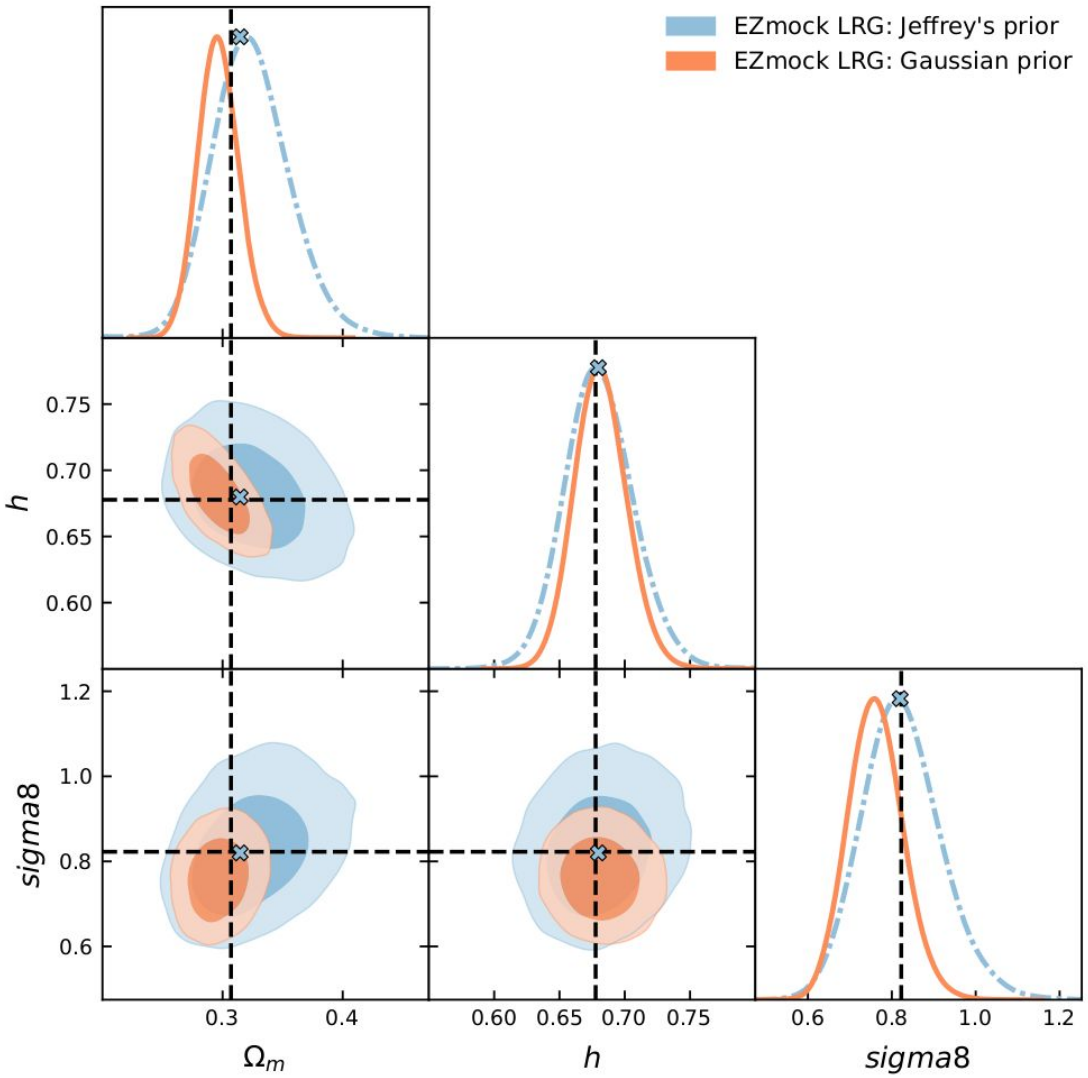
Mitigation of projection effects with Jeffreys prior
(Hadzhiyska et al. 2023)

$$p_J(n) = \sqrt{\det F}$$



CONCLUSION & OUTLOOK

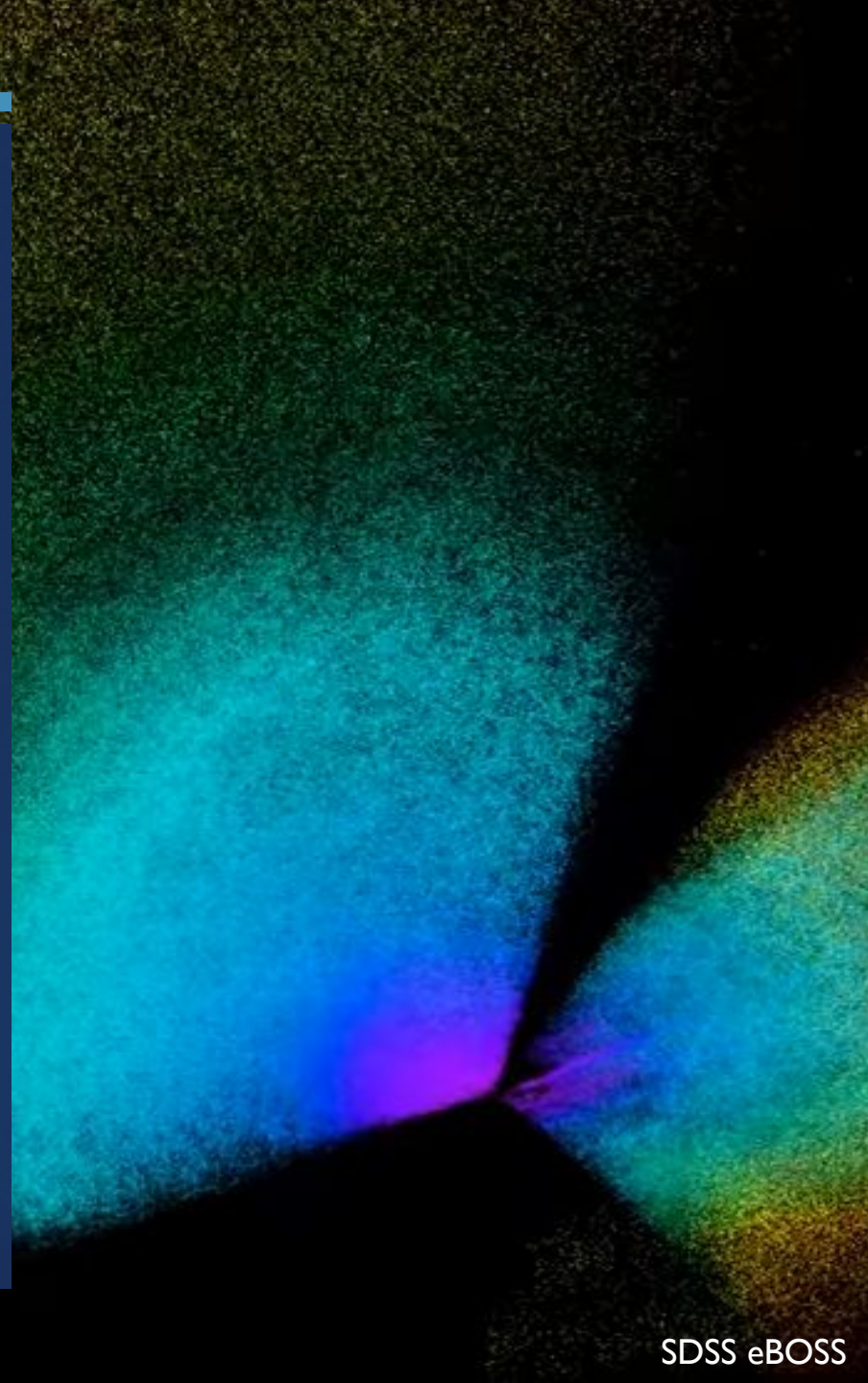
- **Current Status:** Pipeline testing done + Data runs are running

- EDE is one of the **most promising solutions** for the H0 tensions
- **Ongoing discussion** if EDE can fit LSS

- Outlook: further **investigation of analysis choices**
  - Effect of prior choices
  - Projection effects in the EDE model

Any Questions?

Email: rafaela.gsponer@port.ac.uk



SDSS eBOSS