Astrophysical Probes of Axion(Like) particles

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Model and motivations

It is possible to extend the Lagrangian of the Standard Model with a CP-violating term in the QCD sector.

$$L_{SM} \supset -\theta \frac{g^2}{16\pi} Tr(G\tilde{G})$$

However this operatore would generate an electric dipole moment for the neutron; experiments now imply

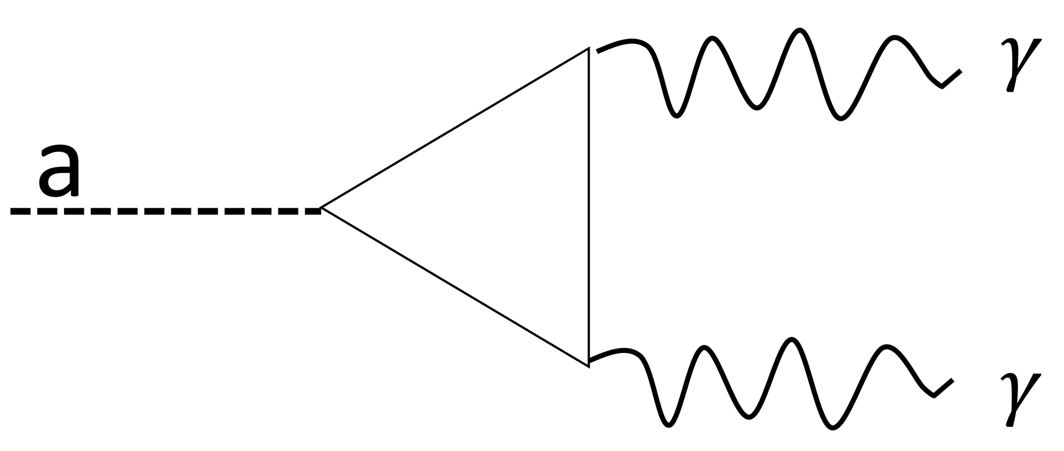
$$\theta \le 10^{-10}$$ CP-STRONG PROBLEM

SOLUTION

Promote θ to a field a(x) which dynamically relaxes to zero : ***the Axion***

$$\mathcal{L} \supset -\frac{a(x)}{f_a}\frac{g^2}{16\pi} Tr(G\tilde{G})$$

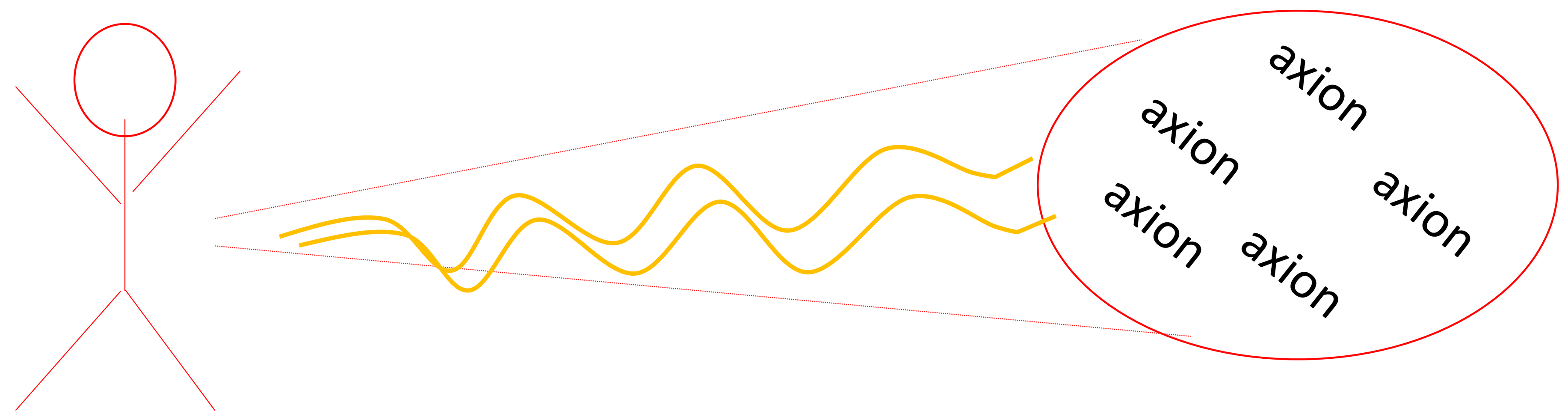
Axion decay



$$\tau_a \sim \frac{1}{{m_a}^3 {g_{a\gamma\gamma}}^2}$$

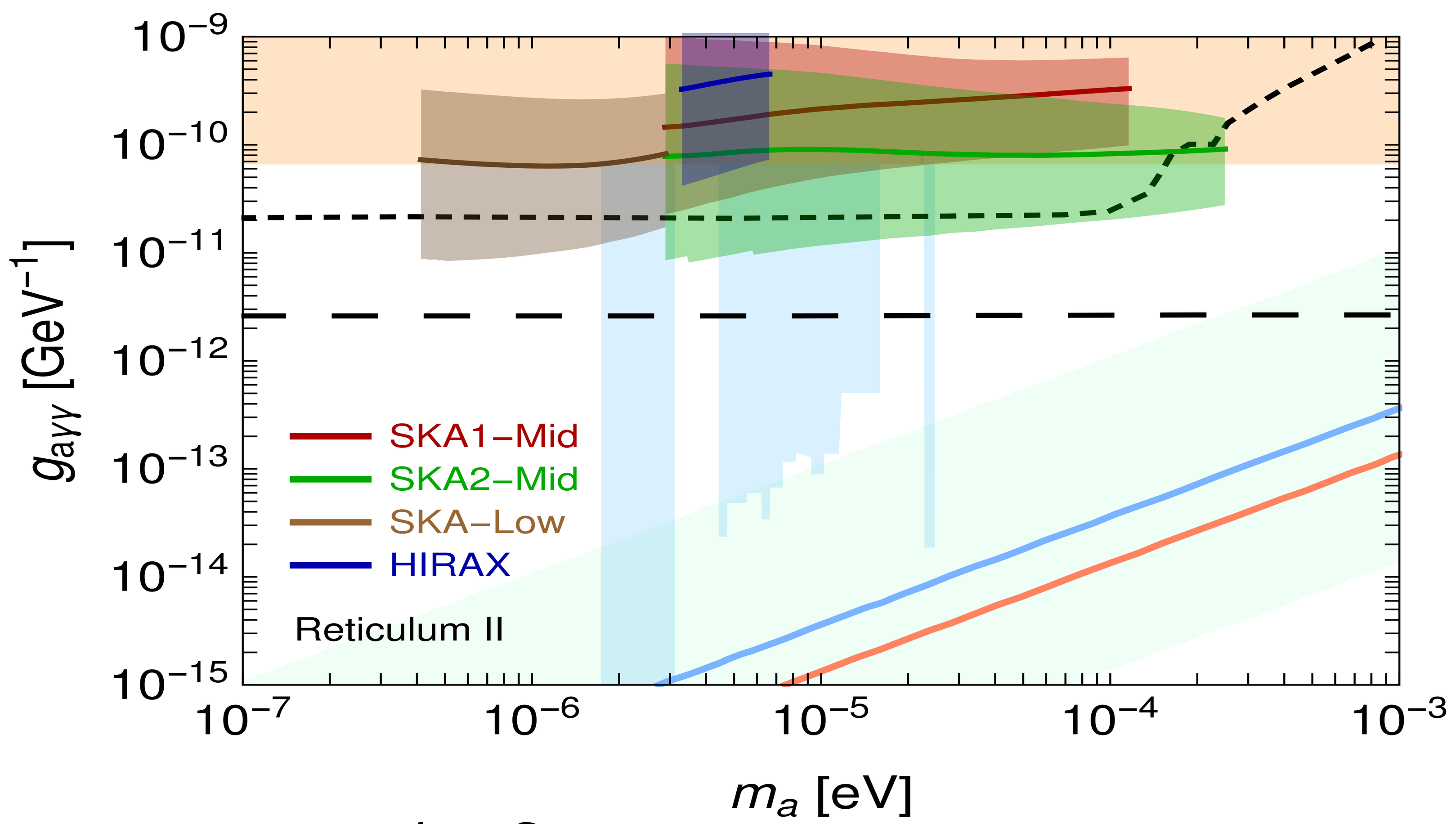
A numerical example

$m_a = 10^{-6} eV$
$g_{a\gamma\gamma} = 10^{-10} GeV^{-1}$ → $\tau_a \sim 10^{32} years$



$$S_{decay} = \frac{\Gamma_a}{4\pi\Delta\nu}\int dl d\Omega \rho_a(l,\Omega)\,(1+2f_\gamma(l,\Omega))$$

We point our **radiotelescope** to astrophysical objects like Dwarf Galaxies and look for *photons* with $E_\gamma = m_a/2$ coming from axion decay.



$$T_{ant} = \frac{A_{eff} S}{k_B}$$

$$T_{min} = \frac{T_{sys}}{\sqrt{t_{obs}\Delta B}}$$

$$\Rightarrow \frac{S}{N} = \frac{T_{ant}}{T_{min}}$$

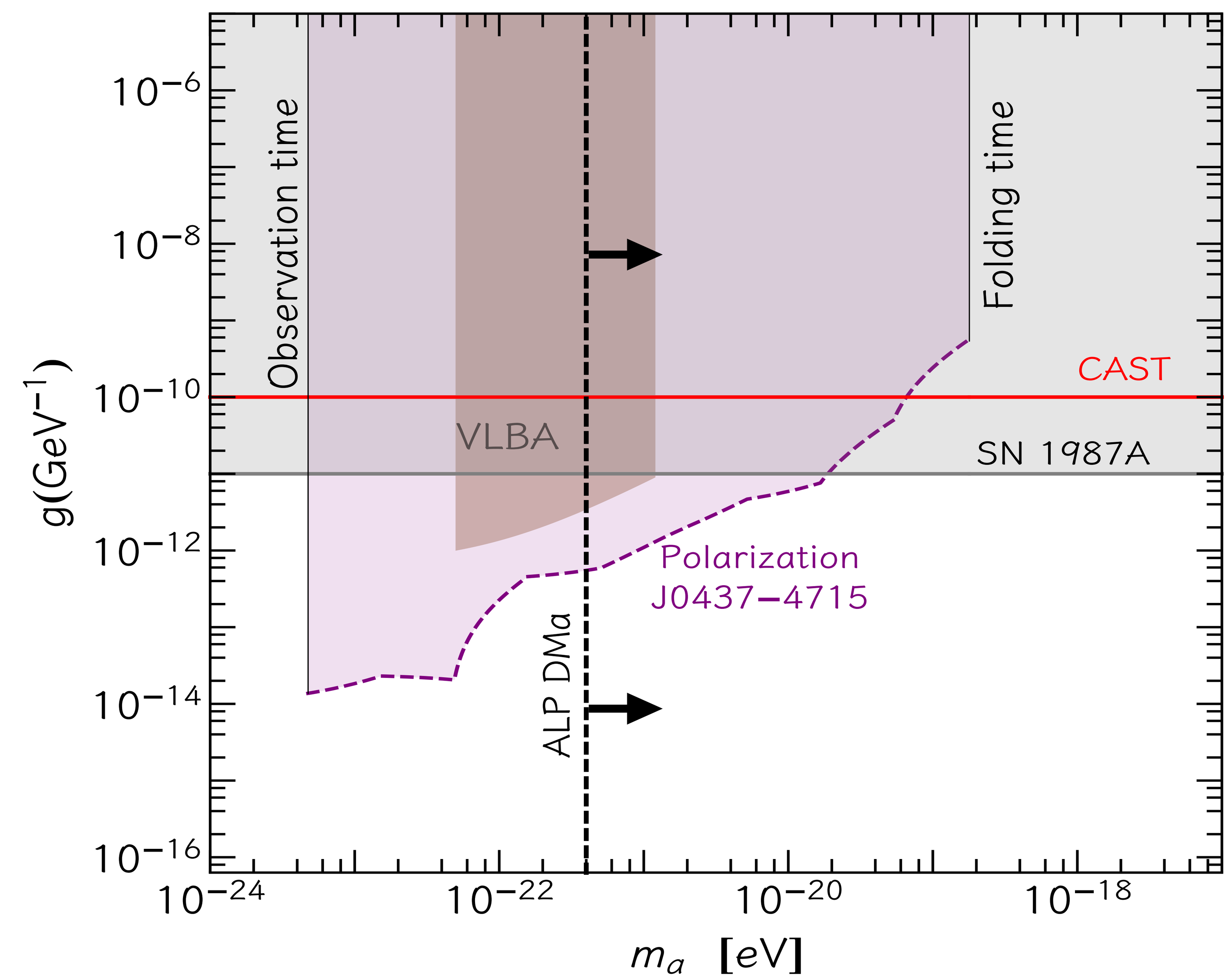
Pulsar polarization measurements

Modified Maxwell Equations

$$\partial_\mu F^{\mu\nu} + \frac{1}{2} g_{a\gamma\gamma}\epsilon^{\mu\nu\alpha\beta}\partial_\mu(aF_{\alpha\beta}) = 0$$

Due to *parity violation* photons with different chiralities propagate at different speed. Given a polarized signal this induces a *rotation of the polarization angle*

$$\theta \sim 1.4 \cdot 10^{-2} \sin(m_a t + \delta) \frac{g_{a\gamma\gamma}}{10^{-12} GeV^{-1}} \frac{10^{-22} eV}{m_a}$$



Summary

Axions and axion-like particles are fascinating dark matter candidates, and astrophysics can provide us new avenues for their detection. In particular, future radio telescopes like SKA can lead to a *discovery* of the axion or an improvement by one order of magnitude of the actual constraints in the mass range $m_a \sim 10^{-6} - 10^{-4} eV$ .Pulsars can instead help to probe very light axion-like particles (aka fuzzy dark matter). Actual pulsar data provide the strongest constraints for masses around $m_a \sim 10^{-20} eV$