Friedmann Lemaître Robertson Walker

This is:

$$ds^2 = -dt^2c^2 + a(t)^2\left(\frac{dr^2}{1-kr^2} + r^2 d\theta^2 + r^2\sin^2\theta\, d\phi^2\right) \quad —(1)$$

Here $a(t)$ is the scaling factor. The specific form of $a(t)$ does not need the field equations. This metric follows from the geometric properties of homogeneity and isotropy. So:

$$g_{00} = -1, \; g_{11} = \frac{a^2(t)}{1-kr^2}, \; g_{22} = r^2, \; g_{33} = r^2\sin^2\theta.$$

Evaluate the Coulomb law and Ampère Maxwell Law.

Matter and energy in the universe is modelled with a perfect fluid.

Friedmann Equations

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3p) \quad - (C8.35)$$

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{k}{a^2} \quad — (C8.36)$$

Hubble Parameter

$$H = \frac{\dot{a}}{a} \quad — (C8.37)$$

2)

The Friedmann equation ((8.36) is:

$$\Omega = 1 + \frac{k}{H^2 a^2} \quad \text{— } ((8.41))$$

where the density parameter is:

$$\Omega = \frac{8\pi G}{3H^2}\rho$$

and the deceleration parameter is:

$$q = -\frac{a\ddot{a}}{\dot{a}^2} \quad \text{— } ((8.38))$$

Open Universe

$$\left.\begin{aligned} a &= \frac{C}{2}(\cosh\phi - 1) \\ t &= \frac{C}{2}(\sinh\phi - \phi) \end{aligned}\right\} \text{— } ((8.48))$$

Flat Universe

$$a = \left(\frac{9C}{4}\right)^{1/3} t^{2/3} \quad (k=0) \text{ — } ((8.49))$$

Closed Universe

$$\left.\begin{aligned} a &= \frac{C}{2}(1 - \cos\phi) \\ t &= \frac{C}{2}(\phi - \sin\phi) \end{aligned}\right\} (k = 1) \text{ — } ((8.50))$$

where

$$C = \frac{8\pi G}{3}\rho a^3 = \text{constant}$$

— (8.51)