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The Absorption of Gravitational Radiation by a Dissipative Fluid

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Abstract. An expression is found in the eikonal approximation for the gravitational radiation absorbed by a dissipative fluid.

1. Introduction

It is our purpose here to derive an expression for the damping of gravitational radiation as it passes through a dissipative fluid. We shall also calculate the entropy production in the fluid due to the passage of the radiation and verify the thermodynamical law $dS = dQ/T$ for a closed system.

We shall find that in the high frequency limit, the radiation is absorbed in a characteristic time η^{-1} where η is the shear viscosity. (We set $c = 1$, $8\pi G = 1$.) This confirms a result of Hawking [1] in a more general context.

The eikonal approximation [2–4] is used. The notation is that of Ref. [4].

2. Notation

The signature of the metric is chosen to be -2. We suppose that in some coordinate system the components of the metric describing the radiation may be written as the sum of two terms: $\tilde{g}_{\mu\nu} = g_{\mu\nu} + \varepsilon h_{\mu\nu}$. The components $g_{\mu\nu}$ of the background metric are relativity slowly varying functions with a characteristic length L. The potential $h_{\mu\nu}$ of the radiation depends explicitly on the point in space-time as well as on a phase function $\omega\phi$. ω is a constant with the dimension of inverse length. The derivative of $h_{\mu\nu}$ is given therefore by

$$\partial_\lambda h_{\mu\nu} = \omega \xi_\lambda \dot{h}_{\mu\nu} + h_{\mu\nu,\lambda},$$

where

$$\xi_\lambda = \partial_\lambda \phi, \quad \dot{h}_{\mu\nu} = \frac{\partial h_{\mu\nu}}{\partial(\omega\phi)}, \quad h_{\mu\nu,\lambda} = (\partial_\lambda h_{\mu\nu})_{\phi = \mathrm{const}}.$$