PROBLEM 9: INTERGALACTIC MAGNETIC FIELD

- Certain blazars have SEDs extending beyond TeV photon energies. These gamma-ray photons interact with background radiation, producing electron-positron pairs.

- Consider an electron of energy $E_\mathrm{e} = \gamma m_\mathrm{e} c^2 = 1$ TeV. Such electron is subject to radiative cooling due to inverse Compton (IC) scattering of the Cosmic Microwave Background (CMB). The cooling rate is $\dfrac{\mathrm{d}\gamma}{\mathrm{d}t} = -\dfrac{4\sigma_\mathrm{T}}{3 m_\mathrm{e} c}\gamma^2 u_\mathrm{CMB}$, where $u_\mathrm{CMB} \simeq 0.25$ eV/cm^3 is the CMB energy density, σ_T is the Thomson cross section.

- Please calculate the cooling length $D_\mathrm{IC/CMB} = c t_\mathrm{IC/CMB} = \dfrac{c\gamma}{|\,\mathrm{d}\gamma/\mathrm{d}t\,|}$.

- What is the magnetic field strength B, for which the Larmor radius of our electron is $R_\mathrm{L} = D_\mathrm{IC/CMB}$?

This problem is worth 5 points. Solutions should be sent as 1-page PDF files to knalew@camk.edu.pl before the next lecture.

PROBLEM 9: SOLUTION

- electron Lorentz factor: $\gamma = \dfrac{E_\mathrm{e}}{m_\mathrm{e}c^2} = \dfrac{1\ \mathrm{TeV}}{511\ \mathrm{keV}} \simeq 2 \times 10^6$

- cooling length:

$$D_\mathrm{IC/CMB} = \frac{c\gamma}{(4\sigma_\mathrm{T}/3m_\mathrm{e}c)\gamma^2 u_\mathrm{CMB}} = \frac{3m_\mathrm{e}c^2}{4\sigma_\mathrm{T}\gamma u_\mathrm{CMB}} \simeq 0.4\ \mathrm{Mpc}$$

- Larmor radius: $R_\mathrm{L} = \dfrac{E_\mathrm{e}}{eB} = D_\mathrm{IC/CMB}$

- magnetic field strength:

$$B = \frac{E_\mathrm{e}}{eD_\mathrm{IC/CMB}} = \frac{4\sigma_\mathrm{T}}{3e}\gamma^2 u_\mathrm{CMB} \simeq 3 \times 10^{-15}\ \mathrm{G}$$