Radiative Processes in Astrophysics / Problem Set #7
Due April 26, 2021

There are a few questions here but they are mostly exercises to familiarize you with the typical scales involved regarding the various effects we have discussed recently.

1. Compton scattering of CMB photons of electrons in hot gas in galaxy clusters leads to a distortion of the spectrum. The distortion is quantifiable by the Compton parameter $y = NkT_e/m_ec^2$, where N is the number of scatterings that occur.

   (a) Explain in words (or maybe a picture) why the spectral distortion can be distinguished from variation of the background CMB temperature from measuring the spectrum alone.

   (b) Estimate y for a galaxy cluster (use the total optical depth to scattering of $\tau \sim 0.003$ from Problem Set #5, and assume $T_e \sim 10^8$ K). On the Rayleigh-Jeans tail of the CMB light, what is the induced fractional difference in the intensity of observed light?

2. Imagine a set of Cherenkov detectors on the wall of a big vat of water, say with refractive index of 1.3. If an electron is created that is heading directly at the wall and briefly emits Cherenkov radiation, it will lead to a set of detections arranged in a ring. Write down how the size of the ring depends on distance to the wall and β for the electron.

3. For a Galactic magnetic field of $B \sim \mu$G, and assuming a mean electron density of $n_e \sim 0.1$ cm^{-3}, what will $\mathrm{d}t/\mathrm{d}\nu$ (i.e. dispersion) and $\mathrm{d}\theta/\mathrm{d}\nu$ (i.e. Faraday rotation) be of a pulsar 1 kpc away be, assuming the magnetic field is toward us along the line of sight. If the magnetic field in the Galactic disk were oriented in azimuthally symmetric circles (it is not!) how would the rotation measure depend on the observed Galactic longitude of the pulsar?

4. A calcium atom is in configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d5p$. What terms are associated with this configuration and which do you expect to be lowest in energy based on Hund's rules? What levels can arise from the lowest energy term?