Production and Detection of an Axion Dark Matter Echo

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OUTLINE

Stimulated axion decay into two photons (The Echo)

The Echo in a cold flow

The Caustic Ring Halo Model

The Isothermal Halo Model

Sensitivity of our proposal

Conclusions
Stimulated axion decay into two photons

\[ \tau_0^a = \frac{64\pi}{m^3 g^2} \]

axion life-time for spontaneous decay

\[ m = 10^{-5}\text{eV} \]
\[ g = 10^{-15}\text{GeV}^{-1} \]

\[ \tau_a = \frac{\tau_0^a}{1 + f_\gamma} \]

Actual Axion Life-Time

\[ f_\gamma = \frac{16\pi^2 \rho_\gamma}{m^3 \Delta \omega} \]

stimulated axion decay

\[ \omega_\gamma = \frac{m}{2} \]

Let’s suppose a power of 1kWatt with a bandwidth of 1MHz during a time of 1 second in a volume of 1 meter cube

\[ f_\gamma \sim 10^{25} \]
Stimulated axion decay into two photons (The Echo)

\[ P_0 \xrightarrow{n_0} \quad \gamma_0 \quad \xrightarrow{n_0} \quad P_0 \]

\[ P_0 \xrightarrow{n_0} \quad \gamma_0 \quad \xrightarrow{a} \quad \gamma \quad \xrightarrow{\gamma} \quad \text{ECHO} \]

\[ P_0 = \frac{1}{16} g^2 \rho \frac{dP_0}{d\nu} t \]

\[ \omega_0 = \omega_- = \frac{m}{2} \]

\[ P_0 = 1\text{kW} \quad t = 1000\text{s} \]

Isothermal dark matter model

\[ P_- \sim 10^{-21}\text{W} \]
The Echo in a cold flow

\[ \omega_0 = \frac{m}{2}(1 + v_\parallel) + \mathcal{O}(v^2) \]

\[ \omega_- = \frac{m}{2}(1 - v_\parallel) + \mathcal{O}(v^2) \]

\[ \phi \simeq 2 |v_\perp| \]

The echo is spread spatially and there is a maximum time during which the echo arrives to the detector

\[ t_{\text{max}} = C \frac{R}{|v_\perp|} \]
The Echo in a cold flow

\[ \rho = \int d^3v \frac{d^3 \rho}{dv^3}(\vec{v}) \]

The echo is spread in frequency

\[ \delta \omega_\perp = \frac{m}{2} \delta v_\parallel \]

\[ P_c = \frac{1}{16} g^2 \rho \frac{dP_0}{d\nu} C \frac{R}{|v_\perp|} \]
The Caustic Ring Halo Model

The local dark matter distribution is dominated by a single flow

\[ \nu = 300 \text{km/s} \quad \delta \nu = 70 \text{m/s} \quad \rho = 1 \text{GeV/cm}^3 \]

\[ B = 4 \times 10^{-8} \text{m} \]

\[ \theta = 0.017 \quad \nu_\perp = 5 \text{km/s} \]
The Isothermal Halo Model

The velocity distribution is Gaussian

\[ \nu = 220 \text{ km/s} \quad \delta \nu = 270 \text{ km/s} \]

\[ \rho = 0.3 \text{ GeV/cm}^3 \]

The echo is spread in all directions

\[ \left\langle \frac{1}{|\nu_\perp|} \right\rangle = \frac{1}{124 \text{ km/s}} \]

\[ B = 1.7 \times 10^{-4} m \]
Sensitivity of our proposal

\[ \frac{s}{n} = \frac{P_c}{T_n} \sqrt{\frac{t_m}{B}} \]

Dicke’s radiometer equation

**Caustic Ring Model**

\[ \frac{dE_0}{d\ln(m)} = 6.5\text{MWyear} \left( \frac{s/n}{5} \right) \left( \frac{10^{-4}\text{eV}}{m} \right)^{1/2} \left( \frac{0.36}{g_\gamma} \right)^2 \left( \frac{T_n}{20\text{K}} \right) \left( \frac{\text{GeV/cm}^3}{\rho} \right) \]

\[ \left( \frac{0.3}{C} \right) \left( \frac{t_m}{10^{-2}\text{s}} \right)^{1/2} \left( \frac{50\text{m}}{R} \right) \left( \frac{|v_\perp|}{5\text{km/s}} \right) \]

**Isothermal Model**

\[ \frac{dE_0}{d\ln(m)} = 4.8\text{GWyear} \left( \frac{s/n}{5} \right) \left( \frac{10^{-4}\text{eV}}{m} \right)^{1/2} \left( \frac{0.36}{g_\gamma} \right)^2 \left( \frac{T_n}{20\text{K}} \right) \]

\[ \left( \frac{0.3}{C} \right) \left( \frac{t_m}{2 \times 10^{-4}\text{s}} \right)^{1/2} \left( \frac{50\text{m}}{R} \right) \]
Sensitivity of our proposal

10 MWyear per factor 2

\[ \rho = 0.3 \text{ GeV/cm}^3 \quad \text{ Isothermal Model } \]

\[ \rho = 1 \text{ GeV/cm}^3 \quad \text{ Caustic Ring Model } \]

\[ \rho = 10 \text{ GeV/cm}^3 \]
Sensitivity of our proposal

10 MW year per factor 2
Conclusions

The echo method is attractive from the experimental point of view, specially for radio-astronomy technology

The echo method is applicable over a wide range of axion mass. Where the Earth’s atmosphere is mostly transparent

\[ 2.5 \times 10^{-7} \text{eV} < m < 2.5 \times 10^{-4} \text{eV} \]

The echo method is much better in the Caustic Ring Model because the density is bigger, has less spread in frequency and less spread in physical space

The sensitivity covers a wide unexplored axion parameter space
Thanks!