A search for DM axions with a Fabry-Pérot haloscope

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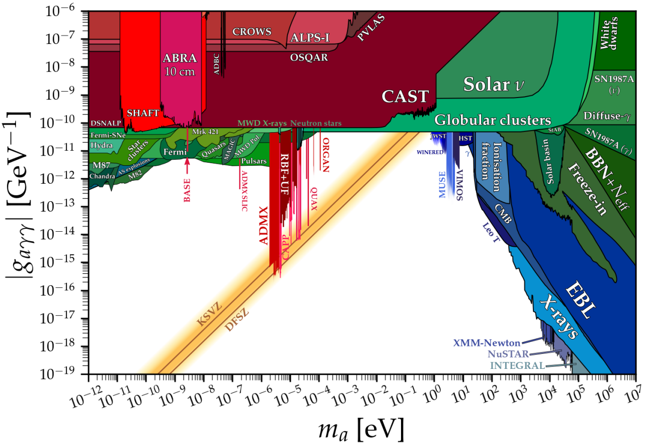
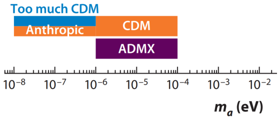
DM Axion search



source: https://cajohare.github.io/AxionLimits/docs/ap.html

CDM Axion:

$\sim 10^{-6} - 10^{-4} eV$

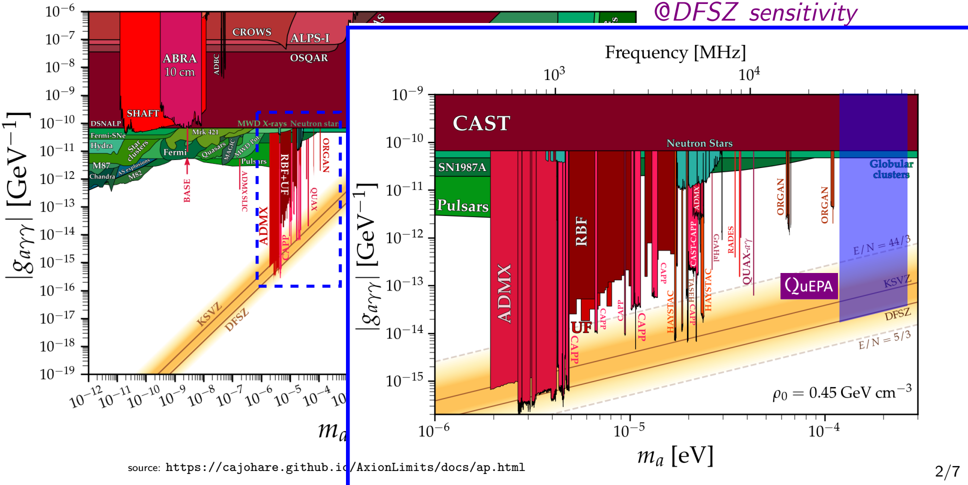


source: 10.1146/annurev.nucl.012809.104433

DM Axion search

Interested range: $125 - 250\ \mu eV$

@DFSZ sensitivity

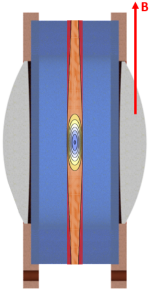


source: `https://cajohare.github.io/AxionLimits/docs/ap.html`

Axion haloscope: overview

- Axion-modified electrodynamics
- Fabry-Pérot cavity
- Fabry-Pérot cavity as Axion haloscope

$$\nabla \times \mathbf{H} = \mathbf{J}_f + \frac{\partial \mathbf{D}}{\partial t} - g_{a\gamma\gamma}\sqrt{\frac{\epsilon_0}{\mu_0}}\mathbf{B}\frac{\partial \mathbf{a}}{\partial t}$$



Jack A. Devlin, TRIUMF 9/4/2023,A new search for dark matter axions using quantum technologies

Axion electrodynamics

Macroscopic
Maxwell equations

$$\nabla \cdot \mathbf{D} = \rho_f$$

$$\nabla \times \mathbf{H} = \mathbf{J}_f + \frac{\partial \mathbf{D}}{\partial t}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

Axion modified Electrodynamics

$$\mathcal{L} = \frac{1}{2}\partial_\mu - \frac{1}{2}m_a^2 a^2 - \frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{4}g_{a\gamma\gamma}F_{\mu\nu}\tilde{F}^{\mu\nu}$$

$$\nabla \cdot \mathbf{D} = \rho_f + g_{a\gamma\gamma}\sqrt{\frac{\epsilon_0}{\mu_0}}\mathbf{B} \cdot \nabla \mathbf{a}$$

$$\nabla \times \mathbf{H} = \mathbf{J}_f + \frac{\partial \mathbf{D}}{\partial t} - g_{a\gamma\gamma}\sqrt{\frac{\epsilon_0}{\mu_0}}\left(\mathbf{B}\frac{\partial \mathbf{a}}{\partial t} + \nabla \mathbf{a} \times \mathbf{E}\right)$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

Source for Axion-electrodynamics https://doi.org/10.1016/j.dark.2019.100339

Axion electrodynamics

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$$\nabla \cdot \mathbf{D} = \rho_f + \cancel{g_{a\gamma\gamma} \sqrt{\frac{\epsilon_0}{\mu_0}} \mathbf{B} \cdot \nabla \mathbf{a}}$$

$$\nabla \times \mathbf{H} = \mathbf{J}_f + \frac{\partial \mathbf{D}}{\partial t} - g_{a\gamma\gamma} \sqrt{\frac{\epsilon_0}{\mu_0}} \left(\mathbf{B} \frac{\partial \mathbf{a}}{\partial t} + \cancel{\nabla \mathbf{a} \times \mathbf{E}} \right)$$

$$\nabla \cdot \mathbf{B} = 0$$

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Spatial dependence negligible for local experiments

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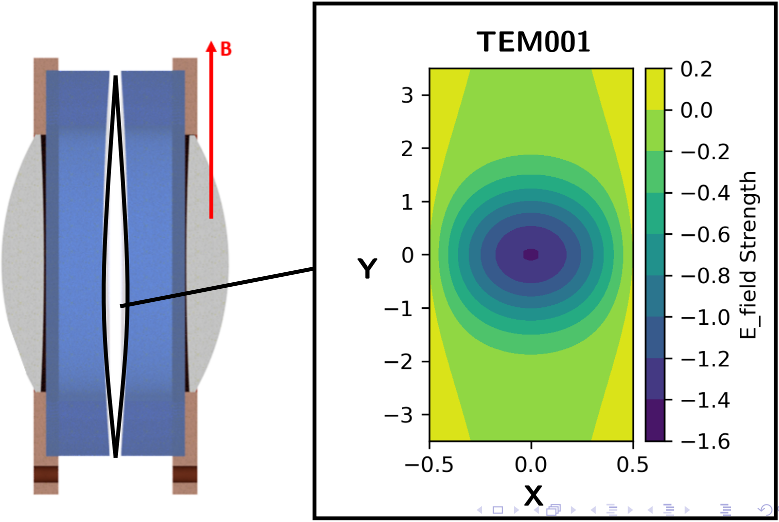
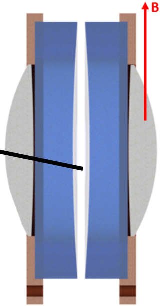
Fabry-Pérot cavity



Fabry-Pérot as Axion haloscope

Sourced electric field
$E = \sum e^{-i\omega_a t} E_m \mathcal{E}_m$



γ extraction power
$P = c^2 \epsilon_0 k \frac{Q_m}{\omega_m} g_{a\gamma\gamma}^2 V_m B^2 \rho_{DM}$

Goals:

$Q \sim 10^6$ for desired cavity mode

Enable tunability to scan

$30 - 60 GHz \Leftrightarrow 125 - 250 \mu eV$

Motivated by **ADMX, ORPHEUS,...**

Larger mode volume than a cylindrical cavity operating in the TM010 mode

Thank you!