

# No more trouble with Hubble

Solving the  $H_0$ -tension  
à la Ellis & Stoeger

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[thegravitygrinch.blogspot.com](http://thegravitygrinch.blogspot.com)



Please look into the light...



...and forget all cosmology you have known



# Our universe in all its complexity



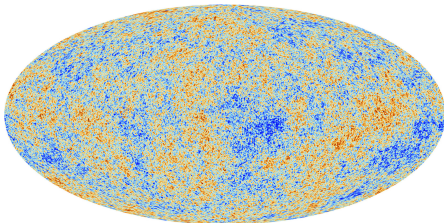
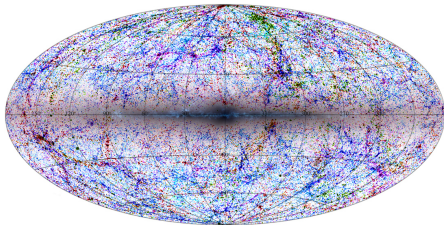
$z \approx 0$

highly  
non-linear  
structures



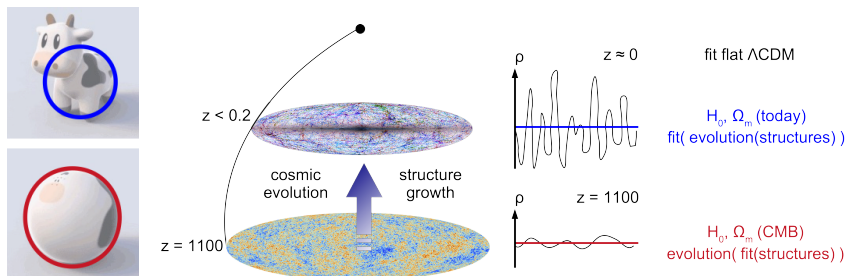
$z = 1100$

almost  
homogeneous  
& isotropic



# The fitting problem in cosmology (Ellis & Stoeger 1987)

find the best-fit (flat)  $\Lambda$ CDM models for observations **today** and at **CMB**:



**evolution( fit(structures) )  $\neq$  fit( evolution(structures) )**

**→ best-fit flat  $\Lambda$ CDM from today and CMB can be different!**

# Independent best-fit $\Lambda$ CDM model parameters

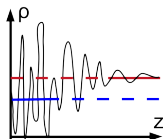
## today (Cepheids + SNe)

$$h = 0.7304 \pm 0.0104$$

$$\Omega_m = 0.285 \pm_{0.012}^{0.013}$$

(Riess et al. 2022)

(Wagner & Meyer 2019)



## CMB

$$h = 0.6727 \pm 0.0060$$

$$\Omega_m = 0.3166 \pm 0.0084$$

(Planck 2020, CMB-only)

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Can the fitting problem account for the  $H_0$ -tension?

# Independent best-fit $\Lambda$ CDM model parameters

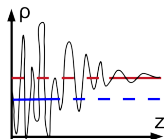
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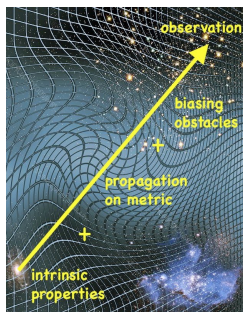
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assume astro & biases are consistent

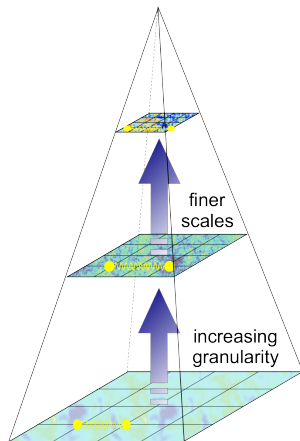
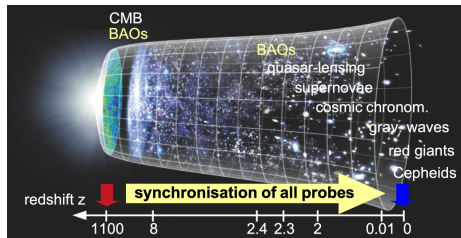
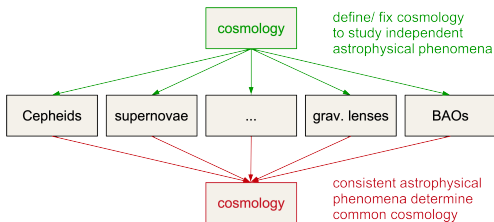
$$D_{\text{com}}(z) = \frac{c}{H_0} \int_0^z \frac{dx}{\sqrt{\Omega_m(1+x)^3 + \Omega_\Lambda}}$$

$$D_{\text{com}}(z) = D_{\text{com}}(z)$$

$$\Omega_m \approx \Omega_m \left( \frac{H_0}{H_0} \right)^2 \stackrel{!}{=} 0.269$$

→ yes, right trend in  $(H_0, \Omega_m)$ !  
clumpy universe difficult to fit!

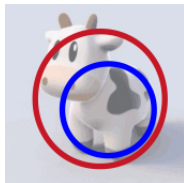
# The solution to the $H_0$ -tension – consistency & synchronisation



→ synchronise all probes over time and scale (using BAOs)



$H_0$ -tension caused by different model fits across scales and time



## Advantages

- no need for additional (dark) physics
- no ad-hoc changes in evolution
- easy to fix by tracing BAOs across cosmic time
- may solve other tensions as well (e.g.  $\sigma_8$ )

Foundations in Ellis 1984, Ellis et al. 1985, Ellis & Stoeger 1987

THANK YOU!



Our white paper on  $H_0$ :

[arXiv:2207.05765](https://arxiv.org/abs/2207.05765)

Cosmo-of-69 web blog:

[cosmoprinciple.wordpress.com](https://cosmoprinciple.wordpress.com)