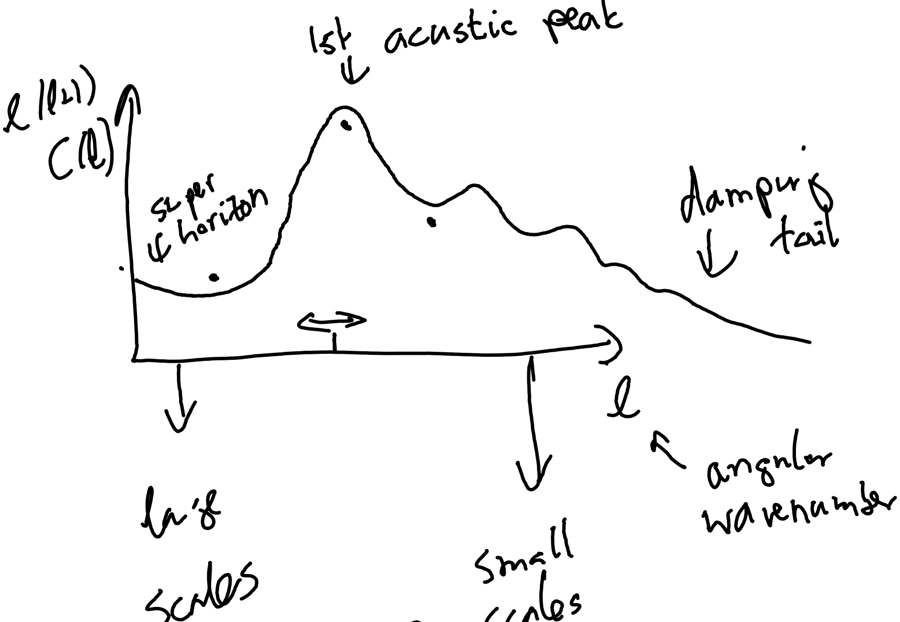
1. What does CMB actually measure?



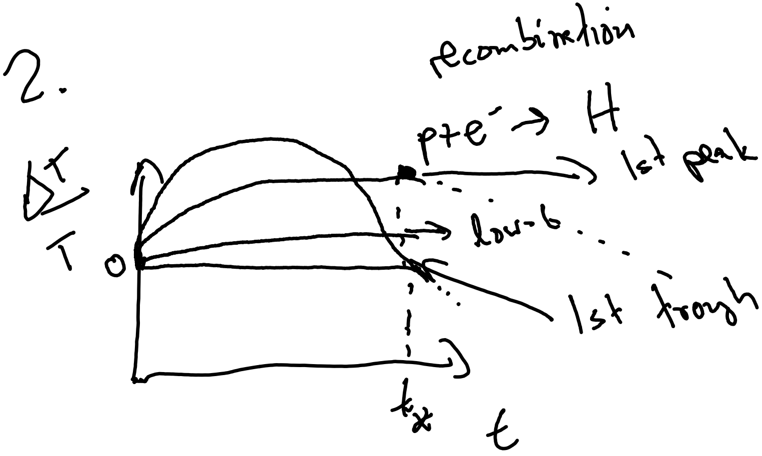
$$\boxed{\frac{\Delta T}{T} \sim 10^{-5}}$$

From $\ell(\ell+1)\,C(\ell)$ we get

* mean densities of CDM, baryons, radiation
  $\Omega_c h^2$, $\Omega_b h^2$, $\Omega_\gamma h^2$
* angular size of sound horizon at recombination

(* amplitude & scale-dep. of primordial fluct.)

2.



→ driven wave eqn.

→ at fixed k ⇒ harmonic oscillator

$\Updownarrow$?

ℓ

* mass ⟺ baryon density
* driving term ⟺ CDM density
* damping tail → matter density via $H(z)$

Sound horizon:

$$(\text{comoving}) \quad r_s = \int_0^{t_*} c_s(t)\,\frac{dt}{a}$$

$$c_s^2 \simeq \frac{1}{3}\left(1 + \frac{3\rho_b}{4\rho_\gamma}\right)^{-1}$$

$$t_* = \int_0^{a_*} \frac{dt}{a\,H(a)} \quad ; \quad a_* = \frac{T_0}{T_{rec}}$$

Ω_m

H_0 from CMB only

$f(\Omega_b, \Omega_m)$

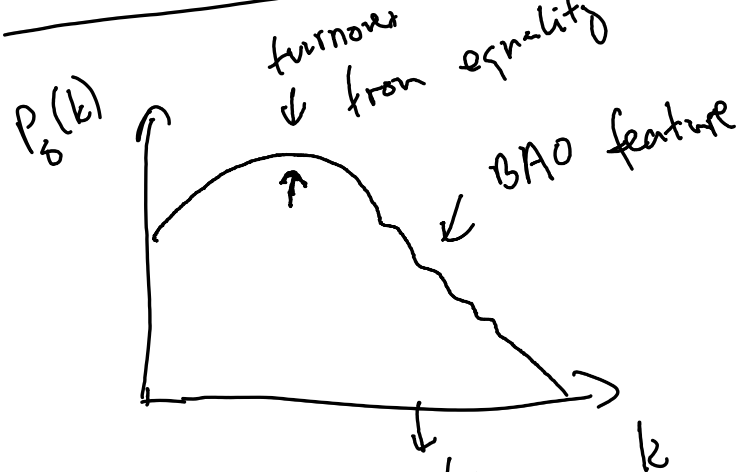
$$\Theta_{CMB} = \frac{r_s}{d_A(z_*)} \leftarrow \frac{1}{H_0} f(\Omega_m, \Omega_{DE}, w_{DE}, \Omega_K)$$

Ω_{DE}	w_{DE}	Ω_K	
$1-\Omega_m$	-1	0	flat ΛCDM
	-1	$\neq 0$	curved ΛCDM

$\Uparrow$

d_A

H_0 from CMB + gal. clustering



angular size of sound horizon at $z_g \approx 0.5$ $\Rightarrow$

$$\Theta_{BAO} = \frac{r_s}{d_A(z_g)}$$

CMB

Ω_b : BBN

Ω_m : P_g

H_0^{-1} × weak dep.