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Agency of Life, Entropic Gravity and Phenomena Attributed to "Dark Matter"

Angus McCoss

Kilbrandon House, Scotland, UK
Email: ammcc0@outlook.com

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Abstract

Entropic gravity theories propose that spacetime and gravity emerge from quantum information entanglements. Vacuum spacetime emerges in the ground state and its area law for entanglement entropy is due to short-range entanglement of neighbouring microscopic degrees of freedom. Matter changes the entanglement entropy in this vacuum and leads to Einstein gravity. Additionally, in a positive dark energy de Sitter Universe, where each conscious agent has a cosmological horizon, a volume law contribution to entanglement entropy is divided evenly over the same degrees of freedom and is caused by long-range entanglement. I propose these complementary short-range and long-range entanglement contributions form a nested small-world network which provides the topological quantum computing foundation for relativistic multi-agent correlations which weave together a universal physics of Nature. The volume law contribution to entanglement entropy surpasses the area law for entanglement entropy at an agent's cosmological horizon. Verlinde interprets gravitational "dark matter" phenomena as polymer-like memory effects caused by the volume contribution to the entanglement entropy. I propose these phenomena are instead multi-agent quantum computational consensus effects due to an equivalent volume contribution to the entanglement entropy. Life is correlated with its environment. Phenomena attributed to unseen "dark matter" particles are proposed here to be founded upon nested observer halos, "spheres of influence or correlation", caused by the consensus Agency of Life. Suitable cosmological conditions for earliest Life in the Universe occurred some 10 billion years ago and older galaxies do not exhibit "dark matter" phenomena. Also, galactic rotation curves flatten beyond their high-radiation centres, due to astrobiology and the Agency of Life living in outlying low-radiation habitable zones. Where baryonic matter is in motion, then the Agency of Life stores its baryonic matter-lagging memory in skewed trails of apparent "dark matter" phenomena in spacetime.

Keywords

Entanglement Entropy, Dark Matter, Small-World Network, Astrobiology, Consciousness

1. Introduction

A major problem in physics is to explain the cause of astronomical phenomena, Φ_{DM}, attributed to "dark matter". Entropic gravity theories [1] [2] [3] offer possible explanations, without recourse to unseen "dark matter" particles. These theories invite probing of their foundations. Might the entanglement entropy perturbations at the roots of such entropic gravity theories be caused by baryonic matter and something else? Could the cause of additional weak entropic gravity phenomena, Φ_{DM}, attributed to "dark matter", be due to the Agency of Life—the capacity of living agents, observers, to make choices which bring about order and which correlate life with its environment?

In our Universe of increasing entropy, living agents generate order through i) environmental information which they purposefully process for evolutionarily advantageous knowledge, ii) structures which they assemble, iii) progeny which they reproduce in their resemblance and iv) non-random evolution, which occurs through time in Darwinian directed cycles of variation, selection and heredity.

The reader is referred to Erwin Schrödinger's reflections on "What is Life?" [4] and to the notes of Steven Hawking, written in a similar vein some 50 years later, about "Life in the Universe" [5] for their accounts of the important interplay between Life and entropy.

I propose that the order which Life increases, in itself and its offspring, organizes the entanglement entropy of spacetime in a nested small-world network of short-range and long-range entanglements, resulting in a weakly gravitating negative entropy that accounts for phenomena, Φ_{DM}, attributed to so called "dark matter". Under this proposal, the spatiotemporal occurrence of Life in the Universe correlates with the spatiotemporal occurrence of Φ_{DM}.

Following this introductory section (§1), the paper presents theoretical developments from current research into entropic gravity (§2.1), a nested small-world network model of entanglement entropy (§2.2) and the negative entropic Agency of Life (§2.3). In the penultimate section (§3), the spatiotemporal concurrence of Life with phenomena, Φ_{DM}, attributed to so-called and unseen "dark matter" is considered. The paper concludes with a discussion (§4) on some ramifications of the ideas.

2. Theoretical Developments

2.1. Entropic Gravity

Emergence of spacetime and gravity from laws of black hole thermodynamics [6] relates to Bekenstein-Hawking entropy [7] [8]

$$S_{BH} = k_B \frac{Ac^3}{4G\hbar} \tag{1}$$

and to Hawking-Unruh temperature [9] [10]

$$T_{HU} = \frac{\hbar\kappa}{2\pi k_B c} \tag{2}$$

where k_B is Boltzmann's constant, A is the horizon area, c is the speed of light, G is Newton's gravitational constant, $\hbar$ is the reduced Planck constant and κ is the surface acceleration.

Verlinde [2] describes emergent gravity in de Sitter space and considers the observer's cosmological horizon of possible information retrieval. It has finite Bekenstein-Hawking entropy and Hawking temperature and κ the surface acceleration is given in terms of c the speed of light, H_0 the Hubble parameter, L the Hubble scale and a_0 the Hubble acceleration scale as follows [11]

$$\kappa = cH_0 = \frac{c^2}{L} = a_0 \tag{3}$$

Gravity is well described by General Relativity at scales far smaller than the Hubble radius because the entanglement entropy is dominated by the area law of the vacuum. However, at long-time and long-distance scales, the vast de Sitter entropy together with very slow thermal dynamics require its modification. Verlinde [2] shows that exactly when the surface mass density falls below the value $a_0/8\pi G$ the reaction force due to the thermal contribution takes over from the familiar gravity force caused by the area law. He explains that adding matter with mass M to de Sitter spacetime decreases its entanglement entropy by $S_M(r)$, where r is the spherical region radius and

$$S_M(r) = -2\pi Mr/\hbar \tag{4}$$

Hossenfelder [3] proposes a generally covariant version of Verlinde's emergent gravity concept. She constructs the Lagrangian which suggests de Sitter space is filled with a vector-field, $\boldsymbol{u}$, that couples to and drags on baryonic matter producing the phenomena Φ_{DM}, attributed to "dark matter". The entropy of the vector-field, $\boldsymbol{u}$, is reduced in the vicinity of matter which corresponds to a decrease of volume occupied by the field. Indeed the vector-field, $\boldsymbol{u}$, condenses in the vicinity of baryonic matter in her proposal. This generates a force directed towards the baryonic matter.

2.2. Nested Small-World Network Model of Entanglement Entropy

A nested small-world network is a type of mathematical graph. Most nodes of such a graph are not neighbours of one another. Quantum information is not localized. However the neighbours of any given node are likely to be neighbours of each other. Furthermore, most nodes can be reached from every other node by a small number of connections. Common in Nature [12] and pervading all scales, nested small-world networks confer efficiencies in the communication and processing of information.

Assuming the Universe is a quantum computer [13], it is proposed that its configuration is also a nested small-world network. A living agent's (observer's) cosmological horizon (boundary of possible information retrieval) comprises long-range entanglements whereas the bulk comprises short-range entanglements. Combined they constitute a nested small-world network (**Figure 1**).

I propose this nested small-world network, of our quantum computer Universe, is a topological network from the Planck scale, through atomic, molecular, brain connectome [14], ecological, planetary, stellar and galactic scales, all the way up to the Hubble scale of the cosmic web and the large-scale structure of the Universe [15]. All components, across all scales, are intrinsically interconnected within the entanglement entropy of this nested small-world network. Significantly, living agents (observers) bridge the extreme scales and hence the Agency of Life causes effects and correlations across all scales. Extreme scales of space-time, the Planck scale and the Cosmic scale, appear inaccessible at the scale of Life. However, the topological quantum computations of the nested small-world network normalise the vast range of scales in our Universe, albeit limited by the speed of light in its physical phenomena.

Through this topological normalisation of scale I propose that living agents influence the outcome of quantum physics experiments (such as particle-wave duality tests) and yet can also correlate galactic scale phenomena, Φ_{DM}, attributed to so called "dark matter" through nested observer halos, or "spheres of influence or correlation". The larger scale phenomena, Φ_{DM}, are due to the collective common histories of countless living agents (on innumerable habitable planets), witnessing and correlating the same entangled astrophysical events. Whereas micro-scale quantum measurement experiments involve few, even single, observers.

Narrow aperture information phenomena (micro-scale with small amounts of information) have a low entanglement within a local minority of the Agency of Life. A small number of living agents focused on microscopic phenomena provide probabilistic and weakly-corroborated witness records. This is the realm of

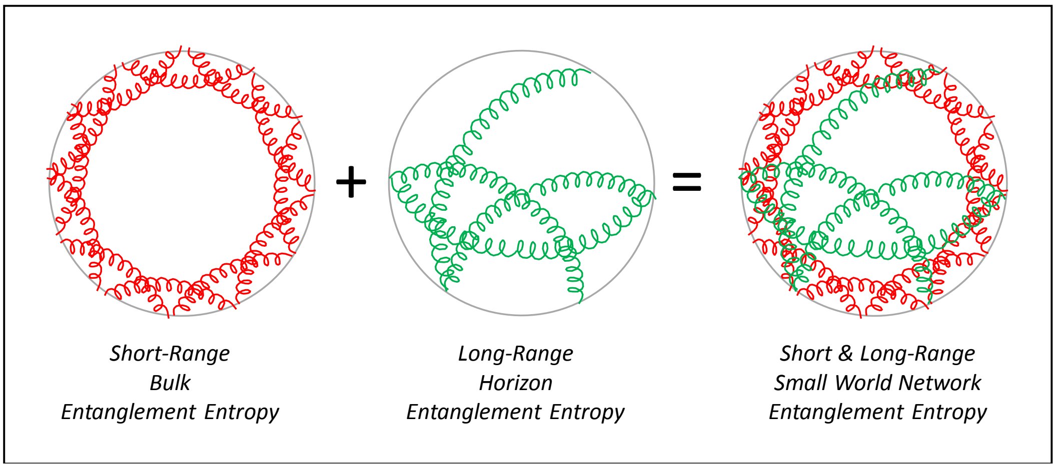

Figure 1. Short-range bulk (red) & long-range horizon (green) contributions to nested small-world network of entanglement entropy.

the area law contribution to entanglement entropy, whereas wide aperture information phenomena (up to cosmic-scale with vast amounts of information) have a high entanglement throughout the multi-agents' horizons. Multitudes of living agents star-gazing at astrophysical marvels provide almost deterministic and strongly-corroborated witness records. This is the realm of the volume law contribution to entanglement entropy and the realm of phenomena, Φ_{DM}, attributed to "dark matter".

2.3. Negative Entropic Agency of Life

The Agency of Life brings about a semblance of order (negative entropy [4]) in our Universe, which in totality is evolving from an initial state of low entropy, to a future state of high entropy. As paraphrased by Buchel [16], Verlinde contends [2] that baryonic matter in a de Sitter Universe with a Hubble constant H produces a bulk contribution to the vacuum entanglement entropy $\delta S_{\text{entangelement}}$. Using the de Sitter temperature $T_{\text{de Sitter}} = \hbar a_0 / 2\pi$, Verlinde interpreted δM in the first law of black hole thermodynamics $T_{\text{de Sitter}} \delta S_{\text{entanglement}} = -\delta M$ with the Dark Matter energy.

In my interpretation $-\delta M$ is simply substituted by $-\delta \Xi$, (negative delta Xi), representing the Agency of Life in equivalent matter energy, thus

$$T_{\text{de Sitter}} \delta S_{\text{entanglement}} = -\delta \Xi \tag{5}$$

This is the main formula and central result of my paper. Through this substitution, I propose the negative entropic Agency of Life results in the spatiotemporal concurrence of Life with phenomena, Φ_{DM}, attributed to so called "dark matter".

In our Universe of increasing entropy, living agents generate contrary order through:

i) Environmental information which they purposefully process for evolutionarily advantageous knowledge e.g. sensory perception, language, mathematical formulae and radio broadcasts.

ii) Structures which they assemble e.g. proteins, DNA, cells, tissue, skeletons, nests, cities, swarms, social networks and the internet.

iii) Progeny which they reproduce in their resemblance e.g. through DNA replication, as evidenced in the organisms on our planet Earth.

iv) Progressive non-random evolution, which occurs through time in Darwinian directed cycles of variation, selection and heredity e.g. from simple organisms with few sensory receptors to advanced intelligent organisms in complex evolving ecosystems.

Adopting the arguments by others above in support of entropic gravity I propose that a weak gravitational acceleration emerges, and compounds through time, arising from the Agency of Life. It operates over long timescales and long distances. This weak gravitational acceleration is emergent and additional to Einstein's fundamental formalisation of gravitation in General Relativity and has spatiotemporal concurrence with living agents.

3. Spatiotemporal Concurrence of Life and "Dark Matter"

In this penultimate section, I shall first emphasise the spatial colocation of Life with phenomena, Φ_{DM} , attributed to "dark matter". Then I shall emphasise the temporal concurrence. Taken together we shall thus see a case for spatiotemporal concurrence, upon a common basis of the Nature of galaxies.

The most common spatial expression of phenomena, Φ_{DM} , attributed to "dark matter" is that observed in the rotation curves of galaxies. The observations of Vera Rubin [17] stimulated the modern era of measuring the rotation curves of galaxies. These consistently show that the rotational velocities of galaxies do not follow the rules of Newton and Einstein which are applicable in smaller orbital systems such as planets around stars and moons around planets. Stars are instead observed to revolve around their galaxy's centre at equal or increasing speed over a large range of distances. The rotation curves are typically plotted as flat beyond the galaxies' star-forming centres.

The proposal in this paper recognises that Life cannot emerge, let alone survive, in the high-radiation star-forming centres of galaxies, whereas Life can and likely does proliferate in the low-radiation, habitable zones, on planets orbiting stars in the benign outer neighbourhoods [18] of galactic disks. I propose a concentration of the Agency of Life, $-\delta\Xi$, in these habitable neighbourhoods is the root cause of phenomena, Φ_{DM} , attributed to "dark matter".

Regarding the temporal expression of phenomena, Φ_{DM} , attributed to "dark matter", let us reflect on the interpretation justified by Hawking [5], that suitable conditions for the emergence of Life in our Universe likely arose some 4 billion years after the Big Bang. Given the age of our Universe, this means galaxies more than 10 billion years ago are lifeless and thus lack the Agency of Life. The recent observations of Genzel *et al.* [19] are of particular pertinence to the proposal in this paper because they determine that disk galaxies more than 10 billion years ago (at the peak of galaxy formation) are also lacking phenomena, Φ_{DM} , attributed to "dark matter", they are in fact dominated by baryonic matter. I suggest this is not coincidental but due to the lack of Life in the first 4 billion years of the Universe's evolution.

Furthermore McGaugh, Lelli and Schombert [20] show that the phenomena, Φ_{DM} , attributed to "dark matter" correlate with baryonic matter. They use measurements of radial accelerations in 153 galaxies to underpin their strong result, which concludes the so called "dark matter" contribution is fully specified by that of the baryons.

Since the occurrences of Life and baryonic matter correlate and given that phenomena, Φ_{DM} , attributed to "dark matter" also correlate with baryonic matter, there is no need to invoke unseen "dark matter" particles, which become a redundant proxy.

Finally, where baryonic matter is in motion, then the Agency of Life stores a record of its baryonic matter-lagging memory in skewed trails of apparent "dark matter" phenomena in space time. Taylor *et al.* [21] discuss a test for such skewed distributions of "dark matter" phenomena and they consider a possible detection in galaxy cluster Abell 3827.

4. Discussion & Conclusions

I have proposed that the phenomena, Φ_{DM} , attributed to "dark matter" can instead be explained by the Agency of Life, $-\delta\Xi = T_{\text{de Sitter}}\delta S_{\text{entanglement}}$. The matter of Life is baryonic and its entangled agency reduces entropy through nested small-world networks of quantum information. The matter of Life is "enlightening". Life is correlated with its environment. Rather than using the shadowy concept of "dark mater", we should instead envisage its attributed phenomena as a consequence of "enlightened matter", $\Phi_{DM} \Leftrightarrow \Phi_{\Xi M}$. The phenomena are geometrically equivalent whilst "dark matter" becomes redundant.

This idea relates to that also explored by Rovelli [22] concerning direct meaningful information, by which we mean strictly physical correlations between living agents and their environments that have evolutionary benefits in terms of Darwinian survival and reproduction. Also within this perspective living agents, observers, are systems that acquire information to stay out of equilibrium [23] and in doing so become correlated with their environments.

Hossenfelder's generally covariant vector-field version of Verlinde's emergent gravity concept [3] provides a model for "dark matter" phenomena, Φ_{DM} , which I attribute through equivalence to "enlightened matter", $\Phi_{\Xi M}$. Through this equivalence, it is proposed that her vector-field, $\boldsymbol{u}$, is the Epistemic Field [24] and that gradients in the field cause Epistemic Drive, as discussed in the author's research programme on Quantum Intelligent Cosmology.

Epistemic Drive is defined as Nature's insatiable appetite for information. Every baryonic thing is claimed to be driven to acquire and process information for evolutionarily advantageous knowledge. The advantage is to out-compute (sic) alternatives, in our quantum computational Universe. The Epistemic Field thus supports and drives an evolving trophic hierarchy of quantum information processing agents [24].

Quantum information apex predators are physically manifest as Black Holes. They consume quantum information heterotrophs, which cascade down the trophic hierarchy through stellar and planetary systems with living agent information predators, such as human beings, to their diverse information prey, including living and lifeless information consumers, from microbes to minerals and molecules. The lifeless information consumers are manifest as baryonic constituents of the physical Universe, which consume Planck scale information autotrophs, the raw fundamental information resources of the teeming quantum vacuum. Topologically, this quantum computational trophic hierarchy is a nested small-world network.

It is the agency of the conscious living agents at the mid-scale within this evolving trophic hierarchy of quantum information processing agents which are of most pertinence to the ideas of this paper. Their conscious agency collectively develops correlations as dispersed populations of observers witness and corroborate a shared history of nested macro-scale events throughout the Universe. In doing so, this collective witnessing establishes relativistic multi-agent quantum computational correlations which weave together a universal physics of Nature at large distances and over long times. The physical effects of this are manifest as additional weak gravitational phenomena attributed to unseen "dark matter" but are in fact due to the multi-agents' volume contribution to the entanglement entropy in emergent gravity.

The nested small-world network model proposed in this paper invites further development through the methods of algebraic topology to quantitatively describe both local and global network properties that emerge from quantum information entanglements. Recent related studies of how the brain processes information involving cliques of neurons bound into cavities [25] are considered pertinent to future multidisciplinary inquiry within the author's research programme on Quantum Intelligent Cosmology.

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