

The 2024 Chengdu Symposium on Particle Physics and Cosmology: Phase Transitions, Dark Matter and Experimental Probes (CPCS 2024)

Contribution ID: 19

Type: **not specified**

Pulsar Polarization Arrays

Monday, 30 September 2024 09:00 (30 minutes)

As one of the major dark matter candidates, the ultralight Axion-Like Dark Matter (ALDM) exhibits a pronounced wave nature on astronomical scales and offers a promising solution to small-scale structure issues within local galaxies. While the linearly polarized pulsar light travels through the ALDM galactic halo, its position angle (PA) can be subject to an oscillation induced by the ALDM Chern-Simons coupling with electromagnetic field. The Pulsar Polarization Array (PPA) is thus especially suited for the detection of the ultralight ALDM, by correlating polarization data across the arrayed pulsars. We conduct the first-ever PPA analysis to detect the ultralight ALDM, using the polarization data of 22 millisecond pulsars from the third data release of Parkes Pulsar Timing Array. To accomplish this task, we develop a Bayesian framework dedicated to analyzing the time series of PA residuals of these pulsars. We find that the PPA provides the most stringent constraints on the ALDM Chern-Simons coupling so far for the relevant mass range. We also demonstrate the crucial role of cross-correlation analysis in recognizing the nature of the derived limits.

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