Astronomy 45. Introduction to Astrophysics

Problem set 3 Due March 16

1. Black Body radiation in the universe

(a) How many photons are there per cubic centimeter in the Universe due to the 2.7 K blackbody microwave background?

(b) When the Big-Bang Universe was a factor of Z smaller in linear dimension (say $Z = 1000$), these same photons were in a volume Z^3 smaller, and (we will learn later) their *temperature* was also larger by a factor Z. What was the radiation density of the universe then ($Z = 1000$), both in ergs/ cm^3 and also in units of proton masses (times c^2) per cm^3?

(c) Suppose the mean density of protons and nucleii *today* is 2×10^{-31}g cm^{-3}. At what redshift factor Z was there more energy in photons than in protons? (Again use $E = mc^2$ in making the comparison.)

2. Stefan-Boltzman applications

(a) If light from a 100 W lightbulb has a color temperature of 3200 K, what is the surface area, in square millimeters, of its filament (neglecting conduction and convection inside the lightbulb)?

(b) Sirius is an A1 star with *absolute* magnitude in V band $M_V = 1.41$. What is its total (bolometric) luminosity in erg/sec? (Hint: Estimate its color temperature from the figure in notes section 3.5.7, then plot a Planck function with that temperature and estimate the fraction of its area in the V band, and see the table in notes section 2.2.1. Your estimates can be rough, e.g. $\pm10\%$.)

(c) What is the radius of Sirius (given its temperature and luminosity)? Give your answer in units of the Sun's radius (6.96×10^{10} cm).

3. Light is aberrated, gravity is not!

(a) Because of the Earth's motion around the Sun, photons from the Sun appear to come from a slightly different direction than they actually do. (See figure of raindrops falling exactly vertically through a moving drainpipe to understand this effect.) Thus, the Sun *appears* at a slightly different place from where it *is*! This is called "aberration." How big is this effect, in degrees of angle?

(b) You might think that gravity, being carried by gravitons is also aberrated by the same angle. Show that, in that case, the Sun's gravitational force would have a small component parallel to the Earth's orbital velocity. Therefore the orbit would lose or gain energy! Which is it, lose or gain? About how long would it take the Earth to change its orbital energy by a significant fraction? (Your answer should rule out the possibility that gravity is aberrated!)