Hardy's entanglement as the ultimate explanation for the observed cosmic dark energy and accelerated expansion

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Abstract: We reason that Hardy's probability of quantum entanglement marks the transition from a smooth 4D to a rugged fractal-like K3 Kähler spacetime. The associated eigenvalue constituting the measurable ordinary energy density in this case is given by Einstein's celebrated formula $E = mc^2$ divided by 22 where m is the mass and c is the speed of light. That way the missing energy is concluded to be a hypothetical so called dark energy amounting to $E(D) = E - E(O)$ where E(O) is the earlier mentioned measurable ordinary energy. By looking deeper at the nature of E(O) and E(D) components of E(Einstein) it becomes evident that E(O) is a quasi potential energy of the quantum particle modeled by the zero quantum set while E(D) is a quasi kinetic energy of the propagating quantum wave as modeled by the empty quantum set of our transfinite quantum set theory. A particularly highly interesting new result of the present work is a demonstration of the independence of dark energy density from the number of the spacetime dimensions of the corresponding theory used.

Keywords: Accelerated Cosmic Expansion, Dark Energy, Hardy's Quantum Entanglement, Superstrings, Ricci Dark Energy, Holographic Principle, 'tHooft-Veltman-Wilson Dimensional Regularization

1. Introduction

In numerous previous publications [1-37] the major problem of accelerated cosmic expansion and the associated puzzle of the missing 95.5% dark energy density of the cosmos was considered [38-44] from a host of different view points using various spacetime theories [1-37]. Thus superstrings, M-theory, holographic principle, Ricci dark energy, Rindler space, fuzzy K3 Kähler, Veneziano model, varying speed of light, Cosserat spacetime and 'tHooft-Veltman-Wilson dimensional renormalization [1] were applied leading to a robust result, namely E(ordinary) = $mc^2/22$, E(dark) = $mc^2(21/22)$ and E = E(ordinary) + E(dark) = mc^2 = E(Einstein) where m is the mass and c is the speed of light in full agreement with cosmological observations, measurement and analysis [37-42].

In the present work we pay special attention to revisiting an earlier result showing the role of Hardy's quantum entanglement [45-47] in deriving ordinary energy and thus indirectly dark energy [1,2]. We amply demonstrate that the so obtained result is independent of the number of topological spacetime dimensions of the used theory [1-37].

2. Analysis

2.1. The Kähler Manifold

The K3 Kähler is well known from the theory of compactified extra dimensions [39]. As a measure for the ruggedness of such a manifold an index called Betti number b_2^- is utilized as an excellent mathematical characterization devise [39]. For a continuous smooth manifold such a Einstein's spacetime we have $b_2^- = 1$. For K3 on the other hand which is a convoluted manifold with 4 complex dimensions b_3^- which counts mainly the holes in this manifold, the value is considerably higher, namely $b_3^- = 22$ [39]. It is not particularly difficult to see that $\lambda = 1/b_2^- = 1/22$ may be thought of as a Weyl scaling factor transferring the Eigenvalue $E = mc^2$ of Einstein's special relativity to E(ordinary energy) = $(mc^2)(\lambda) = mc^2/22$ which marks the smooth-non-smooth boundary. This boundary in turn is a rather good approximation to the non-fractal-fractal phase transition of spacetime [33]. Pondering these results deeper still we will notice that for a fuzzy K3 Kähler we have b_2^- = 1/22.18033989 = $\phi^5/2$ where ϕ^5 is Hardy's probability

for the quantum entanglement of two quantum particles. It follows then that $E(O) = (\phi^5/2)(mc^2) = mc^2/(22.180334)$ represents an entanglement energy of a single quantum particle. Consequently the complimentary Legendre transformation of $E(O)$ gives the disentangled major part of the energy, namely the 95.5% so called missing dark energy

$$E(D) = 1 - E(O) = \left(5\frac{\phi^2}{2}\right)(mc^2) = mc^2\left(\frac{21.8033989}{22.18033989}\right) \quad (1)$$

2.2. Set Theoretical Interpretation of the Result

It is not difficult to derive the preceding ordinary energy relation

$$E(O) = mc^2 \ (\phi^5/2) \quad (2)$$

from E-infinity quantum set theory and find out that the zero set in five intersectional dimensions give us the rest energy of the quantum particle as the familiar measurable ordinary energy [1-37]. On the other hand $E(D)$ is equally easy to derive as the empty set in five additive dimensional space leading to the propagation kinetic energy of the quantum wave [1-37]. Since measurement leads to wave collapse, the energy could not possibly be measured at present unless future development leads to wave collapse free measurement instruments [1-37]. Consequently the wave energy remains unmeasurable and is therefore dubbed dark energy. It is needless to reiterate that this entire situation, i.e. the splitting of Einstein's $E = mc^2$ into two parts takes place only near to the Planck and Hubble length i.e. the extremely small and extremely large length scale and that for almost all other situations, $E = mc^2$ is highly accurate [19,20].

2.3. The Independence of E(O) and E(D) from the Number of the Topological Dimensions of the Used Theory – Quantum Entanglement Interpretation

Hardy's quantum entanglement is one of the most important results in quantum physics which stands on firm theoretical as well as experimental ground. It is also the main door from which the famous transfinite number $\phi = 2/(1+\sqrt{5})$ enters into fundamental physics. Simply stated the maximal quantum probability of two quantum particles is given by Hardy's value [45-47]

$$P(Hardy) = \phi^5. \quad (3)$$

In E-infinity theory it is shown that this value consists of two parts, namely $P_1 = \phi^3$ which is termed the counter factual part while $P_1 = \phi^n$ is the local part where n is the number of the entangled quantum particles. From the above it follows that $P = \phi^5$ could be looked upon as a topological maximal energy, i.e. a topological Planck energy binding two entangled quantum particles together. Thus the share of each particle is clearly a contribution equal to [47]

$$E(topological) = \phi^5/2. \quad (4)$$

We now come to a subtle point which requires us to be open minded and imaginative in applying Emmy Noether's celebrated theorem and the associated flexible exchange of essentially identical basic concepts, namely probability, particles and dimensions. Proceeding in this way we can interpret the pre-particle Hardy entanglement $\phi^5/2$ as a reduction per each topological dimension. Thus an integer topological dimension $D_T = 1$ transmutes to a corresponding "shrunk" quasi Hausdorff fractal dimension equal to

$$D_H = D_T - (\phi^5/2) = 1 - (\phi^5/2) = 5\phi^2/2. \quad (5)$$

Consequently for an n dimensional theory we have $(n)(5\phi^2/2)$. The resulting quasi fractal space dimension is consequently

$$n - (n)(5\phi^2/2) = n[1 - (\phi^5/2)]. \quad (6)$$

Evidently this fixes our scaling factor λ to [1-37]

$$\lambda = \frac{n[1-(\phi^5/2)]}{n} = 1 - (\phi^5/2) = 5\phi^2/2 \cong 21/22. \quad (7)$$

Thus our dark energy density is independent of n and agrees completely with our earlier result [1-37].

3. Conclusion

Ultimately the "mechanical" explanation for the existence of dark energy lies in effect in Hardy's celebrated theorem for two entangled quantum particles as given by ϕ^5 where $\phi = 2/(1+\sqrt{5})$. This effect becomes indirectly noticeable and splits Einstein's formula $E = mc^2$ into two parts, an ordinary and a dark part only at extremely large distances near what appears to be the holographic boundary of the holographic projection of the universe. This projection is modeled by extraordinary precision via the compactified Klein modular curve of E-infinity theory. At such ultra large distances and by Witten's T-duality at the ultra short Planck distances, spacetime undergoes a fractal phase transition marked by a scaling exponent λ equal to 21/22 which is equal to the measured dark energy density of the cosmos

$$E(D) = E(Einstein) \ (\lambda) = (mc^2)(21/22). \quad (8)$$

Since measurement collapses the Hartle-Hawking quantum wave of the universe, this "dark" energy cannot be measured using present measurement technology. The present analysis, as in previous ones, could not have been possible without relying on the techniques and methodology of the fractal-Cantorian spacetime theory developed by G. Ord, L. Nottale and M.S. El Naschie [51-71]. An excellent introduction to fractals and E-infinity quantum spacetime mingling popular scientific writing with mathematical rigor may be found in the Journal of the Institute of Science in Society by Dr. Mae-Wan Ho [72-77].

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