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Creation and Annihilation of Spacetime Elements

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***Abstract*—**Gravitation and the expansion of the universe at a large scale are generally regarded as two completely distinct phenomena. Yet, in General theory of Relativity (GR), they both manifest as 'curvature' of spacetime. We propose a hypothesis which treats these two 'curvature-producing' phenomena as aspects of an underlying process. This process treats spacetime itself as composed of discrete units (Plancktons) and is 'dynamic' in the sense that these elements of spacetime are continually being both created and annihilated. It is these two complementary processes of Planckton creation and Planckton annihilation which manifest themselves as - 'cosmic expansion' on the one hand and as 'gravitational attraction' on the other. The Planckton hypothesis treats spacetime as a perfect fluid in the same manner as the co-moving frame of reference of Friedman equations and the Gullstrand-Painleve metric; i.e., Planckton hypothesis replaces 'curvature' of spacetime by the 'flow' of Plancktons (spacetime). Here we discuss how this perspective may allow a unified description of both cosmological and gravitational acceleration as well as providing a mechanism for inducing an irreducible action at every point associated with the creation and annihilation of Plancktons, which could be identified as the zero point energy.

***Keywords*—**Discrete spacetime, spacetime flow, zero point energy, dark energy.

I. Introduction

THE dynamics of neutral matter and radiation in the universe is largely controlled by gravitation and the Hubble flow. The field equations of General Relativity (GR) relate both to the curvature of spacetime. However, GR regards the source of these two types of interactions as distinct. The source of gravitational interactions is the stress energy tensor associated with matter while Hubble flow is attributed to Dark Energy (DE) - represented by cosmological constant, Λ, in the field equations.

This paper postulates a common mechanism for both gravitation and DE. This mechanism assumes that spacetime is made up discrete elements and it is the creation and annihilation of these elements that gives rise to both gravitation and DE. The creation and annihilation processes manifest themselves as the Zero Point Energy.

II. Large Scale Motion in the Universe

A. Gravitational Motion

Motion under the influence of gravity is governed by the field equations. To analyze the motion of a particular object a particular metric must be chosen. The Gullstrand-Painleve (GP) metric avoids the coordinate singularity at the event horizon and is therefore particularly suitable for exploring motion at any distance from a gravitating mass. Physically, the GP metric describes space falling into the Schwarzchild black hole at the Newtonian escape velocity.

Using the GP metric, the velocity of a test particle in a gravitational field is given by [1], [2]:

$$v_g = -\sqrt{\frac{2GM}{r}}$$

r is the distance between the test particle and gravitating mass.

Since the GP metric can be considered as motion of coordinate frame itself, we assert that the v_g represents the motion of spacetime ("Waterfall" model of black holes) [3].

B. Hubble Expansion

The motion due to Hubble expansion of the universe is described by,

$$v_H = H_{DE} d$$

d is the distance from the observer to the test particle. v_H is attributed to DE driven expansion of the universe. The expansion can be considered as new space being created, pushing existing space away from the observer. Hence, v_H traces the motion of spacetime. Thus, both gravitational and Hubble motion can be considered as being caused by the flow of spacetime itself in which the test particle is embedded.

C. Motion Due to Gravity Reconsidered

Now, we consider the motion of a test particle in a gravitational field, with the observer located on the radial direction defined by the line joining the gravitating mass and the test particle.

Let the observer be situated further from the mass than the test particle, as illustrated in Fig. 1.

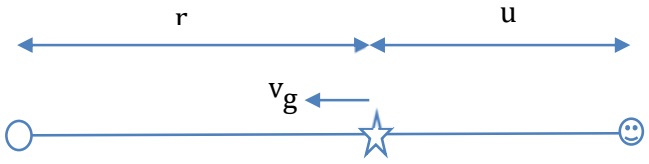

Fig. 1 Motion due to gravity observed along radial axis

$$v_g = -\sqrt{\frac{2GM}{r}}$$

Replacing the mass term, M by effective density, ρ_T, over the volume defined by r, the v_g can be expressed as:

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$$v_g = -\sqrt{\frac{2G\,4\pi\rho_T r^3}{3r}} = -\sqrt{\frac{8\pi G\rho_T r^2}{3}} = -\sqrt{\frac{8\pi G\rho_T}{3}}\,r$$

$$Since, v_g = \dot{r},$$

$$\left(\frac{\dot{r}}{r}\right)^2 = \frac{8\pi G\rho_T}{3} = {H_T}^2, From\ Friedman's first\ equation$$

$$\therefore v_g = -H_T r$$

H_T is not really a constant as it depends on the effective mass density, ρ_T. However, for r >> u (distance between the test particle and the observer), it can be treated as a constant for small changes in r. From the Point of View (POV) of the observer this motion is still linearly dependent on the distance between the observer and the test particle. Just as in the case of Hubble flow, the velocity of the test particle increases linearly with distance from the observer. It may be noted that H_T increases as u increases. Therefore, the test particle accelerates as u increases.

With the discovery that the rate of expansion of the universe is increasing, the Hubble constant itself can no longer be considered a true constant. The cosmological Hubble parameter increases in magnitude due to DE. Thus, both gravitation and Hubble flow both give rise to accelerated motion.

If D is the distance of the gravitating mass from the observer. Then, r = (D – u). Substituting for r in v_g, we get, $v_g = -H_T(D-u)$. Absorbing the constant D into H_T, we obtain $v_g = H_T u - K$, where K = H_TD is a (pseudo) constant. Hence, v_g depends linearly on u. Thus, motion due to gravity and DE *both* are linearly dependent on the distance between the observer and the test particle (or galaxy). *Therefore, it is not possible to determine the cause of the motion from simply measuring the velocity of a test particle in all cases.* Of course, in practice, H_{DE} is isotropic and applies to all galaxies outside the local group, while H_T is unique for each galaxy. In general, therefore, $H_{DE} \neq H_T$, which may serve to distinguish the two types of motions).

III. Drivers of Spacetime Flow

From the preceding, we can consider all motion in the universe as being driven by spacetime flows. These may then be categorized as "outward" flows that drive the Hubble expansion and "inward" flows that can be identified as motion due to gravitation. We therefore propose the following postulates:

Postulates

1. The expansion of universe, described by Friedmann's equation[1] are postulated to be driven by continuous creation of discrete elements of spacetime, termed "Plancktons", at random locations throughout a region of spacetime

Creation of Plancktons defines passage of time locally.

The energy represented by the creation of such an element gives rise to the Zero Point Energy while the "volume" of the element of space determines the rate of expansion of the universe. The droplets or quanta of "space" are termed "Placktons" in honor of the inventor of the idea of quantization.

Note that in the above description, quanta of space were introduced – not quanta of spacetime. This is a deliberate. Time arises through the creation of Plancktons – a change of state that can be used to define time. Creation of Plancktons is therefore regarded as the most fundamental process in the universe – one which creates space in the form of the Plancktons and the process of creation defines time. It is therefore postulated that the expansion of the universe is driven by spontaneous creation of Plancktons (elements of space) randomly over the entire existing universe.

The Planckton creation process injects energy locally and "displaces" existing elements of space displacing existing Plancktons. Displacement of Plancktons creates a gravitational wave which propagates away from the location where the Planckton was created.

2. Matter acts as "sink" of spacetime.

GP metric[2] interpreted as spacetime flow implies spacetime flows into matter.

As noted by Steinhardt and Wasley [6], compactified dimensions are unstable under Null Energy Condition. Plancktons may thus provide the energy needed to maintain matter phase as compactified spacetime dimensions.

IV. Creation and Annihilation of Planckton

A. Planckton Creation Process

We interpret Planck's constant in the expression for Zero Point Energy [9] as a property of the space-time metric itself. Therefore, it can formally be written as, $h = \int \mathcal{L}_Z d^N x$, where, $\mathcal{L}_Z$ is Lagrangian density corresponding to the action represented by, *h*, in N-dimensional space-time.

Since the action of Zero Point Energy [9] can never be zero, it should be included as a separate term in the Einstein–Hilbert action, which can then be written as [5], [10]:

$$S = \int \left[\frac{1}{2\kappa}R + \mathcal{L}_M + \mathcal{L}_Z\right]\sqrt{-g^{(N)}}\,d^{(N)}x$$

$$\delta S = 0 = \int \left[\frac{1}{2\kappa}\frac{\delta(\sqrt{-g}\,R)}{\delta g^{\mu\nu}} + \frac{\delta(\sqrt{-g}\,\mathcal{L}_M)}{\delta g^{\mu\nu}} + \frac{\delta(\sqrt{-g}\,\mathcal{L}_Z)}{\delta g^{\mu\nu}}\right]\delta g^{\mu\nu} d^N x$$

$$\therefore \int \left[\frac{1}{2\kappa}\left(\frac{\delta R}{\delta g^{\mu\nu}} + \frac{R}{\sqrt{-g}}\frac{\delta\sqrt{-g}}{\delta g^{\mu\nu}}\right) + \left(\frac{1}{\sqrt{-g}}\frac{\delta\sqrt{-g}\mathcal{L}_M}{\delta g^{\mu\nu}}\right) + \left(\frac{1}{\sqrt{-g}}\frac{\delta\sqrt{-g}\mathcal{L}_Z}{\delta g^{\mu\nu}}\right)\right]\delta g^{\mu\nu}\sqrt{-g}\,d^N x = 0$$

$$\therefore \left(\frac{\delta R}{\delta g^{\mu\nu}} + \frac{R}{\sqrt{-g}}\frac{\delta\sqrt{-g}}{\delta g^{\mu\nu}}\right) = -2\kappa\left(\frac{1}{\sqrt{-g}}\frac{\delta\sqrt{-g}\mathcal{L}_M}{\delta g^{\mu\nu}}\right) - 2\kappa\left(\frac{1}{\sqrt{-g}}\frac{\delta\sqrt{-g}\mathcal{L}_Z}{\delta g^{\mu\nu}}\right)$$

The left-hand side (LHS) represents the variation of the metric. It can be shown that[3]:

[1] $H = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho_T}{3}$

[2] $g = \left(1 - \frac{2GM}{r}\right)dt^2 - 2\sqrt{\frac{2GM}{r}}\,dtdr - r^2 d\theta^2 - r^2 d\varphi^2$

[3] See [10].

$$\left(\frac{\delta R}{\delta g^{\mu\nu}} + \frac{R}{\sqrt{-g}}\frac{\delta\sqrt{-g}}{\delta g^{\mu\nu}}\right) = R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = G_{\mu\nu}$$

The first term on the Right-Hand Side (RHS) can be re-written as:

$$-2\kappa\left(\frac{1}{\sqrt{-g}}\frac{\delta\sqrt{-g}\mathcal{L}_M}{\delta g^{\mu\nu}}\right) = -2\kappa\left(\frac{\delta\mathcal{L}_M}{\delta g^{\mu\nu}} - g_{\mu\nu}\mathcal{L}_M\right) = 2\kappa T_{\mu\nu}$$

here, $T_{\mu\nu}$ is the stress-energy tensor (this serves as the definition). Similarly, the 2nd term on RHS of the equation evaluates to,

$$-2\kappa\left(\frac{1}{\sqrt{-g}}\frac{\delta\sqrt{-g}\mathcal{L}_M}{\delta g^{\mu\nu}}\right) = -2\kappa\left(\frac{\delta\mathcal{L}_Z}{\delta g^{\mu\nu}} - g_{\mu\nu}\mathcal{L}_Z\right)$$

This equation also represents a stress-energy term. This is the energy of the zero-point field. Therefore, the full field equations can be written as,

$$\therefore G_{\mu\nu} = 2\kappa T_{\mu\nu} - 2\kappa Z_{\mu\nu}$$

At large scales, $\frac{\delta\mathcal{L}_Z}{\delta g^{\mu\nu}} = 0$ and $g_{\mu\nu}\mathcal{L}_Z$ is constant.

$$\therefore G_{\mu\nu} = 2\kappa T_{\mu\nu} - 2\kappa g_{\mu\nu}\mathcal{L}_Z = 2\kappa T_{\mu\nu} - 2\kappa\Lambda g_{\mu\nu}$$

However, at shorter scales the $\frac{\delta\mathcal{L}_Z}{\delta g^{\mu\nu}}$ term can not be ignored.

The insertion of spacetime elements necessarily distorts the metric. Therefore, the magnitude of this term may be very large compared to the term, $\Lambda g_{\mu\nu}$. This may offer a resolution of the cosmological constant problem [8].

Injection of Plancktons occurs at very short scales (<<10^{-15} m) and is interpreted as creation of new space elements. This condition corresponds to the case when $Z_{\mu\nu} \gg T_{\mu\nu}$.

B. Planckton Annihilation Process

When $T_{\mu\nu} \gg Z_{\mu\nu}$, Planckton creation is inhibited. Indeed, we propose that under these conditions Planckton, are annihilated as described in the next section.

From the preceding it is clear that the quantity, $P_{\mu\nu} = T_{\mu\nu} - Z_{\mu\nu}$ determines the balance of Planckton creation and annihilation rates or the effective Planckton flow rate. Thus, this quantity determines if spacetime is expanding or "contracting' (manifested as gravitational motion). In both cases the velocity is given by a version of Hubble's law. Hence, the quantity, $P_{\mu\nu}$, determines the value of effective Hubble's constant in both cases.

The condition $P_{00} > 0$ implies that new Plancktons are being created. The creation of new Plancktons leads to expansion of spacetime manifested as high z supernovae.

The condition $P_{00} <= 0$ indicates that Plancktons are being destroyed and observationally the motion is indistinguishable from gravitational motion.

The other components, $P_{\mu\nu}$ can then similarly be identified with Planckton momentum and pressure distribution w.r.t. the metric.

C. Critical Density and Phase Transition:

In the absence of matter, Plancktons are created at an exponential rate – the rate of creation being proportional to the number of existing Plancktons. Thus, any given region of space will experience increasing pressure from newly created Plancktons, increasing the local Planckton density. Since this density cannot increase without limit at some density the pressure would be relieved by a phase transition. We term this critical Planckton density. The phase transition at the critical density is characterized by a net flow of Plancktons into the region. We identify this phase transition as creation of matter.

The Gullstrand-Painleve (GP) metric [1], [3] can be interpreted as spacetime flow implies spacetime flows into matter ($\mathcal{L}_M > \mathcal{L}_Z$). Therefore, gravity represents Planckton flow towards matter. This idea is similar to Riemann's conception of gravity[4] [4].

From the work of Steinhardt and Wesley [6], we know that compactified dimensions are unstable under Null Energy Condition. Therefore, energy is needed to maintain compactified dimensions. Planckton hypothesis provides a natural description of matter as compactified dimensions representing a denser phase of Planckton fluid. To maintain Planckton density, a constant flow of Plancktons into this region is necessary – representing gravitational motion.

Planckton hypothesis asserts that the term $\frac{\delta\mathcal{L}_Z}{\delta g^{\mu\nu}}$ represents creation of new elements of spacetime and thus injection of energy into the universe. This energy is identified as DE. The Λ is the volume of Spacetime injected into the universe.

V. Summary

"Natural" state (without matter) of the universe is accelerating expansion (inflation).

- Creation of space elements (Plancktons) occurs "everywhere" at random locations
- Planckton creation causes expansion of universe
- Creation event defines passage of time
- Matter is Planckton condensate
- Matter annihilates Plancktons at an even greater density.
- Matter creation retards the accelerated expansion by removing Plancktons
- Modified Hilbert-Einstein action has two additional energy density terms. At large scales compared to Planck length, the first energy term ($\frac{\delta\mathcal{L}_Z}{\delta g^{\mu\nu}}$) can be neglected. At short distance the first term becomes important. The first term, $\frac{\delta\mathcal{L}_Z}{\delta g^{\mu\nu}}$, quantifies the DE injected when Planckton (Spacetime element) is created.

Thus '*the worst prediction in Physics*' may be attributable to relative magnitude of the two additional energy terms,

[4] Bernhard Riemann assumed in 1853 that the gravitational aether is an incompressible fluid and normal matter represents sinks in this aether. So, if the aether is destroyed or absorbed proportionally to the masses within the bodies, a stream arises and carries all surrounding bodies into the direction of the central mass. Riemann speculated that the absorbed aether is transferred into another world or dimension [8].

($\frac{\delta \mathcal{L}_Z}{\delta g^{\mu\nu}}$ and $g_{\mu\nu}\mathcal{L}_Z = \Lambda g_{\mu\nu}$) that arise when the Lagrangian for the zero-point energy is included in the Hilbert-Einstein action.

VI. Conclusions

Zero Point Energy represents creation of elements of space. The minimum action associated with this process is given by Planck's constant, h.

Gravity and DE can be understood as aspects of the same underlying processes of Planckton creation and Planckton annihilation.

DE represents outflow of Plancktons while gravitation represents flow of Plancktons into matter.

Any interaction with action comparable to h displays quantum behavior.

VII. Discussion

This paper has outlined a paradigm for understanding the dynamical nature of spacetime. This paradigm not only provides a way to understand gravitation and Hubble flow as consequences of same underlying process, viz. creation and annihilation of elements of space. This paradigm emerges from attempts to build a model of spacetime to account for the accelerating expansion of the universe.

The expansion of the universe has been well established observationally (Hubble) for over 90 years. Therefore, there is more "space" now compared to an earlier epoch and since Perlmutter et. al. [11] showed that the rate of expansion is accelerating and therefore the rate of creation of additional space is increasing. Moreover, the expansion of the universe has been observed at several different scales – from the entire universe to the scale of galactic clusters. It is natural to ask if the expansion might occur at even smaller scales. The Planckton hypothesis arises from postulating that the expansion occurs at scales below the currently accessible scales but is not manifested as matter and radiation fields overcome the force of expansion.

It has been argued that it is not that more space has been created but rather that it represents more "time" being created (or elapsed). However, passage of time must necessarily be measured by observing changes in the system. Thus, Planckton creation process provides a natural mechanism to define passage of time.

The usual way to describe the expansion in popular literature is to compare the expansion of space as being analogous to the expansion surface of balloon being filled with air. This simple picture provides a model to describe the red-shift of galaxies outside our local group. There are however two major problems with the balloon model of expansion of the universe.

Firstly, the expansion of balloon surface causes the surface to be under increasing stress. This in turn leads to physically measurable change in its properties, such as the speed of acoustic waves on the surface. The expansion of space, on the other hand, does not alter its measurable properties such as the speed of light or the gravitational constant, which controls the degree of curvature resulting from a given amount of stress-energy.

Secondly, again unlike the surface of a balloon, the energy density per unit volume (zero point energy) remains constant with time. This has been termed the "dark energy".

There is another analogy that can be used to describe the observed expansion of the universe which does not suffer from the two problems described above. This is to regard the expansion of the universe as being analogous to the increase of the surface area of a lake due to rain falling on the lake.

In this scenario the properties of the lake surface do not change in time and neither does the local energy density. Thus, energy injected by the Planckton creation process keeps the local energy density constant while also providing a mechanism for driving the expansion.

In particular, the local energy density is maintained by the rate of energy deposited by individual droplets while the surface area increases in proportion to the amount of water deposited by the individual droplets. The kinetic energy of the droplets gives rise to local disturbance which can be identified with zero-point energy. Since the kinetic energy of the droplet can vary greatly for a given volume of the droplet, it is clear that the zero-point energy of this system does not necessarily constrain the rate of expansion of the universe.

In analogy with the lake – droplet model, it is suggested that the expansion of the universe is driven by the constant creation of elements of "space". The energy represented by the creation of such an element gives rise to the Zero Point Energy while the "volume" of the element of space determines the rate of expansion of the universe. The droplets or quanta of "space" are termed "Plancktons" in honor of the inventor of the idea of quantization.

VIII. Additional Notes

The Planckton assumes that newly created elements of space displace existing space elements. Hence, they obey Fermi-Dirac Statistics. Therefore, if Plancktons are created in pairs with opposite spins no bulk angular momentum will be imparted to bulk space. This requirement may lead to entanglement of space elements.

Coulder and Fort [7] note that pilot-waves are nonlinear dissipative systems sustained by external forces. A dissipative system is characterized by the spontaneous appearance of symmetry breaking (anisotropy) and the formation of complex, sometimes chaotic or emergent, dynamics where interacting fields can exhibit long range correlations.

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