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Searching for ultralight bosons using black hole spins measured from gravitational waves

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Clouds of ultralight bosons - such as axions - can form around a rapidly spinning black hole, if the black hole radius is comparable to the bosons' wavelength. The cloud rapidly extracts angular momentum from the black hole, and reduces it to a characteristic value that depends on the boson's mass as well as on the black hole mass and spin. Therefore, a measurement of a black hole mass and spin can be used to reveal or exclude the existence of such bosons. Using hierarchical Bayesian inference, we can simultaneously measure the black hole spin distribution at formation and the mass of the scalar boson. Based on the black holes released by LIGO and Virgo in their GWTC-2, the data strongly disfavors the existence of scalar bosons in the mass range between $1.3 \times 10^{-13}\,\mathrm{eV}$ and $2.7 \times 10^{-13}\,\mathrm{eV}$. Our mass constraint is valid for bosons with negligible self-interaction, that is with a decay constant 10^{14} GeV. The statistical evidence is mostly driven by the two {binary black holes} systems GW190412 and GW190517, which host rapidly spinning black holes. The region where bosons are excluded narrows down if these two systems merged shortly ($\sim 10^5$ years) after the black holes formed. If time permits, we will also discuss the prospect of this search in the coming decade, as well as a multiband technique for precise measurement of boson mass.

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