Direct detection of dark matter through magnetic conversion of axions with a hyper-frequency detector

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Theoretical context

QCD contains $\mathscr{L}_\theta = \frac{\theta}{32\pi^2}\mathrm{Tr}\left(G_{\mu\nu}\tilde{G}^{\mu\nu}\right)$ (vacuum, quark mixing)

θ not observed ($\theta < 10^{-10}$) → Why is QCD CP-invariant?

Fine-tuning problem

Dark matter

Galaxies | Galaxy clusters | CMB

Rotation curves | Velocity dispersion | Collisions | Primordial matter waves

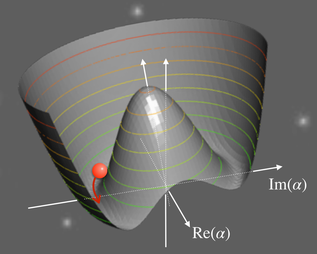
84% of mass is made of unknown

New particle is required

Axions

New U(1) symmetry explain QCD CP conservation

⇒ New particle: the axion is 0⁻, neutral, very light

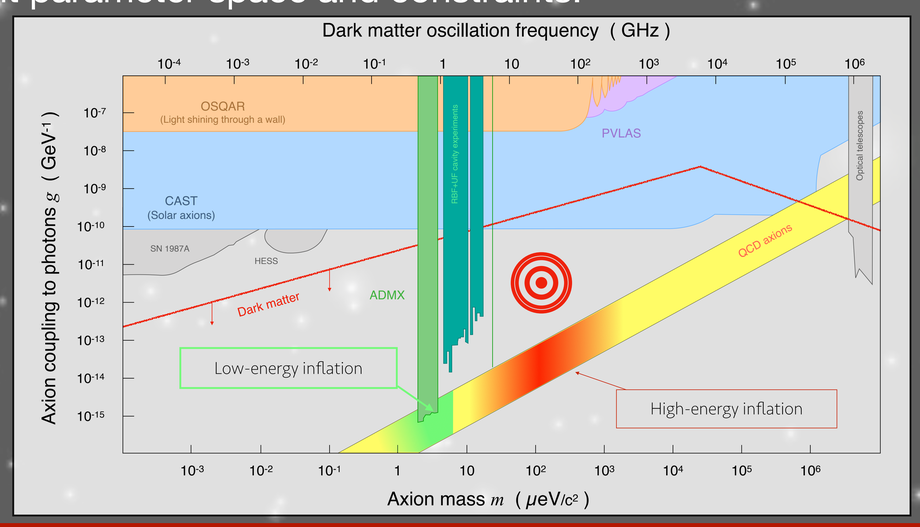


Oscillations after explicit symmetry breaking due to QCD phase transition

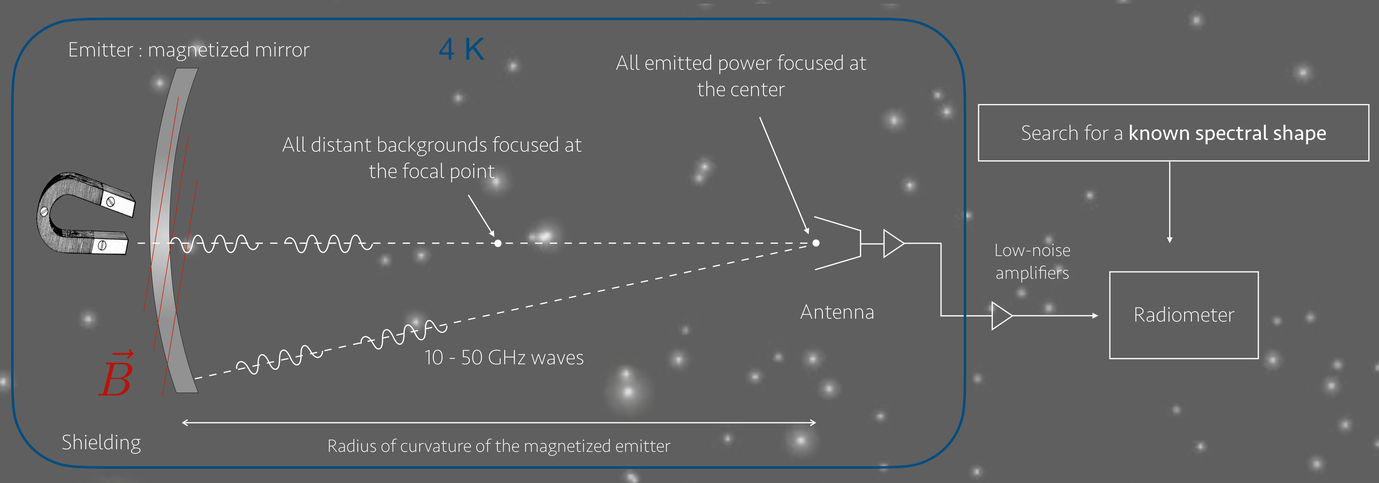
⇒ The axion could be the dark matter

New $\mathscr{L}$ contains effective coupling to photons $gF_{\mu\nu}\tilde{F}^{\mu\nu} \propto g\vec{E}\cdot\vec{B}$

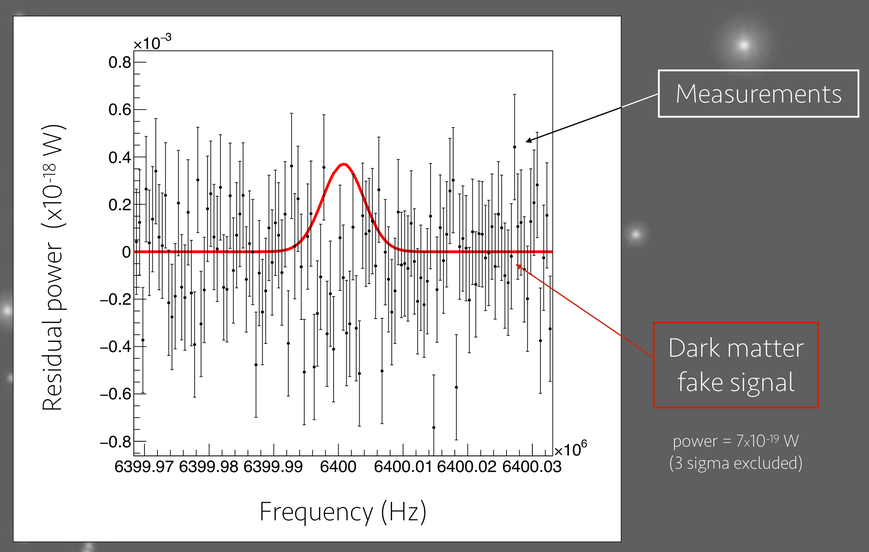
Relevant parameter space and constraints:



The experiment



Dark matter signal:
excess power with known spectral shape



Cryogenic environment: 4 K, He-cooled

Antenna: custom-design horns

Phase 1: permanent magnet (cryo)

Under construction at CEA Saclay

Signal processing with a spectrum analyzer

Phase 2: High-T_c superconductors

Proposed work

- Full characterization of the signal processing with dedicated cryogenic test bench
- Sensitivity estimate for the full magnetic experiment
- Optimization of the detection chain
- Commissionning of the axion experiment, with permanent magnets and superconducting magnets
- Data analysis for phase 1 and 2
- Constraints on axion parameters

The team at CEA

10 physicists, engineers, technicians from IRFU:

Particle Physics Department

Department of Electronics, Detectors, Instrumentation for Physics

Department of Accelerators, Cryogenics and Magnetism

Department of System Engineering

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