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Quantum Measurement for Axion Dark Matter Searches

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The QCD axion, originally motivated as a solution to the strong CP problem, is a compelling candidate for dark matter, and accordingly, the last decade has seen an explosion in new ideas to search for axions. Simultaneously, we have witnessed a revolution in quantum sensing and metrology, with the emergence of platforms enabling ever-greater measurement sensitivity. These platforms are now being brought to bear on axion dark matter searches, with the aim of a comprehensive probe of the phase space for QCD axions. In this talk, I briefly overview efforts to apply techniques evading the Standard Quantum Limit of amplification, such as squeezing, photon counting, and backaction evasion, to axion dark matter searches. I then focus on techniques well-suited to resonant electromagnetic probes of pre-inflationary sub-ueV axions, for which photon counting of the thermal state in the resonator is not advantageous relative to quantum-limited amplification. I describe, in particular, the RF Quantum Upconverter (RQU), a superconducting lithographed device containing a Josephson junction interferometer that upconverts kHz-MHz electromagnetic signals (corresponding to the sub-ueV mass window) to GHz signals. By leveraging mature microwave techniques as well as adapting sensitive measurement schemes utilized in cavity optomechanical systems (e.g., LIGO), the RQU can evade the Standard Quantum Limit. Recent experimental results for the RQU are discussed. I describe plans to integrate the RQU into DMRadio, an experimental campaign for sub-ueV dark matter with the ultimate goal of probing GUT-scale axions, and the Princeton Axion Search, which will probe QCD axions in the 0.8-2 ueV mass range.

Mini Symposia (Invited Talks Only)

Plenary (Invited talks only)

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