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Nuclear Physics B 907 (2016) 646–663

NUCLEAR PHYSICS B

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Inflationary universe from higher derivative quantum gravity coupled with scalar electrodynamics

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Received 29 February 2016; accepted 20 April 2016

Available online 22 April 2016

Editor: Hong-Jian He

Abstract

We study inflation for a quantum scalar electrodynamics model in curved space–time and for higher-derivative quantum gravity (QG) coupled with scalar electrodynamics. The corresponding renormalization-group (RG) improved potential is evaluated for both theories in Jordan frame where non-minimal scalar-gravitational coupling sector is explicitly kept. The role of one-loop quantum corrections is investigated by showing how these corrections enter in the expressions for the slow-roll parameters, the spectral index and the tensor-to-scalar ratio and how they influence the bound of the Hubble parameter at the beginning of the primordial acceleration. We demonstrate that the viable inflation maybe successfully realized, so that it turns out to be consistent with last Planck and BICEP2/Keck Array data.

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http://dx.doi.org/10.1016/j.nuclphysb.2016.04.033

1. Introduction

Recent corrected Planck data as well as latest BICEP2/Keck/Array data propose better quantitative description of the inflationary universe. In its own turn, this increases the interest to theoretical models of inflation (for the reviews, see Ref. [1]) because they maybe better confronted against observational data.

During last years, there were many attempts to take into account quantum effects in order to construct viable inflation in perturbative Einstein QG (for some review, see Ref. [2]). It is quite natural to go beyond semi-classical General Relativity and to investigate the inflationary scenario for multiplicatively-renormalizable higher derivative gravity as well as for string-inspired gravities. The explicit calculation in this direction at strong gravity regime of higher-derivative QG was done in Ref. [3] where possibility of viable QG-induced inflation was proved. Of course, being the multiplicatively-renormalizable theory what gives the chance to evaluate QG corrections, higher-derivative QG represents merely the effective theory. It is known, that in such theory the unitarity problem which is related with the Ostrogradski instability [4] remains to be the open issue. Eventually, in higher-derivative gravity the unitarity maybe restored at the non-perturbative level. Thus, this theory could be considered as good approximation for the effective theory of quantum gravity. One can expect to account for QG effects at least qualitatively within such theory.

The purpose of this work is to study higher-derivative QG effects for Higgs-like inflation. As simplified model we take first massless scalar electrodynamics and investigate RG-improved inflation in such theory. At the next stage, we consider higher-derivative QG coupled to scalar electrodynamics and evaluate the corresponding RG-improved effective potential. The occurrence of viable inflation which is realized thanks to such RG-improved effective potential with account of QG effects is proved.

The paper is organized in the following way. In Section 2 we consider the multiplicatively-renormalizable massless scalar electrodynamics in curved space–time. The form of the renormalization-group improved scalar effective potential is derived in this theory, paying special attention to the non-minimal scalar-gravitational sector. In Section 3 we analyze inflation in frames of above scalar quantum electrodynamics in Jordan frame. We explicitly derive the slow-roll parameters, the spectral index and the tensor-to-scalar ratio showing how the quantum corrections enter in these expressions. We compute the e-folds number and we demonstrate that the model leads to a viable inflationary scenario according with the last Planck and BICEP2/Keck Array data. In Section 4 we consider multiplicatively-renormalizable higher-derivative gravity coupled with scalar electrodynamics. The complicated expression for RG improved effective potential in such theory (with account of QG corrections) is obtained. Section 5 is devoted to the study of QG-induced inflation in comparison with the simplified case of scalar electrodynamics analyzed before. QG does support the realization of inflation. Also in this case, we carefully investigated how the QG corrections enter in the expressions for the slow-roll parameters, the spectral index and the tensor-to-scalar ratio. It is found that the bound of the Hubble parameter describing the quasi-de Sitter solution of inflation is influenced by the correction of the mass scale of the theory. As a consequence, in order to obtain a realistic scenario, the early-time acceleration results to be weaker when the mass decreases. Conclusions and final remarks are given in Section 6.