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GW250114 reveals black hole horizon signatures

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The horizon of a black hole, the "surface of no return," is characterized by its rotation frequency Ω_H and surface gravity κ. A striking signature is that any infalling object appears to orbit at Ω_H due to frame dragging, while its emitted signals decay exponentially at a rate set by κ as a consequence of gravitational redshift. Recent theoretical work predicts that the merger phase of gravitational waves from binary black hole coalescences carries direct imprints of the remnant horizon's properties, via a "direct wave" component that (i) oscillates near $2\Omega_H$, reflecting the horizon's frame dragging and the quadrupole nature of the gravitational radiation, and (ii) decays at an increasing rate characterized by κ, with additional screening from the black hole's potential barrier. In this paper, we report observational evidence for the direct wave in GW250114 with a matched-filter signal-to-noise ratio of $14.0^{+0.2}_{-0.1}$ ($13.5^{+0.1}_{-0.2}$) in the LIGO Hanford (Livingston) detector. The measured properties are in full agreement with theoretical predictions. These findings establish a new observational channel to directly measure frame-dragging effects in black hole ergospheres and explore (near-)horizon physics in dynamical, strong-gravity regimes.

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