# Hairy BTZ Black Hole and Analogue Gravity in Graphene

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Abstract

(2+1)-dimensional Einstein gravity with a negative cosmological constant has a black hole solution which is called the BTZ black hole. It corresponds to a two dimensional rotating black hole that is characterized by its mass and angular momentum. The form of the BTZ metric is conformally related to the metric of the Beltrami trumpet surface. From this relation the out of horizon part of the BTZ black hole can be embedded into three dimensions. Since the low energy electron excitations of graphene are described by the massless Dirac equation and this equation has the conformal covariance property, we can obtain the properties of the Dirac particles moving in a BTZ background from the Dirac pseudo-particles on a Beltrami trumpet shaped graphene sheet. To model the BTZ black hole with a graphene sheet, we find the Dirac equation in the optical BTZ background which has the form of the Beltrami trumpet metric. From the methods of pseudo-Hermitian quantum mechanics we obtain the corresponding Hermitian Hamiltonian of the system. The energy eigenvalues of the Dirac particles are found by using the discrete basis set method. By comparing energy values with the graphene parameters, we propose a possible laboratory model of a BTZ black hole in the form of a graphene sheet with external magnetic and electric fields and a gap opening mass term. Moreover, analogue models of the hairy BTZ black hole, which is the BTZ black hole coupled to a scalar field, on two dimensional materials such as dichalcogenides and topological insulators can also be constructed. In that way, some predictions on the nature of Hawking-Unruh temperature via two dimensional materials can be made.

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