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Astroparticle Physics: Problem Sheet 2

1. In a weak-field small-angle approximation, the axion-photon conversion probability for an axion passing through a coherent transverse magnetic field strength B and length L behaves as ($1/M$ is the axion-photon coupling)

$$P(a \to \gamma) = \frac{B^2 L^2}{M^2}$$

Why does this formula show that this is a quantum-mechanical process?

The CAST experiment at CERN searches for solar axions by looking for axion-photon conversion within sealed LHC magnets pointing at the sun. Assuming $M = 10^{11}$GeV, estimate the production rate of solar axions necessary to produce a single event in 100 hours of observing time.

2. Write the probability of axion-photon conversion (definitions as in question 1) as

$$P(a \to \gamma) = \sin^2(2\theta) \sin^2\left(\frac{\Delta}{\cos 2\theta}\right),$$

with

$$\tan 2\theta = \frac{2B\omega}{M\left(m_a^2 - m_\gamma^2\right)}$$

and

$$\Delta = \frac{(m_a^2 - m_\gamma^2)L}{4\omega}.$$

Take $M = 10^{11}$GeV and plot $P(a \to \gamma)$ for axion energies between 0.1 keV and 10 MeV (use a log scale), for domains with magnetic field 3×10^{-10}T and lengths 1, 3 and 10 kiloparsec. What would happen if an axion passes through many domains, in each of which both the domain length and the direction of the magnetic field changes? Ideally illustrate this graphically and also discuss weaker couplings (e.g. $M = 10^{13}$GeV)

While astrophysical sources of axions are not known, there are many astrophysical sources of photons. Suggest ways to use the inverse process $\gamma \to a$ to search for and constrain axion-like particles and their properties.