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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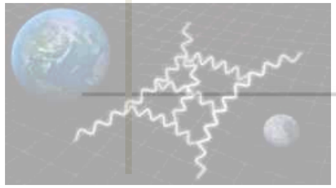
Degeneracy of CMB parameters



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

$$\bar{\omega}_m = 0.1430 \pm 0.0011$$
$$\bar{\omega}_b = 0.02237 \pm 0.00015$$
$$\bar{\omega}_r = (4.64 \pm 0.3)\ 10^{-5}$$
$$\bar{\omega}_k = -0.0047 \pm 0.0029$$
$$\bar{d}_A = (100\ km\ sec^{-1}\ Mpc^{-1})^{-1}(4.62 \pm 0.08)$$

$$\omega_{\rm m} \equiv \Omega_{\rm 0m} h^2$$

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

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

General h(z)

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

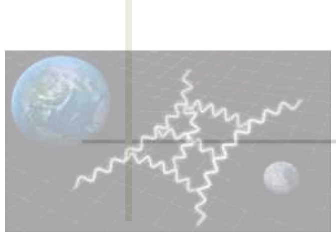
Demand

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

→ **CMB spectrum = Planck Spectrum**

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 H0 problem.

Special case I: wCDM

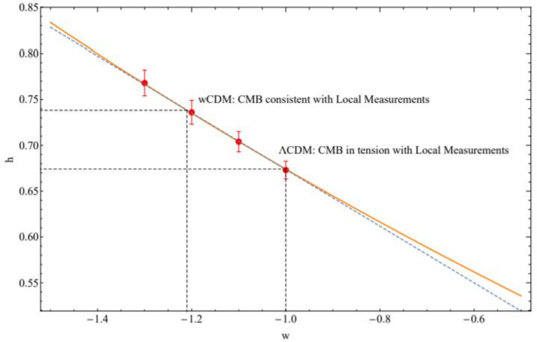


H(z) for wCDM

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

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

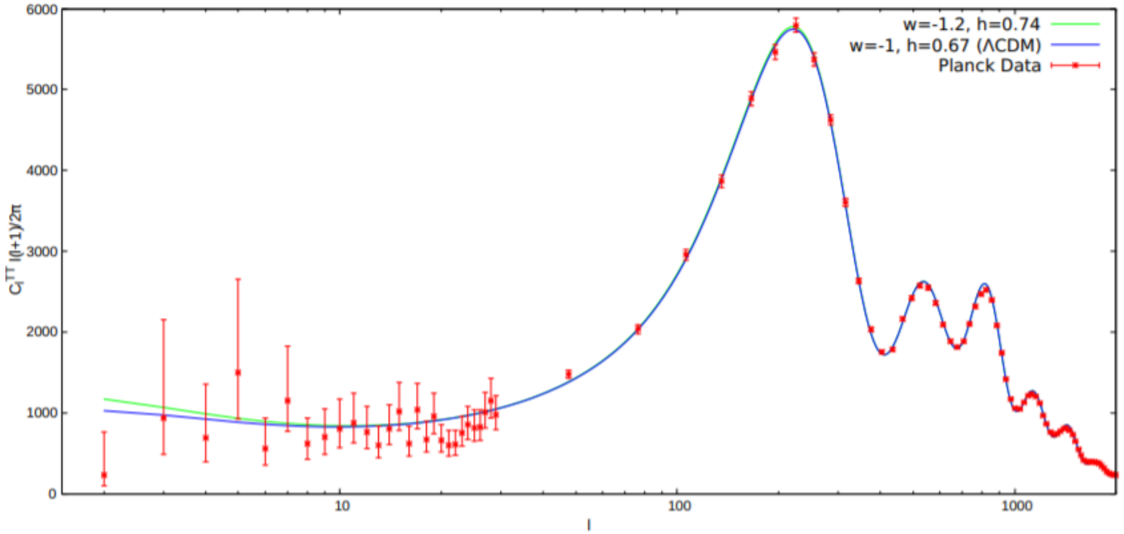
$$\int_0^{z_{rec}} \frac{dz}{h(z)} = \int_0^{z_{rec}} \frac{dz}{h_{Planck}(z)}$$



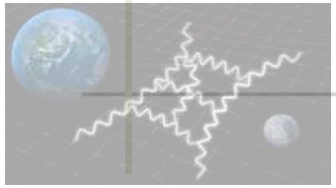
$$h(w) \approx -0.3093w + 0.3647$$

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.



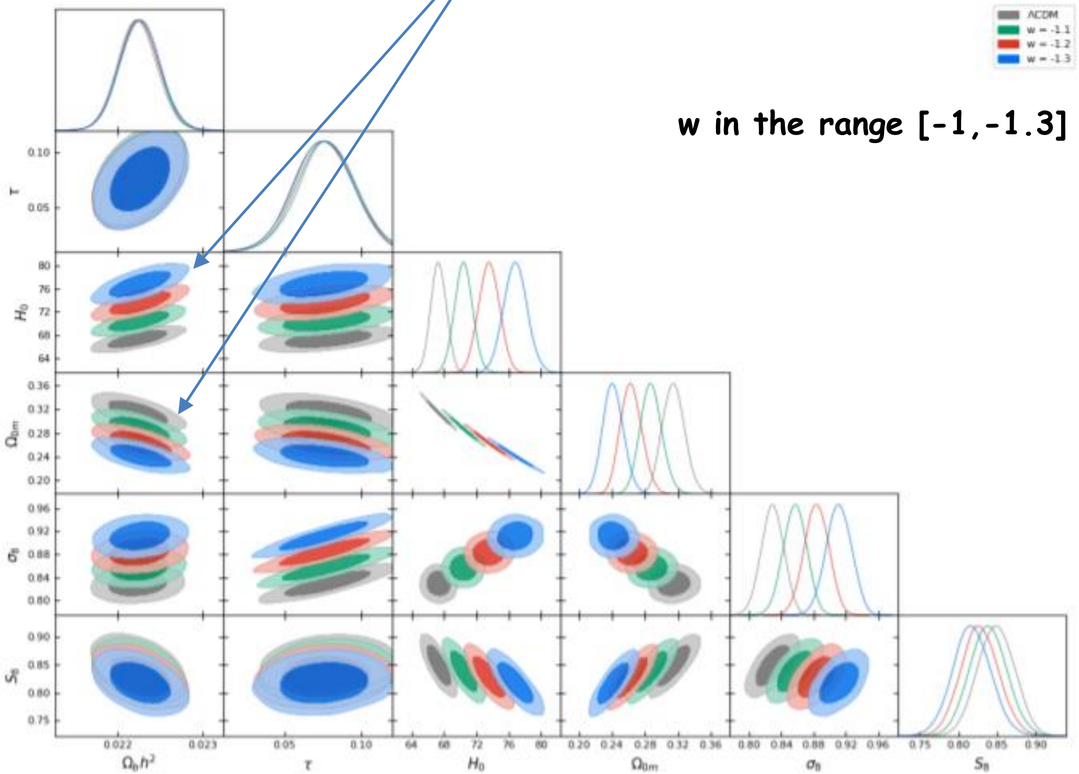
Verifying the degeneracy by fitting to the CMB anisotropy



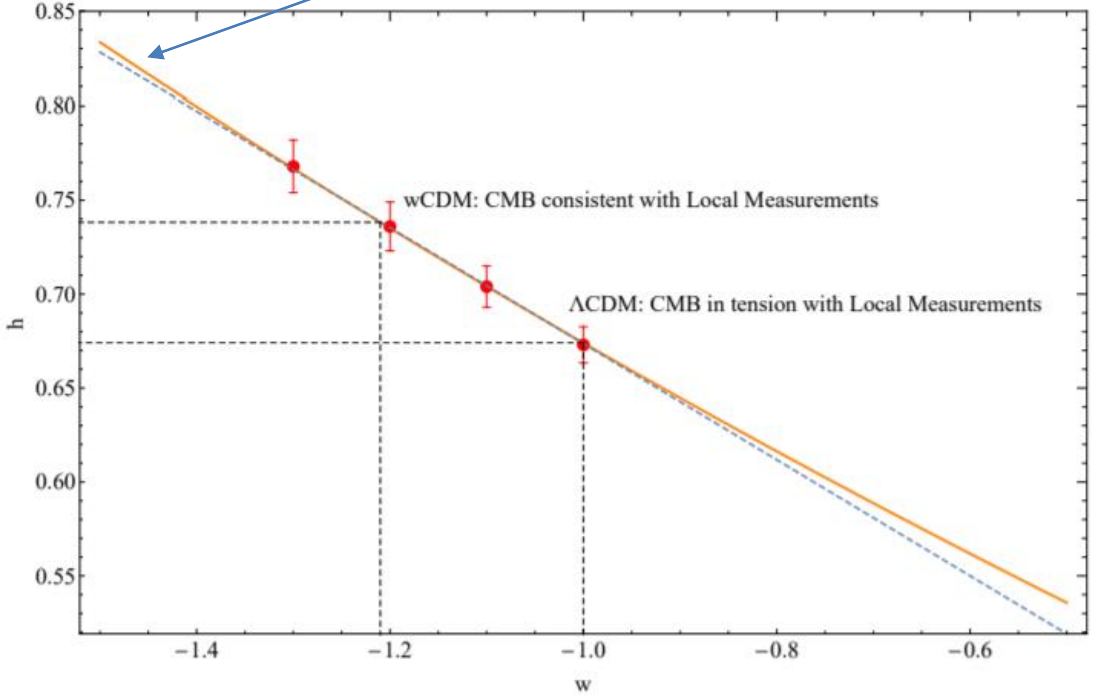
Analytically derived degeneracy verified by fitting to the Planck anisotropy spectrum

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

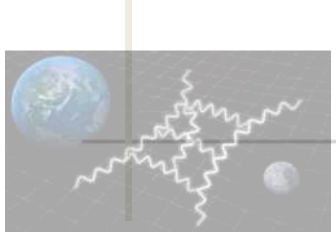
w in the range [-1,-1.3]



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



Special case II: CPL



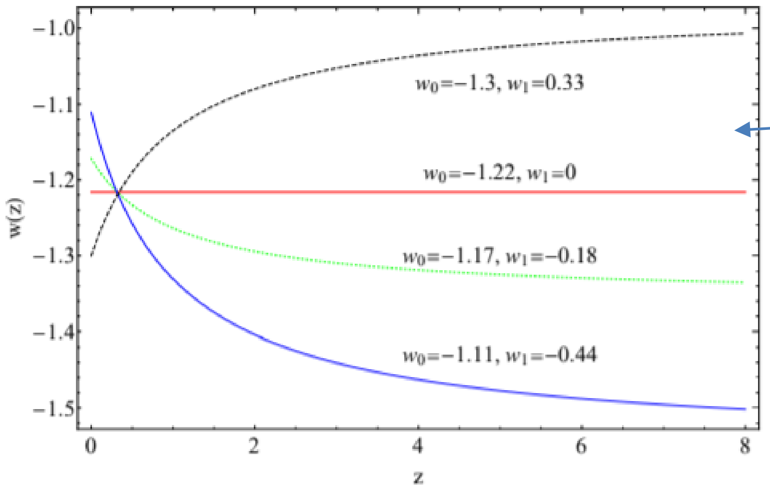
H(z) for CPL

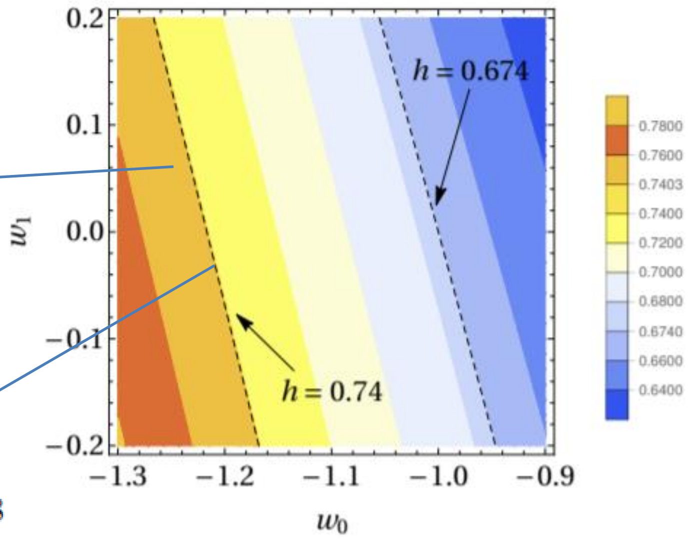
$$w = w_0 + w_1(1-a) = w_0 + w_1 z/(1+z) \Rightarrow H(z) = H_0\sqrt{\Omega_{0\mathrm{m}}(1+z)^3 + \Omega_{0\mathrm{r}}(1+z)^4 + (1-\Omega_{0\mathrm{m}}-\Omega_{0\mathrm{r}})(1+z)^{3(1+w_0+w_1)}e^{-3\frac{w_1 z}{1+z}}}$$

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

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

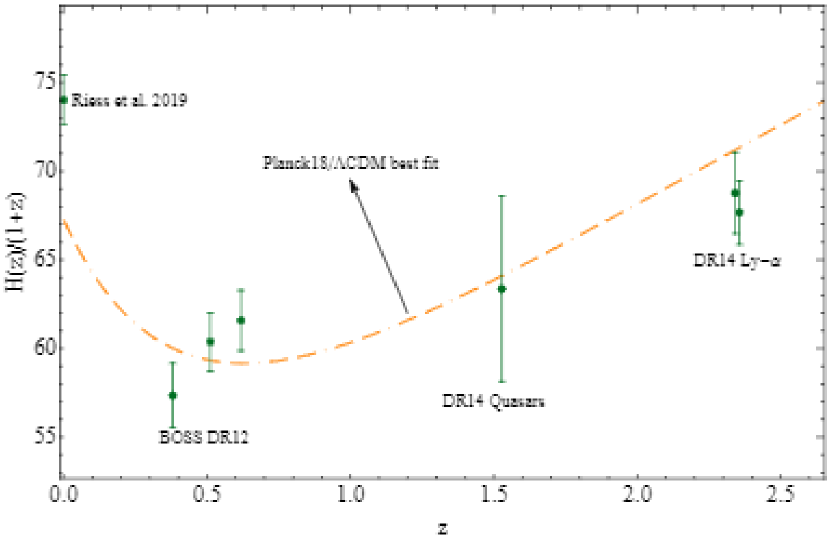
These forms of w(z) correspond to h=0.74 and CMB spectrum identical with Planck/ΛCDM.





$$w_1 \approx -4.17 w_0 - 5.08$$

Problem: Fit to BAO-SnIa data



Deform H(z) so that d_A(zrec) remains invariant and H_0=74 km/sec Mpc and Ω_{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 ΛCDM model in the expansion history of the universe

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

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