Outline

- Go over homework (8.1)
- Newtonian equivalents of Friedmann equations
- Solutions
Friedmann Equations

- First Friedmann equation: \[ \left( \frac{\dot{R}}{R} \right)^2 = \frac{8\pi}{3} G \rho - \frac{k c^2}{R^2} \]

- Acceleration equation: \[ \frac{\ddot{R}}{R} = -\frac{4\pi G}{3 c^2} \left( \rho c^2 + 3P \right) \]

- Energy conservation: \[ \dot{\rho} c^2 = -3 \frac{\dot{R}}{R} \left( \rho c^2 + P \right) \]

- Want to find \( R(t) \)
  - First need to know dependence of \( \rho \) and \( P \) on \( R \).
  - The equation of state of the universe.
Newtonian Model of the Universe

• Model universe as a sphere of radius $R$, mass $M$, density $\rho$.
• Consider motion of a galaxy of mass $m$ at edge of sphere.
  – Kinetic + potential = total energy = $E$
  – Behavior for $E = 0$, $E < 0$, $E > 0$?
  – Do on board, compare to Friedmann equations.

• Find acceleration equation on board, compare to Friedmann

• How do we deal with pressure?
  – Derive third Freidmann equation.
Homework

• For next class:
  – Problem 8.2