Production and Detection of an Axion Dark Matter Echo

Pierre Sikivie
Ariel Arza

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OUTLINE

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Stimulated axion decay into two photons

$$\tau_a^0 = \frac{64\pi}{m^3 g^2}$$ **axion life-time for spontaneous decay**

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

$$\tau_a^0 \sim 10^{42}\text{yr}$$

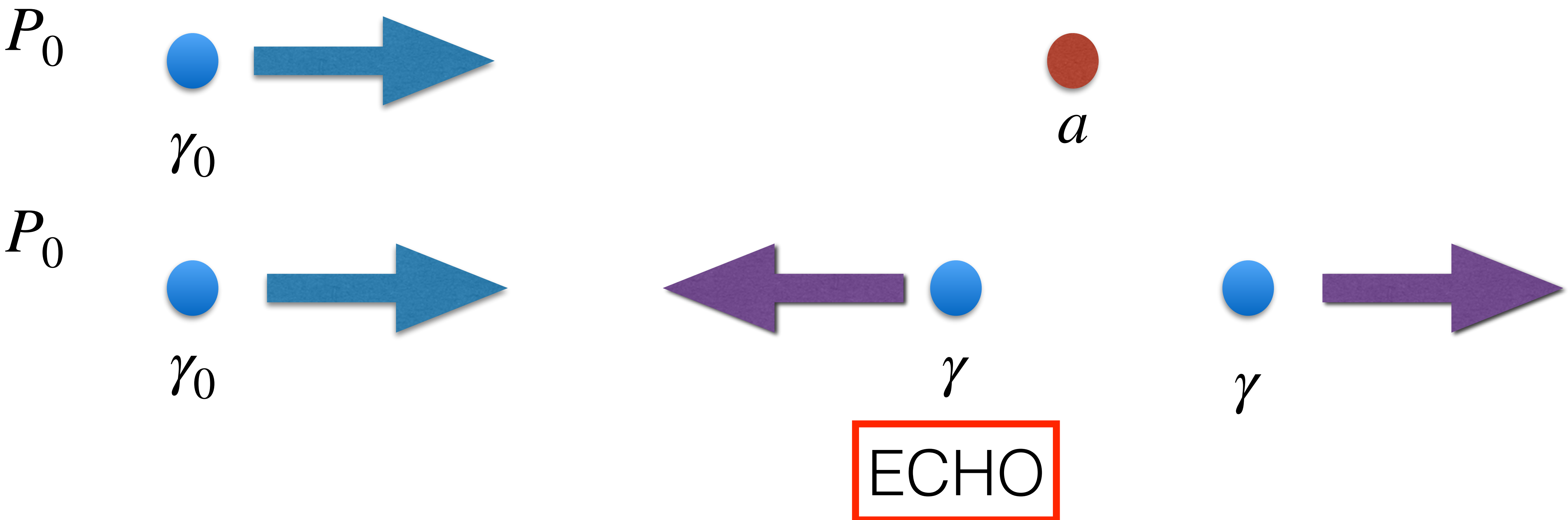
$$\tau_a = \frac{\tau_a^0}{1 + f_\gamma}$$ **Actual Axion Life-Time**

$$f_\gamma = \frac{16\pi^2 \rho_\gamma}{m^3 \Delta\omega}$$ **stimulated axion decay** $$\omega_\gamma = m/2$$

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)

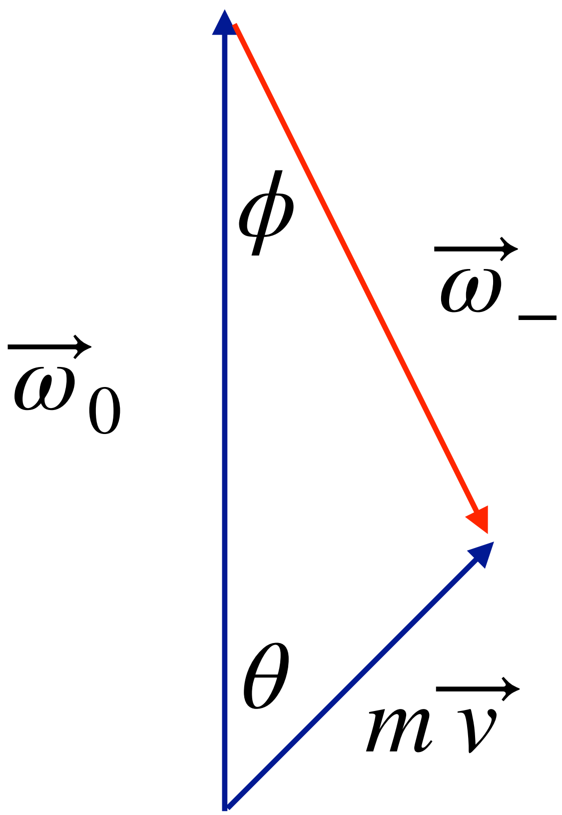


$$P_- = \frac{1}{16} g^2 \rho \frac{dP_0}{d\nu} t \qquad \omega_0 = \omega_- = \frac{m}{2}$$

$P_0 = 1\text{kW}$ $\qquad t = 1000\text{s}$

Isothermal dark matter model → $P_- \sim 10^{-21}\text{W}$

The Echo in a cold flow



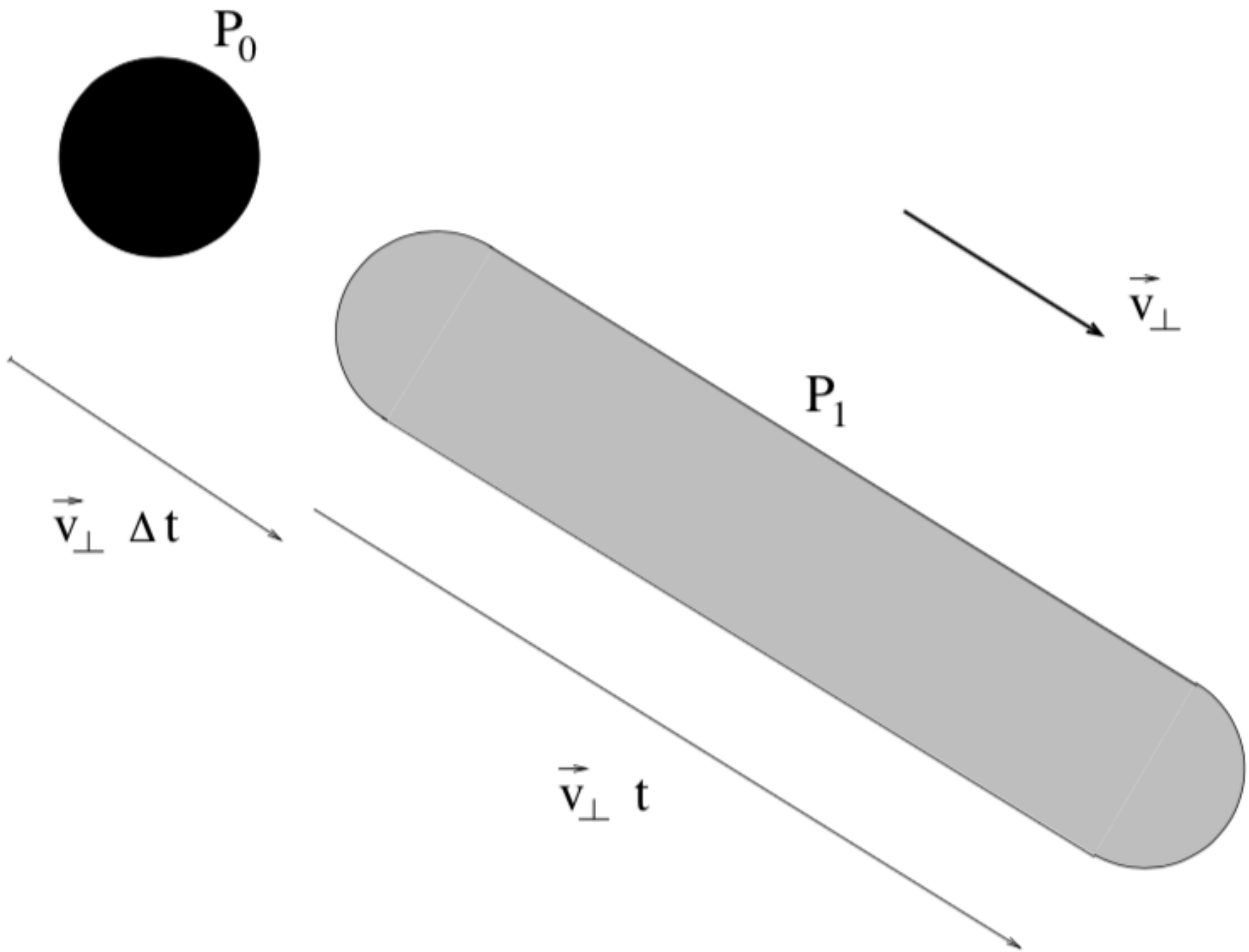
$$\omega_0 = \frac{m}{2}(1 + v_{\parallel}) + \mathcal{O}(v^2)$$

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

$$\phi \simeq 2\,|\,v_{\perp}\,|$$

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

$$t_{max} = C\frac{R}{|\,v_{\perp}\,|}$$


P_0
$\vec{v}_\perp$
P_1
$\vec{v}_\perp \; \Delta t$
$\vec{v}_\perp \; t$

The Echo in a cold flow

$$\rho = \int d^3 v \frac{d^3 \rho}{dv^3}(\overrightarrow{v})$$

The echo is spread in frequency

$$\delta\omega_- = \frac{m}{2}\delta v_\parallel$$

$$P_c = \frac{1}{16} g^2 \rho \frac{dP_0}{d\nu} C \frac{R}{|v_\perp|}$$

The Caustic Ring Halo Model

The local dark matter distribution is dominated by a single flow

$v = 300\text{km/s}$

$\delta v = 70\text{m/s}$

$\rho = 1\text{GeV/cm}^3$

$B = 4 \times 10^{-8} m$

$\theta = 0.017 \Rightarrow v_\perp = 5\text{km/s}$

The Isothermal Halo Model

The velocity distribution is Gaussian

$v = 220\text{km/s}$ $\delta v = 270\text{km/s}$

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

The echo is spread in all directions

$$\left\langle \frac{1}{|v_\perp|} \right\rangle = \frac{1}{124\text{km/s}}$$

$$B = 1.7 \times 10^{-4} m$$

Sensitivity of our proposal

$$s/n = \frac{P_c}{T_n}\sqrt{\frac{t_m}{B}}$$

Dicke's radiometer equation

Caustic Ring Model

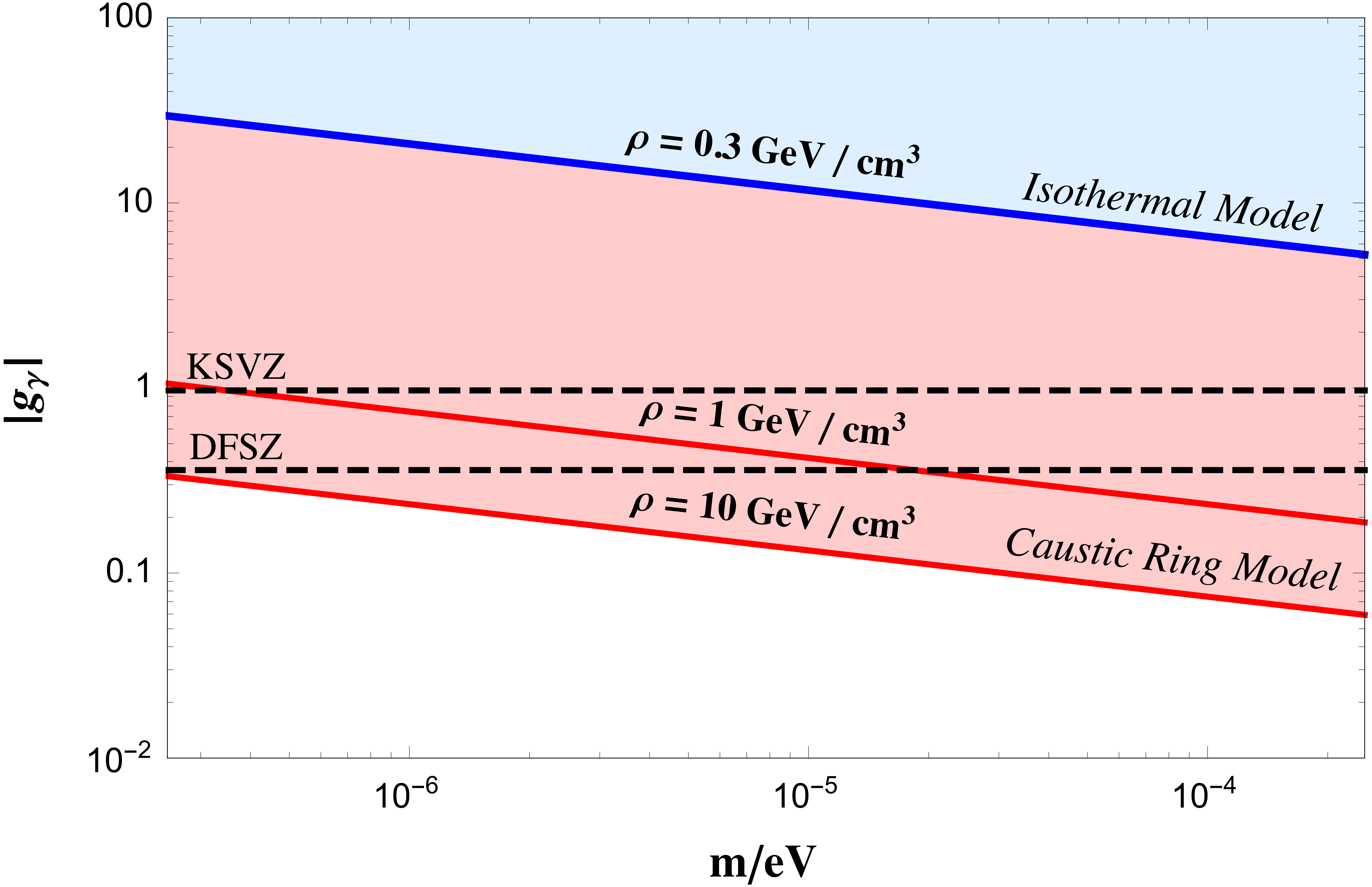
$$\frac{dE_0}{d\ln(m)} = 6.5\text{MWyear}\left(\frac{s/n}{5}\right)\left(\frac{10^{-4}\text{eV}}{m}\right)^{1/2}\left(\frac{0.36}{g_\gamma}\right)^{2}\left(\frac{T_n}{20\text{K}}\right)\left(\frac{\text{GeV/cm}^3}{\rho}\right)$$
$$\left(\frac{0.3}{C}\right)\left(\frac{t_m}{10^{-2}\text{s}}\right)^{1/2}\left(\frac{50\text{m}}{R}\right)\left(\frac{|v_\perp|}{5\text{km/s}}\right)$$

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



Sensitivity of our proposal

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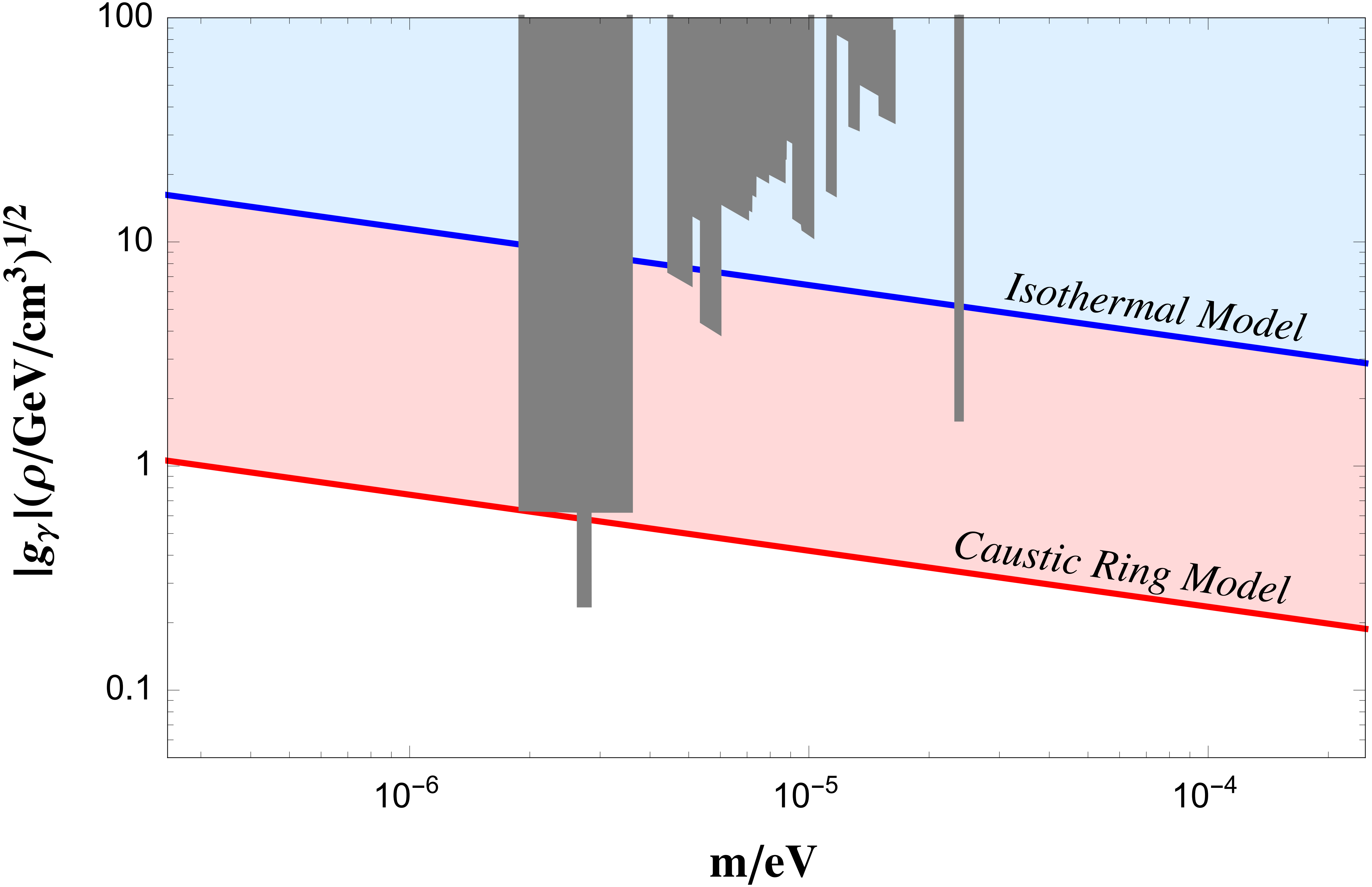

Conclusions

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!