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How Dark Energy Might Be Produced by Black Holes

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Abstract

If confirmed, the new galactic observations in support of rapidly growing supermassive black holes in association with their production of dark energy may provide for a quantum leap forward in our understanding of black holes, dark energy, and universal expansion. The primary implication of these observations is that growth of black holes may well be coupled with universal expansion ("cosmological coupling"). Study of the Flat Space Cosmology (FSC) model, in conjunction with these new observations, suggests a novel mechanism of "black hole dark energy radiation". This brief note gives a rationale for how the high gravitational energy density vacuum within or adjacent to a black hole horizon could be sufficiently energetic to pull entangled pairs of positive matter energy particles and negative dark energy "particles" of equal magnitude out of the horizon vacuum and send them off in opposite directions (*i.e.*, gravitationally-attractive matter inward and gravitationally-repelling dark energy outward). One effect would be that a black hole can rapidly grow in mass-energy without mergers or the usual accretion of pre-existing matter. A second effect would be continual production of dark energy within the cosmic vacuum, fueling a continuous and finely-tuned light-speed expansion of the universe.

Keywords

Astrophysics: Galaxies, Black Holes, Dark Energy, Vacuum Energy, Cosmological Coupling, Flat Space Cosmology, *ER = EPR*, Gravitized Vacuum, Dark Matter, Hawking Radiation

1. Introduction and Background

Physical theories are often based upon symmetries. In the theory of cosmic inflation, for instance, there is a symmetry between the vacuum and matter. A presumed primordial high energy vacuum reaches a critical point where elementary particles of matter and radiation are nearly instantaneously created within the vacuum. Whether or not inflation actually occurred as a remarkably sudden and explosive one-time process in the first 10^{-32} second of cosmic time, the theory at least entertains the possibility of a symmetry between the vacuum and matter.

The exact conditions of the earliest universe are shrouded in mystery for two important reasons. Firstly, we can only currently observe back to the cosmic microwave background (CMB) emission event (*i.e.*, the "recombination epoch"), which was some thousands of years after the Big Bang. Although it may be possible someday to detect gravitational waves of the earlier universe, that remains to be seen. Secondly, there are no Earth laboratories which can simulate the presumed high gravitational energy density environment of the early universe. In fact, there is only one place we can even look to for study of the highest gravitational energy densities in the universe we see today: the vicinity of black hole (BH) horizons. So, it goes without saying, what exactly occurs within the black hole horizon and its adjacent vacuum is currently poorly understood. The high energy density vacuum in such locations is likely to be full of surprises. As with current theories of inflation, we can only guess at what symmetries may exclusively reveal themselves in the vicinity of a BH horizon. Following the examples of inflationary theory and Hawking radiation, the symmetry theory presented herein contains something familiar: A likely intimate relationship, under high energy conditions, between vacuum energy and matter.

In the Flat Space Cosmology model (FSC) [1] [2] much is made of the "cosmological coincidence problem". This problem is due to the remarkable fact that the average cosmic densities of total matter energy and dark energy (*i.e.*, cosmic vacuum energy) are observed and calculated to be the same order of magnitude, with each representing slightly less than one nanojoule of energy per cubic meter of the cosmic vacuum. While current consensus is that the energy density partition of the universe is now approximately 32% total matter energy and 68% dark energy, it should be remembered that, in just the last decade, these numbers have already changed from a previous consensus of about 28% total matter energy and 72% dark energy. It remains entirely possible that the current numbers will converge even further. FSC predicts, largely from spatial flatness observations, that these two percentage numbers will ultimately continue to converge towards 50% total matter energy and 50% dark energy [3] [4].

Regardless of which cosmological model (inflationary cosmology or FSC) one favors at the present time, the "cosmological coincidence problem" is in need of an explanation. Frankly, one is sorely tempted to ask the following question:

"Are matter and dark energy possibly symmetry partners?"

The Preface to *Flat Space Cosmology—A New Model of the Universe* (the first listed reference) puts the relevant questions as follows:

"Are matter energy and dark energy within a scaling cosmic vacuum possibly two sides of the same cosmological coin? Could a continuous link between cosmic vacuum energy density and matter energy density have something to do with quantum nonlocality through instantaneous (*i.e.*, faster than light!) conservation of cosmic energy? We suspect this may be the case in our matter-generating quintessence model. If so, it would not be the first time that matter and energy were found to be deeply interconnected."

New observations have just been reported from a study of the growth in mass of supermassive black holes in elliptical galaxies with redshifts ranging from $0 < z < 2.5$ [5]. Using criteria for coupling of BH mass growth with universal expansion over approximately 9 billion years of cosmic time, they found evidence for such cosmological coupling. There was the expected redshift dependence of the mass growth, and the BH cosmological contribution was interpreted as being in the form of vacuum energy. Furthermore, BH production gave the value of Ω_Λ measured by the 2020 Planck collaboration. Based upon their findings, they proposed that *stellar remnant black holes are the astrophysical origin of dark energy*.

In light of the above background of theory and observations, the purpose of this brief note is to present and discuss a novel theory of a possible symmetry occurring within and adjacent to high gravitational energy density BH horizons.

2. A Theory of Black Hole Dark Energy Radiation

The reader is referred to **Figure 1** for a schematic illustration of how black hole dark energy radiation might work. Curve H represents a BH horizon. The paired arrows represent entangled particle pairs of an electrically-neutral matter particle NM (inwardly-attracted arrow) and a unit (*i.e.*, "particle") of dark energy DE (outwardly-repelled arrow) of equal and opposite-sign energy compared to its matter partner. FSC uses a convention wherein the gravitationally-attracting matter partner energy is "positive" and its gravitationally-repelling dark energy partner is "negative." Their combined virtual particle energy within the vacuum is presumed to add to zero.

Figure 1 illustrates two examples of the proposed particle interaction at or near every energetic black hole horizon. The weak theoretical Hawking radiation interaction is omitted for clarity. The ingested matter adds to the total matter energy and entanglement entropy of black hole BH, causing it to enlarge by an increment of mass and radius corresponding to the energy and entropy added to the BH. Meanwhile, the entangled dark energy partner "particle" is repelled from the BH horizon, owing to the negative sign of its energy. Thus, the negative

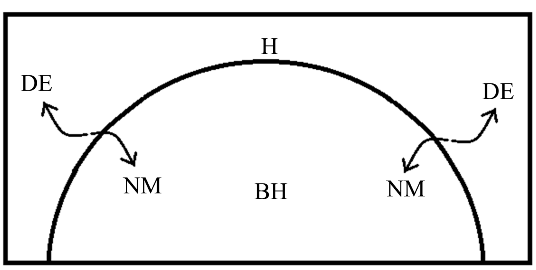

Figure 1. Black hole dark energy radiation (outward) and matter absorption (inward).

energy and the entropy added to the vacuum *balances* the vacuum's loss of potential matter energy among the virtual particles of the high gravitational energy vacuum in the vicinity of the BH horizon. By adding negative energy and entropy to the vacuum, the entangled dark energy partner to the ingested matter particle increases the total dark energy and entropy of the cosmic vacuum, as represented by increasing the surface area (*i.e.*, "gravitational" or "entanglement" entropy) of the cosmic BH horizon in proportion to the BH growth described above. In this manner, black holes embedded within their cosmic parent BH (*i.e.*, our universe) are *cosmologically coupled* to the universe expansion, without violating conservation of energy of the net zero energy FSC universe. At the same time as the FSC universe increases in total positive mass-energy, its total negative dark energy increases negatively by the same amount. The rationale for this type of net zero energy accounting within the cosmic vacuum was anticipated by the mathematical formalism of Dirac, and is more fully described in the third reference. The third figure of that reference is particularly illustrative.

Furthermore, in keeping with the theories known as *ER* = *EPR* and the Holographic Principle [6], what goes on in the bulk is presumably completely encoded within the cosmic BH horizon ("boundary") surface area, which represents the total entropy of the FSC universe (following the Bekenstein-Hawking BH entropy formula, $S = \pi r^2 / l_p^2$). Each square entropy microstate tile in the current FSC horizon is assumed to have sides of two Planck lengths, totalling to 10^{120} such tiles filling the surface area of the *current* FSC BH universe horizon.

3. Discussion

One can readily see from the above theoretical description that, despite the fact that the total matter energy and dark energy continually increase as the universe expands, their average *densities* within the increasing bulk volume *continually decrease*. In the FSC model, the average vacuum energy density following the Big Bang continually decreases, as the universe expands, by roughly 120 base ten logs (*i.e.*, 10^{120}) while the cosmic radius increases roughly 60 base ten logs (*i.e.*, 10^{60}) from the Planck scale epoch to the present. Thus, the FSC quintessence BH universe model's current vacuum energy density of about 10^{-9} joule per cubic meter is lower than the Planck scale epoch vacuum energy density calculated by quantum field theorists by a factor of approximately 10^{120}. One can readily see that there is no "cosmological constant problem", because Λ in the FSC model continually correlates with *inverse* cosmic entropy. This can only happen in a realistic quintessence model such as FSC. This has been shown in several prior FSC publications.

If the new observations of cosmologically-rapid BH growth hold up, the novel BH dark energy radiation theory presented herein would help to resolve a number of current cosmological conundrums. When applied to the FSC model, the nature of cosmic expansion dark energy becomes more understandable. Vacuum energy density, due to its inverse relationship with total cosmic entropy, appears to continually drive a *finely-tuned* expansion of the universe in the forward time direction. This is the "entropic arrow of time." As described above, the "cosmological coincidence" and "cosmological constant" problems can be resolved. Furthermore, the BH holographic principle allows for information in the bulk of black holes of all sizes to be separately encoded in the horizon surface. Thus, as the universe grows, its black holes grow.

If the new observations can be confirmed and generalized, black holes should be continually coupled with universal expansion. They would *not* be expected to evaporate, as envisioned by Hawking! He envisioned BH ingestion of a *negative* energy partner, with corresponding evaporative decrease of BH mass and radius. What is presented herein is essentially a statistically more likely opposite radiative process, now that we have a better understanding of dark energy, which was unknown to Hawking at the time of his particular BH radiation proposal. Thus, astrophysicists would now have a new explanation for rapid BH growth in the early universe which does not entirely rely upon mergers and ongoing accretion of nearby matter. Instead, cosmologically rapid BH growth can, in effect, be *pulled* out of the cosmic vacuum, even if it *appears* to be empty of matter. Einstein's $E = mc^2$ insures this to be the case when the BH-adjacent vacuum is highly-energized, as it certainly must be. Furthermore, BH horizon-encoded information is not lost forever in BH interiors. Accordingly, there should be no "BH information paradox" to worry about. This BH holographic solution has been well-described by theorist Leonard Susskind [7].

It has long been theorized by Roger Penrose [8] that black holes are huge repositories of cosmic entropy, as defined by Bekenstein and Hawking. Hawking and Penrose's cosmological work [9] seemed to imply that our universe could behave in some fashion like a time-reversed BH. This concept inspired creation of the FSC model after Planck satellite observations appeared to support it. However, with the newly-reported observations of Farrah, *et al.*, in conjunction with the novel BH theory presented herein, a concept of BH time-reversal no longer appears to be absolutely necessary for FSC modelling. Somewhat like an infinite series of Russian (Matryoshka) dolls, our BH-like universe might simply be part of a temporally-infinite, fractal-like, hierarchy of BH-producing "parent" and "child" universes, as recently theorized [10] [11].

FSC has now been shown in numerous peer-reviewed physics and cosmology journal publications to be a viable cosmological model which follows general relativity with respect to what we know or suspect about black holes. A summary publication of comparisons made between FSC and the current inflationary standard model (ΛCDM) has identified eleven different categories where FSC appears to be superior [12].

With respect to the accumulated supernovae data (SNe), **Figure 2** is self-explanatory. It should be noted in this figure, first compiled and published by Ned Wright in 2015 with respect to the work of Betoule, *et al.* [13], that FSC, as a Flat Dark Energy Model, closely approximates the solid purple curve, upon which the *observational* blue dashed curve ("Evolving SNe") is *superimposed* (!). Given

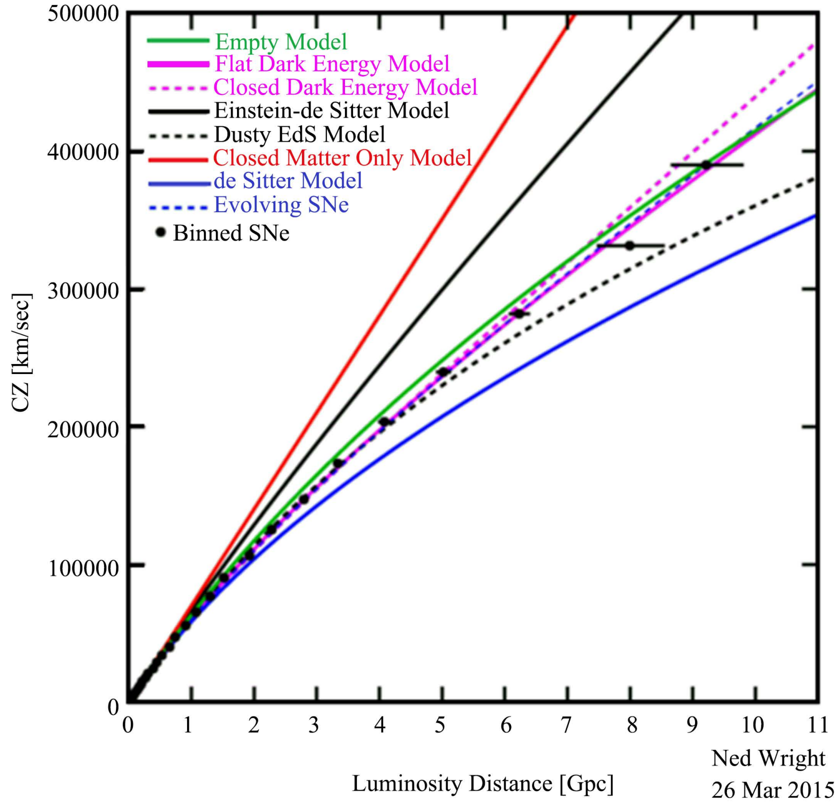

Figure 2. Universe models and SNe Data (FSC corresponds to the solid purple curve).

the accumulated type Ia supernovae data, even a realistic Milne-type finely-tuned "Empty Model" (the solid green curve of a perpetually-balanced net zero energy universe model, also like FSC) cannot yet be ruled out. Given the error bars shown, one does not need to be an expert in statistics to interpret the extremely close correlation between the accumulated SNe data and the Flat Dark Energy and Empty models. It would be foolish, at present, to rule out the possibility that we live in an FSC-like BH universe.

The 4-axis FSC log graph in **Figure 3** [14] shows how total matter mass (baryonic plus dark matter) of the FSC BH cosmological model relates to cosmic time.

One can readily see that the FSC model matter mass-energy *grows steadily* with cosmological time moving in the forward direction. Given the fractal-like nature of such a model, it is not entirely surprising to see that individual black holes can copy this behavior in proportion to growth of the cosmological system as a whole. It is notable that, in the preceding roughly 13 billion years, the FSC model grows in total matter mass by a factor of ten (*i.e.*, one base ten log value). Similarly, over the last roughly 9 billion years, the oldest black holes in the new observational study were "observed" (actually predicted) to grow by about the same amount, assuming that the differently-aged galaxies chosen for study were representative of elliptical galaxy growth between the different time intervals chosen for study. At the time of the FSC book publication (June, 2021), it was

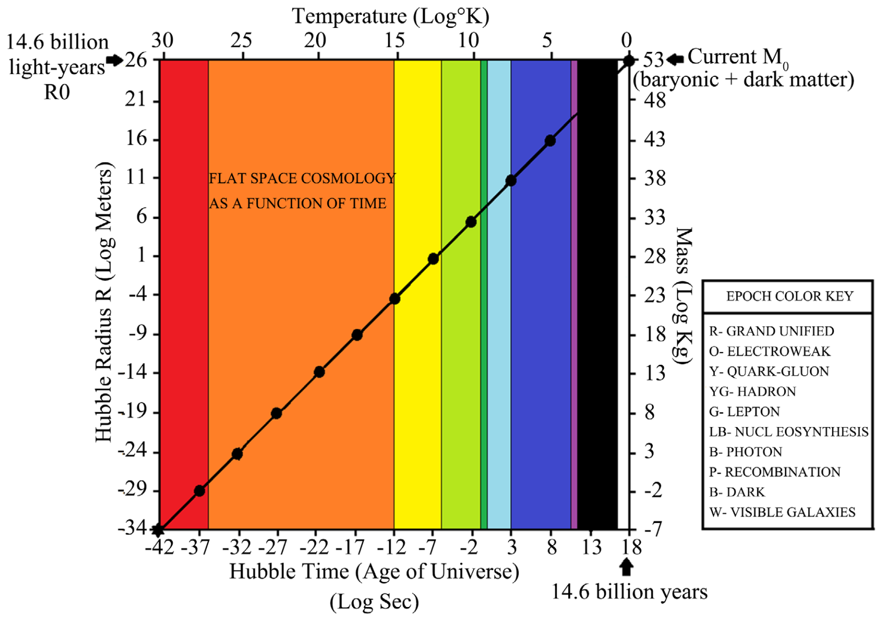

Figure 3. Flat space cosmology vs. time (Color-Coded Cosmic Epochs).

not known by what mechanism a BH model such as FSC could *simultaneously* grow in total matter mass-energy and total dark energy. Given the new observational study results, the present theory of BH dark energy production and BH mass-energy growth now seems entirely plausible as such a mechanism. Further observational studies along similar lines are eagerly anticipated.

A potential side benefit of considering the gravitational energy density of a high energy portion of the vacuum of space is what it may also suggest in regards to dark matter observations. A "gravitized vacuum" concept, as recently introduced [15], could lead to a viable alternative theory to the popular non-particulate MOND theory of dark matter. Thus, consideration of the possible effects of energized vacuum regions (proximal to black holes and to densely-packed galaxies) could open the way to understanding dark matter observations in addition to those pertaining to dark energy. These concepts pertaining to energized vacuum effects, as introduced recently and herein, suggest that the observational and theoretical landscape is now rich with opportunities! Treatment of cosmic vacuum energy density as a perpetual post-inflationary *constant* (as opposed to a spacetime-dependent *scalar* over cosmic time) may soon become a thing of the past. This comports with recent speculation by a number of theorists, including the current author, that many of the answers concerning cosmological conundrums may lie in a deeper physical understanding of the cosmic vacuum.

Not only does Penrose's concept of "gravitational entropy" and his "Weyl curvature hypothesis" seemingly apply to the Bekenstein-Hawking definition of BH entropy and the FSC model [16], but Verlinde's concept of "emergent gravity" (having to do with cosmic entropy and it's possible relationship to gravity) [17] [18] and Van Raamsdonk's concept of "entanglement entropy" from studies of quantum entanglement [19] could conceivably apply as well. Without further discussion on these points, the reader is referred to the attached references exploring these concepts.

With all that has been presented and speculated above, a final word of caution is necessary. This author is in full agreement with Farrah, *et al.*, that the observational results they reported need to be taken in conjunction with numerous caveats and additional confirmatory observational studies.

4. Summary

Following the first observational evidence that rapid black hole (BH) growth is coupled with cosmological expansion ("cosmological coupling"), theorists have been scrambling to make sense of these findings. Although one possible interpretation of the data is that such black holes might be acquiring vacuum energy (*i.e.*, dark energy) interiors, this brief note offers a simpler explanation inspired by inflationary theory and the presumed mechanism of Hawking radiation.

Given the near-certainty that the vacuum very near a BH horizon has a high energy density, it is expected that such a vacuum has a rich sea of virtual particles popping into and out of existence. Largely based upon the FSC model, a theory is offered that entangled pairs of positive matter and negative dark energy particles may be pulled out of the horizon-adjacent vacuum. If such could happen, the likelihood is that the gravitationally-attractive matter particle would cross the horizon and enter the BH interior, while the gravitationally-repelling dark energy partner is repelled deeper into the outer vacuum as "black hole dark energy radiation". The result of this high energy interaction of entangled particles would be continuous BH growth, even in the absence of merger or ordinary accretion activity, while simultaneously stimulating universal expansion by the dark energy radiative process. The net effect of all of this would be *continuous finely-tuned cosmological coupling* between growing black holes and a growing universe while, at the same time, preserving cosmological conservation of energy.

If the proposed theoretical model is indeed correct, the following consequences appear likely: astrophysical black holes might *never* evaporate; the previously inexplicable early and rapid growth of black holes might now be adequately explained; more exotic theories of dark energy would become unnecessary; and the FSC model would, once again, be validated as a globally-accurate and useful cosmological model. Furthermore, as discussed, incorporation of the high energy vacuum concepts mentioned herein might help to resolve a number of current cosmological conundrums. To take but one example, a "gravitized" vacuum, as previously theorized, might also, by the $E = mc^2$ formula, provide an alternative to the non-particulate MOND theory of dark matter.

This author is in full agreement that further confirmatory observational studies are necessary.

Data Availability Statement

All data in this submission, including figures, has been either generated by the author himself or already made available to the author thru open-source materials freely available to the public. Appropriate credit and citations of original sources have been made where required. He is willing to make readily available all data and 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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