UCSB PHYSICS 133 | Professor Martin
GALAXIES AND COSMOLOGY | 2021 Spring Quarter

HOMEWORK #1 (Due 5pm April 2nd)
Observational Foundation

Problem 1: Blackbody Radiation Review
(a, 1 pt) Find the wavelength of peak intensity for the CMB radiation. [Hint: Apply Wien's Law to a 2.7 K blackbody spectrum.]
(b, 1 pt) Find the wavelength of peak intensity for Solar radiation. [Hint: Assume the sun radiates like a 5800 K blackbody.]
(c, 1pt) Find the average energy of a CMB photon. Express your answer in eV.
(d, 1pt) Find the average energy of a Solar photon. Express your answer in eV.
(e, 2 pts) Sketch the spectrum of the Sun and that of the CMB on the same log - log plot. Please use units of wavelength, rather than frequency, for this exercise. Label the axes quantitatively.
(f, 1 pts) Is your sketch a better approximation to the observed spectrum of the Sun or to the measured CMB spectrum? Explain your answer. [Hint: Which spectrum is more nearly a perfect blackbody spectrum?]

Problem 2: Cosmic Microwave Background
(a, 3 pts) Ryden 2.2
(b, 3 pts) Ryden 2.3

Problem 3: Hubble's Law
Hubble discovered that galaxies in the universe are moving away from us at a rate proportional to their distance. The constant of proportionality is measured to be $H_0 \approx 70$ km s^{-1} Mpc^{-1} at the present time.

(a, 1pt) Suppose the recessional velocity of one of Hubble's galaxies is 14,000 km s^{-1} . What is the proper distance to this galaxy?
(b, 1 pt) What is the redshift of a galaxy with a recessional speed of 14,000 km s^{-1} ?
(c, 1 pt) If the expansion rate of the universe has been constant over cosmic time, how old is the universe? Give your answer in Gyr.

Problem 4 (3 pts): Neutrino Mass Limits
Suppose that the difference between the square of the mass of the electron neutrino and that of the muon neutrino has the value $[m(\nu_\mu)^2 - m(\nu_e)^2]c^4 = 5 \times 10^{-5}\,\mathrm{eV}^2$, and that the difference between the square of the mass of the muon neutrino and that of the tau neutrino has the value $[m(\nu_\tau)^2 - m(\nu_\mu)^2]c^4 = 3 \times 10^{-3}\,\mathrm{eV}^2$. (This is consistent with the observational results discussed in section 2.4.) What values of $m(\nu_e)$, $m(\nu_\mu)$, and $m(\nu_\tau)$ minimize the sum $m(\nu_e) + m(\nu_\mu) + m(\nu_\tau)$, given these constraints?
[Hint: The minimum mass of any particle is zero.]