پژوهشگاه دانش‌های بنیادی

Institute for Research in Fundamental Sciences

School of Particles and Accelerators

Search for echoes on the edge of quantum black holes

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Abstract

I perform a template-based search for stimulated emission of Hawking radiation (or Boltzmann echoes) by combining the gravitational wave data from 47 binary black hole merger events observed by the LIGO/Virgo collaboration. With a Bayesian inference approach, I found no statistically significant evidence for this signal in either of the 3 Gravitational Wave Transient Catalogs GWTC-1, GWTC-2 and GWTC-3. However, the data cannot yet conclusively rule out the presence of Boltzmann echoes either, with the Bayesian evidence ranging within 0.3-1.6 for most events, and a common (non-vanishing) echo amplitude for all mergers being disfavoured at only 2:5 odds. The only exception is GW190521, the most massive and confidently detected event ever observed, which shows a positive evidence of 9.2 for stimulated Hawking radiation. The "look-elsewhere" effect for this outlier event is assessed by applying two distinct methods to add simulated signals in real data, before and after the event, giving false (true) positive detection probabilities for higher Bayes factors of 1.5%, 4.4% (35 ± 7 %, 35 ± 15 %). An optimal combination of posteriors yields an upper limit of $A < 0.4$ (at 90% confidence level) for a universal echo amplitude, whereas $A \sim 1$ was predicted in the canonical model. To ensure the robustness of the results, I have employed an additional method to combine the events hierarchically. This approach involves using a target gaussian distribution and extracting the parameters from multiple uncertain observations, which may be affected by selection biases. The next generation of gravitational wave detectors such as LISA, Einstein Telescope, and Cosmic Explorer can draw a better conclusion on the quantum nature of black hole horizons.

Time: 14:30 PM, 11th of August 2024; 21st of Mordad 1403

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