Abstract

It is suggested that Dark Energy in the Universe originates from the energy of the Black Hole radiation. In particular, this radiation is speculated to be dominated by the antigravitons associated with the graviton-antigraviton pairs $G - \bar{G}$ in the horizons. These antigravitons $\bar{G}$ are then considered to form the antigravity force driving the expansion of the universe. With respect to the known data, the involved parameters are investigated.

PACS: 12.60.-i, 04.60.-m, 04.70.-s

Keywords: Dark Energy, Black Hole, Quantum Gravity

One of the hardest puzzles in modern physics and astronomy is the exact origin of Dark Energy (DE) [1]. The evidence of this mysterious invisible energy dates since the observation of the accelerated expansion of the Universe, and is still motivated by the recent observations [2, 3, 4]. Although compared to the fundamental energy density of gravity or that of the Standard Model of particle physics (SM), the current DE under this vision is extremely small $\rho_{DE} \sim (10^{-3} GeV)^4$, but it is the dominant form of cosmic energy, filling roughly $\sim 70\%$, of the total energy density, compared to Dark Matter $\sim 25\%$ and SM (or visible matter) $\sim 5\%$ densities [2, 3, 4]. The observed accelerated expansion in the CDM cosmology is driven by this DE component. Even though various ideas addressing the accelerated expansion of the Universe exist, up to now none
of their parameters is explained and then none of them are particularly well motivated [5, 6, 7, 8]. Thus any attempt enlightening this tiny magnitude, but dominant energy, is welcome.

Other than the Casimir energy which is the most natural candidate for DE [9, 10, 11], Black Hole Radiation (BHR), whose existence has been proved theoretically by Hawking [12, 13, 14, 15], can also be considered as a candidate for DE. In fact, due to quantum fluctuation near to BH horizons, constant conversion into pairs of particle-antiparticle close to the event horizon where one of which falls into the BH while the other escapes. This makes the BH appears, for an outside observer, as emitting particles. From an energy conservation point of view, this radiation reduces the mass and the BHs and is therefore known as BH evaporation. Moreover, each BH evaporation is characterized by a temperature called Hawking temperature. Different derivations of the HR in many spacetime models with different kind of quantum particles have been considered [16].

In this paper, we consider the possibility that the dominating mysterious DE is the energy of the BHR is the universe. For that, we focus on the case where the BHR is essentially antigravitational, originated from the pairs graviton-antigraviton \(G - \overline{G}\) creation near to the BH horizons, where the gravitons \(G\) fall into the BH while the antigravitons \(\overline{G}\) escape and thus get emitted and dominates the BHR and forms in this way an antigravitational force. We investigate the properties of such antigraviton-dominated BHR according to the known DE data \(^1\).

First, we present the current status of DE. Then we show the relation between the BHR and DE and investigate the properties of the antigravitational BHR with respect to known data. Although the existence of DE is almost confirmed by the recent observations of the acceleration of the universe, its nature remains unveiled [1, 2, 3, 4]. The energy density of the universe reads

\[
\rho = \rho_{DE} + \rho_{DM} + \rho_{SM},
\]

where DM and SM stand for Dark Matter and SM (visible matter) respectively. This mysterious hidden energy is now known to dominate the energy of the universe, by uniformly filling the empty space. It corresponds to a vacuum energy quite close to the neutrino mass scale

\[
\frac{\rho_{DE}^{1/4}}{m_\nu} \sim 1,
\]

\(^1\)Throughout the work we use natural units where \(\hbar = c = 1\).
but in comparison to the $TeV$ scale currently experienced at the LHC, to the GUT scale or to the Planck scale, it happens to be extremely small

$$\frac{\rho_{DE}^{1/4}}{M_{TeV}} \sim 10^{-15}, \quad \frac{\rho_{DE}^{1/4}}{M_{GUT}} \sim 10^{-21}, \quad \frac{\rho_{DE}^{1/4}}{M_{Planck}} \sim 10^{-30}. \quad (3)$$

From this hierarchy (1),(2), a remarkable numerical coincidence is noticed between these scales, it is

$$\rho_{DE}^{1/4} \sim \frac{M_{GUT}}{M_{Planck}} eV \sim 10^{-3} eV. \quad (4)$$

That is, the DE scale happens to be related to the Planck scale through the intermediary GUT scale. It is likely that this is not a proper coincidence, and then, there may exist a deeper connection between these extreme fundamental scales that result in such an interplay. Indeed, the relation (4) leads to understand the DE as a manifestation of a vacuum energy that is necessarily connected with the quantum structure of spacetime at $M_{Planck}$.

The trivial way of thinking about the possible connection of DE with the Planck scale is in terms of a vacuum energy related to the presence of virtual particles due to the quantum fluctuation of spacetime at $M_{Planck}$. These off shell short-lived particles are produced in pairs of particle-antiparticle $\nu - \bar{\nu}$ and mutually annihilate. In some cases, however, these pairs could be broken apart in the presence of some sort of external fields so that their annihilation is avoided and become real particles. This can happen near to the BH horizons where the pairs of virtual particles are not annihilated because of the strong gravitation field of the horizon leading to the absorption of one particle of the pair while leaving the other free to escape and thus get emitted to form the BHR. That is, we posit that the underlying mechanism that induces the DE could be resulted from the case where the virtual particles near to the BH horizons are graviton-antigraviton pairs $\nu - \bar{\nu}: G - \bar{G}$ where the gravitons $G$ fall into the BH while the antigravitons $\bar{G}$ does not and get emitted and thus become real and dominate the BHR that we assume forms the known DE density in the universe

$$\rho_{DE} \equiv \rho_{\Sigma}. \quad (5)$$

A possible scenario could be provided by higher dimensional models including string and M-theories involving extra dimensions. At near horizons of four dimensional black holes, in such theories, can be given by the following product

$$AdS_2 \times S^2 \times X^n \quad (6)$$

where $X^n$ is a $n$-dimensional compact space. It is recalled that one can have $n = 6$ and $n = 7$ associated with string theory and M-theory, respectively. This
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involves Calabi-Yau and G2 manifolds. From mathematical point of view, the
universe, in this way, is 4+n-dimensional space.

From four-dimensional point of view, the anti-graviton scape to the extra
dimensions associated with the compact part of the space-time where the DE
data can be discussed using data analysis factorization. The idea is to describe
the DE data without having prior knowledge on it form the associated predictive models. It is possible to project such data into the compact spaces that
may encode all hidden physical data associated with many universe physical
problems. It looks like a projection method allowing to confine the DE in the
internal spaces. In this way, DE density should be associated with the comp-
actification scenario. Precisely, the extra dimensions could contribute to such
density in terms of the geometric deformations controlling either the size and
the shape. The natural question is how these things are linked. In M-theory
and string theory, the 3-cycles are relevant for studying such deformations ei-
ther in Calabi-Yau and G2 manifolds. We conjecture that DE density can be
associated with the size of such cycles

$$\rho_{DE} \sim L^{-4}$$ (7)

where $L$ is associated with the size of involved 3-cycles.

In connection with the large volume scenario in string theory, some scalar
fields can be used to estimate the size of such cycles. In this way of seeing
things, there are many approaches to introduce scalar in such compactifica-
tions. For instance in type IIA superstring associated with one 3-cycle, the
size can be linked to the axion decay constant

The possible connection of DE and BHs in universe have been addressed.
The main idea of this work is that the DE driving the accelerating expa-
sion of the universe could be interpreted as the antigravitons radiated by BHs.
In fact, we have shown that this can happen near to the BH horizons where
the pairs of graviton-antigraviton $G - \overline{G}$ are not annihilated because of the
strong gravitation field of the horizon leading to the absorption of the gravi-
ton $G$ while leaving the antigraviton $\overline{G}$ free to escape and thus get emitted
to form an antigravitationa radiation. We have investigated this antigravita-
tional radiation in a five dimensional generic BH in the framework of the
flat Friedmann-Robertson-Walker model and exhibited that the corresponding
energy density $\mu_{\overline{G}}$ with a negative pressure $p_{\overline{G}}$ whose magnitude equals its
positive energy density $\mu_{\overline{G}} \equiv \rho_{\overline{G}} \equiv \rho_{DE}$. We have then manifested that with
an energy density smaller than the energy density of the universe $\rho_{\overline{G}} \langle \rho$, an
accelerating expansion effect in the universe is driven by this antigravitationa radiation pressure.
The relation between BHs and DE in the universe in this model may shed some
light on the possible connection with other known phenomena in fundamental
high-energy theories of higher-dimensionalspacetime. Deeper investigations remain well motivated.

Acknowledgements. The author would like to thank S-E. Ennadifi and A. Belhaj for fruitful discussion.

References


Received: February 17, 2019; Published: March 15, 2019