Contribution ID: **199** Type: **not specified**

Theory: On the canonical equivalence of Jordan and Einstein frames

Monday, September 4, 2023 2:45 PM (15 minutes)

A longstanding issue is the equivalence between the Jordan and the Einstein frames. It is believed, but not completely proved, that the cosmological physical observables are the same in the two frames. Our aim is to tackle this problem from the perspective of the Hamiltonian formalism. For this reason, we will perform the Hamiltonian analysis of the Brans-Dicke theory with Gibbons-Hawking-York boundary term both in the Jordan and the Einstein frames. Contrary to several claims made in the literature in the past, it will be shown that the transformations from the Jordan to the Einstein frames are not Hamiltonian canonical transformations. We will show that if we perform a gauge fixing on the lapse and shifts functions and implement them as secondary Dirac's constraints in the ADM formalism, the primary first-class constraints will become second class. In this way, we can eliminate these degrees of freedom replacing the Poisson brackets with the Dirac' s brackets and solve the second-class constraints. On this reduces phase space, the Hamiltonian transformations from the Jordan to the Einstein frames are Hamiltonian canonical transformations. In our opinion, this does not mean that Jordan and Einstein frames, from Hamiltonian point of view, are physically equivalent. In fact, we have only shown that solutions of the equations of motion in the Jordan frame can generate solutions of the equations of motion in the Einstein frame. Furthermore, we will see that the Jordan Frame is canonically equivalent, under some transformations called anti-Newtonian transformations, to a frame whose solutions, in the limit, behave as Carrollian Gravity.

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Session Classification: Parallel Sessions