

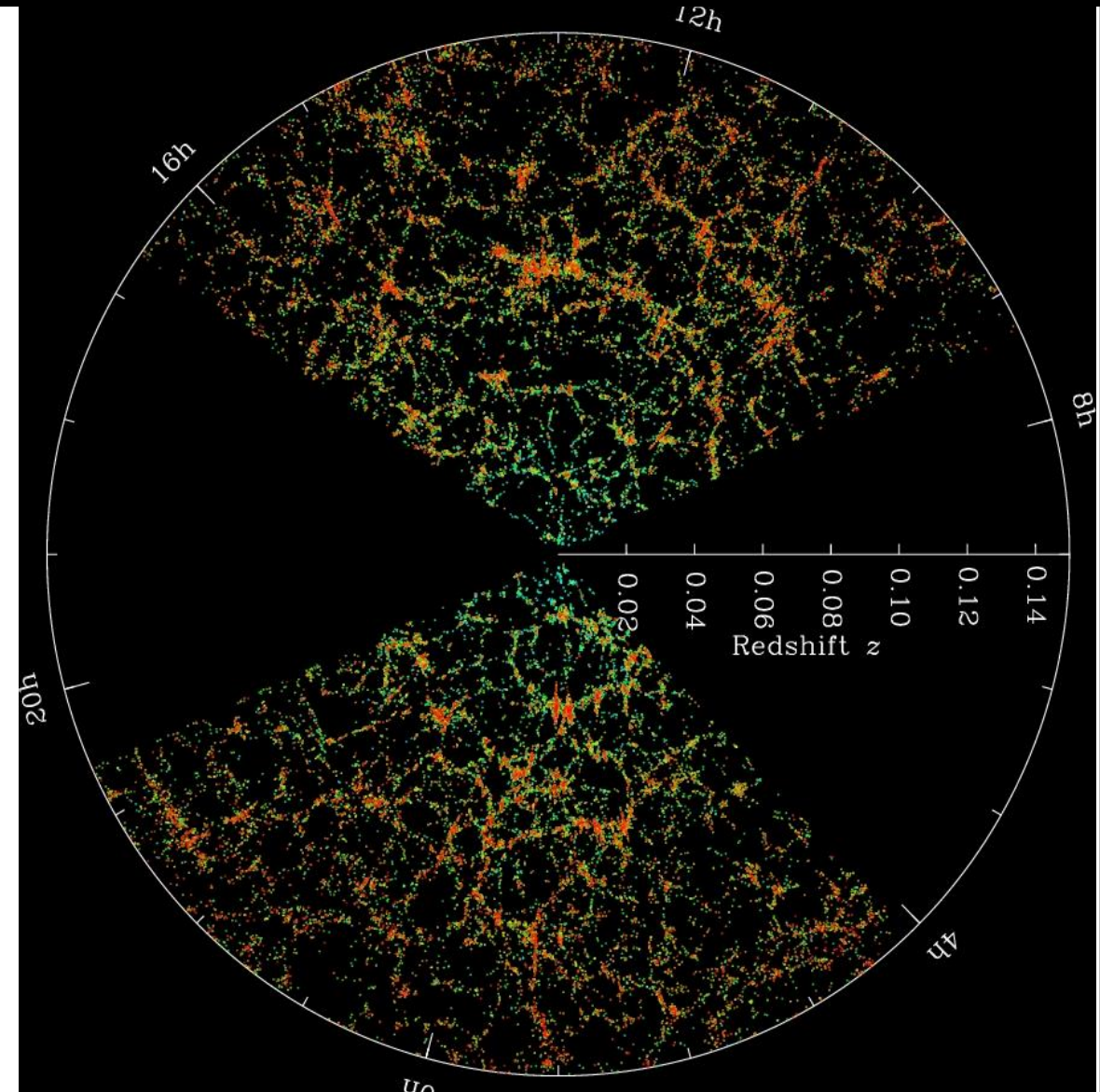
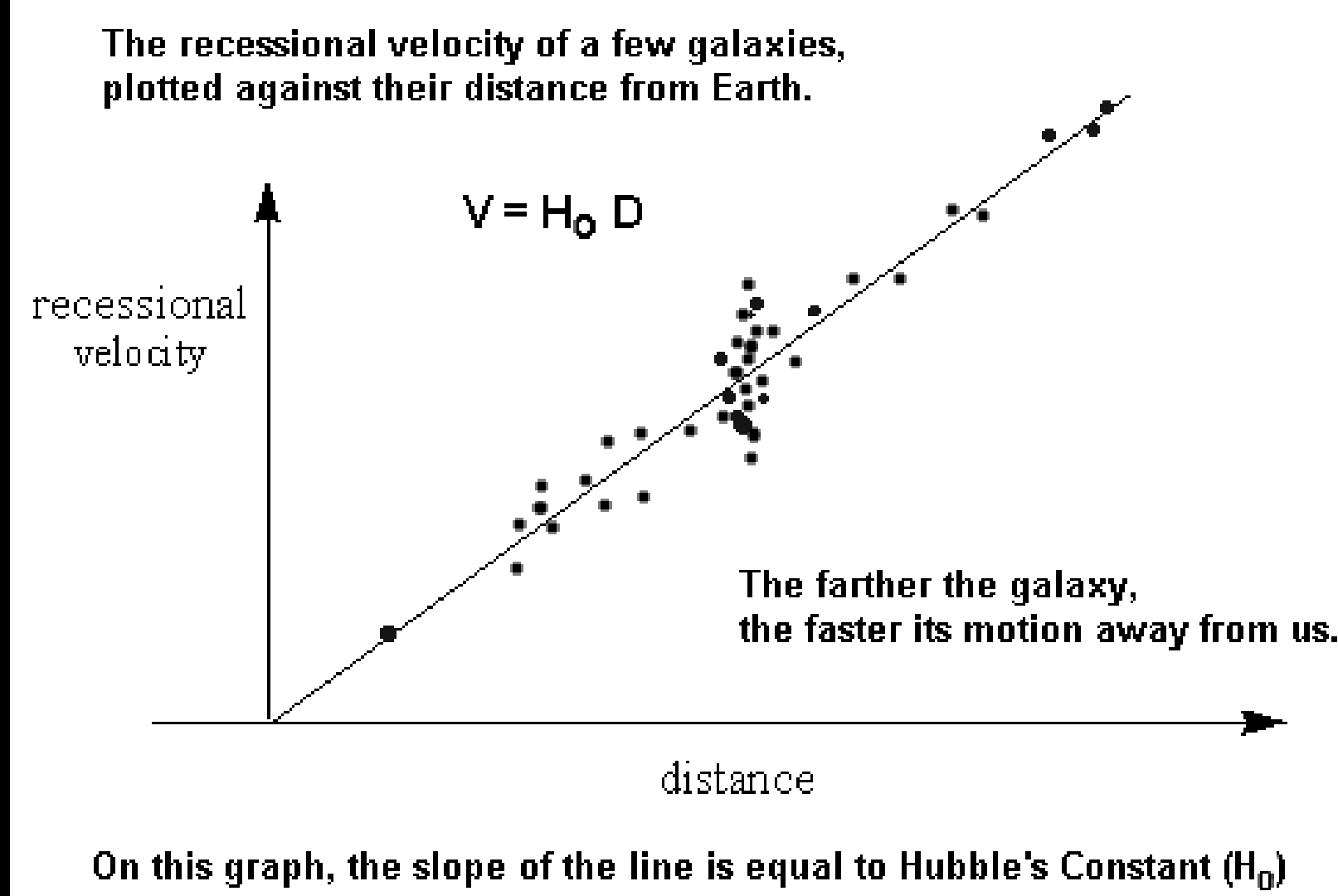
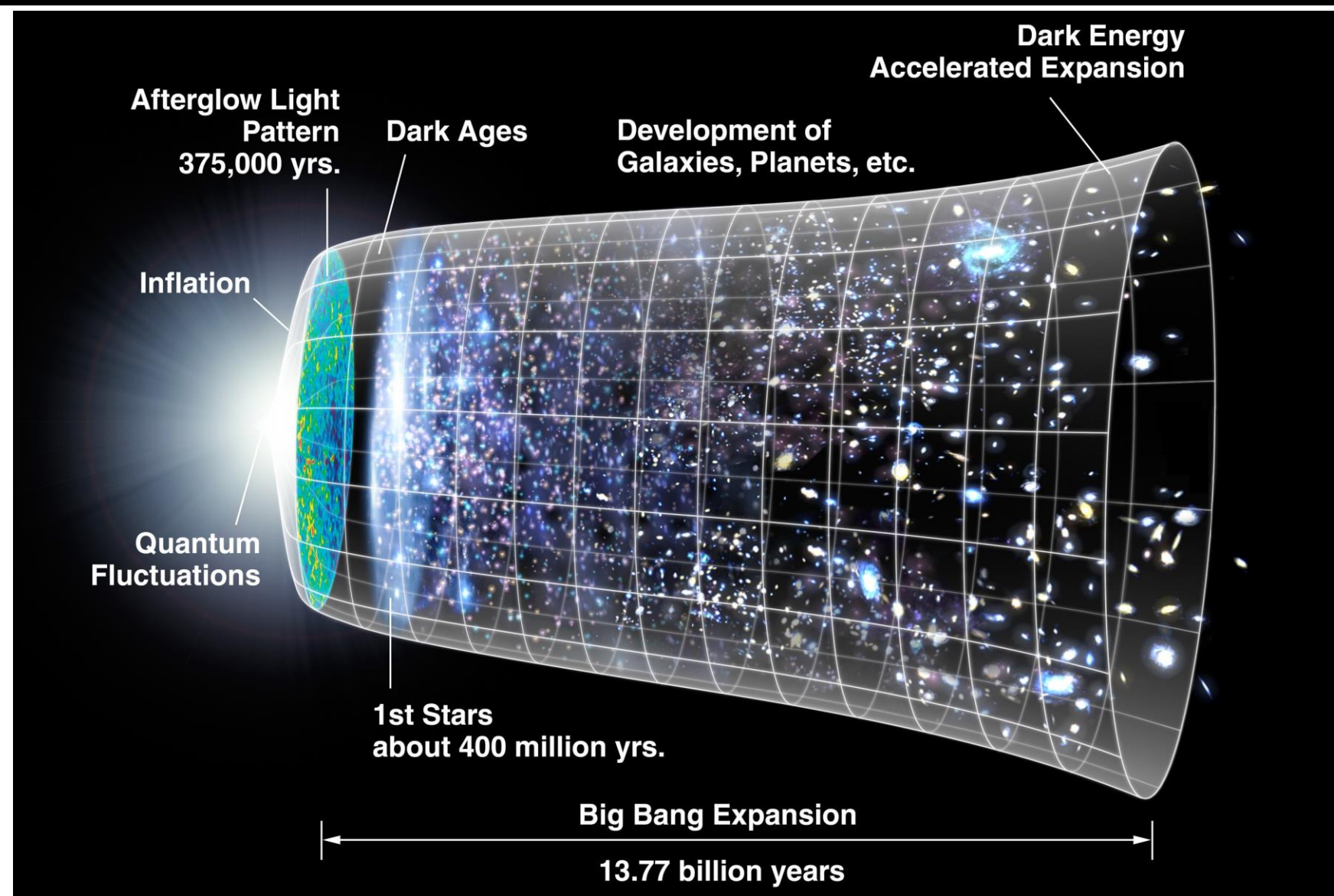
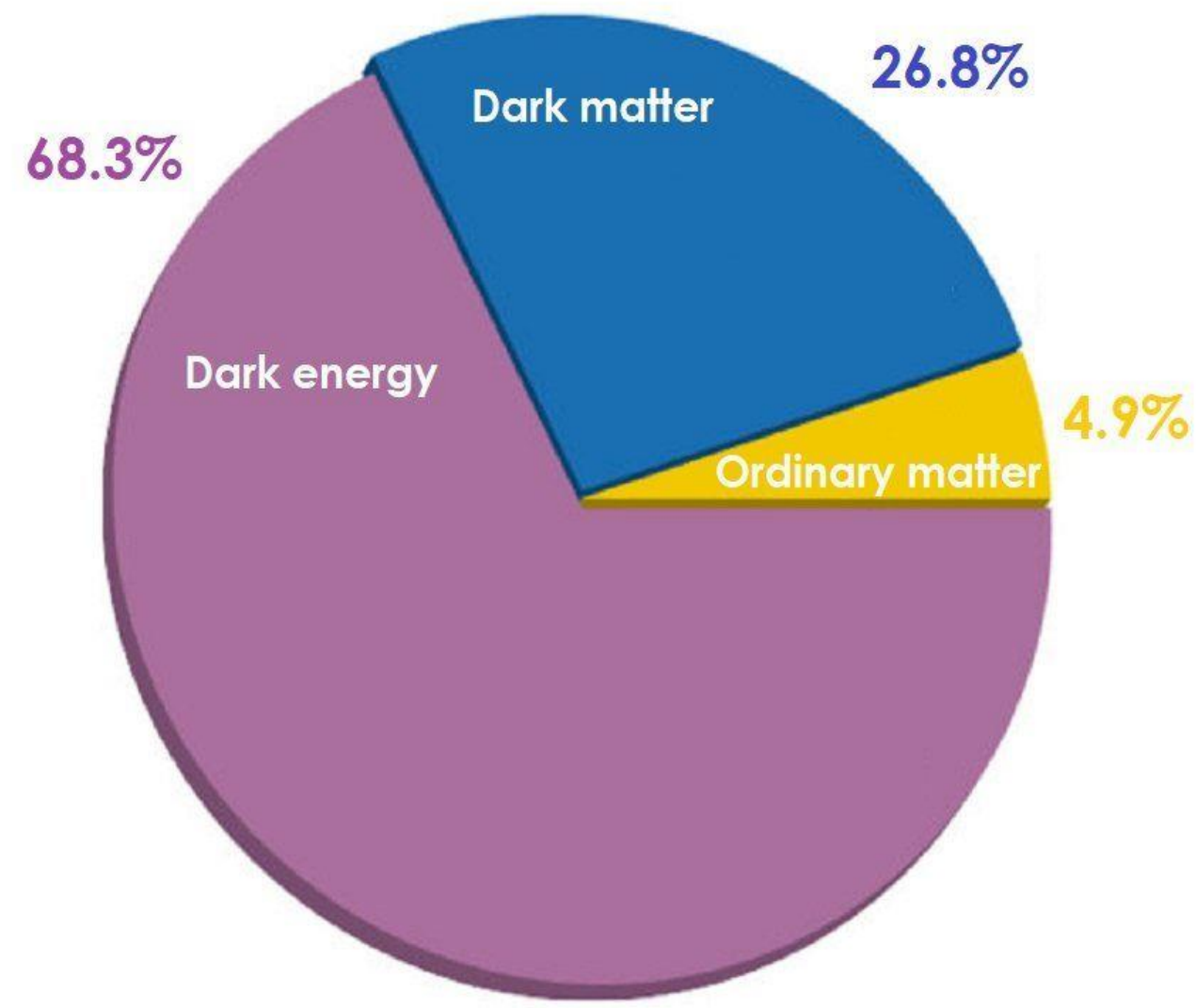
Towards a possible solution of Hubble tension with Horndeski gravity

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arXiv: 2301.09382

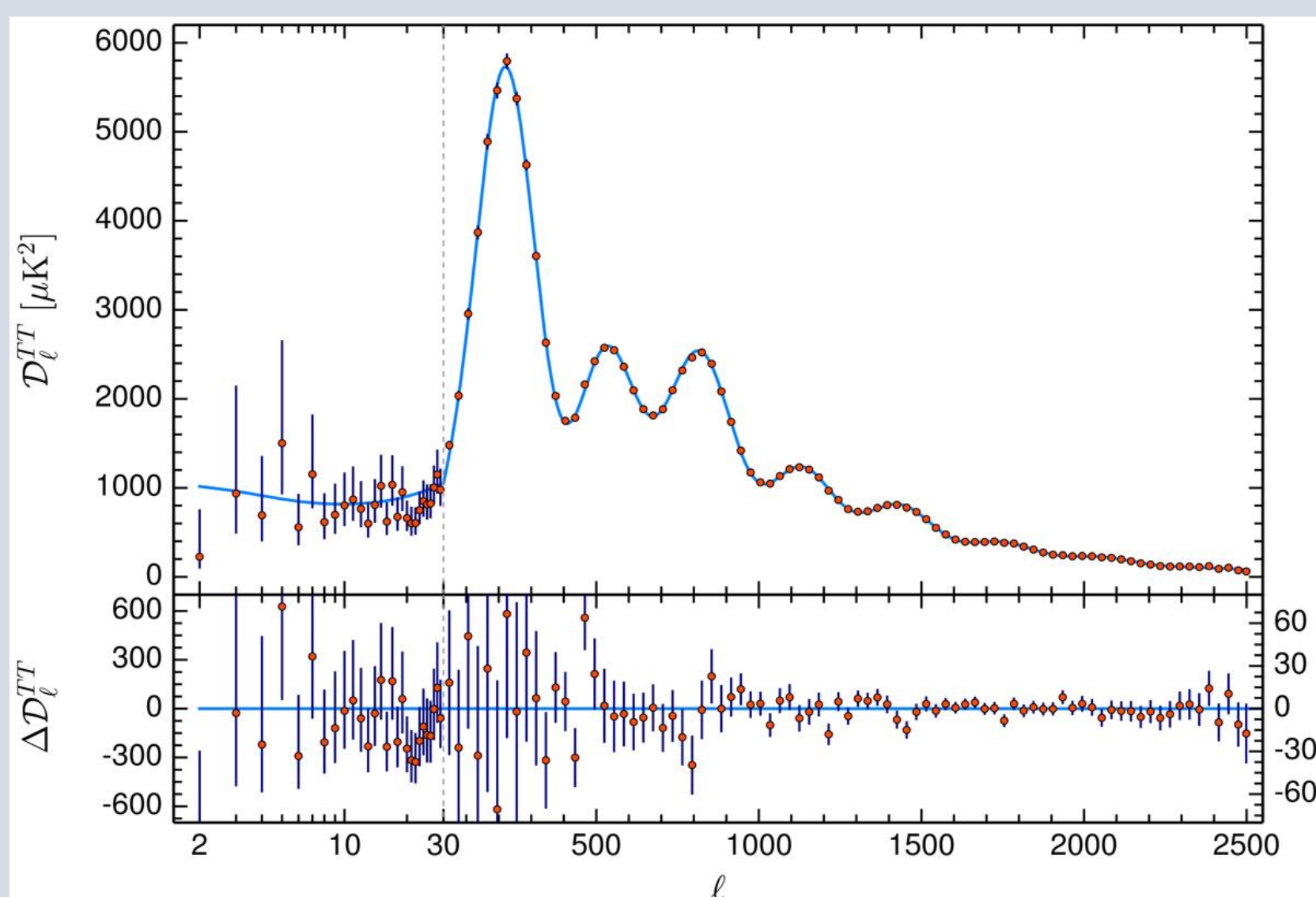
Present Understanding of the Universe: Λ CDM Model



Hubble Tension: A Challenge to Standard Model of Cosmology ?

Early Time Measurements

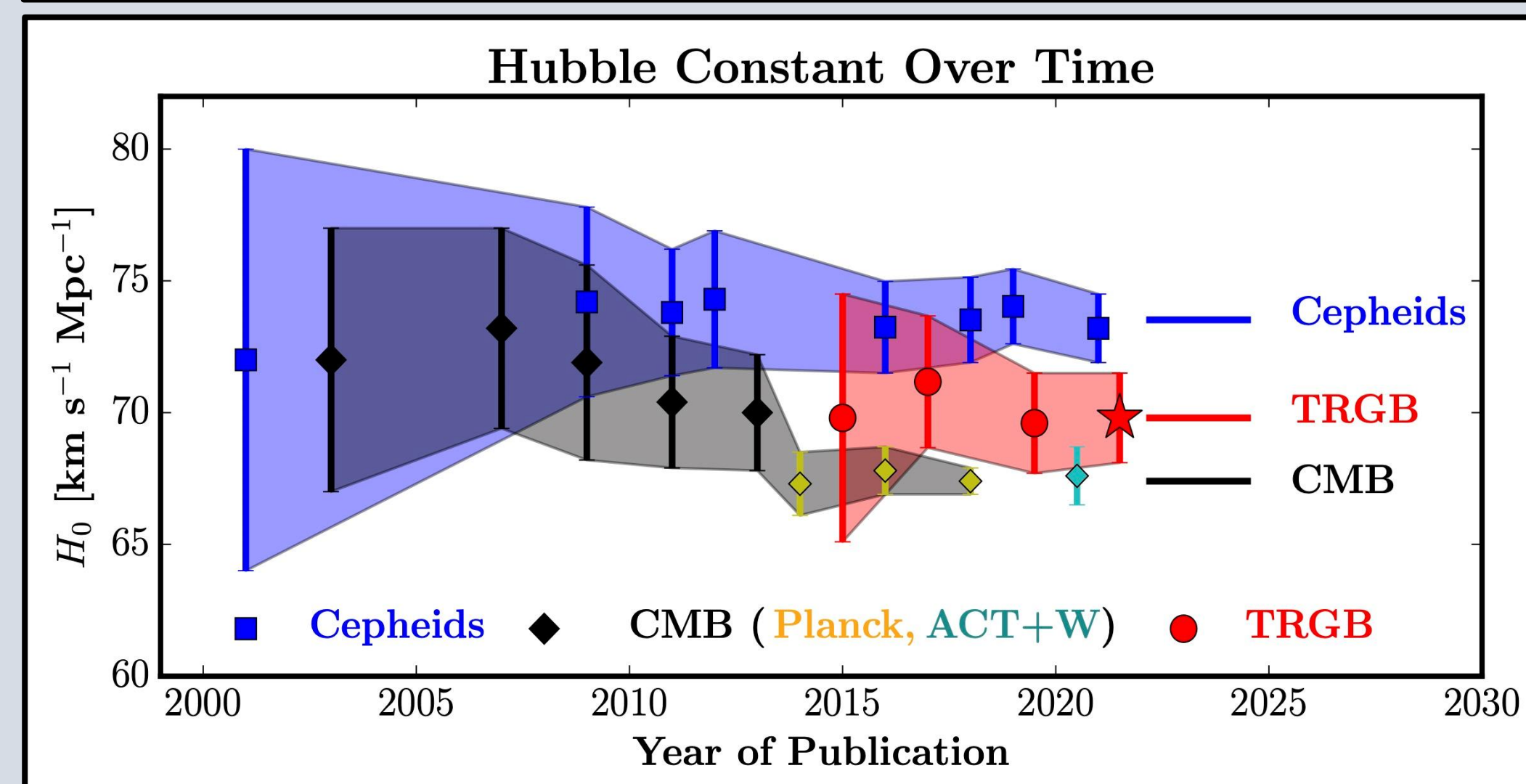
- Cosmic Microwave background: H_0 is inferred from CMB power spectrum assuming the Λ CDM model of universe.



$$H_0 = 67.4 \pm 0.54 \text{ km/sec/Mpc}$$

(as per Planck 2018)

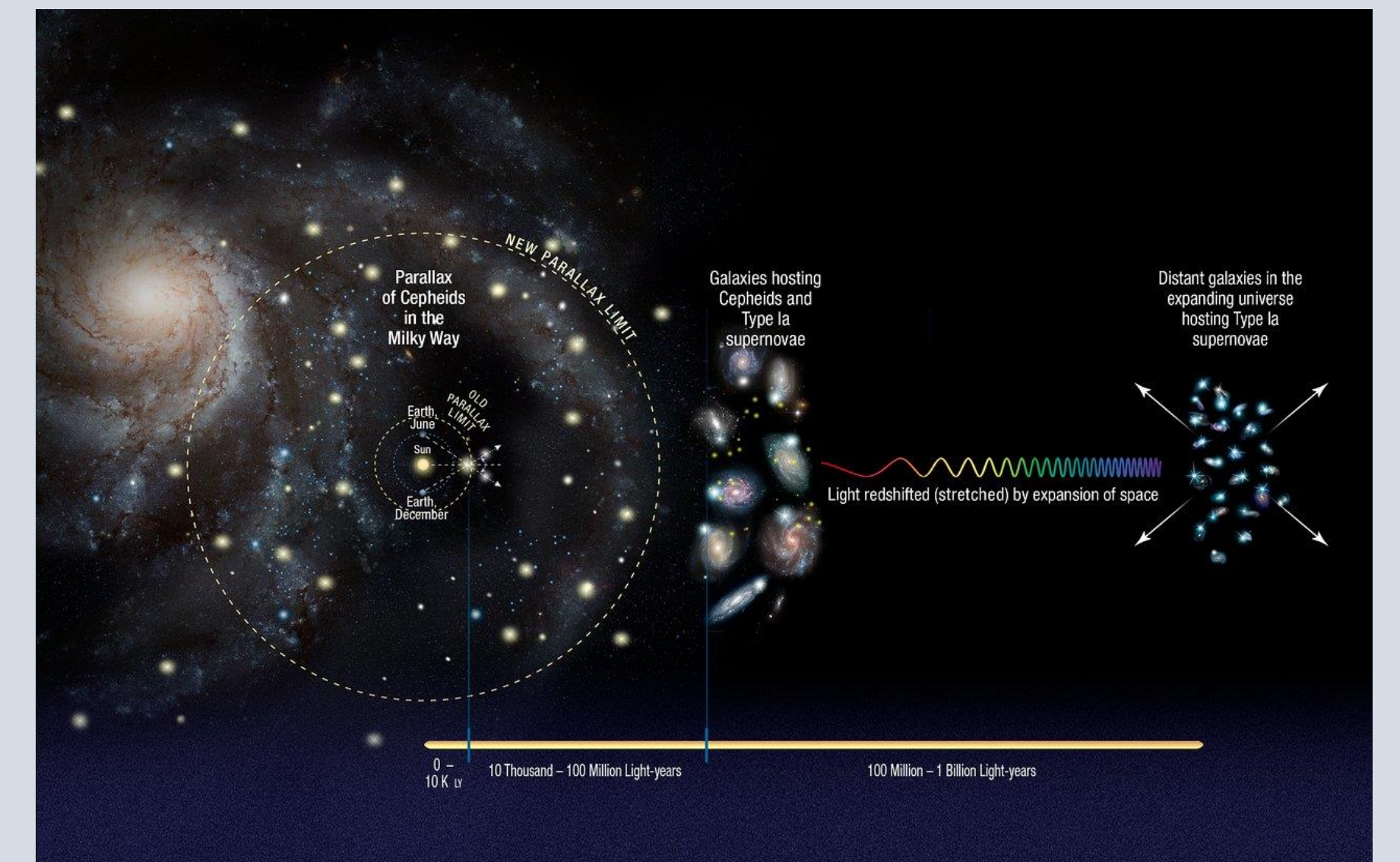
Hubble Tension refers to the mismatch between the values of H_0 inferred from early time and late time measurements.



How to address the H_0 tension?
Modification to the standard Λ CDM?

Late Time Measurements

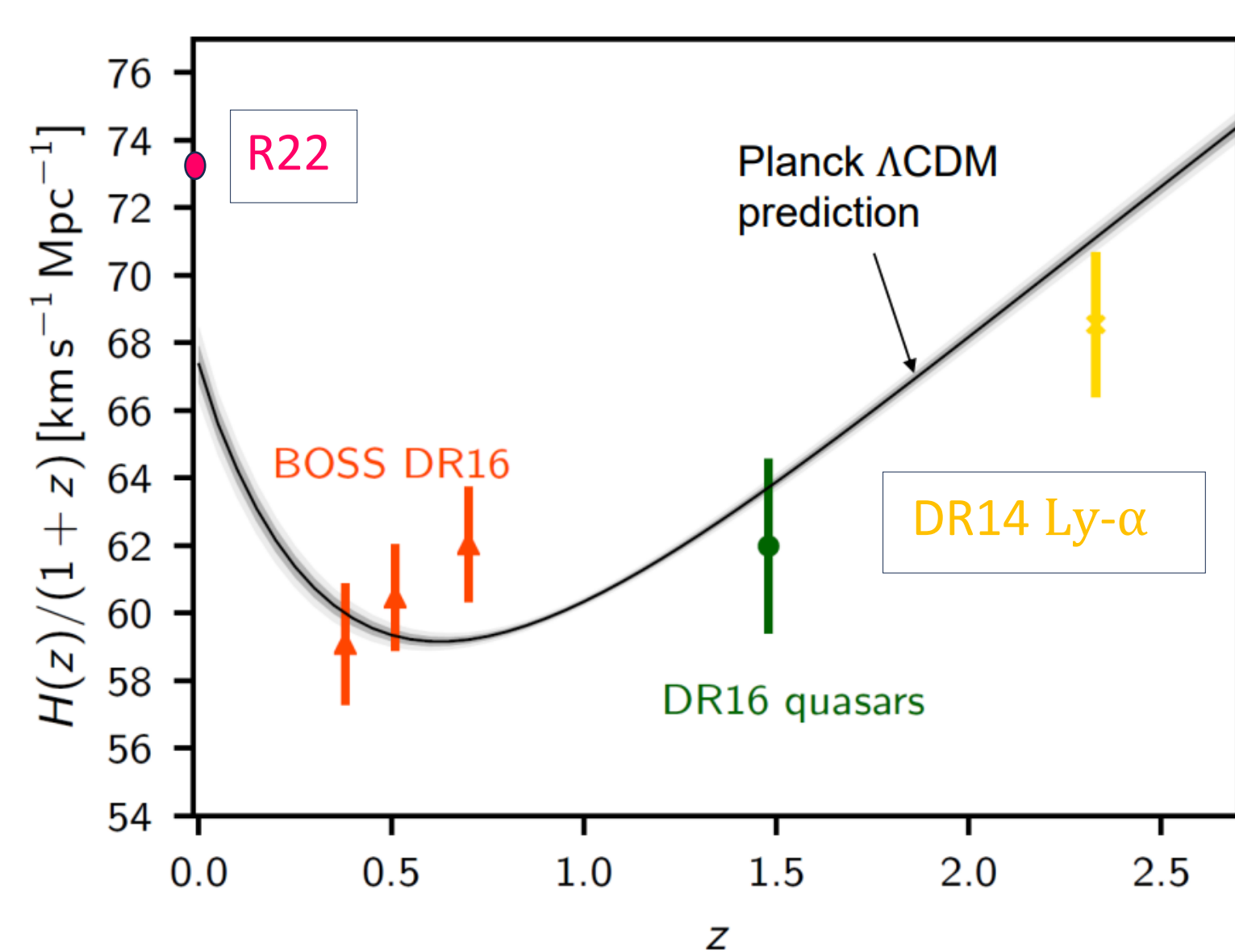
- Distance Ladder techniques: standard candles to calibrate distances to galaxies and using Hubble's law to estimate H_0 .



$$H_0 = 73.2 \pm 1.04 \text{ km/sec/Mpc}$$

(as per SH0ES 2022)

Anomaly: BAO Ly- α measurement of $H(z)$ at $z \sim 2.34$



$\sim 2\sigma$ tension with Λ CDM prediction

Need for a non-trivial dynamical dark energy ?

- In order to successfully resolve H_0 tension, the dark energy models must exhibit a phantom divide behavior. (Heisenberg et al 2022)
- The equation of state of dark energy must transit from $w > -1$ to $w < -1$.
- To explain BAO Ly- α measurement of expansion history, a negative dark energy at high redshifts is favored by observational reconstructions. (Sahni et al 2014)
- A dynamical dark energy with negative energy density at high redshifts, giving a phantom crossing behavior: a plausible solution for cosmological tensions!!

Our Model: A possible solution

- We work in the framework of generalised scalar-tensor theory called Horndeski theory.
- Lagrangian for the dark energy scalar field:

$$\mathcal{L}_\phi = G_4(\phi)\mathcal{R} - G_3(\phi, X)\square\phi - \frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - V(\phi)$$

Non-minimal coupling (NMC) kinetic term (K)

Self-interaction (SI) (Galileon) Scalar field potential

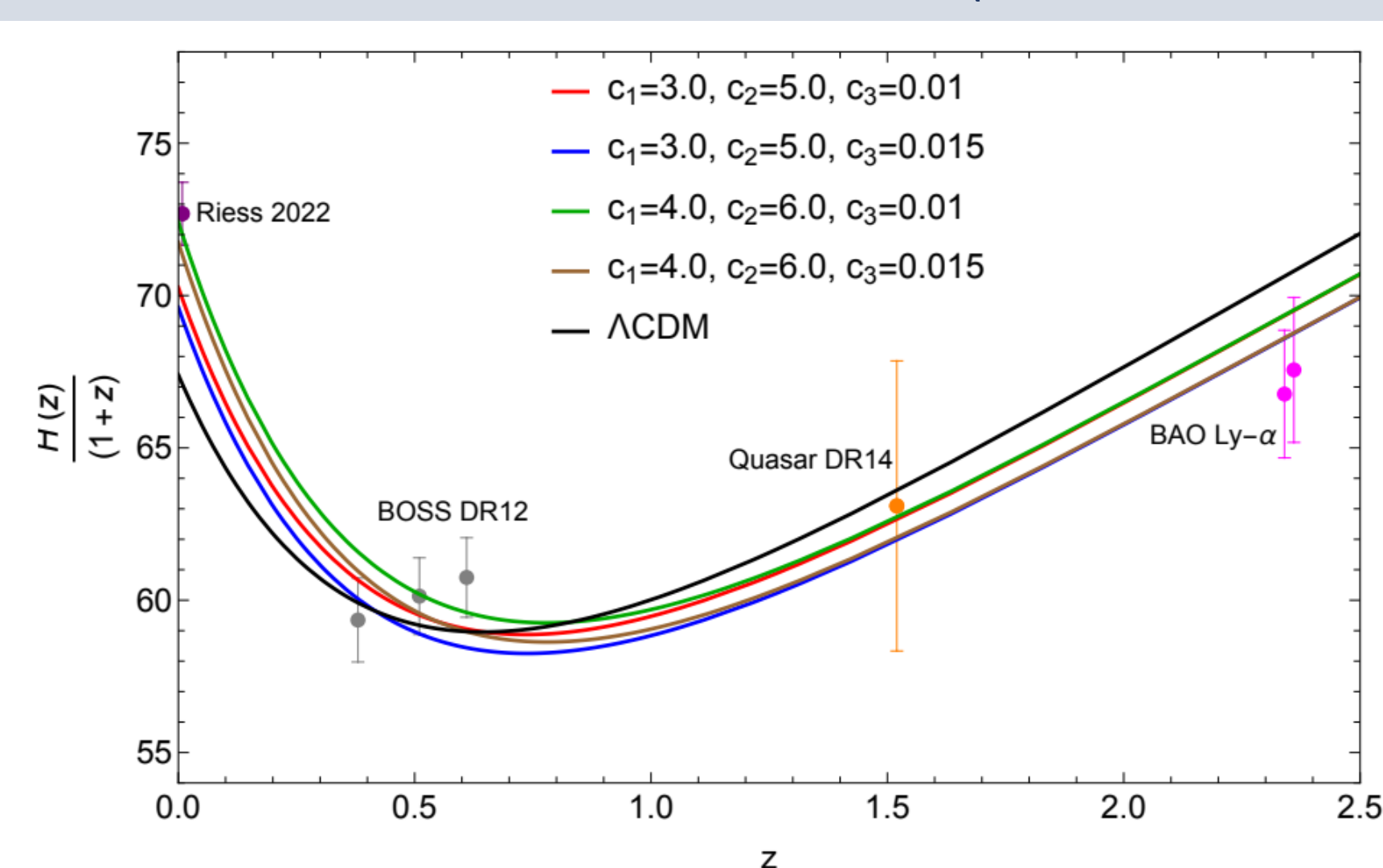
$$G_3(\phi, X) = c_1\phi + c_2X$$

$$G_4(\phi) = \frac{1}{2} + c_3\phi$$

c_1, c_2 and c_3 are the free parameters, controlling strengths of coupling terms.

Features of the Model

(arXiv: 2301.09382)

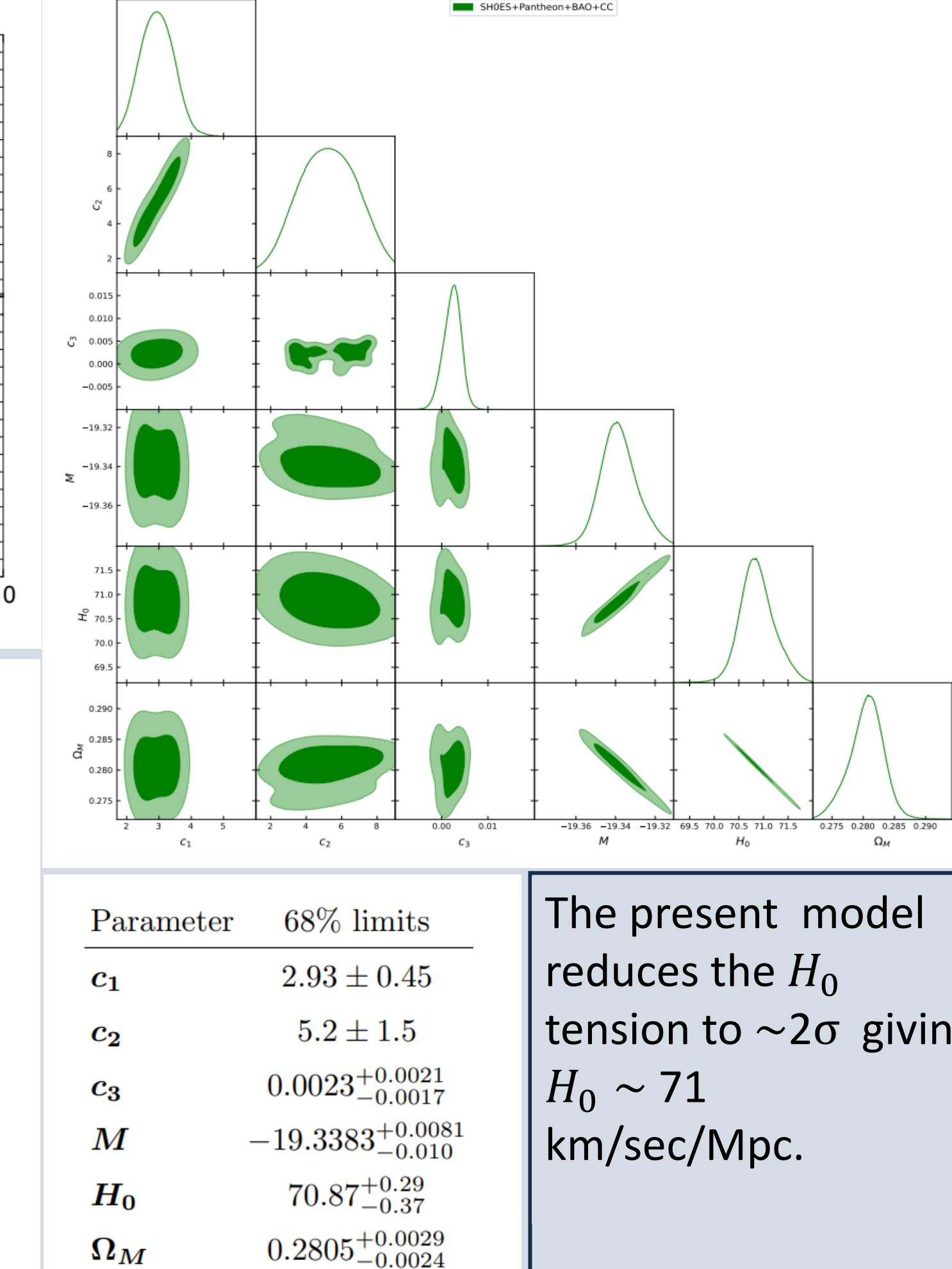
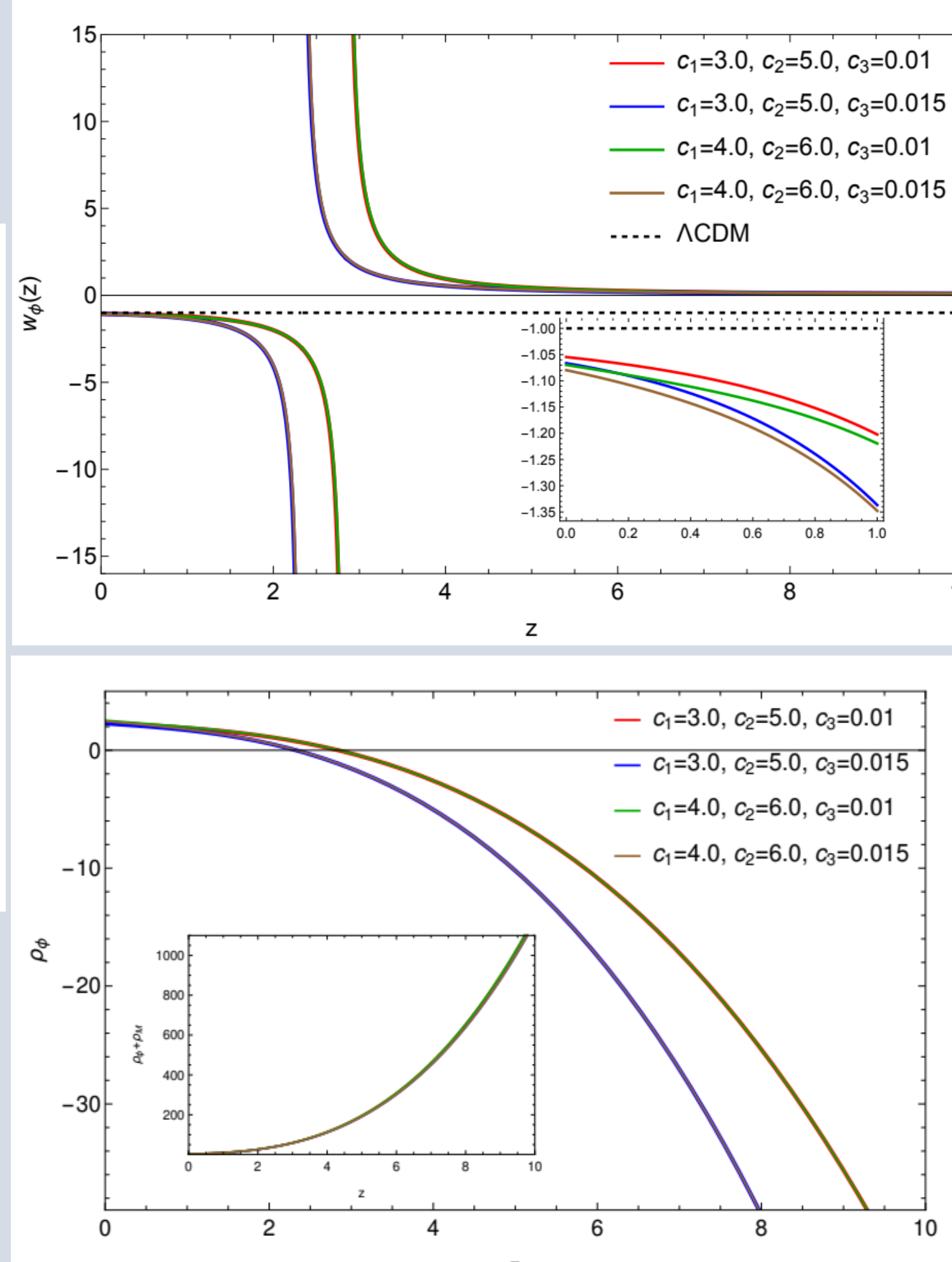


$$\rho_\phi = \frac{1}{2}\dot{\phi}^2 + V(\phi) - 6c_3\phi H^2 - 6c_3H\dot{\phi} - c_1\dot{\phi}^2 + 3c_2H\dot{\phi}^3$$

(NMC) (SI)

Dominates at low z as ϕ increases.

Dominates at high z as $H \uparrow$ as $z \uparrow$.



Conclusion

- H_0 tension may indicate towards new physics beyond standard Λ CDM model.
- Working in the framework of Horndeski gravity, we propose a dark energy model to address the Hubble tension.
- The proposed scenario reduces the Hubble tension to $\sim 2\sigma$.
- We are looking at evolution of perturbations in the given model to see imprints on other cosmological tensions.