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General Relativistic Shock Waves that Induce Cosmic Acceleration

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A family of global shock-wave solutions of the Einstein field equations for a perfect fluid are constructed. These shock-wave solutions consist of an interior self-similar expanding wave and an exterior self-similar static wave, separated by a spherical shock surface. The interior and exterior fluids are assumed to have isothermal equations of state of the form $p = \sigma\rho$ and $\bar{p} = \bar{\sigma}\bar{\rho}$ respectively, with the strictly positive constants σ and $\bar{\sigma}$ representing a single parameter for each wave. The interior wave has an additional parameter, denoted by a, which represents how perturbed this wave is from a Friedmann-Lemaître-Robertson-Walker spacetime with the same equation of state. The joining of the interior and exterior waves forms a shock-wave solution when mass and momentum are conserved across the shock surface, which places a constraint on the three parameters. The resulting shock-wave solution is thus a two-parameter family of solutions. For $\sigma = \bar{\sigma}$, the two-parameter family becomes a one-parameter family and such solutions model the general relativistic version of an explosion within a static, singular, isothermal sphere. Interestingly, the two-parameter family of shock waves solve the Einstein field equations in the absence of a cosmological constant, but despite this, a cosmic acceleration is still present in the interior wave, with the acceleration parameterised by a. This fact follows from the pioneering work of Smoller and Temple. The presence of this acceleration in the absence of a cosmological constant opens up the question of whether a vast primordial shock-wave could give rise to the cosmic acceleration observed today without the need for dark energy.

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