# PROBLEM SET 3 – Astronomy 113

**1.** Assume that there are $10^{-75}$ galaxies per cubic centimeter in the Universe and that each galaxy has a mass of $10^{11}\mathrm{M}_\odot$ within a radius of 8 kpc. If all galaxies have flat rotation curves between 8 kpc and some fixed radius $R$, then how does the density parameter of galaxy mass, $\Omega_{\mathrm{galaxies}}$, depend on $R$?

**2.** A galaxy with luminosity $L$ is at a redshift $z = 1$. By what factor will its expected flux differ between the steady–state universe, and Friedmann $\Lambda = 0$ models with $q_o = 0$, $1/2$, and 1?

**3.** A standard candle has spectral luminosity $L_\nu = C\nu^{-\pi}$, where $C$ is a constant. What is the $K(z)$ correction in the flux–redshift relation for such a standard candle if all fluxes are measured today between frequencies $\nu_a$ and $\nu_b$?

**4.** If the current temperature of the microwave background is 2.7 K, and if the present density parameter of the universe is $\Omega_o$, at what redshift did the energy density of matter equal the radiation energy density?

**5.** In a radiation dominated universe, what is the time dependence of the Hubble parameter, $H$, and of the deceleration parameter, $q$?

**6.** You make two measurements of the microwave background radiation temperature on earth from opposite directions on the sky (180 degrees apart). If the result of these measurements are 2.702 K and 2.715 K from these two directions, then what is the temperature of the microwave background, and what lower limit can you set on the earth's velocity with respect to a co-moving observer? Assume the measurements are exact.