V.6 Effect of individual parameters on C_ℓ's

We parametrize ΛCDM by $(\omega_m, \omega_b, \Omega_\Lambda, A, n)$

① $\omega_m \nearrow \Rightarrow z_{eq} \nearrow$, $\eta_{eq} \searrow$, earlier equality. so, longer stage $\eta_{eq} \leq \eta \leq \eta_{dec}$ - All peaks decrease, especially 1st one (ISW).

$\Rightarrow h = \sqrt{\frac{\omega_m}{1-\Omega_\Lambda}} \nearrow$, so $d_A \searrow$, $\frac{d_s}{d_A} \nearrow$, $\theta_{peaks} \nearrow$, $\ell_{peaks} \searrow$

② $\omega_b \nearrow \Rightarrow \omega_b/\omega_r \nearrow$, enhancement of odd peaks

$\Rightarrow c_s \searrow$, $d_s \searrow$, $\ell_{peaks} \nearrow$

↳ more Silk damping, 4th and higher peaks $\searrow$

③ $\Omega_\Lambda \nearrow \Rightarrow z_\Lambda \nearrow$, longer Λ-domination, LISW $\Rightarrow$ higher C_ℓ's for smallest ℓ's

$\left.\begin{matrix} \Omega_\Lambda \nearrow \\ h \nearrow \end{matrix}\right\} \Rightarrow d_A \searrow$, $\ell_{peaks} \searrow$

④ $A \nearrow$: all C_ℓ $\nearrow$

⑤ $n \nearrow$: high ℓ's $\nearrow$ with respect to small ℓ's

Previous section: 6 effects in CMB spectrum (Most of primordial spectrum counts for two: amplitude & tilt)

This section: 5 parameters triggering the 6 effects

$5 < 6 \Rightarrow$ ALL PARAMETERS MEASURABLE IN PRINCIPLE!!

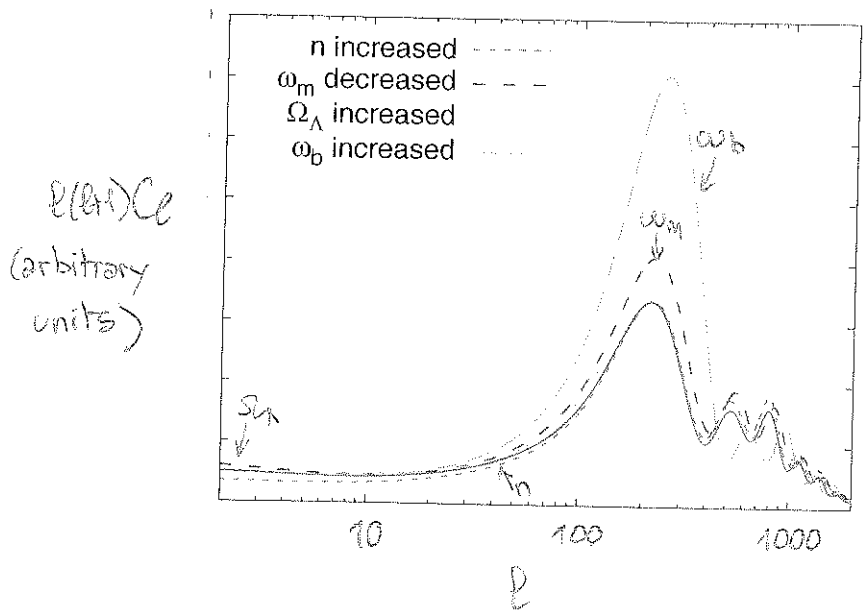
These effects can be checked with numerical codes, for instance CAMB by Lewis & Challinor.

Web interface:

http://lambda.gsfc.nasa.gov/toolbox

click on CAMB ⟶ "web-based interface"

Examples illustrating the effect of $\omega_M, \omega_b, \Omega_\Lambda, n$:



See also "CMB movies" at:

http://space.mit.edu/home/tegmark

click on Max's menu ⟶ CMB movies

Note all 6 parameters measurable to some extent, since there is instrumental noise and cosmic variance...

Concluding remarks

* what we did not do:
  - → add massless neutrinos
  - → " massive neutrinos
  - → " reionization
  - → discuss CMB polarization anisotropies
  - → discuss LSS observation through weak lensing
  - → discuss CMB-LSS cross-correlation

* power of CMB+LSS: parameter extraction plots in:
  - Dunkley et al. 0803.0586 [astro-ph] (WMAP)
  - Komatsu et al. 0803.0547 [astro-ph] (WMAP + LSS)
  - Chiang et al. 0906.1181 [astro-ph]
  - Brown et al. 0906.1003 [astro-ph]

  (QUaD & BICEP: recent CMB measurements)

for WMAP, ACBAR, QUaD (CMB) and SDSS (matter power spectrum)

parameter	CMB data	CMB+LSS data
$\Omega_b h^2 = \omega_b$	0.0227 ± 0.0005	0.0227 ± 0.0005
$\Omega_c h^2 = (\omega_m - \omega_b)$	0.108 ± 0.005	0.108 ± 0.004
Ω_Λ	0.75 ± 0.03	0.75 ± 0.02
A	depends on	units/definitions
n	0.962 ± 0.013	0.962 ± 0.013
H_0 (km/s/Mpc)	72.4 ± 2.4	72.7 ± 1.7
Age (Gyr)	13.66 ± 0.11	13.66 ± 0.10

ΛCDM (see 0906.1003)