

# Quantum Scale Symmetry

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Quantum scale symmetry is the realization of scale invariance in a quantum field theory. No parameters with dimension of length or mass are present in the quantum effective action. Quantum scale symmetry is generated by quantum fluctuations via the presence of fixed points for running couplings. As for any global symmetry, the ground state or cosmological state may be scale invariant or not. Spontaneous breaking of scale symmetry leads to massive particles and predicts a massless Goldstone boson. A massless particle spectrum follows from scale symmetry of the effective action only if the ground state is scale symmetric. Approximate scale symmetry close to a fixed point leads to important consequences for observations in various areas of fundamental physics.

We review consequences of scale symmetry for particle physics, quantum gravity and cosmology. For particle physics, scale symmetry is closely linked to the tiny ratio between the Fermi scale of weak interactions and the Planck scale for gravity. For quantum gravity, scale symmetry is associated to the ultraviolet fixed point which allows for a non-perturbatively renormalizable quantum field theory for all known interactions. The interplay between gravity and particle physics at this fixed point permits to predict couplings of the standard model or other “effective low energy models” for momenta below the Planck mass. In particular, quantum gravity determines the ratio of Higgs boson mass and top quark mass. In cosmology, approximate scale symmetry explains the almost scale-invariant primordial fluctuation spectrum which is at the origin of all structures in the universe. The pseudo-Goldstone boson of spontaneously broken approximate scale symmetry may be responsible for dynamical dark energy and a solution of the cosmological constant problem.

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