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Maximal hypersurface in a D-dimensional dynamical spacetime

In this article, we set up a variational problem to arrive at the equation of a maximal hypersurface inside a spherically symmetric evolving trapped region. In the first part of the article, we present the Lagrangian and the corresponding Euler-Lagrange equations that maximize the interior volume of a trapped region that is formed dynamically due to infalling matter in D-dimensions, with and without the cosmological constant. In the second part, we explore the properties of special radii, which we call Reinhart radii, that play a crucial role in approximating the maximal interior volume of a black hole. We derive a formula to locate these Reinhart radii in terms of coordinate invariants like area radius, principle values of the energy-momentum tensor, Misner Sharp mass, and cosmological constant. Based on this formula, we estimate the location of Reinhart radii in various scenarios:(a) the case of static BTZ black holes in 2+1 dimensions and for the Schwarzschild, Schwarzschild-deSitter, and Schwarzschild-Anti deSitter black holes in D-dimensions. We plot the location of the Reinhart radii in relation to the event horizon and cosmological horizon in a static D-dimensional scenario, (b) cosmological case: we prove that these Reinhart radii do not exist for homogeneous evolving dust for the zero and negative cosmological constant but exist in the presence of positive cosmological constant when the scale factor is greater than a critical value. We also show the relation between these Reinhart radii and Kodama vector.

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