Tutorial 2

Cosmology and Galaxy Formation (PHY654)

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- Duration of the tutorial session is 60 minutes.
- You can use your notes, books, online material.
- You can discuss the problems with your friends and you can ask the instructor for help.

NAME:
Registration No. :

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1. Friedmann equations for a universe with flat space containing non-relativistic matter and the cosmological constant can be written as:

$$\left(\frac{\dot{a}}{a}\right)^2 = H_0^2 \left[\Omega_{nr}\left(\frac{a_0}{a}\right)^3 + \Omega_\Lambda\right]$$

and

$$\frac{\ddot{a}}{a} = H_0^2 \left[-\frac{1}{2}\Omega_{nr}\left(\frac{a_0}{a}\right)^3 + \Omega_\Lambda\right]$$

Solve for scale factor as a function of time by requiring that $a = 0$ when $t = 0$. [1]

2. Show that at early times, $a(t) \propto t^{2/3}$, as expected in the matter dominated era. [0.5]
3. Show that at late times, the scale factor varies exponentially with time. [0.5]
4. If $\Omega_\Lambda = 0.7$ then find out the redshift at which non-relativistic matter and cosmological constant contribute equally to the energy density in the universe. [0.5]
5. If $\Omega_\Lambda = 0.7$ then find out the redshift at which the expansion of the universe begins to accelerate. [0.5]