Cosmology Tutorial 9

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April 8, 2017

1

1.1

In the radiation era fluctuations are frozen into a high density radiation field.

Radiation	Plasma	Neutral
=	=	+
=	=	+
=	+	+

Table 1: Baryonic Isothermal

1.2

Silk damping occurs in the radiation era but Silk mass is reduced after decoupling.

Radiation	Plasma	Neutral
-	-	+
+	+	+
+	+	+

Table 2: Baryonic Adiabatic

1.3

Fluctuations on small scales remain undamped.

Radiation	Plasma	Neutral
+	+	+
-	+	+
-	+	+

Table 3: CDM

1.4

Damping occurs due to free-streaming when particles are relativistic before t_{eq}.

Radiation	Plasma	Neutral
-	+	+
-	+	+
-	+	+

Table 4: HDM

2

$$k_x = n_x \frac{2\pi}{100}$$
$$2\frac{2\pi}{100} = .126$$
$$3\frac{2\pi}{100} = .188$$

so n_x must be either 0,2 or 3. The wavelengths are:

$$\frac{2\pi}{2} = \pi$$
$$\frac{2\pi}{3} = 2.094$$

There are $3^3 = 27$ permutations of n_x, n_y and n_z. For $1 < k < 2$ the interval is 10 times larger so presumably there are 10 times as many permutations i.e. 270? .

3

3.1

The Horizon scale at matter-energy equality is approximately 100 Mpc. The amplitude of fluctuations is $\approx 10^{-4}$.

3.2

Redshift	Amplitude	Log(Amplitude)	Log(a)
4×10^7	10^{-8}	-8	-7.6
6.6×10^6	10^{-7}	-7	-6.8
2.2×10^6	10^{-6}	-6	-6.3
1.4×10^6	10^{-5}	-5	-6.1
6.3×10^5	10^{-4}	-4	-5.7
39000	10^{-3}	-3	-4.6
490	.01	-2	-2.7
29	.1	-1	-1.5
2.2	1	0	-0.5

Table 5: Question 3 data

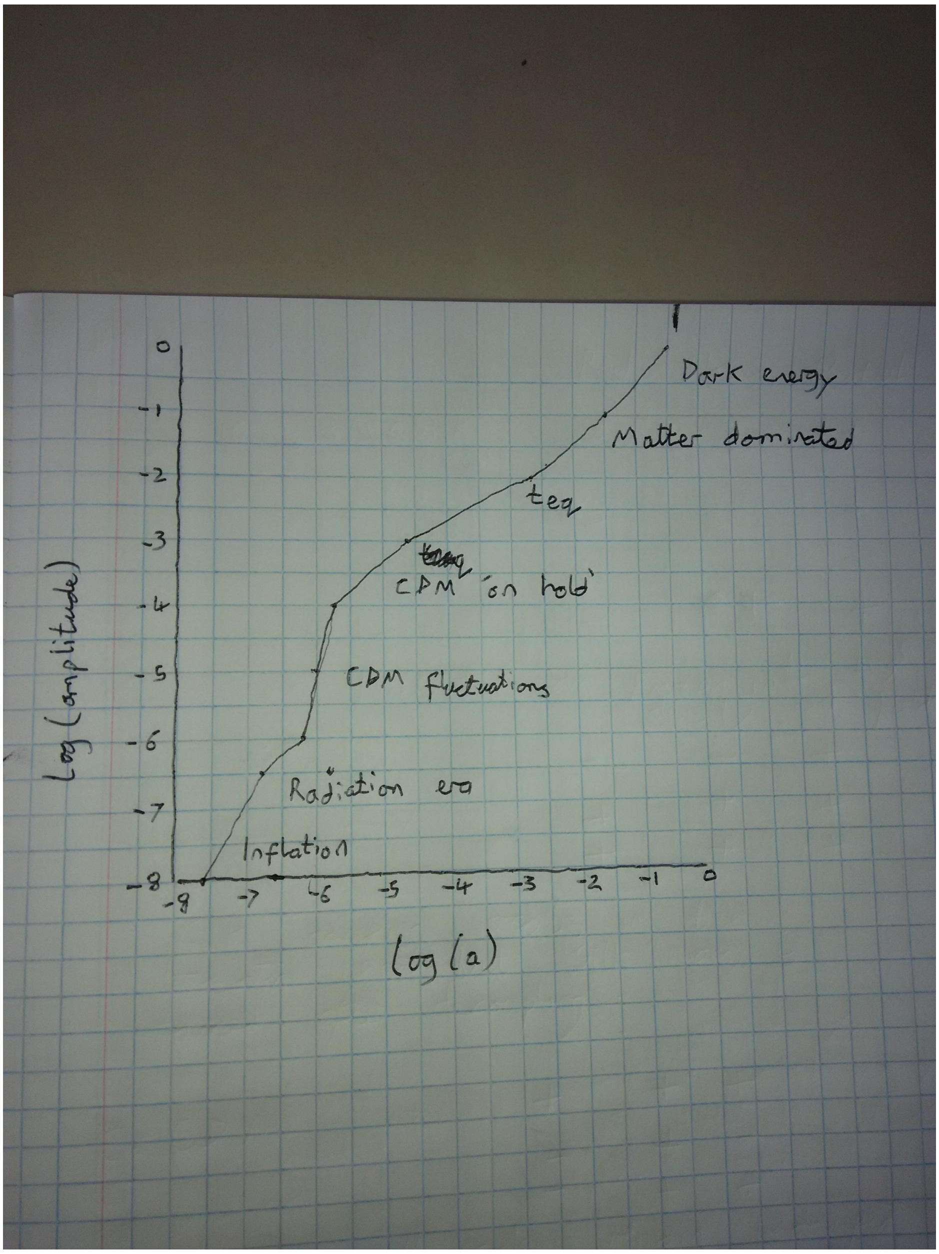

Figure 1:

4

Horizon problem - regions of the sky more than $1^\circ(\approx 200Kpc)$ were never in causal contact before decoupling so no information could have been exchanged. So why it is so isotropic?

Flatness problem - Why is $\Omega = 1$ in universe today? The early universe must have had $\Omega = 1$ as well (proof is in the notes).

Inflation solves the horizon problem because the causal horizon could have been larger in the past. Inflation also predicts that $\Omega = 1$ because size of universe was so large after inflation that any curvature would have been negligible.

5

$$
\begin{aligned}
&K_0 = 1 + .227N_\nu \\
&N_\nu = 3.046 \\
&K_0 = 1.691 \\
&10^{-35} = 1.691^{-\frac{1}{2}} \left(\frac{1.52 \times 10^{10}}{T}\right)^2 \\
&\left(\frac{1.52 \times 10^{10}}{T}\right)^2 = \frac{10^{-35}}{.769} \\
&\frac{1.52 \times 10^{10}}{T} = \sqrt{1.3 \times 10^{-35}} \\
&T = \frac{1.52 \times 10^{10}}{3.6 \times 10^{-18}} \\
&T = 4.22 \times 10^{27} K \\
&kT = 8.62 \times 10^{-5} eV K^{-1} \times 4.22 \times 10^{27} K \\
&= 3.64 \times 10^{23} eV \\
&= 3.64 \times 10^{14} GeV
\end{aligned}
$$

I couldn't answer the last bit.