Problem set 4 FYS9130 – Week 39

1. **Journal club**

   Read one or more of the papers (ADD, RS1, RS2 or DGP) and summarize the main idea. Do you see any problems?

2. **Unnatural units (toy problem)**

   Assume new units defined by

$$g = 1 = 9.81\text{m}/s^2 \tag{1}$$
$$G = 1 = 6.67 \cdot 10^{-11}\text{N}m^2/kg^2 \tag{2}$$

   a) Find 1m, 1N, 1J and 1kg measured in seconds.

   b) Calculate the Planck mass in seconds.

3. **Cosmolgy with a scalar field (quintessence)**

   The Friedmann equations are:

$$\frac{\dot{a}^2}{a^2} = \frac{1}{3M_P^2}\left(\frac{1}{2}\dot{\phi}^2 + V(\phi)\right) \tag{3}$$
$$-2\frac{\ddot{a}}{a} - \frac{\dot{a}^2}{a^2} = \frac{1}{M_P^2}\left(\frac{1}{2}\dot{\phi}^2 - V(\phi)\right) \tag{4}$$

   which can also be combined into the scalar field equation of motion:

$$\ddot{\phi} + 3\frac{\dot{a}}{a}\dot{\phi} + V'(\phi) \tag{5}$$

   a) Solve these equations for $V = 0$ (Hint:$\phi = k \ln t + \phi_0$)

   b) Solve these equations for $V(\phi) = Ae^{-\frac{\lambda\phi}{M}}$
   (Hint: $\phi = k \ln t + \phi_0$, show that $k = \frac{2M_P}{\lambda}$ and $V(\phi_0) = \frac{6(2-\lambda^2)M_P^2}{\lambda^4}$)

   c) Find Ω_{kin} and Ω_{pot} with the definitions

$$\Omega_{\text{k}in} = \frac{\rho_{kin}}{\rho_{cr}} = \frac{\frac{1}{2}\dot{\phi}^2}{\rho_{cr}} \tag{6}$$
$$\Omega_{\text{pot}} = \frac{\rho_{\text{pot}}}{\rho_{cr}} = \frac{V(\phi)}{\rho_{cr}} \tag{7}$$
$$\rho_{\text{cr}} = 3H^2M_P^2 \tag{8}$$
$$H = \frac{\dot{a}}{a} \tag{9}$$