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Black hole superradiance of interacting multi-fields

Ultralight bosonic fields can undergo exponential amplification around rotating black holes through black hole superradiance. This process can result in black hole spin-down, continuous gravitational-wave emission, and many other observable consequences, providing a powerful probe of dark particles in the strong-gravity regime. In particular, the LVK Collaboration has placed constraints on dark scalars with masses around 10^{-12} eV.

While most existing studies assume a single field, the dark sector may contain multiple particle species with nontrivial interactions. In this work, we investigate black hole superradiance in the presence of multiple interacting fields. In particular, we compute the corrections to the superradiant growth rates induced by interactions with other fields, study the nonlinear evolution of the superradiant system, and discuss the observational implications.

We find that interactions can significantly suppress black hole superradiance and modify the superradiant evolution, even if the coupled field is not itself superradiant. We demonstrate that multi-field interactions can qualitatively alter superradiance phenomenology and should be incorporated when deriving robust constraints on the dark sector from black hole spin measurements and gravitational-wave observations.

Primary author(s) : Dr ZHANG, Jun (International Center for Theoretical Physics Asia-Pacific)

Presenter(s) : Dr ZHANG, Jun (International Center for Theoretical Physics Asia-Pacific)