Contribution ID: **51** Type: **selected talk**

Canonical variational completion of 4D Gauss-Bonnet gravity

Saturday, 26 September 2020 16:35 (20 minutes)

We consider a recent proposal to obtain a finite contribution of second derivative order to the gravitational field equations in $D = 4$ dimensions from a renormalized Gauss-Bonnet term in the action. In previous works, it has been shown that the resulting field equations cannot be obtained as the Euler-Lagrange equations from a diffeomorphism-invariant action. Here we use techniques from the inverse calculus of variation as an independent confirmation that the suggested truncated Gauss-Bonnet field equations cannot be variational, in any dimension. For this purpose, we employ canonical variational completion, based on the notion of Vainberg-Tonti Lagrangian, which consists in adding a canonically defined correction term to a given system of equations, so as to make them derivable from an action. We find that in $D > 4$ the suggested field equations can be variationally completed, which yields a theory with fourth order field equations. In $D = 4$ the variationally completed theory diverges. Our findings are in line with Lovelock's theorem, which states that, in 4 dimensions, the unique second-order Euler-Lagrange equations arising from a scalar density depending on the metric tensors and its derivatives, are the Einstein equations with a cosmological constant.

This contribution is based on arXiv:2009.05459.

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Session Classification: Beyond General Relativity