ASTR 320 - Theoretical Astrophysics

Spring 2013

Homework Assignment No. 2

1. At a time $t_1 = 1$ sec after the big-bang, the temperature of the Universe is approximately $T_1 = 10^{10}$ K.

   (a) At this time, is the Universe radiation dominated or mass dominated?

   (b) Free neutrons have a lifetime of about 880 sec. By what factor does the scale R of the Universe change during one neutron lifetime? I.e., compute the ratio $R(t_2)/R(t_1)$, where $t_2 = 881$ sec.

   (c) What is the temperature $T(t_2)$? By what factor does the energy density of the radiation, u_R , change during this time?

   (d) How does the number density of neutrons change during this interval?

2. Titan, Saturn's largest satellite, has a radius of 2575 km and a mass of 1.3455×10^{23} kg.

   (a) What is the surface gravity of Titian?

   (b) Titian's atmosphere is mostly molecular nitrogen, N_2 . If we take the temperature of the atmosphere to be 85 K (and constant), find the scale height in km of Titian's atmosphere.

   (c) How does this compare to the scale height of Earth's atmosphere?

3. Consider the solar nebula, the disk of gas and dust orbiting the sun before the formation of the planets.

   (a) Use equation (21) of the notes

   $$H = \left(\frac{kT}{m}\right)^{1/2} \left(\frac{GM_*}{R^3}\right)^{-1/2}, \tag{1}$$

   to estimate the scale height, H, of the disk at the radius of the Earth's orbit. (Use the sun's present mass, $M_\odot = 2 \times 10^{33}$ g, take $T = 300$K, and assume the composition is mostly molecular hydrogen, H_2.)

   (b) How does the disk's scale height compare to its radius at this distance from the proto-sun?

   (c) Repeat the calculation for Jupiter's orbital radius (5.2 AU), assuming $T = 130K$.

Due: 21 February 2013