Cosmology (PHYSDSE05: Astrophysics and Cosmology)
Problem Set-1

1. Consider the analogy of the expanding sphere, discussed in class. Now consider the three cases, namely $U > 0$, $U = 0$, and $U < 0$. In each case what can you say about the expansion? Find parametric solutions for the three cases. They are equivalent to what you would get in a negatively curved Universe, flat Universe and positively curved Universe.

2. Show that the Friedmann, acceleration and the conservation equations are not independent of each other. You can derive any one of the equations from the other two.

3. In class we have shown that for non-relativistic matter $\rho \propto 1/a^3$ and $a \propto t^{2/3}$. Show that the energy density of non-relativistic matter falls as t^2. Using Friedmann equations show that the energy density of radiation falls as t^2 too. Find out the redshift at which the energy density of matter was equal to the energy density of radiation. This epoch is called the matter-radiation equality epoch or simply the equality epoch. What was the relative size of the Universe at that epoch compared to the current epoch?

4. Read the 'Planck 2018 : Cosmological Parameters papers' and make a short write-up (200 words) of the key results on the measurement of the cosmological parameters.

5. As we discussed in class we need to numerically solve the Friedmann equation for a multi-component Universe. We solved Friedmann equation for cosmological constant, matter and radiation only universes in class. Now assume the universe to be empty and it just has curvature. Solve the Friedmann equation and show the relationship between scale factor and time? Do you get constant expansion, accelereted expansion or deccelerated expansion in this case?

6. The distance between Presidency University and Princeton University is 12750 km. According to Hubble's law at what speed is Princeton University receding from Presidency? Give your answers in mm/year. Is this motion actually happening? Why or why not?