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Signatures of ultralight bosons in the orbital eccentricity of binary black holes

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We show that the existence of clouds of ultralight particles surrounding black holes during their cosmological history as members of a binary system can leave a measurable imprint on the distribution of masses and orbital eccentricities observable with future gravitational-wave detectors. Notably, we find that for nonprecessing binaries with chirp masses < 10 solar masses, formed exclusively in isolation, larger-than-expected values of the eccentricity, i.e. > 0.01 at gravitational-wave frequencies ~ 10^(−2) Hz, would provide tantalizing evidence for a new particle of mass between [0.5,2.5]×10^(−12) eV in nature. The predicted evolution of the eccentricity can also drastically affect the in-band phase evolution and peak frequency. These results constitute unique signatures of boson clouds of ultralight particles in the dynamics of binary black holes, which will be readily accessible with the Laser Interferometer Space Antenna, as well as future mid-band and Deci-hertz detectors.

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