GRAVITO-WHAT FIELDS?

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Recent decades have seen the increasing application to gravitational physics of various approaches to splitting spacetime into space plus time. Some of these have been developed more fully than others, but all of these formalisms tend to suffer either from a lack of connection to the spacetime geometry when based on coordinate systems or geometric characterizations thereof, or from a lack of contact with such systems if based on spacetime projection. Little if any effort has been made to explore the relationship among these approaches, all of which come from the same spacetime geometry.

Certainly splittings are important in enabling our spatial intuition to extend to nonlinear gravitational physics, but the power of utilizing spacetime geometry should not be lost entirely. It is relatively simple to put all of the various approaches into a single geometrical setting and make their relationships more transparent. This is important in clarifying the definition of the spatial gravitational force fields which have a long history in various contexts and have recently been tagged with the catchy terminology gravitoelectric and gravitomagnetic force fields[1] in an analogy with electromagnetism.[2,3] Maxwell's equations themselves have been approached in a number of ways, not all of which are geometrically clear, and again the relationships between them are not obvious.

A 4-dimensional framework is introduced based on a parametrized nonlinear reference frame consisting of a slicing (foliation) of a region of spacetime by a family of hypersurfaces accompanied by a transverse congruence of curves with a parametrization induced by a parametrization of the family of slices, to be referred to as a threading. The slicing point of view requires a spacelike slicing, while the threading point of view requires a timelike congruence; when both causality conditions are satisfied, one can transform between them. Using spacetime frames adapted to this geometry and then introducing the natural projection adapted to the slicing and threading and the two orthogonal projections adapted to the slicing and threading individually, leads to an interpretation of components in terms of measurements by observers in the two points of view. Evolution is then defined in terms of the 1-parameter group of diffeomorphisms associated with the parametrized threading. Splitting the spacetime connection in the appropriate way then leads to the precise definition of gravitoelectric and gravitomagnetic vector and tensor fields in both points of view, as well as a clarification of the three possible decompositions of Maxwell's equations[4–6] and their relation to the congruence formalism with no accompanying slicing.[7] As a simple application, the Sagnac effect[8] is easily discussed in this language.

References

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