Quasinormal frequencies of the Dirac field in the massless topological black hole

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Motivated by the recent computations of the quasinormal frequencies of higher dimensional black holes, we exactly calculate the quasinormal frequencies of the Dirac field, propagating in D-dimensional ($D \geq 4$) massless topological black hole. From the exact values of the quasinormal frequencies for the fermion and boson fields we discuss whether the recently proposed bound on the relaxation time of a perturbed thermodynamical system is satisfied in the D-dimensional massless topological black hole. Also we study the consequences of these results.

Keywords: Quasinormal modes; massless topological black hole; Dirac field; relaxation time.

Motivados por el cálculo de las frecuencias cuasinormales de agujeros negros cuyo número de dimensiones D es mayor o igual a cuatro, en el presente artículo calculamos exactamente las frecuencias cuasinormales del campo de Dirac moviéndose en el agujero negro topológico de masa cero con $D \geq 4$. Usando los valores exactos de las frecuencias cuasinormales para los fermiones y bosones, discutimos si el límite, recientemente propuesto, sobre el tiempo de relajamiento de un sistema termodinámico perturbado se satisface en el agujero negro topológico de masa cero con $D \geq 4$. Adicionalmente estudiamos algunas consecuencias de estos resultados.

Descriptores: Modos cuasinormales; agujero negro topológico de masa cero; campo de Dirac; tiempo de relajamiento.

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1. Introduction

The physical systems for which we exactly solve their equations of motion can be expected to play a significant role in several lines of research. For these physical systems we exactly calculate the physical quantities that for other systems we calculate by using approximate methods. Also in many research areas, the physical insight that is obtained by studying the exactly solvable systems can be used to infer some details about the behavior of more complex physical systems.

The quasinormal modes (QNMs) of a black hole are solutions to the equations of motion for a classical field that satisfy the appropriate radiation boundary conditions at the horizon and at the asymptotic region. The quasinormal frequencies (QNFs) of a field are valuable quantities since these are determined by a few parameters of the black hole and the field [1-3], for example, the QNFs of the Kerr-Newman black hole are determined by the mass, angular momentum, and charge of the black hole and the mode of the field. Hence if we measure the QNFs of a field, then we can infer the values of the mass, angular momentum, and charge of the Kerr-Newman black hole.

Also the QNMs allow us to study the linear stability of the black holes, because if we find QNMs whose amplitude increases in time, then the black hole may be unstable [1-3]. Recently the QNMs have found applications in several research lines. For example,

a) the AdS/CFT correspondence of string theory [2,4,5],

b) the determination of the area quantum of the black hole event horizon [6,7],

c) the expansion of functional determinants in some thermal spacetimes [8,9],

d) the expansion of the "distant past" Green functions used in self-force calculations [10].

For many relevant spacetimes their QNFs must be calculated approximately, hence we use numerical methods or perturbation methods [1-3]. Nevertheless, recently exact calculations of the QNFs for several spacetimes have been presented. Among these we enumerate the following:

a) three-dimensional static and rotating BTZ black holes [5,11-13],

b) three-dimensional charged and rotating black holes of the Einstein-Maxwell-dilaton with cosmological constant theory [14-17],

c) two-dimensional dilatonic black hole [18,19]

d) five-dimensional dilatonic black hole [18,19],

e) D-dimensional de Sitter spacetime ($D \geq 3$) [20-26],

f) BTZ black string [27],

g) Nariai spacetime [28][i]

In the following paragraphs we comment on another D-dimensional anti-de Sitter black hole for which the exact values of its QNFs have been calculated.

We notice that the AdS/CFT correspondence of string theory motivated many studies on the QNFs of anti-de Sitter black holes [2,4,5], because this correspondence proposes that the QNFs of the anti-de Sitter black holes determine the relaxation time of the dual conformal field theory [4,5]. (See