ADMX - the Axion Dark Matter eXperiment

Daniel Bowring, on behalf of the ADMX collaboration

APS-DPF 2017

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Axions and WIMPs

WIMPs scatter as quanta

- WIMP-nucleon scattering detector strategies
- Mass $\sim$ 10s-100s of GeV?

Axions scatter as classical waves

- Coherently oscillating “clouds”
- $h/p \sim 100$ m
- Phase coherent signals $\sim$ ms.
- $\mu$eV $< m_a <$ meV

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Axion mass is only loosely constrained by theory/measurement.

- \( \mathcal{L}_{a\gamma\gamma} = g_{a\gamma\gamma} a E \cdot B \)
- DFSZ model for \( a \rightarrow \gamma\gamma \) detection relevant to DM axions. Points are predictions from theory.
- ADMX has demonstrated DFSZ-compatible sensitivity.
Signal power and SNR drive haloscope design.

\[
P \approx 0.5 \times 10^{-21} \, \text{W} \cdot \left( \frac{\rho_a}{0.5 \times 10^{-21} \, \text{g} \cdot \text{cm}^3} \right) \left( \frac{f_a}{1 \, \text{GHz}} \right) \times \left( \frac{g_{a\gamma\gamma}}{0.36} \right)^2 \left( \frac{V}{500 \, \text{L}} \right) \left( \frac{B}{7 \, \text{T}} \right)^2 \left( \frac{\min(Q_c, Q_a)}{10^5} \right) C
\]

Dicke radiometer equation explains design constraints:

- Signal power is limited: \( P \propto B^2 V \)
- \( t \lesssim 100 \, \text{s} \) for realistic run schedules
- System noise temperature \( T_s = T_{\text{phys}} + T_N \)
- At the quantum limit, \( T_N \to 48 \, \text{mK} \) at 1 GHz
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ADMX Overview

- 500 MHz - 1 GHz cavity
- 7 T solenoid
- $^3$He-$^4$He dilution refrigerator
- SQUID amplifiers
Quantum-limited amplifiers

- MSA = microstrip SQUID amplifier; JPA = Josephson Parametric Amplifier
- Recall $SNR \propto 1/T_s$. 
Quantum-limited amplifiers issue \( \geq 1 \) photon of noise per resolved mode.

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C. Caves, 1982

Characterization of noise temperature

Example Cavity Noise Measurement
Multiple MSA Biases

On Resonance
150 mK Cavity

Off Resonance
300 mK Attenuator

Digitized Power (Arb. Units)

Bias #4 (Optimal)
Bias #3
Bias #2
Bias #1

Frequency (MHz)

672.25  672.3  672.35  672.4  672.45
ADMX operations overview

1. Scan cavity frequency, integrate each frequency bin to desired SNR
3. Rescan candidates
4. Detection committee reviews persistent $> 3\sigma$ candidates:
   ▶ Switch to resonant mode with poor axion coupling
   ▶ Attenuate $B$-field (recall $P \propto B^2$)
   ▶ Blind signal injection
First axion search at DFSZ sensitivity!
Projected ADMX-G2 discovery potential

![Graph showing the discovery potential of ADMX-G2 with cavity frequency and axion mass on the axes. The graph highlights the ADMX G2 discovery potential and the DFSZ region.](image-url)
Projected ADMX-G2 discovery potential

Current experiment operates at DFSZ sensitivity in 500 MHz-1 GHz range.
Projected ADMX-G2 discovery potential

ADMX “sidecar” cavity used to test piezo tuning. TM$_{010}$ mode can probe 4-6 GHz, TM$_{020}$ mode can probe 6-7 GHz.
Projected ADMX-G2 discovery potential

Fabrication underway for 4-cavity array, 1-2 GHz.
Projected ADMX-G2 discovery potential

Fermilab concept for \( \geq 2 \) GHz cavity.
Quantum computing technology may be the path to $\sim 10$ GHz searches.

Quantum nondemolition measurements with solid-state qubits allow us to count single photons, beat the standard quantum limit.

Akash Dixit, (UC student, funding from Heising-Simons Foundation, talk on Tuesday, 1:50 pm, IARC.

Please visit our new and growing lab at SiDet this Friday!
Thanks for your attention!


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