Chapter 10

The Cosmic Microwave Background

The time for discussion of the global dynamics of the Universe is over. We now move on to the question of why it is said to be the **Hot Big Bang**. From now on I will concentrate on the case of a flat Universe with no cosmological constant; this sounds significant but we will see during Chapter 13 that this is always a good approximation during the early evolution of the Universe, even if the present Universe is not flat or possesses a cosmological constant.

10.1 Properties of the microwave background

The crucial observation which swayed the Big Bang/Steady State Universe debate in favour of the former was the detection of the cosmic microwave background radiation reported in 1965. This radiation bathes the Earth from all directions, and is now known to accurately take on the form of a black-body with temperature

$$T_0 = 2.725 \pm 0.001 \text{ Kelvin}\,, \tag{10.1}$$

as shown in Figure 2.4. As a first step, let's work out how much energy that corresponds to, in comparison to the critical density.

We studied the properties of thermal distributions in Section 2.5.2. The black-body spectrum is given by equation (2.8). We found the total energy density $\epsilon_{\rm rad}$ of radiation at temperature T by integrating the energy density over the black-body distribution, obtaining equation (2.10)

$$\epsilon_{\rm rad} \equiv \rho_{\rm rad} c^2 = \alpha T^4\,, \tag{10.2}$$

where

$$\alpha \equiv \frac{\pi^2 k_{\rm B}^4}{15\hbar^3 c^3} = 7.565 \times 10^{-16}\,{\rm J\,m^{-3}\,K^{-4}}\,, \tag{10.3}$$

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