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Searching for Ultralight Particles with Black Holes and Gravitational Waves

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The LIGO detection of gravitational waves has opened a new window on the universe. I will discuss how the process of superradiance, combined with gravitational wave measurements, makes black holes into nature's laboratories to search for new light bosons, from axions to dark photons. When a bosonic particle's Compton wavelength is comparable to the horizon size of a black hole, superradiance of these bosons into 'hydrogenic' bound states extracts energy and angular momentum from the black hole. The occupation number of the levels grows exponentially and the black hole spins down. One candidate for such an ultralight boson is the QCD axion with decay constant above the GUT scale. Current black hole spin measurements disfavor a factor of 30 (400) in axion (vector) mass; future measurements can provide evidence of a new boson. Particles transitioning between levels and annihilating to gravitons may produce thousands of monochromatic gravitational wave signals, and turn LIGO into a particle detector.