Is Spacetime Locally Inertial for General Relativistic Shock Wave Solutions?

Moritz Reintjes [1], Blake Temple (co-author)[2]

[1] IMPA - Instituto Nacional de Matemtica Pura e Aplicada

[2] University of California in Davis

Abstract:
It is an open question whether solutions of the coupled Einstein Euler equations are smooth enough to admit locally inertial coordinates at points of shock wave interaction, or whether "regularity singularities" exist. A *regularity singularity* is a point where the gravitational metric tensor would be no smoother than Lipschitz continuous in any coordinate system. Such a metric regularity would be too low for spacetime to be locally inertial, which raises the possibility of new gravitational effects to exist, as discussed in [3] for the example of a scattering-type effect in gravitational waves by a regularity singularity. Nevertheless, a metric tensor Lipschitz continuous across a *single* shock surface can be mapped by a coordinate transformation to a metric tensor with sufficient regularity for locally inertial coordinates to exist, as shown Israel's famous 1966 paper. However, generalizing Israel's method of proof to the case of even the simplest shock wave interaction seems hopeless. In [1, 2], we develop a new method to address basic shock wave interactions and prove that the metric regularity can be lifted sufficiently for locally inertial coordinates to exist. Our result generalizes Israel's result to shock interactions and shows that regularity singularities do not exist in these basic cases, but whether such singularities exist in more complicated shock wave solutions of the Einstein Euler equations remains an open problem.

References

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[3] M. Reintjes and B. Temple, *Regularity Singularities and the Scattering of Gravity Waves in Approximate Locally Inertial Frames*, May 2015, arXiv:1506.04074.