Time Travel Using Degenerate Metrics

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Abstract:
In classical gravity theory, we present explicit examples of vacuum solutions that admit the possibility of time travel (to the past) through their geodesics. These geometries are built upon metrics whose determinant can continuously go to zero over some extended region of the spacetime. These solutions to the first order field equations satisfy the energy conditions. One may see the existence of these solutions as a motivation to revisit the status of causality in the formulation of classical gravity.

Summary:
The possibility of obtaining theoretical models of time machine spacetimes within Einstein's theory of general relativity, as well as the practical feasibility of such a potential construction, have been and still is a matter of open debate. Whereas Einstein's equations (with or without matter) have been shown to admit spacetime solutions that exhibit closed timelike curves (and hence implying a possible realization of time travel), they seem to violate either one or the other among the standard stability criteria motivated by classical and quantum physics. To emphasize, while some of them fail to satisfy the energy conditions, others are either unstable against quantum fluctuations or are supported by matter fields which have no realization in nature.

Here we construct spacetime solutions of gravity theory in vacuum, with the special property that their geodesics allow the possibility of a time travel. These (non-Einsteinian) geometries exhibit both the possible phases of the tetrad fields associated with zero and non-zero determinant, respectively, over different regions of the same spacetime. To emphasize, all these configurations satisfy the first order (Hilbert-Palatini) equations of motion in vacuum everywhere, a framework that is known to admit spacetime solutions with degenerate tetrad fields. At the region with the noninvertible phase, there exist turning points of the affine parameter for timelike and null geodesics. Thus, a proper clock (along a timelike geodesic) which might cross any of these points must start running backwards in time.

While vacuum solutions of first order gravity may in general exhibit nontrivial torsion whose origin is purely geometric, the acausal geometries pre- sented here are all torsionfree by construction. These configurations satisfy all the energy conditions. In addition, these solutions are free of any divergence in the curvature two-form fields or in the lower dimensional curvature scalars that could be associ- ated with the zero-determinant phase.

At this stage, one should not demand that the acausal solutions presented here could be actual time machines, before a deeper understanding of the properties of these vacuum solutions emerges through further investigations. These solutions could bring in interesting implications in the context of a possible violation of causality within

classical gravity theory built upon the noninvertible (non-Einsteinian) phase.

References:

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