

## Ay 127 – Homework #3

**Distributed on May 17, due by 5 pm on Friday, May 24 (directly to the TA)**

Unlike the exercises done in the class, you have to do these on your own.

1. The observed local energy density of the cosmic far-infrared background (CIRB) is  $u_{\text{CIRB}} \approx 7 \times 10^{-15} \text{ erg cm}^{-3}$ . Assume that the background is generated by a population of obscured starbursts with a mean luminosity  $\langle L \rangle \approx 10^{12} L_{\odot}$ , with all energy emerging in the mid/far IR, with a mean redshift  $\langle z \rangle \approx 3$ , each lasting on average  $\Delta t \approx 3 \times 10^7 \text{ yr}$ .
  - a. How many such starbursts should there be in the entire observable universe, in order to account for the CIRB?
  - b. Estimate the comoving number density of their progeny at  $z \sim 0$ , and compare it with the estimated comoving number density of normal galaxies today. (Hint: estimate the total comoving volume of the observable universe first; an order-of-magnitude, reasoned estimate is OK.)
  - c. Assuming the yield of nuclear reactions of 7 MeV/nucleon, how much helium was generated by these starbursts? How much metals, assuming the ratio of helium to metals production by mass  $\Delta Y / \Delta Z = 5$ ? If each of these starbursts was in a galaxy with a baryonic mass  $M \approx 10^{11} M_{\odot}$ , what is the mean metallicity of the resulting stars?
  
2. Suppose that all DM is in the form of black holes with a mass  $M_{\bullet} \approx 10^6 M_{\odot}$ , distributed uniformly in the comoving volume.
  - a. What is their local number density per  $\text{Mpc}^3$ ? What is the probability of one of them passing through the Milky Way halo now? [15% of the credit for this problem]
  - b. Roughly how many of them are there on the sky? State your assumptions. [25%]
  - c. Estimate how many quasars are on the sky. Make reasonable assumptions about the redshifts. Estimate how often there be gravitational lensing events, with the black holes lensing the background quasars? Again, state your assumptions. [60%]