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Abstract

The entropy problem in cosmology led Penrose to suggest that the gravitational field itself must carry entropy to satisfy the Second Law of Thermodynamics. Following this direction, Clifton, Ellis, and Tavakol (CET) proposed a framework describing the thermodynamics of the free gravitational field with a unique gravitational entropy and temperature. Adopting a geometrical approach, we relate this thermodynamic temperature of the free gravitational field to the non-affinity of real null geodesics in a Newman-Penrose tetrad. This formulation naturally links various temperature functions, including the CET, Hawking, and Unruh temperatures, in their appropriate limits. The analysis is carried out within the realm of local rotational symmetry, although the result extends to other Petrov Type D geometries, including Kerr spacetime. We find that the geometrical and causal transport equations for this temperature function yield a hyperbolic wave equation driven by a forcing term that arises from Weyl curvature and matter. Finally, we discuss physical interpretations by relating this geometrical temperature to the gravitational red/blue shift of light rays propagating along null geodesics.