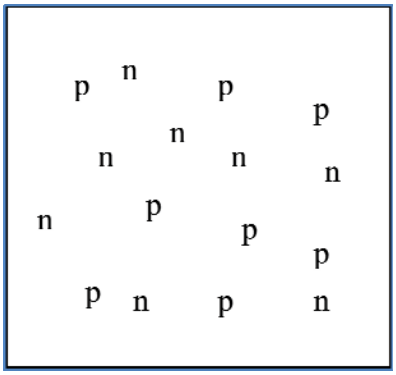
AST 207 Homework 9 Ans Due at start of class
19 November 2010
No late papers

1. The picture shows a sample of the universe 0.001 s after the big bang, when the expansion parameter was 6×10^{-12}. (Recall that the expansion parameter is distance/(present distance). The box was a cube 2×10^{-11}m on a side. There are 8 neutrons, 8 protons, and lots of light in the box.



   a. (5 pts.) The box expands with the universe. Draw its contents just before helium formed (at 3 minutes, when the expansion parameter is 2.3×10^{-9}). The number must be precise to 10%; for example, drawing 15 protons is OK if the actual number of protons is 16.

      Key idea: Just before helium formed, the neutrons were free, and the ratio of the number of neutrons to the number of protons was the same as it is now, 1:7.

      There are 2 neutrons and 14 protons in the box.

   b. (3 pts.) What is the temperature of the radiation in the box when helium formed?

      Key idea: The temperature of the radiation changes as a^{-1}, where a is the expansion parameter.

      The present temperature is 2.7K, and the expansion parameter is 1. When helium formed, the temperature is $2.7\text{K}/2.3\times10^{-9}=1.2\times10^{9}$ K.

   c. The box expands with the universe. (3 pts.) Draw its contents at the present time. Assume the box is not from some special place such as in a star, or in a galaxy.

      Key idea: When helium formed at 3min, the neutrons became locked up in ^{4}He, which means the number of neutrons does not change.

      With 2 neutrons, one ^{4}He nucleus forms. There are 12 protons left. Inside the box is one ^{4}He and 12 H.

   d. (3 pts.) How big is the box now?

      No key ideas; this asks the definition of the expansion parameter.

      (Width of box at 0.001s)/(Current width of box)=(a at 0.001s)/(Current a)

      2×10^{-11}m/(Current width of box) = 6×10^{-12} / 1

      Current width of box =3.3m