Observational Cosmology
Year 3 Assessed Problems # 1

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due on Oct 30, 2019 at 3:30 pm (TSO)

Consider a flat universe with zero cosmological constant. The radiation energy density is measured to be

$$\Omega_{r,0} = 0.16$$

at the epoch corresponding to $t = t_0$ and $a = a_0$. Here a and t have the usual meaning of scale factor and cosmic time, respectively.

1. Determine the value of a/a_0 for which $\rho_r = \rho_m$, where ρ_r and ρ_m are the mass-energy density in radiation and matter, respectively. **[2]**

2. What is the corresponding redshift z? **[1]**

3. Evaluate the critical density ρ_c at $a = a_0/2$ as a function of $\rho_{c,0}$, the critical density at $a = a_0$. **[2]**

4. Evaluate the time it takes for this universe to evolve from $a = a_0/2$ to $a = a_0$. Express the result as a function of H_0, the Hubble parameter at $t = t_0$. **[2]**

5. Is the total energy of this universe conserved as it expands? Why or why not? And, would your answer change if the universe also had a component of dark energy? Why or why not? **[3]**

Guidelines

- This sheet accounts for **10% of the credit of the course. Marks are in bold within brackets.**