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The neutrino gravitational memory from a core collapse supernova: phenomenology and physics potential

General Relativity predicts that the passage of matter or radiation from an asymmetrically-emitting source should cause a permanent change in the local space-time metric. This phenomenon, called the \emph{gravitational memory effect}, has never been observed, however supernova neutrinos have long been considered a promising avenue for its detection in the future. With the advent of deci-Hertz gravitational wave interferometers, observing the supernova neutrino memory will be possible, with important implications for multi messenger astronomy and for tests of gravity. In this work, we develop a phenomenological (analytical) toy model for the supernova neutrino memory effect, which is overall consistent with the results of numerical simulations. This description is then generalized to several case studies of interest. We find that, for a galactic supernova, the dimensionless strain, $h(t)$, is of order $\sim 10^{-22} - 10^{-21}$, and develops over a typical time scale that varies between $\sim 0.1 - 10$ s, depending on the time-evolution of the anisotropy of the neutrino emission. The characteristic strain, $h_c(f)$, has a maximum at a frequency $f_{max} \sim \mathcal{O}(10^{-1}) - \mathcal{O}(1)$ Hz. The detailed features of the time- and frequency-structure of the memory strain will inform us of the matter dynamics near the collapsed core, and allow to distinguish between different stellar collapse scenarios. Next generation gravitational wave detectors like DECIGO and BBO will be sensitive to the neutrino memory effect for supernovae at typical galactic distances and beyond; with Ultimate DECIGO exceeding a detectability distance of 10 Mpc.

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