Accepted Manuscript

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PII: S0378-4371(18)30509-0
DOI: https://doi.org/10.1016/j.physa.2018.04.081
Reference: PHYSA 19513

To appear in: *Physica A*

Received date : 26 August 2017
Revised date : 29 January 2018

Please cite this article as: M. Mirtorabi, S. Miraboutalebi, A.A. Masoudi, L. Farhang Matin, Quantum gravity modifications of the relativistic ideal gas thermodynamics, *Physica A* (2018), https://doi.org/10.1016/j.physa.2018.04.081

Quantum gravity modifications of the relativistic ideal gas thermodynamics

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April 17, 2018

Abstract

In the frame work of the generalized uncertainty principle, we study the theoretical modifications induced by the quantum gravity on the thermodynamics of the relativistic ideal gas. The merit of this work is that we have applied two different research methods while the results of both methods point to a complete consistency between them. These approaches emerge from different viewpoints of the incorporation of the underlying theory. Here, we call them as the modified Hamiltonian method and the modified density of states method. In the first method, we have an active viewpoint and suppose that the Hamiltonian is modified via the momentum transformation induced by the theory. However, in the second method, we adopted rather a passive interpretation and consider a transformation of the coordinates as a result of the theory. In order to have a time invariant volume element of phase space, this method leads to a redefinition of the density of states. We show that these approaches expectedly lead to the same partition functions and hence are equivalent. Since, there are two models of the generalized uncertainty principle, with quadratic and linear momentum terms, we show these equivalencies are established for both models. We obtain the modifications of the thermodynamics of the relativistic ideal gas induced by the quadratic model and estimate the consequences for the limiting case the nonrelativistic domains. All the results are in agreement with the previous issues. Also the results for the extreme relativistic and asymptotic ultrarelativistic domains are obtained which shows novel properties. In addition, we indicate that the black body energy spectrum will be changed, due to the quantum gravity corrections, but this effect can be seen at high temperature limits.

Keywords: *Generalized uncertainty principle, Quantum gravity, Relativistic ideal gas, Liouville theorem.*

1 Introduction

In the large speed accelerators, heavy ions can be accelerated to obtain very high kinetic energy. These ions forms an ensemble approximately of ideal gas with relativistic velocities. The quantum gravity effects at Planck scales appear at high energy domains and have remarkable effects on the statistics of such relativistic ideal gas ensemble. Hence, these accelerators provide us with right laboratories to examine the effects and the phenomena relevant to the quantum gravity. One of the most important issues of the quantum gravity is the prediction of the existence of a minimal observable length. Specifically, in order to observe very small scale of lengthes, it is necessary to use high energetic beams. These beams create minimal black holes and hence a minimal length is required to describe the horizon of these black holes. However, quantum mechanics does not predict this length scale in the form of the traditional canonical commutation relation. Instead, a reformed Heisenberg algebra is required to explain the existence of the minimal length scale, [1] and [2]. Several models are presented by different quantum gravity theories to generalize the uncertainty principle (GUP) which indicate the existence of a minimal length. The most popular GUP model is based

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