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Black-hole superradiance: probing ultralight bosons with compact objects and gravitational waves

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Ultralight bosonic fields (e.g. stringy axions, axion-like particles, dark photons, light spin-2 fields) are compelling dark-matter candidates and provide a serious alternative to the WIMP paradigm. These fields have eluded particle detectors so far, but can dramatically affect the strong-gravity dynamics of compact objects (black holes and compact stars) in various detectable ways. Light bosonic fields can trigger superradiant instabilities which have peculiar signatures, e.g. they produce "gaps" in the mass-spin diagram of astrophysical black holes and predict a measurable spin-down rate of pulsars. These effects can be used to constrain axion-like particles, to derive bounds on dark photons and on the mass of the graviton, as well as to constrain the fraction of primordial black holes in dark matter. Because of their tiny mass and coupling to the Standard Model, detecting axions and other light bosons in the lab is extremely challenging. However, boson condensates formed through superradiance would emit a periodic gravitational-wave signal (whose frequency is related to the boson mass) which can be detected with present and future gravitational-wave interferometers, either as stochastic background or as continuous resolvable sources. The theoretical potential of these phenomena as almost-model-independent smoking guns for physics beyond the Standard Model are presented.

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