Contribution ID: **13** Type: **not specified**

Construction of degenerate higher order scalar-tensor theories

Wednesday 23 September 2020 11:30 (20 minutes)

Scalar-tensor theories represent extensions of Einstein's gravity through the inclusion of a scalar field with non-minimal coupling. An analysis of these theories has been carried out within the framework of non-degenerate theories (determinant of the Hessian matrix is zero). Therefore, it is feasible to increase the space of modified theories including the cases in which there is degeneracy, thus circumventing the conditions of the instability theorem of Ostrogradsky. From a phenomenological perspective, the expansion of the scalar-tensor theory space opens the possibility of new and attractive explanations to different open questions in cosmology and astrophysics, e.g., the nature of dark energy, dark matter and inflation. The first step for the construction of these theories is to determine the degeneracy conditions for a Lagrangian dependent on a metric tensor $g_{\mu\nu}$ and a scalar field ϕ. Subsequently, the most general action is constructed with quadratic terms in the second derivative of the scalar field. Hence the name of quadratic theories. In general, an action of this type reproduces field equations of order higher than two. However, when the degeneracy conditions are applied, the dangerous degrees of freedom are eliminated away. Thus, we want to find a classification of all degenerate scalar-tensor theories of higher order (in the field equations) quadratic (in the power of the field derivatives in the Lagrangian). These theories, being degenerate, are generally free from instabilities.

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Session Classification: CoCo