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Ring formation from black hole superradiance through repeated particle production on bound orbits

Ultralight bosonic fields around a rotating black hole can extract energy and angular momentum through the superradiant instability and form a dense cloud. We investigate the particle ring formation mechanism induced by black hole superradiance. We examined the dynamics of axion-like particles ϕ and χ with a large mass hierarchy and a trilinear coupling around a rotating black hole. Against the background of a superradiant cloud formed by the ϕ field, χ particles are resonantly excited and accumulate in bound orbits to form ring-like structures. Combining analytical approximations and numerical evolution, we describe the resonance-triggered dynamics as well as the evolution of the superradiant cloud and particle rings, along with their final steady-state distribution characteristics. This study reveals a new mechanism for generating bound-state particles through resonance in superradiant clouds and highlights its potential significance for studying particle physics interactions in strong gravitational fields.

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