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Referee report on the doctoral thesis

Investigation of geometrical and physical properties of exact spacetimes

By Ondřej Hruška

The well-known Plebanski-Demianski family of metrics represents a general expanding Petrov type D vacuum solution to the Einstein equations. In addition, it also allows for an aligned non-null Maxwell field and the cosmological constant. It contains exact spacetimes of the highest physical importance, such as the Schwarzschild and Kerr black holes and their charged counterparts and many other interesting spacetimes, including the C-metric. It has been shown by Griffiths and Podolský in 2006 that by a degenerate transformation a non-expanding limit of the Plebanski-Demianski family can be obtained. The resulting large family of (electro)vacuum type D Kundt spacetimes is characterized by five continuous and two discrete parameters.

The main goal of this thesis is to study various geometrical and physical aspects of the non-expanding Plebanski-Demianski family. The main part of the thesis is based on three papers published in renowned journals (two papers in Physical Review D and one paper in Classical and Quantum Gravity).

In the first section, the physical meaning of free parameters in the non-expanding Plebanski-Demianski family is studied. First, the maximally symmetric backgrounds obtained by setting almost all parameters to zero are studied. Then individual parameters are turned on and the corresponding metrics are studied. It is shown that members of this family can be understood as generalizations of the B-metrics. The second section is devoted to studying again the maximally symmetric backgrounds in the non-expanding Plebanski-Demianski family in more detail. In particular, eleven new diagonal forms of (anti-)de Sitter spacetimes are thoroughly analyzed. The third section focuses on the physical interpretation of the B-metrics (a subcase of non-expanding Plebanski-Demianski family) and their relation to the so-called A-metrics via (infinite) boosts. In particular, it is shown that AII and BI metrics represent AI metric (Schwarzschild-(anti-) de Sitter) boosted to superluminal speed. This results in the interpretation of the BI metric as the gravitational field of a tachyon in Minkowski or -(anti-)de Sitter spacetime.

This thesis contains several interesting and original results published in leading journals in the field. It clearly demonstrates the author's ability to perform original research independently. Apart from a very few minor typos (e.g. Eqs. (2) and (8) and in the first sentence of Section 4.1), I have not noticed any mistakes.

The thesis is of high quality and fully satisfies the required conditions for a doctoral thesis and thus I am happy to recommend its acceptation as a doctoral thesis at the Faculty of Mathematics and Physics of the Charles University.

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I have the following questions:

1) Some partial generalizations of the Plebanski-Demianski metrics are known in higher dimensions. Would it be possible to perform non-expanding limit for such higher-dimensional metrics or is such procedure inherently limited to the four-dimensional case?

2) Similarly, is it possible to perform the infinite boost for higher-dimensional Schwarzschild?

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