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How Gravitational Effects on the Quantum Vacuum Might Explain Dark Energy and Dark Matter Observations

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Abstract

Following a brief review of the "black hole dark energy radiation" and "gravitized vacuum" references, a novel theory of how gravity might affect the quantum vacuum is proposed. This overarching theory proposes that the gravitational field of a sufficiently concentrated collection of matter and/or energy *upregulates* the virtual particle activity of the adjacent quantum vacuum, thus its energy density and lensing capacity. In contrast to general relativity, the particle and wave duality of quantum physics is necessary for understanding quantum vacuum gravitational effects. Very recent supporting and pending observational studies are discussed, including the ingenious and extremely sensitive vacuum scale to be deployed for the Archimedes Experiment. Support or falsification of this proposal may be imminent.

Keywords

Quantum Vacuum Theory, Dark Energy, Dark Matter, Black Holes, Archimedes Experiment, Black Hole Dark Energy Radiation

1. Introduction and Background

In the April 2023 issue of *Journal of Modern Physics*, this author presented a novel theory [1] to explain the new observations in support of black hole (BH) mass increase tightly coupled to dark energy-driven universal expansion ("cosmological coupling") [2]. To summarize, it was proposed that the high gravitational field at or near an astrophysical BH horizon might have sufficient capacity to separate entangled pairs of matter and dark energy virtual particles within the vacuum and send them off in opposite directions as newly-made real particles (*i.e.*, positive energy matter into the BH and negative dark energy deeper into the cosmic vacuum). Figure 1 is a schematic illustration of two such interactions, wherein H is the horizon, NM is a neutral matter particle and DE is its negative energy partner. A symmetry argument was made, partially inspired by Dirac's mathematical formalism (a "Dirac sea" of positive and negative *energy* eigenstates) [3], but also by Hawking's opposite symmetry proposal of BH *thermal* radiation. One can consider the newly-proposed emission to be "black hole dark energy radiation".

With reference to dark matter, the concept of a gravitized vacuum was introduced in 2018 [4] and defined as follows:

"A gravitized vacuum is operationally defined as the vacuum of space sufficiently close to any gravitating massive body, or collection of bodies, such that its gravitational energy density is observed, or expected, to be greater than that of deep intergalactic space."

It was hypothesized that subtle gravity-induced density differences between the circumgalactic/galactic vacuum and the deep intergalactic vacuum might account for the lensing and inertial effects we currently ascribe to dark matter. In accordance with this principle, a volume of gravitized vacuum should weigh more than an equal volume of deep intergalactic vacuum. While not explicitly stated, the idea was that *the lensing capacity of a volume of gravitized vacuum is directly correlated to the total energy* (*or mass*) *density of its virtual particles*. This can be referred to as the "activity" of the quantum vacuum at a given time and location. Effectively, the gravitized vacuum concept attempts to insert the activity of the quantum vacuum into the causal chain between the gravitating body and the spacetime curvature that body induces. In other words, *it is proposed that the gravitized vacuum is the inertial lensing "material" which we currently refer to as "dark matter"*.

At the time of the gravitized vacuum proposal, a schematic diagram of an experimental apparatus to test this proposal was presented. This can be seen herein in Figure 2. The key feature of the experimental apparatus is an extremely sensitive scale to weigh the control and gravitized samples. The apparatus must be in a vibration-free environment, chilled to as low a temperature as possible, and the testing chamber must be a tightly-sealed near-total vacuum. It was feared at the time of publication that a sufficiently-sensitive apparatus might not be achievable, but one quickly learns not to underestimate the ingenuity of experimental

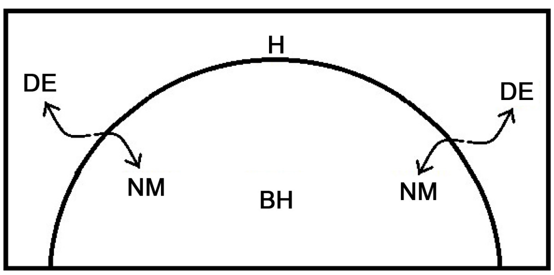

Figure 1. Black hole dark energy radiation (outward) and matter absorption (inward).

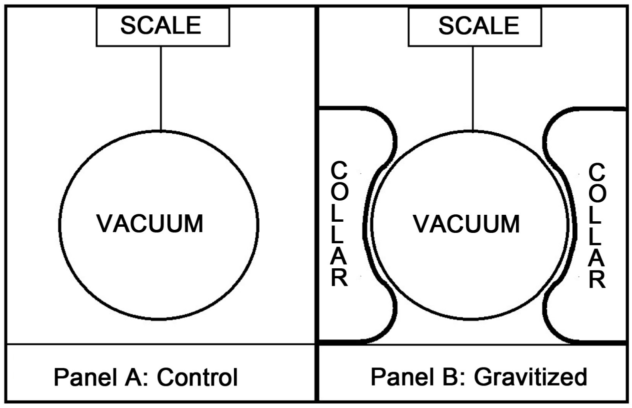

Figure 2. Experimental apparatus for weighing the control and gravitized vacuum.

physicists! See the Discussion section.

It is the purpose of this paper to present a novel theory of how gravity might affect the quantum vacuum and to briefly discuss what is known currently and what can be predicted for observations in the near future.

2. A Theory of Gravitational Effects on the Quantum Vacuum

Given the above speculations concerning how black holes might be cosmologically coupled to universal expansion by "black hole dark energy radiation", and how a gravitized vacuum might explain gravitational lensing and inertial effects attributed to "dark matter", the following overarching quantum vacuum theory is proposed:

"The gravitational field of a sufficiently concentrated collection of matter and/or energy upregulates the virtual particle activity of the adjacent quantum vacuum, thus its energy density and lensing capacity."

In other words, this proposal implies a *proportionality* between the strength of a vacuum gravitational field and its virtual particle activity. It is believed that this might, in fact, be a necessary feature for the development of a successful theory of quantum gravity.

3. Discussion

To date, gravitational effects on quantum particles, whether the particles are virtual or real, are completely unknown. They can be safely ignored in the low gravitational energy environment in which we find ourselves. However, it seems highly likely that gravitational effects on such particles cannot be ignored in the vicinity of a BH horizon. This is why the "black hole dark energy radiation" proposal may have some merit, particularly in the context of the new observations made by Farrah, *et al.* In general, gravitational effects on the quantum vacuum may be so subtle that they can only be appreciated on the largest (*i.e.*, galactic and intergalactic) scales. With the possible exception of the pending Archimedes Experiment (see below), it is difficult to imagine how any Earth laboratory could make much experimental progress in understanding the quantum vacuum. However, if the theory presented herein is to be taken seriously, supporting observations will be necessary, although somewhat difficult to obtain. This could be why dark energy and dark matter observations remain so mysterious to modern scientists, despite their obvious successes with the Standard Particle Model and much of Big Bang theory.

The theory proposed herein offers a quantum vacuum explanation for a better understanding of dark energy and dark matter observations. Interestingly, the dark energy phenomenon of non-decelerating cosmological expansion might be explainable with the finely-tuned *particulate* theory offered in the first reference. Whereas, following the fourth reference, the entity typically referred to as dark *matter* might be explainable as a smoothly-distributed vacuum energy density state with *wavelike* lensing properties adjusting as the local density varies according to local gravitational field strength. So, it is perhaps the *dual nature* (*i.e.*, particle and wave nature) of quantum physics of the vacuum which may allow for the mysteries attributable to dark energy and dark matter to be better understood.

As for observational support of the quantum vacuum theory proposed herein, there are now several important studies just reported and/or pending. Firstly, one could predict that a rind (*i.e.*, density spike) of "dark matter" would be observable around the most accessible stellar-mass black holes. These should be small enough to have a horizon energy density corresponding to a high spacetime curvature, and yet close enough to be observed and measured. The first study to make *indirect* observations of such density spikes was just recently published on January 30, 2023 [5]. Two binary star systems containing a black hole showed abnormally fast orbital decays, matching a computer simulation of a dark matter dynamical friction model. Equivalently, one could also say that this finding was due to an unexpectedly large "drag" caused by a greater-than-expected spacetime curvature, in the form of lensing dark matter, around the black holes in these binaries. The equivalence of both such explanations is fully in keeping with the increased vacuum energy density theory of "dark matter" presented herein. Results of observational studies along similar lines are pending in the very near future.

As for acquiring *laboratory* evidence of the potentially-variable energy density of the quantum vacuum, the May 2023 issue of Scientific American reports remarkably fast progress on construction of a highly sophisticated balancing scale [6] much improved in its design in comparison to that shown in **Figure 2**. It will be used in the upcoming Archimedes Experiment. The current iteration makes use of a balancing beam with the control on one arm and the experimental sample on the other. Most importantly, movement of the beam in response to phase transitions in the sample material will be read with the aid of a laser interferometer designed to be possibly even more sensitive than the LIGO system. A sensitivity to vacuum buoyancy force changes of as little as 10^{-16} Newtons may be possible!

This is a remarkable "weighing scale" for the vacuum. If this apparatus is successful in preliminary testing, it is hoped that something like it can be tested in widely-varying gravitational field settings, perhaps even including during space travel or within deep chambers on the Moon or Mars. In the not-too-distant future, we may well have proof that changing the gravity environment changes the "activity" of quantum vacuum fluctuations and thus the measured energy density of the vacuum. If the magnitude of such anticipated changes can be correlated to astrophysical observations, we may soon have further support for the gravitational effects on the quantum vacuum proposed herein. If so, there should be an improved understanding of the quantum vacuum (a holy grail of modern physics), what we are currently referring to as dark energy and dark matter, and possibly a final resolution of the cosmological constant problem. We are truly living in interesting times.

4. Summary

This paper briefly describes how the mysteries of dark energy and dark matter might be explained by an improved understanding of gravitational effects on the quantum vacuum. After reviewing the vacuum theories underpinning "black hole dark energy radiation" and the "gravitized vacuum" as dark matter, an overarching quantum vacuum theory is proposed with respect to gravity:

"The gravitational field of a sufficiently concentrated collection of matter and/or energy upregulates the virtual particle activity of the adjacent quantum vacuum, thus its energy density and lensing capacity."

One of the ironies of this proposal is that dark *energy* can be treated as *particulate* radiation from high gravity field compact bodies. Another irony is that a gravitized *vacuum* of variable energy density in comparison to that of the deep intergalactic vacuum could be what we refer to as dark *matter*. The particle and wave duality of quantum physics, in contrast to general relativity, allows for such equivalencies.

Additional observational support for this approach may come in the near future. Further studies along similar lines by Farrah *et al*. and Chan and Lee are pending and eagerly anticipated. It is likely that trials of the Archimedes Experiment in different gravitational fields will yield interesting results with respect to "weighing" the quantum vacuum. Support or falsification of this proposal may be imminent.

Data Availability Statement

All materials in this submission, including figures, have been generated by the author. Appropriate credit and citations of original sources have been made where required. He is willing to make readily available all materials used in the production of this submission.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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