Due Thursday March 3, 2016

Please answer all questions clearly and concisely. You are strongly encouraged to discuss the homework with your classmates, but you must complete the written homework by yourself, and of course, the material you submit must be your own.

1. Ryden 11.1
2. Ryden 12.1

3. A bit about inflation. Let’s assume for the moment that inflation began when the universe was $10^{-36}$ s old, and ended when it was $10^{-33}$ s. I want you to suppose that before inflation, the density of the universe was critical, with all of the contents being made up of a fluid with $w = 1/3$.

   (a) Write down the Friedman equation for the period before inflation.
   (b) What was the Hubble constant as a function of time?
   (c) What was the Hubble constant at the beginning of inflation?
   (d) If the density is critical, what was the effective mass density of the field?
   (e) What was the equivalent temperature? Use $a_B T^4 = \rho_c c^2$.
   (f) What energy (in GeV) does that correspond to?
   (g) Using our standard $T = T_0/a$ relation, what was the expansion scale of the universe at that time?
   (h) Assume that for the period of inflation, the Hubble constant is fixed. By what factor does the universe increase in size?

4. I’d like you to get some practical experience, measuring structure in the universe. You will be dealing with data. I have prepared 3 datafiles and put them on the course website. For students with LAST names:

   - A-C - “delta_model1.txt”
   - D-M - “delta_model2.txt”
   - N-Z - “delta_model3.txt”

These files are column delimited in the following format:

   x y delta

Where the x and y positions are assumed to be in $h^{-1}$ Mpc. To make things simple, the “universe” in each case is only 2d, and the boundaries are assumed to be periodic (e.g. a pacman universe). For your universe:

   (a) Plot the density field.
   (b) Compute $\sigma_R$. This will involve throwing down random circles (they’d be spheres in 3d) of radius $R$, and computing the RMS of the mass inside them. Remember, though, that this is a pacman universe so some parts of your circle will loop around to the other side of the box.

   Generalize your code to plot the real-space density field, $\sigma_R$, from $R = 1 h^{-1}$ Mpc to $R = 16 h^{-1}$ Mpc.
   (c) Compute and plot the power spectrum.