Abstract

We study the quantum gravity imprint on particle physics and cosmological phenomena. We show that combining particle physics and cosmology with quantum gravity results in non-trivial conditions on the low energy theories and quantum gravity models.

We discuss how the Grand Unified Theories can be UV-completed by quantum gravity at the Planck scale in a model-independent way. This results in a set of conditions that constrain the possible parameter space stemming from UV-completion by quantum gravity. We find that within the studied model the deepest minima are either non-Standard Model like or require large threshold corrections to realize the Standard Model as low energy theory. For models with multiple vacua, we study the domain walls' evolution depending on the initial conditions and shape of the potential.

In the cosmological setting, we elaborate on the path integral formulation of quantum gravity. We show that for the Hořava-Lifszyc gravity, the non-flat and non-homogenous cosmologies do not contribute to the Euclidean path integral. On the other hand, we show that Hořava-Lifszyc gravity satisfies the finite-action selection principle, that has been proposed as a model independent solution of the black hole singularities.

Our study of Grand Unified Theories within the asymptotically safe approach points out towards "transplanckian" breaking and hence proton stability under certain assumptions. On the other hand, in the Standard Model, the asymptotic safety constrains the Higgs mass to take the smallest value such that the electroweak vacuum is stable. Considering the current top quark mass measurements, this value is $m_H \approx 130$ GeV, five GeV above the experimental value. Here we consider the predictions of the Higgs mass in various Beyond Standard Model scenarios, where this prediction can be improved. As we show, the inclusion of new $U(1)$ symmetry can potentially give the correct prediction for this mass.

Then we discuss the Weak Gravity Bound in the Abelian vector field system, limiting the gravitational fluctuations' strength. We find that the bound does not restrict the number of vector species, unlike the scalar case. We investigate the gauge invariance of the results.

The (no) eternal inflation principle has been put forward based on swampland considerations in string theory. The natural question arises whether similar conditions hold in other approaches to quantum gravity. We consider asymptotic safety models with and without gravity in the context of eternal inflation. The existence of UV fixed point generically flattens the potential, and our findings suggest no tension between eternal inflation and asymptotic safety in contradistinction to string theory.

Within the text, we also discuss various caveats of the formulation of asymptotically safe gravity, provide specific examples for asymptotic safety in quantum mechanics and discuss the possible connections between asymptotic safety and string theory.