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Exploring Axions through the Photon Ring of a Spherically Symmetric Black Hole

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In this study, we examine the phenomenon of photon axion conversion occurring in the spacetime surrounding a black hole. Observations of the black hole in the center of the M87 galaxy (M87 *) through the Event Horizon Telescope imaged polarized synchrotron emission at 230 GHz on event horizon scales. Specifically, we focus on the potential existence of a magnetic field around the supermassive black hole M87*, which could facilitate the conversion of photons into axions in close proximity to the photon sphere. While photons traverse through the curved spacetime, they spend time near the photon sphere, where conversion of these photons into axions takes place. Photons with an impact parameter below a critical value will enter the black hole's event horizon, while those with exactly the critical impact parameter will move in an unstable circular orbit around the black hole which eventually results in a bright ring. The conversion of photons to axions reduces the number of photons escaping the photon sphere, resulting in a dimming effect on the bright ring. To explore the possibilities of detecting these hypothetical axion particles, we propose observing the photon sphere using higher resolution telescopes. By doing so, we can gain valuable insights into the conversion mechanism as well as the nature of the spherically symmetric black hole geometry. Moreover, we also investigate how the photon ring luminosities are affected if the black hole possesses a charge parameter. For instance apart from U(1) electric charge, the presence of extra dimension may induce a tidal charge with a characteristic signature. It is important to note that the success of the conversion mechanism relies on the axion-photon coupling and mass. As a result, the modified luminosity of the black hole's photon ring offers a valuable means of constraining the axion's mass and coupling parameter within a certain range. Thus our findings contribute to a better understanding of photon axion conversion in the environment of a black hole spacetime and helps us explore the possible existence of extra spatial dimension.

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