Cosmology

Part A (problems to be handed in)

1. What is the present density parameter of massive neutrinos (assuming direct hierarchy, and consider both relativistic and non-relativistic neutrinos)?

(**7 points**)

2. Show that due to the relative motion of an observer with rest-frame K and the CMB with rest frame K' (moving with velocity β=v/c at an angle θ with respect to K), the observer measures the rest-frame blackbody spectrum temperature T', as a blackbody spectrum with temperature T_{obs}:

$$T_{\rm obs} = \frac{T'}{\gamma\,(1-\beta\,\cos\theta)}$$

(7 points)

3. Show that the maximum possible value of the primordial helium fraction is

$$Y_{max} = \frac{2f}{(1+f)}$$

where $f=n_n/n_p <= 1$.

(**6 points**)

4. Decoupling of relativistic species. Neutrino temperature today.

a) Show that when relativistic species decouple from all interactions, their particle distribution remains self-similar to an equilibrium distribution but with a temperature that decreases inversely proportional to the scale factor.

(**2 points**)

b) Using the conservation of entropy, compute the effective temperature of the relic background of relativistic neutrinos today.

(**3 points**)

Part B (problems to be discussed in class)

1) Derive redshift of matter-radiation equality.
2) Calculate the slow roll parameters for $V(\Phi)= \lambda\, \Phi^{n.}$
3) Discuss the different cosmological horizons.
4) Discuss the magnetic monopole problem.
5) Discuss alternatives to single scalar field inflation.
6) Discuss the Planck 2018 constraints on inflation.