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Electromagnetic memory in arbitrary curved spacetimes

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The gravitational memory effect and its electromagnetic (EM) analog are potential probes in the strong gravity regime. In the literature, this effect is derived for static observers at asymptotic infinity. While this is a physically consistent approach, it restricts the spacetime geometries for which one can obtain the EM memory effect. To circumvent this, we evaluate the EM memory effect for comoving observers (defined by the 4-velocity u_{μ}) in arbitrary curved spacetimes. Using the covariant approach, we split Maxwell's equations into two parts—projected parallel to the 4-velocity u_{μ} and into the 3-space orthogonal to u_{μ}. Further splitting the equations into 1 + 1 + 2-form, we obtain the acceleration vector of the comoving observer located in a two-dimensional (2D) surface orthogonal to the direction of propagation of the EM waves. We refer to this expression as the master equation for the EM memory in an arbitrary curved spacetime. The master equation corresponding to the acceleration of the comoving observer in the 2D surface provides a physical understanding of the contribution to the EM memory. For instance, the leading order contribution only requires information about the total energy density of the EM field, while the subleading contributions contain information about the spacetime geometry and the other components of the energy-momentum tensor of the EM field. To our knowledge, this is the first time a transparent and easily applicable final expression for electromagnetic memory has been derived for a general curved spacetime. We then obtain EM memory for specific spacetime geometries and demonstrate the advantages of our approach.

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