Gravitational energy-momentum and thermodynamics

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Abstract

We present a detailed analysis of the so-called "square root of Bel-Robinson" (SQBR), proposed in the literature as an energy-momentum tensor for the gravitational field. Being constructed exclusively from the Weyl part of the Riemann tensor, the SQBR encapsulates the geometric properties of free gravitational fields in terms of optical scalars of null congruences: making use of the general decomposition of any energy-momentum tensor, we explore the thermodynamic interpretation of such geometric quantities by providing a (tentative) generalized first law of gravitational thermodynamics. While the matter energy-momentum is identically conserved due to Einstein's field equations, the SQBR is not necessarily conserved and dissipative terms could arise in its vacuum continuity equation. We discuss the possible physical interpretations of such mathematical properties, both in general and in the specific cases of Kerr black hole and pp-waves spacetimes.