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Area spectrum of the D-dimensional de Sitter spacetime

A. López-Ortega

Centro de Investigación en Ciencia Aplicada y Tecnología Avanzada, Unidad Legaria, Instituto Politécnico Nacional, Calzada Legaria # 694 Colonia Irrigación, Delegación Miguel Hidalgo, México, D.F., C.P. 11500, Mexico

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ABSTRACT

The determination of the quantum area spectrum of a black hole horizon by means of its asymptotic quasinormal frequencies has been explored recently. We believe that for D-dimensional de Sitter horizon we must study if the idea works. Thus taking into account the local description of the thermodynamics of horizons proposed by Padmanabhan and the results of Hod, Kunstatter, and Maggiore we study the area spectrum of the D-dimensional de Sitter horizon.

1. Introduction

Supposing that the horizon area of a black hole is an adiabatic invariant and taking into account Ehrenfest principle, in 1974 Bekenstein proposed that the horizon area of a black hole in equilibrium has a discrete and equally spaced spectrum of the form [1–4]

$$A_n = \epsilon \hbar n, \quad n = 0, 1, 2, \ldots, \tag{1}$$

where ϵ is a coefficient of order 1. There are several proposals for the value of ϵ, among these $\epsilon = 8\pi$ and $\epsilon = 4\ln(k)$, where k is an positive integer, frequently appear in the literature. See [5–30] for some references.

The exact value of the quantity ϵ must be determined by a quantum theory of the gravity. Nevertheless the computation of ϵ by means of semiclassical methods has been previously explored. In this research line, in Ref. [15] Hod suggested that in the semiclassical limit the quantum of the black hole area can be determined from the asymptotic value of the real part of the complex quasinormal frequencies (QNF).[1] This proposal is usually known as Hod's conjecture.

Using the spectrum of the quasinormal modes (QNM) [31–33] and Bohr's correspondence principle Hod was able to deduce the value of $4\ln(3)\hbar$ for the quantum of area for four-dimensional Schwarzschild black hole [15]. This value is according to a rigorous statistical interpretation of its entropy [3–6,15,21]. Owing to these facts, Hod's proposal increases the interest in the search for a statistical derivation of the black hole entropy and in the quantization of the corresponding horizon area. See for example Refs. [16–20] where these ideas are explored.

Based on Hod's conjecture, in Ref. [21] Kunstatter explains a method that allows to fix the spacing of the area spectrum for Schwarzschild black hole from the asymptotic value of its QNF. Key points in Kunstatter's analysis are Hod's conjecture, the first law of thermodynamics for the spacetime under study, and Bohr–Sommerfeld quantization of a classical adiabatic invariant [21].

Nevertheless Hod's conjecture has found some difficulties [22, 23]. For example, in Ref. [15] Hod considered transitions from the ground state to excited states with large n [22]. Also the asymptotic value of the real part of the QNF is not universal, it can depend on the field type and spacetime studied [22,23]. Another problem is that for Kerr black hole it predicts a discrete but not equally spaced area spectrum [16], however for this black hole we expect an equally spaced area spectrum [1–4,8].

To overcome some of these difficulties, in Ref. [22] Maggiore suggested that the QNM of a black hole can be described as a set of damped harmonic oscillators. Based on this suggestion and on

E-mail address: alopezo@ipn.mx.

[1] The QNF are the oscillation frequencies of a field that satisfies the radiation boundary conditions of a spacetime. For extensive reviews on the computation and application of the QNF in several research lines see Refs. [31–33].

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