Outline

- Go over homework (8.2)
- Einstein equations with cosmological constant
- Friedmann equations with cosmological constant
- Observable effects of cosmological constant/dark energy

Einstein Equations

- The Einstein tensor is only a function of the metric.

$$G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi G}{c^4} T_{\mu\nu}$$

- It is possible to add another term to the Einstein tensor without destroying its transformation properties. The term must be a constant multiplied by the metric.

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

- This changes the Friedmann equations...

Friedmann Equations

- First Friedmann equation: $$\left(\frac{\dot{R}}{R}\right)^2 = \frac{8\pi}{3} G\rho - \frac{k c^2}{R^2} + \frac{\Lambda}{3}$$
- Acceleration equation: $$\frac{\ddot{R}}{R} = -\frac{4\pi G}{3 c^2}\left(\rho c^2 + 3P\right) + \frac{\Lambda}{3}$$
- Energy conservation: $$\dot{\rho} c^2 = -3\frac{\dot{R}}{R}\left(\rho c^2 + P\right)$$
- Key feature is that Λ can lead to a positive acceleration.
- Interpret Λ as energy density, show that it eventually dominates expansion of the universe.

Homework

- For next class, problem 8.3.
- Have a nice spring break!