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Mach's Principle and Particle-antiparticle pairs: A Heuristic Stable Wormhole Mechanism for Swift Dynamics in Spacetime, Non-locality and Time Travel

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ABSTRACT

The following paper is purely hypothetical in nature in that it is based on pure hypothesis and mathematical physics. The effect of Mach's principle on the quantum regime has been studied especially with reference to the quantum mechanical vacuum and the Hawking radiation. A new concept of history dependent "energy reservoir" has been introduced as a consequence of Mach's principle and associated with every free quantum particle-antiparticle pairs, based on Feynman's idea of sum over histories of a particle and application of Mach's principle to the quantum regime. A new H-field-anti-H-field has been associated with this reservoir that is shown to have a repulsive gravitational effect. It is in principal possible that these fields constructs a wormhole in spacetime taken as a (non-)classical one. This is in accord with the fact that wormholes cannot be constructed by classical means for all observable matter with positive energy. The large distance traversed by a particle in curved space in a very short time scale has been treated as a barrier penetration problem. The tunnel effect is produced by the associated H-field via the wormhole mechanism. An expression has been derived for the transmission coefficient for the potential (distance) barrier. The time scale of travel from one event situated x^k to another event situated $x^k + \Delta x^k$, where Δx^k is very large, being very small, to any stationary or inertial observer in his proper frame the particle will appear to travel with velocities $v_{particle} \geq c$ (c being the velocity of light in vacuo space). From this it implicitly

follows that the particle will have traveled from a time co-ordinate t corresponding to x^k to another time co-ordinate $t \pm \Delta t$ corresponding to the co-ordinate $x^k + \Delta x^k$ i.e. the particle will appear to have violated causality of spacetime and traveled in time.

Keywords**:** Mach's principle; non-classical spacetimes; particle-antiparticle pairs; wormholes; spacetime quantum tunneling; quantum particle dynamics; non-locality

1. INTRODUCTION

A number of attempts have been made in deriving a mathematically consistent theory of quantum general relativity – a quantum theory of spacetime and geometrodynamics (QGD). The general theory of relativity (GRT) ceases to function below the Planck's length: $l_{pl} = \left(G\hbar / c^3\right)^{1/2} = 1.6\times10^{-35} m$, and hence is a classical approximation to a more general theory viz., QGD. Such a theory however, has not been realized to date. A method due to Feynman [1], concerning a start off with manifestly Lorentz-invariant rules for calculating transition amplitudes involving gravitational transitions and then tinkering with them to eliminate the occurrence of unphysical particles of helicities $0,\pm1$ in physical states, has been carried out to completion by Fadeev, Mandelstam, DeWitt, et.al. [2]; also noteworthy is Misner's work on Feynman quantization of GRT [3]. Scherk and Schwarz [4] have shown that if the string theory is applied to gravity with the tension in the string increased 10^{39} times that used to describe the strong force the predictions of the string coincide with those of general relativity and furthermore the theory also functions well below the Planckian length scale and makes predictions therein. This has created a new wave of interest in the Super String Theories (SSTs) and a relatively recent 11 dimensional version called the M-Theory (short for Membrane Theory). Most notable is Wheeler's idea of quantum foam structure of spacetime at length scales below l_{pl}, not only due to the quantum shimmering but rendered so mainly by spacetime itself churned into a lather of distorted geometry, developed in collaboration with Misner, which provided with an exact picture of spacetime at Planckian length scales wherein the classical GRT is combined with the Heisenberg uncertainty principle (HUP). Accordingly, it was the Planck's length that set the scale for the quantum fluctuations in spacetime, now stirred at this scale into the writhing turbulence of myriad multiply connected domains [5].

The dynamics of a particle in such quantum foam has been studied extensively by Hawking et.al. [6]. The question of the structure of the spacetime (physical) singularity in the language of quantum spacetime has been dealt with in various ways (see, e.g., [7]). Recently, the loop quantization approach of Ashtekar et.al. (see, [8] and references therein) seem to be showing some promises. The swift dynamics of an object such as a spaceship has been considered by Alcubierre [9]. Such methods however are beyond the reach of current experimental techniques. The motion of a particle down a wormhole such as the Einstein-Rosen Bridge of wormhole is not possible due to its extreme instability. Since wormhole geometry is not classically viable it becomes mandatory to consider semi-classical and quantum geometrodynamic alternatives for wormhole dynamics of a particle. The current paper, which is based on pure hypothesis, deals with a similar situation except that here every free quantum particle-antiparticle pairs are given the ability to construct a wormhole by utilizing a H-field-anti-H-field associated with their "existence reservoir", which depends on the history of the particle- antiparticle pair, and with the help of this wormhole make large scale displacement in curved space in a relatively short time scale.

2. THEORETICAL CONSIDERATIONS

A free particle is defined as one, which is subjected to no forces of any kind and so, moves in a region of constant potential. We know that the energy of a quantum particle is quantized when it is in bounded states, e.g., a square well. For the free particle there is no such restriction on the energy and we have a continuum of the energy spectrum associated with such a particle. However, in the curved spacetime manifold, each and every particle, bound or unbound, is subject to the (unscreened) gravitational force (in fact, curved spacetime means gravity) arising from the curvatures produced by the local mass distributions. The classical geometric G-field is given by the Einstein field equations;

$$R_{ik} - \frac{1}{2} g_{ik} R = -\kappa T_{ik} \qquad (1)$$

where, $G_{ik} = R_{ik} - \frac{1}{2} g_{ik} R$ is the trace of the Riemann tensor R_{ijkl}, known as the Einstein's tensor, describing the average curvature produced in spacetime by a source(s); R_{ik} is the Ricci tensor, R is the scalar curvature or curvature invariant, g_{ik} is the fundamental metric tensor and T_{ik}, the energy-momentum tensor of the source(s). κ is Einstein's constant of gravitation, $\kappa = \frac{8\pi G}{c^4}$. Henceforth, we shall adopt geometrized units viz., $G = c = k_B = 1$.

Long ranged forces are currently known to be transmitted either by the gravitational field (the metric tensor) or by the electromagnetic field (vector potential). As such, it is natural to conclude the existence of other scalar fields that also produce their corresponding long-ranged forces. This of course has already been suggested. For a homogeneous gravitational field, the particle, in the absence of any other force or collisions with any other particle, will fall with the same acceleration as any other particle in that field and the same goes for the antiparticle. A term for energy-momentum or stress energy of empty space of the form: $T_{ik}^{vac} = \frac{\lambda}{8\pi} g_{ik}$, shall be added to T_{ik} so as to enable the H-field to interact with this stress energy and create a wormhole and yet the stress energy is chosen to be so small that it its appearance in (1) is almost entirely insignificant and hence doesn't interfere with the line element for wormhole geometry or with the possibilities of occurrence of singularities in spacetime. The particle-antiparticle pair must have been created at some time in the past, very distant or relatively recent, in some physical process. I assign to all these particle-antiparticle pairs, due to their existence, an "existence reservoir" (ER) of negative energy density. The quantum dynamical properties of particle-antiparticle pairs can be interpreted, from the Mach's principle, to arise from a cosmic field associated with the ER. According to the CPT theorem, to every particle there corresponds an antiparticle so that their interaction creates energy exactly equivalent to their masses (with $G = c = k_B = 1$) and here we choose particle-antiparticle pairs, physical or virtual. Thus, when the terms corresponding to the ER of the particle makes their appearance in the Einstein-Hilbert action, additional terms corresponding to the ER of the antiparticle also make their appearance in the action and are negative in sense with respect to the terms corresponding to the particle in accordance with Wheeler-Feynman-Dyson realization of an antiparticle as the same particle moving forward and then backwards in time. The history of the particle is influenced by the presence of the particles and antiparticles or ponderable and imponderable matter (and energy) in the background and hence its history is dependent on the histories of these particles. The corresponding H-field-anti-H-field of the particle-antiparticle pairs are scalar in nature and denoting the derivative of the H-field-anti-H-field with respect to the spacetime coordinate x^k by H_k so that $H^k = g^{ik} H_i$, we have;

$$A_{EH} = \frac{1}{16\pi} \int R\sqrt{-g}\, d^4x + \varsigma_{00}^{par} - \frac{1}{2} k_0 \int_0^t H_k H^k \sqrt{-g}\, d^4x - \frac{1}{2} k_0 \int_t^0 H_k H^k \sqrt{-g}\, d^4x + \varsigma_{00}^{antipar}, \quad (2)$$

(ς is "zeta") where, the limit of the integral is from the time of its creation taken as 0 to the time at which the wormhole creation is considered, taken as t. Note that $\varsigma_{00}^{par} + \varsigma_{00}^{antipar} = 0$; ς_{00}^{par} and $\varsigma_{00}^{antipar}$ are time-time coefficients of the history of the particle-antiparticle pair and $\varsigma_{00} = \varsigma^{00}$ for all particle-antiparticle pairs. These represent the path-dependent and the path-independent coefficients corresponding to each component particle of the particle-antiparticle pair. Despite that, the path-independent coefficients have no physical significance in four-dimensional spacetimes.

After coming into existence, the particle will follow a world line that is a geodesic, unique for it the spacetime continuum (and consequently, so will the antiparticle). As such, it will have a unique history with which will be associated least action. The longer the history of the particle (or the antiparticle), more enhanced is the energy in the ER (i.e., it becomes more and more negative given the direction of its history). The negative nature is ascribed to the convention that the particle and all such particles curve spacetime whereas physics is simple when it is analyzed locally i.e., in spacetime devoid of effects of gravitation (locally Lorentzian). As seen from (2), the energy of the ER doesn't append to the spacetime curvature, the corresponding energy-momentum tensor takes the form:

$$T_{(H)}^{ik} = -k_0 (H^i H^k - \frac{1}{2} g^{ik} H^j H_j) . \quad (3)$$

For $k_0 > 0$, we have $T_{(H)}^{00} < 0$. The H-field thus, has a negative energy density that produces a repulsive gravitational effect making the spacetime in the neighborhood of the particle under question to expand. The antiparticle also tunnels by the same mechanism and may reach the same event as does the particle but in case it doesn't, the entropy of the isolated particle-antiparticle system will increase. The time scale for which it expands is inestimably small. Now, for the given conventional direction of time and hence the history of any particle, the entropy always increases in the course of every spontaneous process in the universe with respect to our particle. Thus, $T^{00}_{(H)}$ can be related to the entropy‘s’ (which is determined by the length of the particle history) as,

$$T^{00}_{(H)} = -\,\sigma S \theta \qquad (4)$$

where, σ (“sigma”) is a dimensionless constant and θ is the temperature at the instant t mentioned above.

In curved spacetime, the world line of the particle will also be curved though in view of the singularity theorems of Penrose and Hawking [10], there will exist at least one point in the spacetime manifold where the curvature is not aligned with the world line [11], i.e.,

$$u_{[i} R_{j]mn[h} u_{k]} u^m u^n \neq 0 \qquad (5)$$

Here, the box denotes antisymmetrization.

Per se, in this manifold, the distance between one event characterized by x^k and another event characterized by $x^k + \Delta x^k$ can be quite large. Sometimes certain unforeseen physical conditions may require our bradyonic (free fall, $v_{particle} << c$) particle to traverse this distance in a relatively much shorter time scale. Here, the vacuum stress energy density plays an imperative role so as to evade this classical paradox without perturbing the solution giving the line element of the wormhole geometry. The quantum particle now evaluates this possibly large distance as a barrier of thickness approximately given by $l = \int_{x^k}^{x^k+\Delta x^k} dl$ with $dl^2 = -\,g_{ik}\, dx^i\, dx^k$. The kinetic energy of the particle being (T) insufficient to cross this barrier to directly reach the event in spacetime characterized by $x^k + \Delta x^k$, it will evoke the energy of the H-field which will create a repulsive effect to stretch the spacetime in the neighborhood of the particle. The anti-H-field of the antiparticle will carry out a similar CPT invariant action. This negative energy density thus creates a wormhole. The action of the H-field is expressed by:

$$\mathcal{L}_H = \left(\partial_k \partial^k\right)\left(H^k H_k\right) - \mu_0^2 \left(H^k H_k\right) - k_0^2 \left(H^k H_k\right)^2, \qquad (6)$$

where, $\mathcal{L}_H$ is the effective Lagrangian of the H-field with μ_0 being the mass of the particle.

The energy density required by the wormhole is negative (as measured by a stationary observer). This wormhole characterized by a constant 'b' with dimensions of length and is characterized by the line element,

$$ds^2 = -dt^2 + dr^2 + (b^2 + r^2)[d\theta^2 + \sin^2\theta\, d\varphi^2] \tag{7}$$

which is our solution to the Einstein field equations (1) in orthonormal basis. The constants μ_0, k in (6) determine the value of 'b' as well as of the duration of existence of the wormhole.

As mentioned earlier, the H-field mechanism by which this wormhole is created is consistent with the fact that it is impossible to construct a wormhole of type (7) by classical for all realistic matter described classically by energy-momentum positivity condition viz.,

$$T_{ik}u^i u^k \geq 0\,, \tag{8}$$

for all time-like vectors u^i (i.e., $u^i u_i < 0$) so that the energy density of observable matter, ρ, is always positive ($\rho \geq 0$). The equality holds in (8) if $R_{ik} = 0$.

2. 1. Tunneling mechanism and dynamics of the particle-antiparticle pair

The metric (8) is similar to that of flat spacetime. It is independent of time, t. It is spherically symmetric because a surface of constant 'r' and 't' has the geometry of a sphere. At very large 'r', the spacetime is approximately flat; except for the value $b = 0$, the geometry is otherwise never flat and in the abovementioned case will provide for a tunnel through the otherwise vast distance in the curved spacetime manifold.

The distance between x^k and $x^k + \Delta x^k$ will be set up by a potential barrier with an approximate value of '$-\frac{1}{2}g_{00}$' where g_{00} is the time-time component of the metric tensor. Use has been made of the approximation that since our particle is in free fall (non-relativistic),

$$g_{00} \approx -(1 + 2\phi_G)\,. \tag{9}$$

The energy density of the particle being described by $T_{00}^{(par)}$, this coupled with the energy density of the H-field will give a net energy density,

$$T_{00}^{(tot)} = T_{00}^{(par)} + T_{00}^{(H)}\,. \tag{10}$$

Here, $T_{ik}^{(H)} = T_{(H)}^{\alpha\beta} g_{\alpha i} g_{\beta k}$ correspond to the covariant components of the energy-momentum tensor of the H-field.

Once inside the wormhole, the particle will fall but not so freely, rather more swiftly propelled by the wormhole closing at the end; it (the wormhole) is open at the end $x^k + \Delta x^k$ till the particle reaches the designated event in spacetime corresponding to our latter coordinate at any end the wormhole will exist for an inestimably short time scale given by the uncertainty relation $\tau_{(H)} \approx \left| \frac{\frac{1}{2}\hbar}{T_{(H)}^{00}} \right|$. The mass of the particle being 'μ_0', the transmission coefficient will be determined by l, mentioned earlier, the constant b, ϕ_G and $T_{00}^{(H)}$. Since, b is related to $T_{00}^{(H)}$, we take a dimensional guess that some force, say that provided by the H-field, connects these two. I first construct a force of Planckian dimensions giving thereby

$$F_{Pl} = c^4 / G \ . \tag{11}$$

Assuming that the force connecting b and $T_{00}^{(H)}$ is proportional to Planck's force by a dimensionless factor ϖ, $T_{00}^{(H)}$ now takes the form

$$T_{00}^{(H)} = b \cdot kF_{Pl} \ . \tag{12}$$

The transmission coefficient is calculated and found to be by simple substitutions

$$D = D_0 \exp\left[-2l/\hbar \sqrt{2\mu_0 (\phi_G - T_{00}^{(Tot)})} \right] \ , \tag{13}$$

where,

$$D_0 = -32 \left[\left(\frac{T_{00}^{(par)} + T_{00}^{(H)}}{g_{00}} \right) - 2 \left(\frac{T_{00}^{(par)} + T_{00}^{(H)}}{g_{00}} \right)^2 \right] \tag{14}$$

and,

$$\phi_G - T_{00}^{(Tot)} = -(\tfrac{1}{2} g_{00} + T_{00}^{(par)} + T_{00}^{(H)}) \ . \tag{15}$$

To any stationary or inertial observer making measurements in his proper frame, the particle will appear to exceed the velocity limit placed by its non-zero rest mass and as such for our observer, it may appear that the velocity of the particle, $v_{particle}$, will have taken such values that $v_{particle} \geq c$ (c being the velocity of light in vacuo space). This is consistent with GRT.

Since the Lagrangian for the geodesic of the particle with respect to its travel through the wormhole is

$$L\left(\frac{dx^k}{d\tau}, x^k\right) = \left\{\left(\frac{dt}{d\tau}\right)^2 - \left(\frac{dr}{d\tau}\right)^2 - (b^2 + r^2)\left[\left(\frac{d\theta}{d\tau}\right)^2 + \sin^2\theta\left(\frac{d\varphi}{d\tau}\right)^2\right]\right\}^{1/2}, \quad (16)$$

the equations of the geodesic of the particle are found to be

$$\frac{d^2t}{ds^2} = 0, \quad (17\text{-a})$$

$$\frac{d^2r}{ds^2} = r\left[\left(\frac{d\theta}{ds}\right)^2 + \sin^2\theta\left(\frac{d\varphi}{ds}\right)^2\right], \quad (17\text{-b})$$

$$\frac{d}{ds}\left[(b^2 + r^2)\frac{d\theta}{ds}\right] = (b^2 + r^2)\sin\theta\cos\theta\left(\frac{d\varphi}{ds}\right)^2, \quad (17\text{-c})$$

$$\frac{d}{ds}\left[(b^2 + r^2)\sin^2\theta\frac{d\varphi}{ds}\right] = 0. \quad (17\text{-d})$$

We know that the only nonvanishing Christoffel symbols for wormhole (7) are

$$\Gamma^r_{\theta\theta} = -r, \quad (18\text{-a})$$

$$\Gamma^r_{\phi\phi} = -r\sin^2\theta, \quad (18\text{-b})$$

$$\Gamma^\theta_{r\phi} = \Gamma^\theta_{\phi r} = \frac{r}{b^2 + r^2}, \quad (18\text{-c})$$

$$\Gamma^\theta_{\phi\phi} = -\sin\theta\cos\theta, \quad (18\text{-d})$$

$$\Gamma^\phi_{r\phi} = \Gamma^\phi_{\phi r} = \frac{r}{b^2 + r^2}, \quad (18\text{-e})$$

$$\Gamma^\phi_{\phi\theta} = \Gamma^\phi_{\theta\phi} = \cot\theta. \quad (18\text{-f})$$

The quantum particle starts at coordinate radius $r = R$ and reaches the corresponding point $r = -R$ at the other end of the wormhole which opens into a new sheet of spacetime containing the coordinate $x^k + \Delta x^k$, so that the elapsed proper time is

$$\Delta\tau = {2R}/{v_{particle}}. \quad (19)$$

The large distance free fall travel can thus be evaded and a test quantum particle of the particle-antiparticle pair or the pair itself (both the particles of the pair may travel together through the wormhole under CPT invariance) can go around this problem when subjected to certain special physical conditions, as already mentioned at the beginning, by cutting short through the spacetime and digging channels in the fabric of spacetime.

Since, the free quantum particle is unbound, up to a certain size limit every classical particle appearing in pair with an antiparticle can also use this mechanism and travel swiftly. (An antiparticle in a CPT universe can also separately use its anti-H-field and travel swiftly on similar lines of the particle; that it then may or may not reach the same destination as the particle by this separate mechanism) Also, it is worthwhile to note that the particle because of its swift travel through spacetime via the wormhole geometry, will have reached at the same space coordinate in spacetime at a time different from the time at which it would otherwise have reached the same event, thus making time travel quantum mechanically viable. Also, the special physical constraints mentioned above are geometrodynamic and quantum mechanical (or quantum gravitational and tidal) being worked upon by the author.

2. 2. The interpretation of the quantum mechanical vacuum and quantum shimmering

The quantum shimmering due to the clicking on and off of the virtual particle-antiparticle pairs (vacuum polarization) are as a possibility attributed to this mechanism (since the history of these virtual pairs is the longest as the history of the vacuum is the longest at any given cosmic time) wherein the particles with energy lower than the vacuum energy travel from one event to another via worm hole geometry (however the special condition for such low energy particles is so strong and inflexible that it holds valid for such particles or antiparticles at all points in spacetime).

By means of the Mach's history field the particle-antiparticle pairs make quick undetectable appearances over very short time scales, traveling from one event to another constantly by means of the wormhole mechanism; (therefore making them seem virtual) thereby making it look like quantum shimmering.

Here, the mention of rigidity of the special physical condition for the case of the virtual pairs implies that the condition making the test particle to take a shorter (action) route between two distant spacetime coordinates by activating the ER and hence the H-field is common to all free particles of quantum domain.

Whether physical or virtual, the Mach's principle applies equally well to both and the quantum shimmering is a property to be attributed to the effect of the Mach's principle on the quantum mechanical (or Heisenberg's) vacuum.

2. 3. Mach's principle and the Hawking radiation

The tidal gravitational forces at the horizon of a black hole is a sufficient condition for a particle-antiparticle pair to become real separate and tunnel through the fabric of the spacetime via a wormhole mechanism. In this mechanism of the Hawking radiation, the unique feature is that an observer in his proper frame will definitely observe a steady decrease in the area of the event horizon, but not necessarily detect the emitted radiation which will (or may) open out at any event in the universe including at the horizon or at a considerable distance from it.

3. CONCLUSIONS

The aforementioned mechanism yields many possible theories for travel with super-luminal velocities and time-travel. It is now possible that the actual space time as a circuit with various connections at floating and from time to time the various spacetime circuits are closed or on i.e., wormholes are created and particles flow from one point to other by shorter routes by means of the wormhole circuitry. Henceforth the wormhole circuitry will be referred to as the "tube system". Finally, it seems that the mechanism discussed in this paper provides a plausible cause for non-locality in quantum theory and measurement.

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