Homework Set (Week 10)
Introduction to Astroparticle Physics

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1 Galactic axion dark matter and the local Θ value

The pseudoscalar axion field can be expressed in the form $\Phi = \Theta f_a$ where f_a is the Peccei-Quinn scale and $-\pi < \Theta < +\pi$ an angular variable that represents the Θ parameter of QCD. If axions are indeed the dark matter of our galaxy, how large is Θ in our neighborhood?

Hints: The local dark matter density is taken to be $\rho_{\rm DM} = 300$ MeV cm^{-3}. The energy density of the nonrelativistic axion field is $\frac{1}{2}(m_a^2\Phi^2 + \dot\Phi^2)$. The relation between the axion mass m_a and f_a was given in the lectures to be $m_a f_a = m_\pi f_\pi \sqrt{z}/(1+z)$ where $z = m_u/m_d = 0.56$ is the up/down quark mass ratio.

2 Occupation number of galactic dark matter axions

If axions are the dark matter of the galaxy, how large are the occupation numbers of the axion field modes? Numerical value, assuming the axion mass is $m_a = 10$ μeV?

Hint: Assume the local dark matter density $\rho_{\rm DM} = 300$ MeV cm^{-3} and assume the velocity distribution corresponds to an isothermal halo model of the form

$$\frac{{\rm d}n}{{\rm d}v} = n_0 \frac{4\,v^2}{\sqrt{\pi}\,\sigma^3}\,{\rm e}^{-v^2/\sigma^2}$$

with $\sigma = v_{\rm rot} = 220$ km s^{-1}.