1 Weekly main assignment for week 4 AST3220

Prepare for class (to be discussed in plenary)

a) If you haven't done 1.4 from the lecture notes already, do it now. Then write down the expression for the total energy without making any assumptins on the density. Assume instead that the energy is conserved in both space and time, i.e. your total energy should equal an unknown constant.

Assuming that a is the only quantity that changes with time, and that the density is just uniformly spread out with the expansion (or compressed with the contraction) of the universe, so that

$$\rho = \frac{\rho_0}{a^3}$$

Use this to turn your expression for the consservation of energy into the first Friedmann equation.

b) In a) you have used a part of the first law of thermodynamics (that of energy conservation) to show the first Friedmann equation. Let's see if we can't get more cosmology from it.

The full first law of thermodynamics reads: TdS

$$TdS = dE + pdV$$

where T is temperature, S is entropy, E is energy, p is pressure and V is volume.

An adiabatic process is one where entropy is conserved. Very near adiabaticity in the universe expansion is an asssumption which is supported by observational evidence.

In a homogeneous and isotropic universe all physical quantities depend only on time.

Use these facts and that ρ is the energy density to obtain the equation of adiabatic expansion:

$$\dot{\rho} = -3\frac{\dot{a}}{a}\left(\rho + p\right)$$

in units where $c = 1$.

c) Combine the above equation with the derivative of the first Friedmann equation to obtain the second Friedmann equation

Prepare or at least look at before class

Exercises 1.10, 1.5 and 1.9 in the lecture notes.