

Late Time approaches to the H_0 Tension and Degeneracy of Cosmological Parameters

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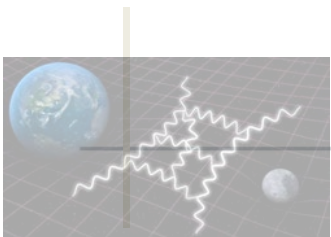
Talk based on:

H_0 tension, phantom dark energy, and cosmological parameter degeneracies

G. Alestas (Ioannina U.), L. Kazantzidis (Ioannina U.), L. Perivolaropoulos (Ioannina U.) (Apr 20, 2020)

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Degeneracy of CMB parameters



These cosmological parameters fix to high accuracy the form of the CMB anisotropy spectrum

$$\bar{\omega}_m = 0.1430 \pm 0.0011$$

$$\bar{\omega}_b = 0.02237 \pm 0.00015$$

$$\bar{\omega}_r = (4.64 \pm 0.3) 10^{-5}$$

$$\bar{\omega}_k = -0.0047 \pm 0.0029$$

$$\bar{d}_A = (100 \text{ km sec}^{-1} \text{ Mpc}^{-1})^{-1} (4.62 \pm 0.08)$$

$$\omega_m \equiv \Omega_{0m} h^2$$

General $h(z)$

$$h(z) = [\Omega_{0r} h^2 (1+z)^4 + \Omega_{0m} h^2 (1+z)^3 + (h^2 - \Omega_{0m} h^2 - \Omega_{0r} h^2) f_{DE}(z)]^{1/2}$$

Demand

$$d_A(\omega_m, \omega_r, \omega_b, h, w(z)) = \int_0^{z_r} \frac{dz}{H(z)}$$

$$\int_0^{z_{rec}} \frac{dz}{h(z)} = \int_0^{z_{rec}} \frac{dz}{h_{Planck}(z)}$$

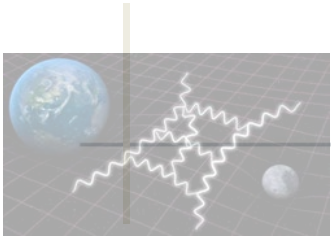


CMB spectrum = Planck Spectrum

$$H_0 = 100 h \text{ km sec}^{-1} \text{ Mpc}^{-1}$$

This method can be used to find general degeneracy relation between $w(z)$ and H_0 .
Fixing $h(z=0)=h=0.74$ gives the $w(z)$ forms that can potentially resolve the H_0 problem.

Special case I: wCDM



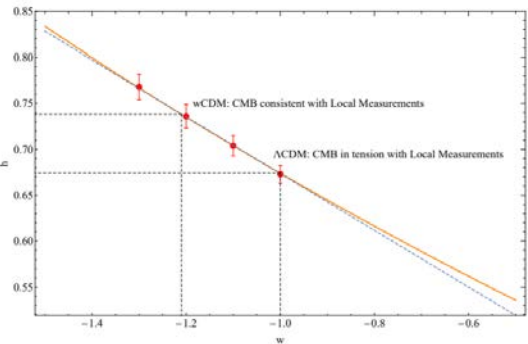
H(z) for wCDM

$$H(z, \omega_m, \omega_r, \omega_b, h, w(z)) = H_0 \sqrt{\Omega_{0m}(1+z)^3 + \Omega_{0r}(1+z)^4 + (1 - \Omega_{0m} - \Omega_{0r})(1+z)^{3(1+w)}}$$

$$\begin{aligned} \bar{\omega}_m &= 0.1430 \pm 0.0011 \\ \bar{\omega}_b &= 0.02237 \pm 0.00015 \\ \bar{\omega}_r &= (4.64 \pm 0.3) 10^{-5} \end{aligned}$$

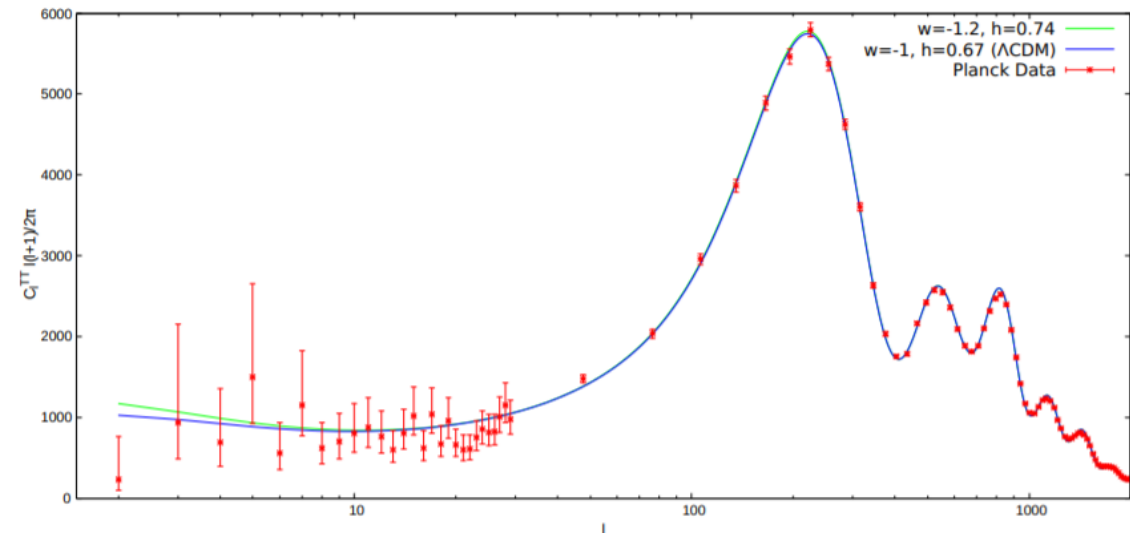
$$\int_0^{z_{rec}} \frac{dz}{h(z)} = \int_0^{z_{rec}} \frac{dz}{h_{Planck}(z)}$$

$$h(w) \approx -0.3093w + 0.3647$$



For h=0.74 this gives w=-1.22

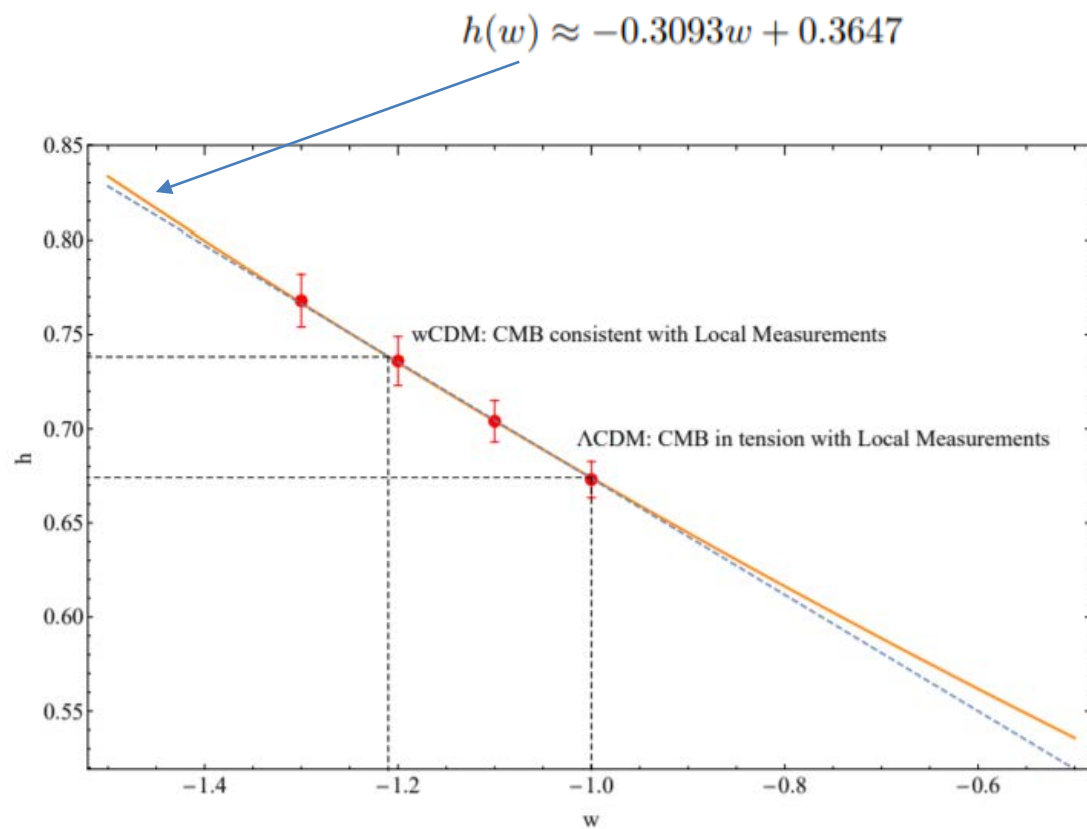
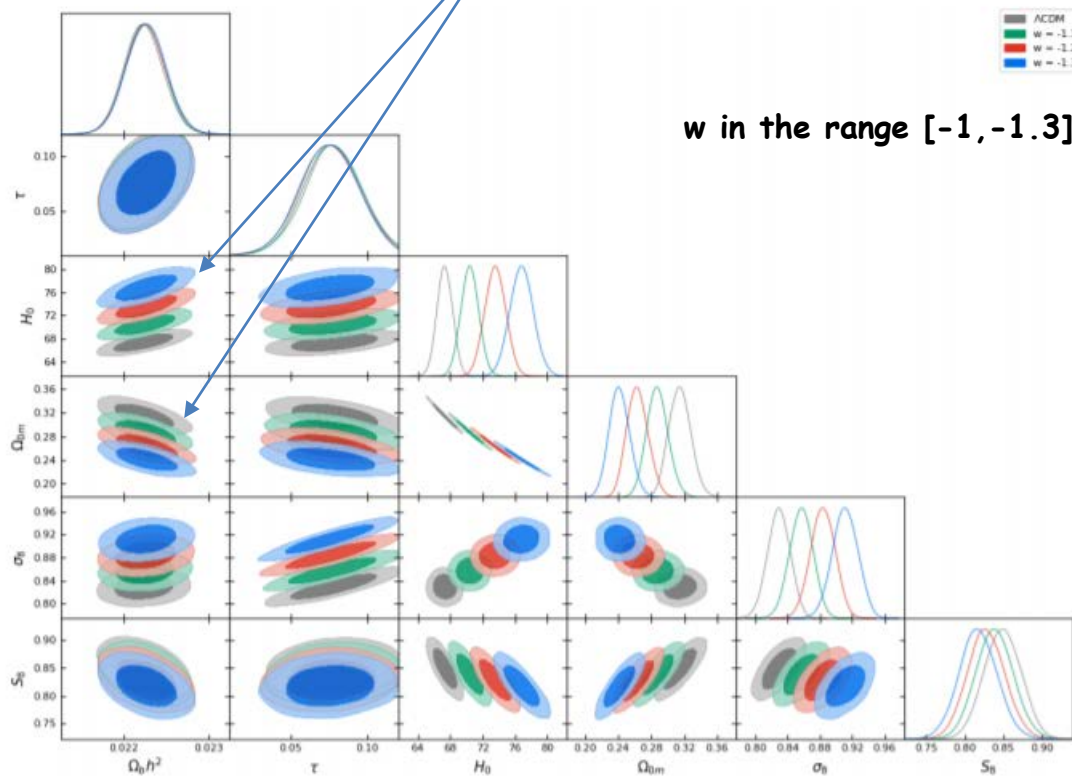
This value of w corresponds to h=0.74 and CMB spectrum identical with Planck/ΛCDM.



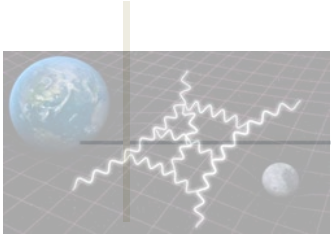
Verifying the degeneracy by fitting to the CMB anisotropy

Analytically derived degeneracy verified by fitting to the Planck anisotropy spectrum

As w decreases the best fit H_0 increases while $\Omega_0 h^2$ remains constant.



Special case II: CPL



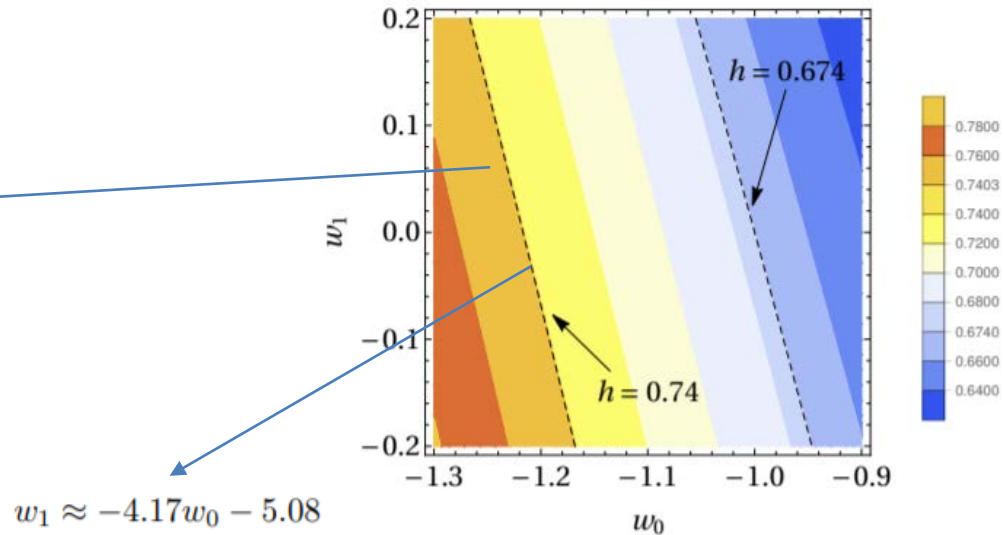
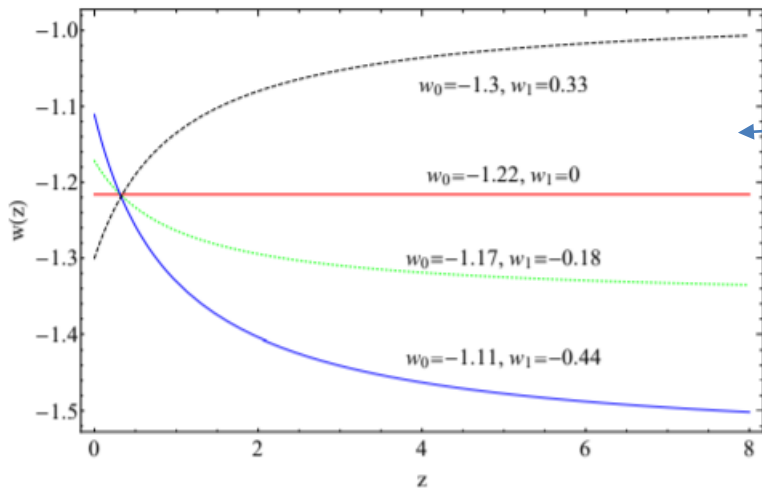
$H(z)$ for CPL

$$w = w_0 + w_1(1 - a) = w_0 + w_1 z / (1 + z) \quad \longrightarrow \quad H(z) = H_0 \sqrt{\Omega_{0m}(1+z)^3 + \Omega_{0r}(1+z)^4 + (1 - \Omega_{0m} - \Omega_{0r})(1+z)^{3(1+w_0+w_1)} e^{-3\frac{w_1 z}{1+z}}}$$

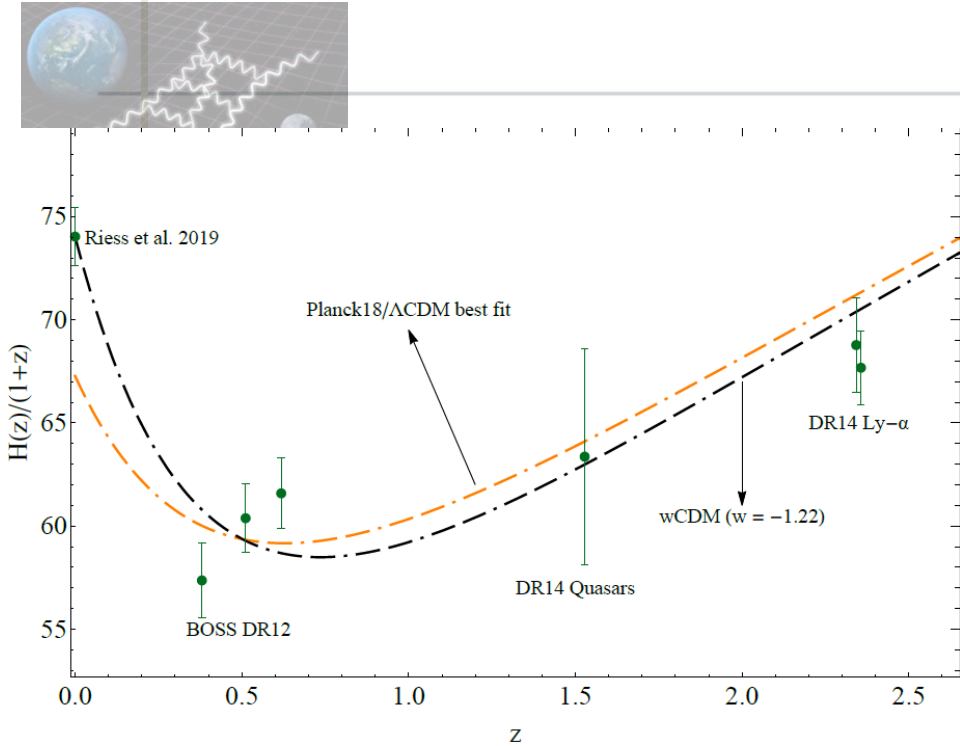
$$\begin{aligned} \bar{\omega}_m &= 0.1430 \pm 0.0011 \\ \bar{\omega}_b &= 0.02237 \pm 0.00015 \\ \bar{\omega}_r &= (4.64 \pm 0.3) 10^{-5} \end{aligned}$$

$$\int_0^{z_{rec}} \frac{dz}{h(z)} = \int_0^{z_{rec}} \frac{dz}{h_{Planck}(z)}$$

These forms of $w(z)$ correspond to $h=0.74$ and CMB spectrum identical with Planck/ Λ CDM.



Problem: Fit to BAO-SnIa data



Deform $H(z)$ so that $d_A(z_{rec})$ remains invariant and $H_0=74$ km/sec Mpc and $\Omega_{0m}=0.143$.

$$\int_0^{z_{rec}} \frac{dz}{h(z)} = \int_0^{z_{rec}} \frac{dz}{h_{Planck}(z)}$$

Shifting $H(z)$ upwards misses the BAO, SnIa data which are much more constraining than shown in the figure.

Need to also impose for all BAO redshifts

$$\int_0^{z_{BAO}} \frac{dz}{h(z)} = \int_0^{z_{BAO}} \frac{dz}{h_{Planck}(z)}$$

**Q: Is there a form of $H(z)$ that satisfies these constraints?
Oscillations?**

Hints for possible low redshift oscillation around the best fit Λ CDM model in the expansion history of the universe

L. Kazantzidis, H. Kogo, S. Nesseris, L. Perivolaropoulos, A. Shafieloo (Oct 7, 2020)

e-Print: 2010.03491 [astro-ph.CO]