24 Jan 2012 **Ay 21** E.S. Phinney

Galaxies and Cosmology

Problem Set 3

Due **in class**, 31 January 2012

Reading: Carroll and Ostlie (2nd edition), pages 1070-1080 and pages 1144–1171 of Chapter 29.

Homework Problems:

1. **Olber's paradox revisited:** Consider a 10Gyr-old Newtonian non-expanding universe. Pretend all the stars in it are sun-like, turned on 10 Gyr ago and have been shining steadily ever since (note that they are just reaching the end of their main-sequence lifetimes, so would all turn off very soon, after a brief blaze as red giants!). Also pretend that in the near-infrared K-band, where dust absorption is much less than in optical bands, the total galaxy luminosity density is the same as in our real local universe $2.0 \times 10^8 L_{\odot,K}\mathrm{Mpc}^{-3}$, allowing the mean density of sun-like stars to be estimated. In this toy universe, what is the probability that a random line of sight from earth intercepts the surface of a star (i.e. what fraction of the night sky would be covered by stars)?

2. **Fiat lux:** Suppose that at some time in the very recent past all the hydrogen and helium (baryon density $\rho_b = 4.2 \times 10^{-31}$g cm^{-3}, about 75% hydrogen (= 1 baryon) by mass and 25% helium (= 4 baryons) by mass) in the universe had been instantly fused into iron in stars, and the released energy thermalised into black body radiation, say by Fred Hoyle's iron needles.

   a) Calculate the current temperature of this black body radiation.

   b) At what wavelength would the black body spectrum peak, and what region of the electromagnetic spectrum would this be (e.g. gamma-ray, infrared, radio, etc?).

   c) The mean bolometric luminosity per unit volume emitted by stars in the universe today is about $3 \times 10^8 L_\odot \mathrm{Mpc}^{-3}$. How long would it take stars at this rate to fuse all the hydrogen and helium in the universe? Compare to the present age of the universe.

   d) Explain how your results above may be applied to Olber's paradox.

3. C& O problem 29.18

4. C& O problem 29.19

5. C& O problem 29.20