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Effects of Superradiance in Active Galactic Nuclei

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A supermassive black hole (SMBH) at the core of an active galactic nucleus (AGN) provides room for the elusive ultra-light scalar particles (ULSP) to be produced through a phenomenon called \textit{superradiance}. This phenomenon produces a cloud of scalar particles around the black hole by draining its spin angular momentum. In this work, we present a study of the superradiant instability due to a scalar field in the vicinity of the central SMBH in an AGN. We begin by showing that the time-evolution of the gravitational coupling α in a realistic ambiance created by the accretion disk around the SMBH in AGN leads to interesting consequences such as the amplified growth of the scalar cloud, enhancement of the gravitational wave emission rate, and appearance of higher modes of superradiance within the age of the Universe. We then explore the consequence of superradiance on the characteristics of the AGN. Using the Novikov-Thorne model for an accretion disk, we divide the full spectrum into three wavelength bands- X-ray ($10^{-4} - 10^{-2}$ μm), UV (0.010-0.4~μm), and Vis-IR (0.4-100~μm) and observe sudden drops in the time-variations of the luminosities across these bands and Eddington ratio ($f_{\rm Edd}$) with a characteristic timescale of superradiance. Using a uniform distribution of spin and mass of the SMBHs in AGNs, we demonstrate the appearance of depleted regions and accumulations along the boundaries of these regions in the planes of different band-luminosities and $f_{\rm Edd}$. Finally, we discuss some possible signatures of superradiance that can be drawn from the observed time-variation of the AGN luminosities.

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