Asymptotic security in the theory of gravity, the Higgs portal and the Conformal Standard Model

Description for general public

The discovery of the Higgs boson in 2012 confirmed fully the predictions of the Standard Model of elementary particles entirety. This model allows to predict the results of experiments carried out in particle accelerators with extreme precision. However, for many reasons, both observational and theoretical, it should be supplemented with additional interactions. It has nineteen free parameters, whose values cannot be explained. In addition, this model has a problem with the description of key phenomena in the physics of the Early Universe, such as baryogenesis or inflation. It also has theoretical problems, not related to direct observation. One of these problems is the hierarchy problem, the problem of the proper choice of low-energy vacuum in this model.

One of the proposals to solve these problems is the Conformal Standard Model, belonging to a wider class of models that we will call the Higgs portal models. They are based on the addition of an additional scalar particle that will interact mainly with the Higgs boson. The conformal Standard Model, despite a small extension of the current theory, provides a mechanism allowing for bariogenesis through resonant leptogenesis, and its further extensions allow it to explain inflation in a manner consistent with the data from the Planck probe. The hierarchy problem is solved by a mechanism of softly broken conformal symmetry. This mechanism is to arise from the fundamental theory of quantum theory of gravity which is unknown.

The description of gravity at the quantum level is very difficult because it is a non-renormalized theory. Many solutions to this problem have been proposed, such as string theory or loop quantum gravity. The hypothesis proposed by Steven Weinberg is that although gravity is non-renormalized, however it possesses a well-defined behaviour for very large energies, i.e. it has an ultraviolet interacting fixed point, that allows the theory to be considered as fundamental. It turns out that the assumption of this, not confirmed yet, hypothesis has a huge impact on the physics of elementary particles. It can be shown that the mass of the Higgs boson ceases to be arbitrary, and can be exactly one. However, the Standard Model, even supplemented with asymptotic freedom, can not be complete.

In our work, we would like to check the implications of the Weinberg hypothesis for the Standard Model extensions. With some additional assumptions, that we will check, it will be possible to predict the mass of the second scalar particle postulated by models with the Higgs portal and its interaction with the Higgs boson. This would give quantitative predictions for models of this type that can be tested in the Large Hadron Collider. For the Conformal Standard Model, it will also be possible to determine the mass of the dark matter particle postulated by this model.

Moreover, the early stages of the Universe's evolution are a natural arena of events described by these models. Inflation models, in which the role of inflation-inducing fields are the non-minimal coupled Higgs field (field related to the Higgs boson) and the second field from the Higgs portal, are currently one of the most serious candidates to explain this phenomenon. They impose along with leptogenesis a limitation on the parameters of the Conformal Standard Model. In our work, we would like to examine these limitations and compare them with the results obtained with the assumption of asymptotic security.

Finally, some similarities can be observed in the assumptions of the mechanism of softly broken conformal symmetry and the behaviour of asymptotically safe theories. So we will try to derive this mechanism from the Weinberg hypothesis. Then we would show that the scales of energy observable in Conformal Standard Model actually rise from the fundamental theory and this theory is the asymptotically safe theory of quantum gravity.