

ASTRON 329/429, Fall 2017 – Problem Set 5

Due on Wed. Nov. 22, by 5 PM in Alex Gurvich's mailbox.

Solve problems 9.1, 9.2, and 9.4 in Ryden, plus the following problem.

I. CMB prediction. George Gamow was the first to predict the existence of the cosmic microwave background, in 1948. (His prediction was ahead of its time and unfortunately had fallen into obscurity before by the time the CMB was discovered in the 1960's.) The purpose of this problem is to reconstruct Gamow's line of argument. Gamow knew that nucleosynthesis must have taken place at a temperature $T_{\text{nuc}} \approx 10^9$ K, and that the age of the Universe is currently $t_0 \approx 10$ Gyr.

First assume that the Universe is flat and contains only radiation. With these assumptions, what was the energy density ϵ at the time of nucleosynthesis? What was the Hubble parameter H at the time of nucleosynthesis? What was the time t_{nuc} at which nucleosynthesis took place? What do these assumptions imply for the current temperature T_0 of the radiation filling the universe today? If the Universe switched from being radiation-dominated to being matter-dominated at a redshift $z_{\text{eq}} > 0$, would this increase or decrease the predicted T_0 for fixed values of T_{nuc} and t_0 ? Explain your answer. Your solution to this problem can involve order-of-magnitude estimates rather than exact calculations.