SEARCH FOR HIGH FREQUENCY DARK MATTER AXIONS

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Dark Matter

Evidence across many length scales:

From oscillations in the CMB…

…to stellar velocities in galaxies.
Strong CP Problem

Theory of strong force contains several charge/parity symmetry violating terms of expected order 1. Measurements of neutron electric dipole moment reveal no violation, to order $10^{-9}$.

The Peccei-Quinn Mechanism provides an answer.
The Axion

Weinberg, Wilczek: this implies a new particle, the axion!

- Only decay is to 2 photons, lifetime $\sim 10^{50}$ sec $\rightarrow$ Dark.
- Has a small mass $\rightarrow$ Matter.
- In general, predicted properties match cold dark matter.
Axion Haloscope

A strong magnetic field converts axions into detectable photons.

Enhance measurement by setting cavity resonance to axion frequency.

Enhanced coupling depends on $\mathbf{E} \cdot \mathbf{B}$ in cavity.
Axion Mass Window

Classical Axion Dark Matter Window

Axion Coupling $|G_{A\gamma\gamma}|$ (GeV$^{-1}$)

Axion Mass $m_A$ (eV)

- Lasers
- Helioscopes
- RF Cavity
- Too Much Dark Matter
- Axion Cold Dark Matter
- ADMX
- SN1987A Excluded
- Dark Matter Too Hot
- Telescopes
Open Resonators

Reflector

Magnetic field

Wire planes

Reflector

To Detector

Electric field
Resonance Tuning

Power transmission

Frequency
Data-Taking
Automated Control
Analysis

Normalize power spectra and divide out structure:
Analysis

Predicted Axion Coupling for a Single Scan

\( (G_{a\gamma\gamma})^2 \) Prediction (GeV\(^{-2} \))

Frequency (MHz)
Analysis

Predicted Axion Coupling for All Scans

\((G_{a\gamma\gamma})^2\) Prediction (GeV\(^{-2}\))
Results

Axion Coupling Limits

Axion Mass (μeV)

Orpheus

ALPS (2010)

CAST (2011)

QCD axions
Further Work

- Increase B field by using superconducting wire
- Decrease noise by operating at cryogenic temperature
- Increase cavity Q with better reflectors
Conclusions

• The axion, if real, explains two mysteries: dark matter and the strong CP problem.
• The open resonator technique extends ADMX’s reach to higher frequencies.
• Initial Orpheus results constrain the axion – photon coupling to be under $6 \times 10^{-7}$ for $68.2 – 72.4 \, \mu\text{eV}$ axions.
• With improvements, this technology can find or exclude high mass dark matter axions.
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