COSMOLOGY (PROBLEM SET) 2019.6.7

1. Those who do not submit answers by the deadline will not get the course credit.
2. Write your name and student number on every answer paper.
3. Submission deadline: 17:00, 19 June
4. Place of submission: mail box in front of H189, main building
5. If you have questions, please write to suyama@phys.titech.ac.jp

1. Problem

   In 2017, a quasar (very luminous astrophysical object) was discovered. The redshift when the quasar emitted the observed light was $z = 7.54$. Estimate the age of the Universe at that redshift. Use the following cosmological parameters.

   $$H_0 = 70 \text{ km/Mpc/s}, \quad \Omega_\Lambda = 0.7, \quad \Omega_m = 0.3,$$

2. Problem

   A standard explanation of quasars is intense radiation emanating from gas surrounding a supermassive black hole. The gas around the black hole acquires kinetic energy as it falls into the black hole. The kinetic energy converts into heat and the gas temperature increases. As a result, radiation emanates from the hot gas.

   The observed flux of light from the quasar in the first problem was 2.4×10^{-16} J/m^2/s. Assuming that the radiation is isotropic, estimate the absolute luminosity of the gas surrounding the supermassive black hole, and compare it with the solar luminosity.

3. Problem

   Suppose there was an extra radiation in addition to photons and neutrinos during the bigbang nucleosynthesis. It can be gravitons, neutrinos in the fourth generation, or unknown particles. Does the abundance of the helium produced by BBN increase or decrease compared to the case where there is no such extra radiation? Write “YES” or “No” first, and then explain why you think so.