Astronomy & Astrophysics manuscript no. main
February 22, 2023

Calculating the CMB power spectrum blah blah

Nanna Bryne[1,2]

[1] Institute of Theoretical Astrophysics (ITA), University of Oslo, P.O. Box 1029 Blindern, N-0315 Oslo, Norway
[2] Center for Computing in Science Education (CCSE), Dept. of Physics, University of Oslo, P.O. Box 1048 Blindern, N-0316 Oslo, Norway
e-mail: `nanna.bryne@fys.uio.no`

February 22, 2023

ABSTRACT

ABSTRACT

Key words. cosmic microwave background – large-scale structure of universe

Note to self: "-" is hyphen, "–" is en dash and "—" is em dash

1. Introduction

Remember to include the following in this section:

- GOAL: predict the CMB (and matter) fluctuations through the power spectrum, starting from first principles + learn about the various physical processes that is happening in order to explain the results
- divided into four steps: two concerning background cosmology and two concerning perturbations and ... (?)
- remember to state abbreviations, e.g. cosmic microwave background (CMB)

2. Milestone I: Background cosmology

The geometry of the background is determined by the Friedmann-Lemaître-Robertson-Walker (FLRW) metric (Eq. (3)).

2.1. Theory

We assume the constituents of the universe to be cold dark matter (CDM), baryons (b), photons (γ), neutrinos (ν),[1] and a cosmological constant (Λ) dark energy comment?. We leave the curvature (k) as a variable for now. The density parameter Ω_i associated with cosmological component $\mathrm{i} \in \{\mathrm{CDM}, \mathrm{b}, \gamma, \nu, \Lambda, k\}$ can be written in terms of the ...

$$\Omega_\mathrm{i}(a) = \frac{\Omega_\mathrm{i0}}{a^{3(1+\omega_\mathrm{i})}H^2(a)/H_0^2}, \quad \Omega_\mathrm{i0} \equiv \Omega_\mathrm{i}(a\!=\!a_0) \tag{1}$$

blah blah As a notational relief, we introduce the parameters associated with total matter (M) and total radiation (R):

$$\Omega_\mathrm{M} = \Omega_\mathrm{CDM} + \Omega_\mathrm{b} \tag{2a}$$
$$\Omega_\mathrm{R} = \Omega_\gamma + \Omega_\nu \tag{2b}$$

[1] For the sake of consistency — will not consider neutrinos fixxx

The FLRW line element is given by

$$\begin{aligned}\mathrm{d}s^2 &= -\mathrm{d}t^2 + a^2(t)\delta_{ij}\mathrm{d}x^i\mathrm{d}x^j \\ &= a^2(t)\left(-\mathrm{d}\eta^2 + \delta_{ij}\mathrm{d}x^i\mathrm{d}x^j\right)\end{aligned} \tag{3}$$

$$H(a) = H_0\sqrt{\Omega_\mathrm{M0}a^{-3} + \Omega_\mathrm{R0}a^{-4} + \Omega_{k0}a^{-2} + \Omega_{\Lambda0}} \tag{4a}$$
$$\mathcal{H}(a) = H_0\sqrt{\Omega_\mathrm{M0}a^{-1} + \Omega_\mathrm{R0}a^{-2} + \Omega_{k0} + \Omega_{\Lambda0}a^2} \tag{4b}$$

We will use the logarithmic scale factor $x \equiv \ln a$ as our main time variable, allowing us to rewrite the above equations by the substitution $a = e^x$.

We have the relations

$$\frac{\mathrm{d}t}{\mathrm{d}\eta} = a, \quad \frac{\mathrm{d}x}{\mathrm{d}t} = H, \quad \frac{\mathrm{d}x}{\mathrm{d}\eta} = \mathcal{H} \tag{5}$$

and the operators

$$\frac{\mathrm{d}}{\mathrm{d}t} = H\frac{\mathrm{d}}{\mathrm{d}x}, \quad \frac{\mathrm{d}}{\mathrm{d}\eta} = \mathcal{H}\frac{\mathrm{d}}{\mathrm{d}x} \tag{6}$$

2.2. Implementation details

2.3. Results

Here is Tab. 1

Event	**Time**		
	x	z	t
R-M equality	-8.67		
M-DE equality			
$\ddot{a} > 0$			
today			13.86 Gyrs
$\eta(0)/c$			

Table 1. The logarithmic scale factor (x), redshift (z) and cosmic time (t) of various milestones in the history of the universe.

This is Fig. 1 from (Callin 2006)

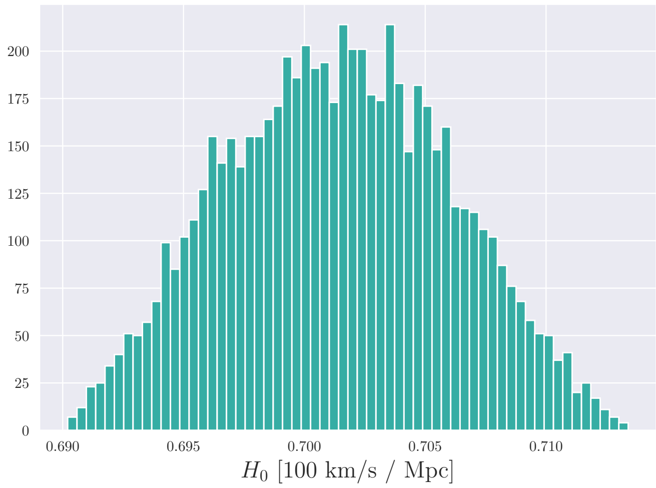

Fig. 1. Duration as

3. Conclusion

References

Callin, P. 2006, arXiv e-prints, astro