Abstract

This dissertation explores scale-invariant extensions of the Standard Model (SM) Higgs scalar sector, addressing the unexplained origin of mass scales such as the electroweak scale and the Planck mass. We explore frameworks where scale symmetry is preserved at the classical and quantum levels and broken dynamically. We also focus on incorporating Weyl gravity prescription, which naturally introduces a dilaton field coupled to the Higgs boson.
Theoretical foundations, including the quantum effective potential and scale-symmetric regularization, Weyl geometry, and quantum field theory at finite temperature, are reviewed. We then analyze a scale-invariant Higgs sector, incorporating quantum corrections, and examine the roles of gravity, dilaton effects, and the Weak Gravity Conjecture.
One of the key contributions is the study of spontaneous scale symmetry breaking at high temperatures, providing a natural mechanism for mass generation in the early Universe. We analyze temperature corrections to the one-loop effective potential and simulate the evolution of the Higgs and dilaton fields in a hot expanding Universe. We show that certain initial conditions for this evolution can lead to a physically viable vacuum state. Finally, we explore inflation in this framework, introducing a kinetic term for the dilaton and extending gravity to Weyl geometry, both of which affect the model's inflationary dynamics.
These findings support the search for a more fundamental theory where mass scales arise from underlying symmetries rather than arbitrary parameters.

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