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Interactive quadratic gravity

K. Kleidis, A. Kuiroukidis, D.B. Papadopoulos

Department of Physics, Section of Astrophysics, Astronomy and Mechanics, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece

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Abstract

A quadratic semiclassical theory, regarding the interaction of gravity with a massive scalar quantum field, is considered in view of the renormalizable energy–momentum tensor in a multi-dimensional curved spacetime. According to it, a self-consistent coupling between the square curvature term $\mathcal{R}^2$ and the quantum field $\Phi(t,\vec{x}\,)$ should be introduced in order to yield the "correct" renormalizable energy–momentum tensor in quadratic gravity theories. The subsequent interaction discards any higher-order derivative terms from the gravitational field equations, but, in the expense, it introduces a *geometric source* term in the wave equation for the quantum field. Unlike the conformal coupling case ($\sim \mathcal{R}\Phi^2$), this term does not represent an additional "mass" and, therefore, the quantum field interacts with gravity not only through its mass (or energy) content ($\sim \Phi^2$), but, also, in a more generic way ($\mathcal{R}^2\Phi$). Within this context, we propose a general method to obtain mode-solutions for the quantum field, by means of the associated Green's function in an anisotropic six-dimensional background.
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1. Introduction

In the last few decades there has been a remarkable progress in understanding the quantum structure of the non-gravitational fundamental interactions [14]. On the other hand, so far, there is no quantum framework consistent enough to describe gravity itself [17], leaving string theory as the most successful attempt towards this direction [7,16,18]. Within the context of General Relativity (GR), one usually resorts to the perturbative approach, where string theory predicts corrections to the Einstein equations. Those corrections originate from higher-order curvature terms arising in the string action, but their exact form is not yet being fully explored [16].

A self-consistent mathematical background for *higher-order gravity theories* was formulated by Lovelock [11]. According to it, the most general gravitational Lagrangian reads

$$\mathcal{L} = \sqrt{-g}\sum_{m=0}^{n/2}\lambda_m \mathcal{L}^{(m)}, \tag{1}$$

where λ_m are constant coefficients, n denotes the spacetime dimensions, g is the determinant of the metric tensor and $\mathcal{L}^{(m)}$ are functions of the Riemann curvature tensor $\mathcal{R}_{ijkl}$ and its contractions $\mathcal{R}_{ij}$ and $\mathcal{R}$, of the form

$$\mathcal{L}^{(m)} = \frac{1}{2^m}\delta^{j_1\ldots j_{2m}}_{i_1\ldots i_{2m}}\mathcal{R}^{i_1 i_2}_{j_1 j_2}\ldots\mathcal{R}^{i_{2m-1}i_{2m}}_{j_{2m-1}j_{2m}}, \tag{2}$$

where Latin indices refer to the n-dimensional spacetime and $\delta^{j_1\ldots j_{2m}}_{i_1\ldots i_{2m}}$ is the generalized Kronecker sym-

E-mail address: kuirouki@astro.auth.gr (A. Kuiroukidis).

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