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Detecting Axion Dark Matter with Black Hole Polarimetry

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The axion, as a leading dark matter candidate, is the target of many on-going and proposed experimental searches based on its coupling to photons. Ultralight axions that couple to photons can also cause polarization rotation of light which can be probed by cosmic microwave background. In this work, we show that a large axion field is inevitably developed around black holes due to the Bose-Einstein condensation of axions, enhancing the induced birefringence effects. Therefore, we propose measuring the modulation of supermassive black hole imaging polarization angles as a new probe to the axion-photon coupling of axion dark matter. The oscillating axion field around black holes induces polarization rotation on the black hole image, which is detectable and distinguishable from astrophysical effects on the polarization angle, as it exhibits distinctive temporal variability and frequency invariability. We present the range of axion-photon couplings within the axion mass range $10^{-21} - 10^{-16}$ eV that can be probed by the Event Horizon Telescope. The axion parameter space probed by black hole polarimetry will expand with the improvement in sensitivity on the polarization measurement and more black hole polarimetry targets with determined black hole masses.

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