Abstract

Ultralight bosons with masses in the range $10^{-13}\,\mathrm{eV} \leq m_b \leq 10^{-12}\,\mathrm{eV}$ can induce a superradiant instability around spinning black holes (BHs) with masses of order 10-100 $M_\odot$. This instability leads to the formation of a rotating "bosonic cloud" around the BH, which can emit gravitational waves (GWs) in the frequency band probed by ground-based detectors. The superposition of GWs from all such systems can generate a stochastic gravitational-wave background (SGWB). In this work, we develop a Bayesian data analysis framework to study the SGWB from bosonic clouds using data from Advanced LIGO and Advanced Virgo, building on previous work by Brito *et.al.* (2017). We further improve this model by adding a BH population of binary merger remnants. To assess the performance of our pipeline, we quantify the range of boson masses that can be constrained by Advanced LIGO and Advanced Virgo measurements at design sensitivity. Furthermore, we explore our capability to distinguish an ultralight boson SGWB from a stochastic signal due to distant compact binary coalescences (CBC). Finally, we present results of a search for the SGWB from bosonic clouds using data from Advanced LIGO's first observing run. We find no evidence of such a signal. Due to degeneracies between the boson mass and unknown astrophysical quantities such as the distribution of isolated BH spins, our analysis cannot robustly exclude the presence of a bosonic field at any mass. Nevertheless, we show that under optimistic assumptions about the BH formation rate and spin distribution, boson masses in the range $2.0 \times 10^{-13}\,\mathrm{eV} \leq m_\mathrm{b} \leq 3.8 \times 10^{-13}\,\mathrm{eV}$ are excluded at 95% credibility, although with less optimistic spin distributions, no masses can be excluded. The framework established here can be used to learn about the nature of fundamental bosonic fields with future gravitational wave observations.