Review Article

On Quantum Gravity & Graviton from Non-Mainstream Perspective

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ABSTRACT

The natures of quantum gravity and graviton are reviewed and explored from the non-mainstream perspectives. It turns out that quantum gravity is likely manifestation of quantum entanglement and mediated by wave-functions of elementary particles as nonlocal objects. Thus, each elementary particle has its corresponding gravitons comprised of its external and internal wave-functions as nonlocal objects. This new understanding allows one to reconcile quantum mechanics with general relativity and explain dark matter and dark energy as nonlocal effects on the cosmic scales. To make the transition from quantum gravity to general relativity, it is theorized that: (1) Ricci scalar R and metric tensor $g_{\mu\nu}$ are originated from and determined by the collective internal and external wave functions of the matter present; (2) in the absence of nonlocal effect of remote matter through quantum entanglement, R and $g_{\mu\nu}$ are only correlated to momentum-energy tensor of the local matter; (3) in the presence of nonlocal effect of remote matter through quantum entanglement, R and $g_{\mu\nu}$ are also influenced by the nonlocal effect of the remote matter currently interpreted (or seen) as dark matter and/or dark energy. Some of the important consequences of this theory are the following: (1) gravitational fields (gravitons as nonlocal objects comprised of internal and external wave functions) may not carry localized or directly detectable momentum and energy; and (2) there may be no gravitational wave since gravity is nonlocal and instantaneous.

Key Words: quantum gravity, graviton, quantum entanglement, wave function, external, internal, nonlocal object, dark matter, dark energy.

1. Introduction

Quantum gravity seeks description of gravity based on the principles of quantum mechanics in order to reconcile quantum theory with general relativity and build a theory of everything. However, mainstream approaches seem to be inadequate for various reasons [see, e.g., 1-2]. Here we review the authors' own alternative approaches and progress over the last several years [3-6] and explore new approaches to reconcile quantum gravity with general relativity.

2. The Origin of Gravity [3]

In Ref. [3], the ontological origin of gravity was explored by thinking outside the mainstream notions of quantum gravity. It was argued that gravity originates from prespacetime, is the

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manifestation of quantum entanglement, and implies genuine instantaneous interconnectedness of all matters in the universe. That is, the principle of non-local action is advocated. This view is a reductionist expression of Newton's instantaneous universal gravity and Mach's Principle. Ref.[3] is an extension of the authors' earlier papers advocating a holistic and unified theme of reality in which spin is the primordial self-referential process driving quantum mechanics, spacetime dynamics and consciousness [see, e.g., 7]. The connection between quantum entanglement and Newton's instantaneous universal gravity and Mach's Principle is natural.

Microscopically gravity is assumed to be fable and negligible and macroscopically it is ubiquitous and pervasive. It seems to penetrate everything and cannot be shielded. However, there is no consensus as to its cause despite of the efforts of many people. Presumably, this status of affair is due to the lack of any experimental guidance. There are many general and technical papers written on the subject. The authors' propositions were and still are the following [3]:

1) Gravity originates from the primordial spin processes in non-spatial and non-temporal prespacetime and is the macroscopic manifestation of quantum entanglement.
2) Thus, gravity is nonlocal and instantaneous, as Newton reluctantly assumed and Mach suggested. It implies that all matters in the universe are instantaneously interconnected and many anomalous effects in astronomy such as red shift, dark energy, dark mass and Pioneer effect may be resolved from this perspective.
3) Potentially, gravity can be harnessed, tamed and developed into revolutionary technologies to serve the mankind in many areas such as instantaneous communication, spacetime engineering and space travel.

The idea of instantaneous gravity is nothing new. Newton's law of universal gravitation implies instantaneous "action at a distance" which he felt deeply uncomfortable with, but Newton was not able to find a cause of gravity [8]. Later Mach suggested that "[t]he investigator must feel the need of... knowledge of the immediate connections, say, of the masses of the universe…[t]here will hover before him as an ideal insight into the principles of the whole matter, from which accelerated and inertial motions will result in the same way" [9]. Ontologically, Mach's above suggestion is a form of holism and implies that gravity is relational and instantaneous.

It was Einstein who fulfilled Mach's "relational" suggestion of gravity by discovering general relativity [10]. He also coined the phrase Mach's principle. However, was such fulfillment at the sacrifice of Mach's "immediate connections" by assuming that the speed of gravity is the speed of light? Einstein's general relativity is now the mainstream theory of gravity, but it is in apparent conflict with quantum mechanics – the most successful theory of the 20^{th} century which Einstein himself helped to build. Einstein called quantum entanglement "spooky action at a distance" in the famous EPR debate [11]. However, it seems that Einstein's camp is on the losing side of the debate today as many recent experiments have shown that quantum entanglement is physically real [see, e.g., 12]. It was argued in [3] that a theory of gravity, which includes general relativity as an approximation, be built from the properties of quantum entanglement.

Ontologically, we have argued in [7] that quantum entanglement arises from the primordial self-referential spin processes which are envisioned by us as the driving force behind quantum mechanics, spacetime dynamics and consciousness.

First, spin is deeply connected to the microscopic structure of spacetime as reflected by the Dirac equation for Dirac spinor field representing the fermions [13]. Indeed, Penrose had considered early on that spin might be more fundamental than spacetime and invented spinor and twistor algebras for a combinatorial description of spacetime geometry [14-15]. Bohm and Hiley generalized the twistor idea to Clifford algebra as a possible basis for describing Bohm's "implicit order" [16]. Recently various spin foams have been formulated as extensions to Penrose's spin networks for the purpose of constructing a consistent theory of quantum gravity [see, e.g., 17]. Many others have also study the nature of spin from both classical and quantum-mechanical perspectives. For example, Newman showed that spin might have a classical geometric origin. By treating the real Maxwell Field and real linearized Einstein equations as being embedded in complex Minkowski space, he was able to interpret spin-angular momentum as arising from a charge and "mass monopole" source moving along a complex world line [18].

Second, Sidharth discussed the nature of spin within the context of quantized fractal spacetime and showed that spin is symptomatic of the non-commutative geometry of space-time at the Compton scale of a fermion and the three dimensionality of the space result from the spinorial behavior of fermions [19-20]. He showed that mathematically an imaginary shift of the spacetime coordinate in the Compton scale of a fermion introduces spin ½ into general relativity and curvature to the fermion theory [19]. The reason why an imaginary shift is associated with spin is to be found in the quantum mechanical zitterbewegung within the Compton scale and the consequent quantized fractal space-time [*id.*]. Further, according to Sidharth, a fermion is like a Kerr-Newman black hole within the Compton scale of which causality and locality fails [19-20].

Third, Burinskii showed that in spite of the weakness of the local gravitational field, the gravity for a spin ½ fermion as derived using the classical Kerr-Newman Kerr solution (Kerr's Gravity) has very strong stringy, topological and non-local action on the Compton distances of the fermion, polarizing the space-time and electromagnetic field and controlling the basic quantum properties of the fermions [21]. Thus, Kerr's Gravity may suggest possibly deep connections between the mass-energy relationship of matter and the quantum properties of particles [*id.*].

Fourth, Makhlin showed that the axial field component in the spin connections of the Dirac spinor field provides an effective mechanism of auto-localization of the Dirac spinor field into compact objects, presumably representing the fermions, and condition that the compact objects are stable leads to the Einstein's field equations [22]. He suggested that the physical origin of the macroscopic forces of gravity between any two bodies is a trend of the global Dirac spinor field to concentrate around the microscopic domains where this field happens to be extremely localized [*id.*]. He further suggested that the long distance effect of the axial field is indistinguishable from the Newton's gravity which according to him reveals the microscopic nature of gravity and the origin of the gravitational mass [*id.*].

We emphasized in [3] that prespacetime means a non-spatial and non-temporal domain but it is not associated with an extra-dimension in the usual sense since there is no distance or time in such domain. So, prespacetime is a holistic domain located outside spacetime but connected through quantum entanglement to everywhere in spacetime enabling Newton's instantaneous universal gravity and Mach's "immediate connections" [3]. It has similarity to Bohm's concept of implicate order and other non-local hidden variable theories [see, e.g., 23]. The said prespacetime is a "world" beyond Einstein's relativistic world through which quantum entanglement can be used to produce instantaneous signaling as we have demonstrated experimentally [4].

In short, it was argued in [3] that it is natural to link gravity to the property of quantum entanglement; and, indeed, doing so will not only provide a cause to Newton's instantaneous universal gravity but also realize Mach's "immediate connections' discussed above. Therefore, it was proposed in [3] that gravity originates from the primordial spin processes in non-spatial and non-temporal prespacetime and is the macroscopic manifestation of quantum entanglement.

Finally, it was argued in [3] that the principle of science dictates that a hypothesis/proposition should only achieve scientific legitimacy if it is experimentally verified. Thus, we have designed and carried out experiments to verify these propositions and the results were subsequently reported in Ref. [4].

3. Experiments Testing Nonlocal Gravitational Effect [4]

In Ref. [4], the experimental findings of non-local chemical, thermal and gravitational effects in simple physical systems, such as reservoirs of water quantum-entangled with water being manipulated in a remote reservoir, were reported. With the aids of high-precision instruments, it was found that the pH value, temperature and gravity of a liquid such as water in the detecting reservoirs can be non-locally affected through manipulating water in the remote reservoir. In particular, the pH value changes in the same direction as that being manipulated; the temperature can change against that of local environment; and the gravity can change against local gravity [4]. The motivation for measuring gravity change of one reservoir of water, while manipulating water in a remote reservoir quantum-entangled with the former, is to investigate whether gravity is a non-local effect associated with quantum entanglement [3-4].

The successes of the experiments reported in Ref. [4] were achieved with the aids of high-precision analytical instruments. They include an Ohaus Voyager Analytical Balance with capacity 210*g*, resolution 0.1*mg*, repeatability 0.1*mg* and sensitivity drift 3 PPM/ºC, a Control Company traceable-calibration digital thermometer with resolution 0.001ºC and repeatability 0.002ºC near 25ºC in liquid such as water (estimated from calibration data provided), and a Hanna microprocessor pH meter Model 213 with resolution 0.001 and repeatability 0.002. The other key apparatus is a 25-litre Dewar filled with liquid nitrogen and positioned remotely at a desired distance which not only provided the drastic changes in the water being manipulated but also served as a natural Faraday cage blocking any possible electromagnetic influence between the water being measured and the water being manipulated. Also vital to the success of the experiments reported in [4] was the stable environment found in an underground room which shields many external noises such as mechanical vibration, air turbulence and large temperature change.

To conduct the experiments reported in Ref. [4], quantum-entangled stock water in individual volumes of 500*ml* or similar quantities was prepared as reported in [24]. For example, in one procedure 500*ml* fresh tap water in a closed plastic reservoir was exposed to microwave radiation in a 1500*W* microwave oven for 2*min* and then left in room temperature for 24 hours before use. In another procedure, 500*ml* bottled natural water was simply left in room temperature for at least 30 days before use. It was found previously that the stock water prepared according to these procedures is quantum-entangled [24].

Figure 1 shows a diagram of the key experimental setup and Figure 1A is a photograph of the actual key experimental setup except that the 25-litrer Dewar was not located near the measurements as shown but at a remote location:

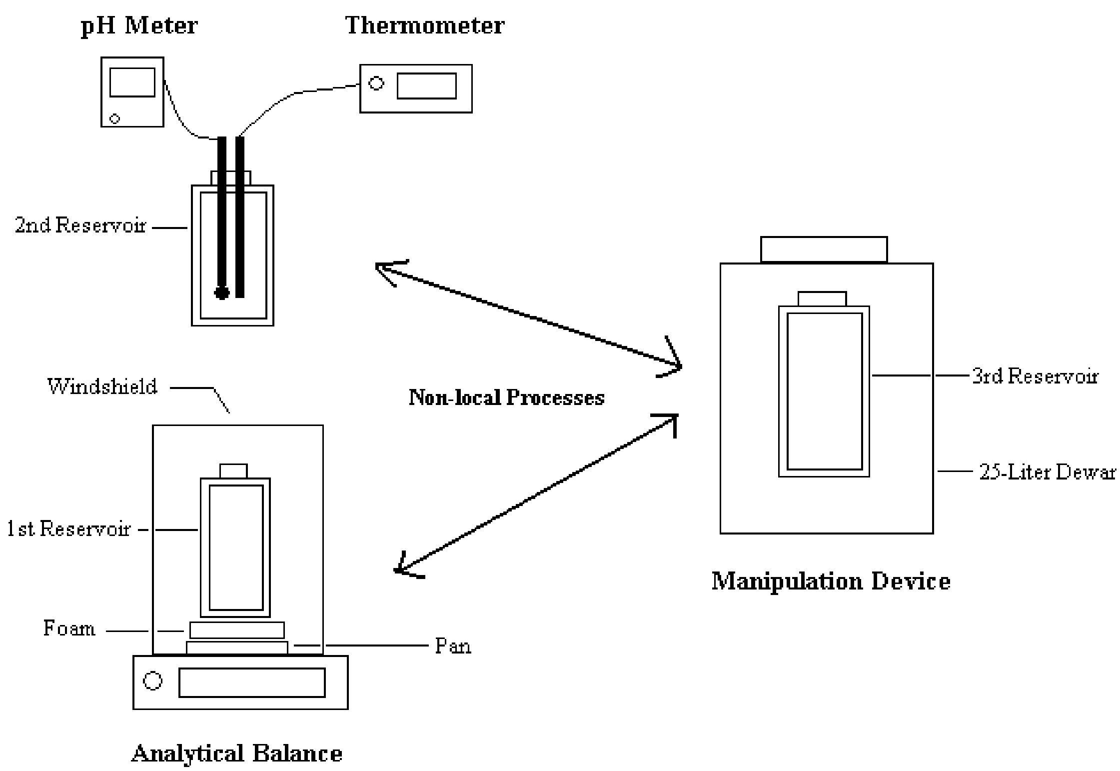

Figure1: Illustration of the key experimental setup.

Figure1A. Photograph of the actual key experimental setup except that the 25-litrer Dewar was not located near the measurements as shown but at a remote location described in the text.

The above setup included [4]: (1) the analytical balance calibrated internally and stabilized in the underground room for more than one week before use and a tightly closed plastic first-reservoir containing 175*ml* water split from the 500*ml* stock water which is placed on the wind-shielded pan of the balance with 1-inch white foam in between as insulation; (2) the digital thermometer and calibrated pH meter placed into the middle of a glass second-reservoir containing 75*ml* water split from the 500*ml* stock water which is closed to prevent air exchange; and (3) the 25-litre Dewar containing 15-25 litres of liquid nitrogen which is located at a distant of 50 feet from the underground room and a tightly closed plastic third-reservoir containing 250*ml* water split from the 500*ml* stock water to be submerged into the liquid nitrogen in the Dewar at a specified time.

Experiments with the above setup were carried out as follows [4]: (1) prepare the 500*ml* quantum-entangled stock water, divide the same into 175*ml*, 75*ml* and 250*ml* portions and put them into their respective reservoirs described above; (2) set up the experiment according to Figure 1 and let the instruments to stabilize for 30*min* before any measurements is taken; (3) record for 20*min* minute-by-minute changes of pH value and temperature of the water in the first-reservoir and weight of the second-reservoir with water before submerging the third reservoir into liquid nitrogen; (4) submerge the third-reservoir with water into liquid nitrogen for 15*min* or another desired length of time and record the instrument readings as before; and (5) take the third-reservoir out of liquid nitrogen, thaw the same in warm water for 30*min* or longer and, at the same time, record the instrument readings as before. Control experiments were carried out in same steps with nothing done to the water in the third-reservoir.

Figure 2 shows weight variations of the first-reservation during the three stages of manipulation of the water in the remote third-reservoir [4]. Before the submersion of the remote third-reservoir into liquid nitrogen the weight being measured drifted lower very slowly. But almost immediately after the remote third-reservoir was submerged into liquid nitrogen, during which the temperature and physical properties of water being manipulated drastically changed, the weight of the first-reservoir dropped at an increased rate, and after the frozen water was taken out the liquid nitrogen and thawed in warm water the weight of the same first stopped dropping and, in some cases, even rose before resuming drifting lower as further discussed below. In contrast, the control experiments did not show such dynamics. The weight difference from control in which no freeze-thaw was done at the point of thawing is about 0.25*mg*. Statistical analysis performed on data collected after freezing for 10*min* show that the results are significantly different under these different treatments/settings.

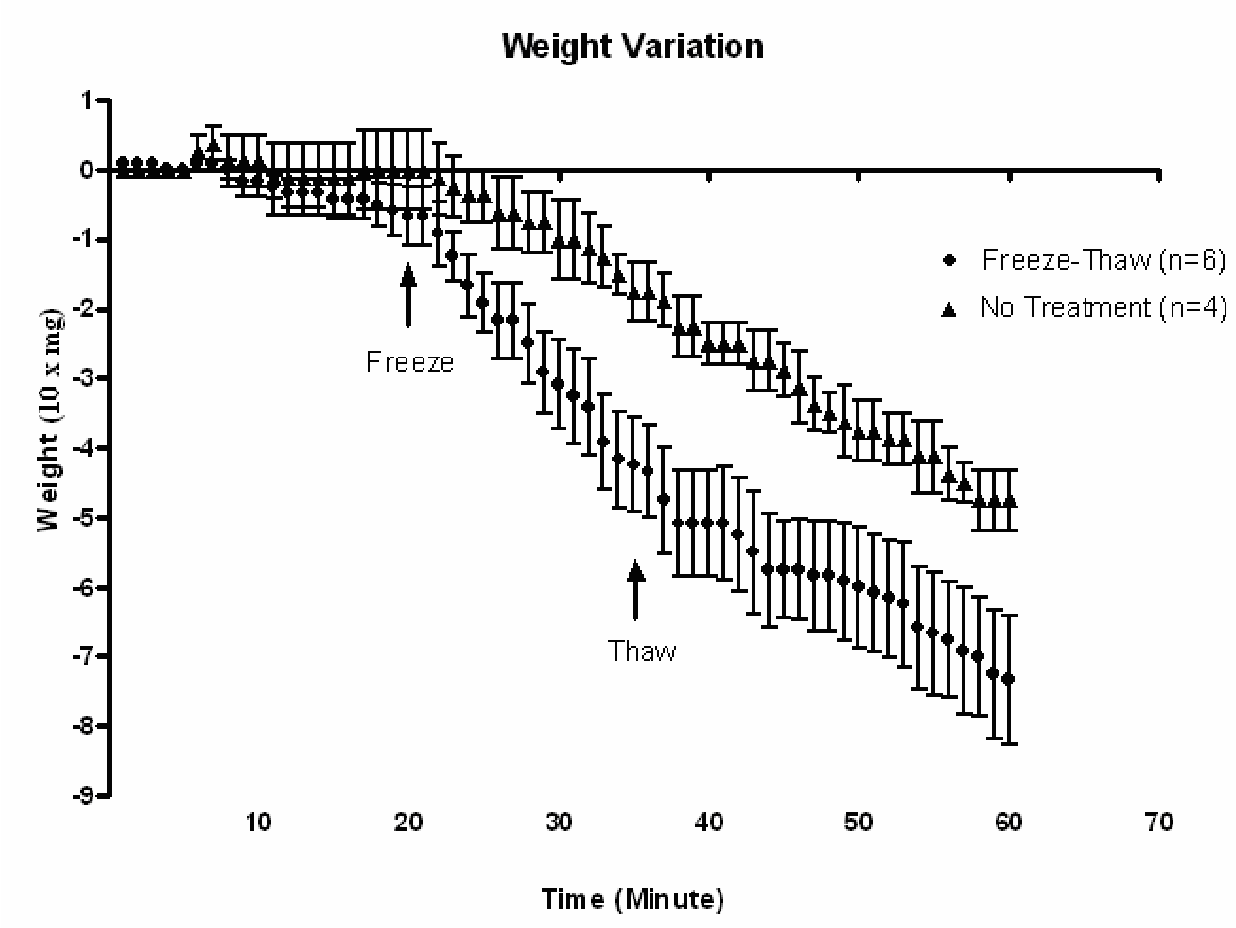

Figure 2. Weight variations under remote manipulations of water quantum-entangled with water being weighed. The weight at the starting point is set to zero and the results shown were obtained from one batch of quantum-entangled water. The weight differences from control in which no freeze-thaw was done at the point of thawing is about 0.25*mg*. In some cases, the weight of the water being weighed not only briefly stop dropping for several minutes but also rose briefly for several seconds to minutes as shown in Figure2A.

As shown in Figure 2A, in some cases, the weight of the water being measured not only stopped dropping for several minutes but also rose. The signatures of freezing induced weight decreases and thawing induced weight increases for three different thawing times are very clear.

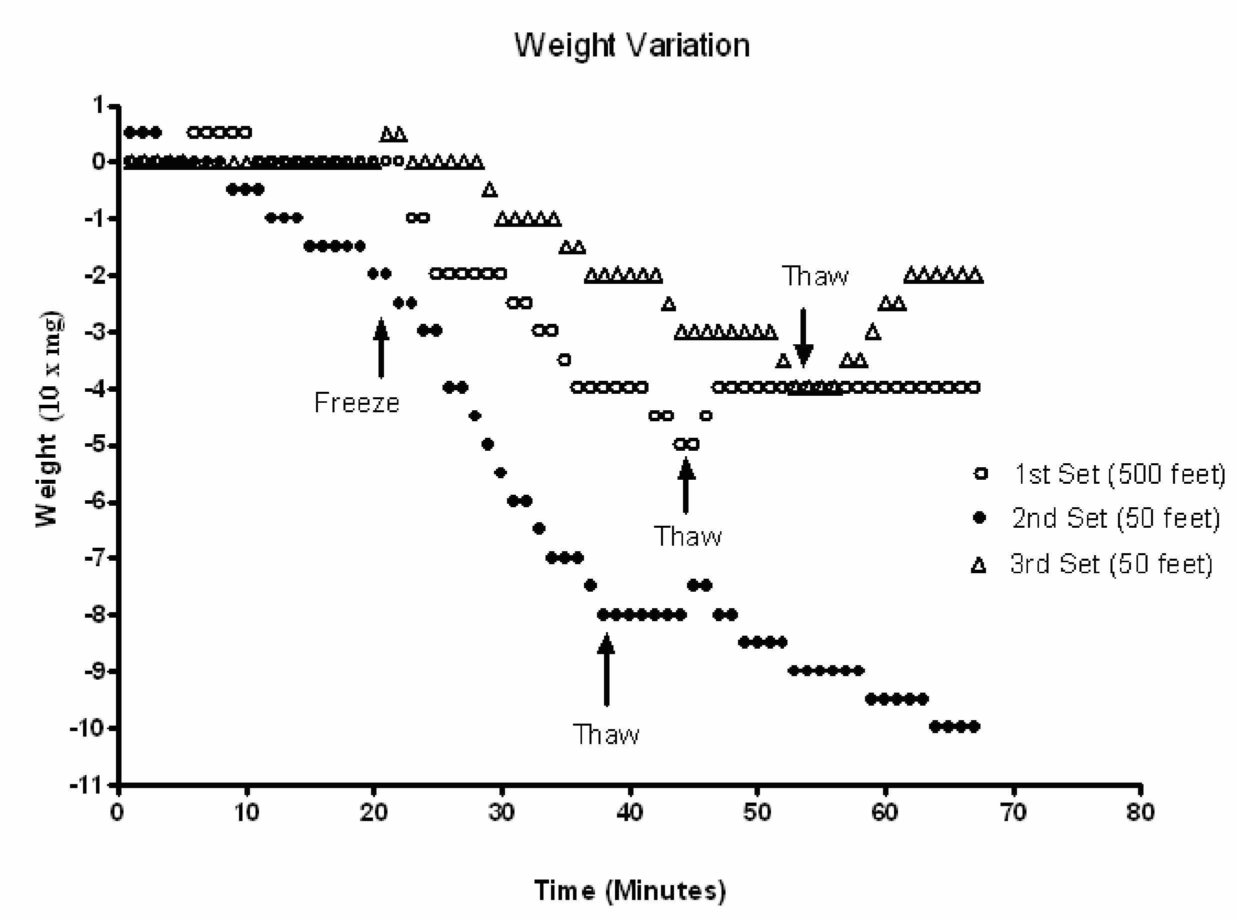

Figure 2A. Examples of weight variations under remote manipulations of water quantum-entangled with water being weighed. The onset of increased weight loss started either at the time of freezing treatment or slightly later. The signatures of thawing induced weight increases were clear for the three different thawing times. The distances shown are the respectively distances of the Dewar to the location of measurement in each experiment.

In addition, Figure 2B shows one example of weight and temperature variations under the same remote manipulation of water quantum-entangled with water being weighed and measured respectively. Again, the signatures of freezing and thawing induced weight and temperature decreases and increases are respectively very clear.

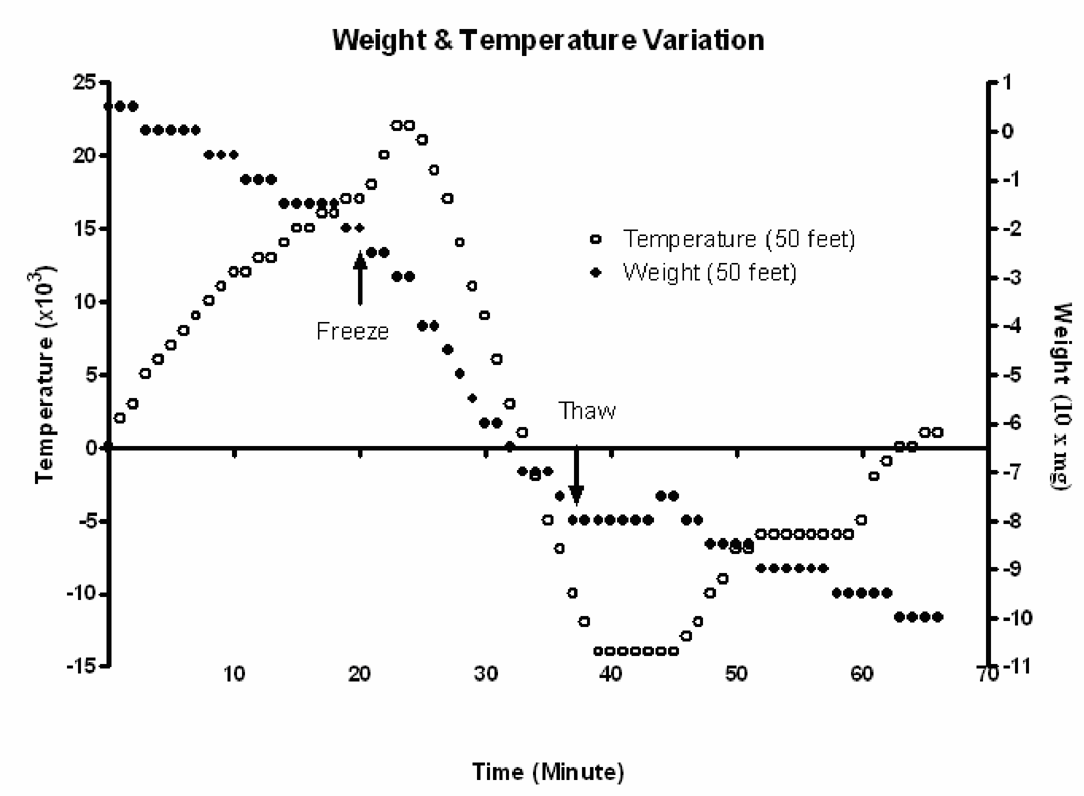

Figure 2B. One example of weight and temperature variations under the same remote manipulation of water quantum-entangled with water being weighed and measured respectively. The onset of increased weight loss started at the time of freezing treatment but the onset of temperature decrease against environmental temperature started a few minutes later after freezing treatment started. The signatures of thawing induced weight and temperature increases were clear. The distance shown is the distance of the Dewar to the location of measurement.

Further, Figure 2C shows another example of weight and temperature variations under another same remote manipulation in which the Dewar was located about 500 feet away from where the measurements were taken. The general background trend of decreasing temperature was due to environmental temperature change. Yet again, the signatures of freezing and thawing induced weight and temperature variations were respectively are very clear.

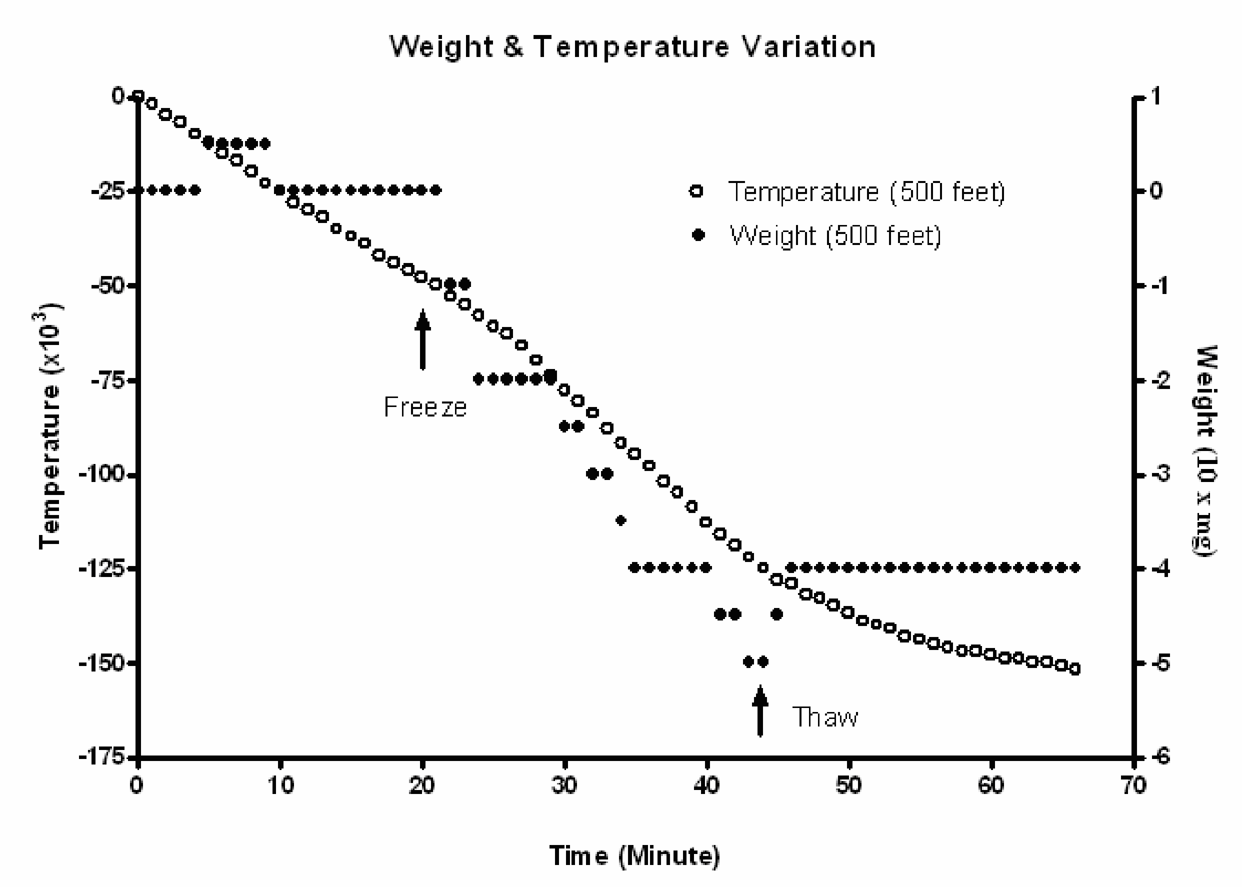

Figure 2C. Second example of weight and temperature variations under another same remote manipulation of water quantum-entangled with water being weighed and measured respectively. The general background trend of decreasing temperature was due to environmental temperature change. The onset of increased weight loss started at the time of freezing treatment but the onset of increased temperature loss started a few minutes later after freezing treatment started. The signatures of thawing induced weight increase and slow down of temperature loss were again clear. The distance shown is the distance of the Dewar to the location of measurement.

As reported in [4], with all experimental setups and their variations described therein, we observed clear and reproducible non-local effects with the aids of high-precision analytical instruments and under well-controlled conditions. The physical observables used for measuring the non-local effects are simple ones which can be measured with high precisions. These effects are, even under the most stringent statistical analysis, significantly above and beyond what were noticeable in the control experiments.

Through careful analysis, we have excluded the possibility that the observed weight variation was a secondary local effect due to heat loss and/or sensitivity drift of balance associated with temperature change induced by the remote manipulation [4]. First, during the period of remote manipulation the total temperature change was less than 0.08ºC so the total heat loss for the 175ml water in the first-reservoir is about 60*J*. In contrast, the weight loss during remote manipulation was on average about 0.25*mg* which is $2.25x10^9 J$ in energy unit. Second, the first-reservoir and the pan of the balance were separated by 1-inch white foam to prevent heat transfer to the analytic balance. Even in the highly unlikely scenario that this temperature change somehow affected the overall temperature of the balance, the associated sensitivity drift of the balance was about 0.03*mg* which is about 10 times smaller than what's actually observed. In addition, Figures 2A, 2B and 2C also show several other signatures of remote freeze-thaw treatment as the sole cause of the observed weight variations. Therefore, the observed gravity variation is a genuine and direct non-local effect associated with quantum entanglement.

We chose to use liquid nitrogen in a large Dewar placed at a distant location for manipulating water in our experiments because it can provide drastic changes in temperature and properties of water in a very short period of time [4]. Our expectation was that, if the quantum entities inside the water being measured are able to sense the changes experienced by the quantum entities in the water being manipulated through quantum entanglement and further utilize the information associated with the said changes, the chemical, thermal and gravitational properties of the water might be affected through quantum entanglement mediated non-local processes [See, e.g., 3]. The most logical explanation for these observed non-local effects is that they are the consequences of non-local processes mediated by quantum entanglement between quantum entities in the water being measured and the remote water being manipulated [4].

In short, the experiments reported in Ref. [4] shows that the gravity of water in a detecting reservoir quantum-entangled with water in a remote reservoir can change against the gravity of its local environment when the latter was remotely manipulated. However, as with many other experimental findings, independent replications are the key to verify our results. Therefore, we urge all interested scientists and the like to do their own experiments to verify and extend our findings. Perhaps the most shocking was the experimental demonstration of Newton's instantaneous gravity and Mach's instantaneous connection conjecture and the relationship between gravity and quantum entanglement.

4. The Origin of Dark Matter and Dark Energy [5]

In Ref. [5], the origin of dark matter and dark energy was explored among other topics in light of the experimental findings reported in [4]. It was suggested that dark matter is the cosmological manifestation of quantum entanglement but seen as additional gravity caused by invisible matter under some cosmological conditions [5]. In contrast, it was suggested that dark energy is the cosmological manifestation of reverse quantum entanglement but seen as anti-gravity caused by negative pressure on the cosmological scale [5].

5. Quantum Self-Gravity in the Principle of Existence [6]

The authors' results in Refs [3-5] partly lead to the development of the principle of existence reported in Ref. [6]. To understand quantum gravity, we should first understand what self-gravity is in the quantum realm and pre-quantum realm.

According to the principle of existence [6], there is no self-gravity before there is any differentiation of ether in prespacetime. The state of existence is simply $e^{i0}=1$. Once the initial phase distinction (yin and yang) is created but before the governing law is born, self-gravity is embodied in the coupling of e^{-iM} and e^{+iM} in $e^{-iM}e^{+iM}=1$. After an elementary particle and its governing are created, self-gravity of the said elementary particle is embodied in its quantum equation [6].

For example, an electron and its governing law in Dirac form are created according to the principle of existence [6] as follows ($c=\hbar=1$):

$$1=e^{i0}=e^{i0}e^{i0}=e^{+iL-iL}e^{+iM-iM}=(\cos L+i\sin L)(\cos L-i\sin L)e^{+iM-iM}=$$
$$\left(\frac{m}{E}+i\frac{|\mathbf{p}|}{E}\right)\left(\frac{m}{E}-i\frac{|\mathbf{p}|}{E}\right)e^{+ip^\mu x_\mu-ip^\mu x_\mu}=\left(\frac{m^2+\mathbf{p}^2}{E^2}\right)e^{+ip^\mu x_\mu-ip^\mu x_\mu}=\frac{E^2-m^2}{\mathbf{p}^2}e^{+ip^\mu x_\mu-ip^\mu x_\mu}=$$
$$\left(\frac{E-m}{-|\mathbf{p}|}\right)\left(\frac{-|\mathbf{p}|}{E+m}\right)^{-1}\left(e^{-ip^\mu x_\mu}\right)\left(e^{-ip^\mu x_\mu}\right)^{-1}\rightarrow\frac{E-m}{-|\mathbf{p}|}e^{-ip^\mu x_\mu}=\frac{-|\mathbf{p}|}{E+m}e^{-ip^\mu x_\mu}\rightarrow$$
$$\frac{E-m}{-|\mathbf{p}|}e^{-ip^\mu x_\mu}-\frac{-|\mathbf{p}|}{E+m}e^{-ip^\mu x_\mu}=0\rightarrow\begin{pmatrix}E-m & -|\mathbf{p}|\\ -|\mathbf{p}| & E+m\end{pmatrix}\begin{pmatrix}a_{e,+}e^{-ip^\mu x_\mu}\\ a_{i,-}e^{-ip^\mu x_\mu}\end{pmatrix}=0$$
$$\rightarrow\begin{pmatrix}E-m & -\boldsymbol{\sigma}\cdot\mathbf{p}\\ -\boldsymbol{\sigma}\cdot\mathbf{p} & E+m\end{pmatrix}\begin{pmatrix}A_{e,+}e^{-ip^\mu x_\mu}\\ A_{i,-}e^{-ip^\mu x_\mu}\end{pmatrix}=\begin{pmatrix}E-m & -\boldsymbol{\sigma}\cdot\mathbf{p}\\ -\boldsymbol{\sigma}\cdot\mathbf{p} & E+m\end{pmatrix}\begin{pmatrix}\psi_{e,+}\\ \psi_{i,-}\end{pmatrix}=0 \quad (5.1)$$

Now, we ask what is quantum self-gravity (or self-quantum-entanglement) in this fundamental equation? The answer is that it is simply the interaction (relationship) between nonlocal objects $\Psi_{e,-}$ and $\Psi_{e,+}$ respectively as external and internal gravitons ($c=\hbar=1$):

$$\begin{pmatrix}(E-m)\psi_{e,+}=\boldsymbol{\sigma}\cdot\mathbf{p}\,\psi_{i,-}\\ (E+m)\psi_{i,-}=\boldsymbol{\sigma}\cdot\mathbf{p}\,\psi_{e,+}\end{pmatrix}\text{ or }\begin{pmatrix}i\partial_t\psi_{e,+}-m\psi_{e,+}=-i\boldsymbol{\sigma}\cdot\nabla\psi_{i,-}\\ i\partial_t\psi_{i,-}+m\psi_{i,-}=-i\boldsymbol{\sigma}\cdot\nabla\psi_{e,+}\end{pmatrix} \quad (5.2)$$

For another example, a linear photon and its governing law are created according to the principle of existence [6] as follows ($c=\hbar=1$):

$$1=e^{i0}=e^{i0}e^{i0}=e^{+iL-iL}e^{+iM-iM}=(\cos L+i\sin L)(\cos L-i\sin L)e^{+iM-iM}=$$
$$\left(+i\frac{|\mathbf{p}|}{E}\right)\left(-i\frac{|\mathbf{p}|}{E}\right)e^{+ip^\mu x_\mu-ip^\mu x_\mu}=\left(\frac{\mathbf{p}^2}{E^2}\right)e^{+ip^\mu x_\mu-ip^\mu x_\mu}=\frac{E^2}{\mathbf{p}^2}e^{+ip^\mu x_\mu-ip^\mu x_\mu}=$$
$$\left(\frac{E}{-|\mathbf{p}|}\right)\left(\frac{-|\mathbf{p}|}{E}\right)^{-1}\left(e^{-ip^\mu x_\mu}\right)\left(e^{-ip^\mu x_\mu}\right)^{-1}\rightarrow\frac{E}{-|\mathbf{p}|}e^{-ip^\mu x_\mu}=\frac{-|\mathbf{p}|}{E}e^{-ip^\mu x_\mu}\rightarrow$$

$$\frac{E}{-|\mathbf{p}|}e^{-ip^{\mu}x_{\mu}}-\frac{-|\mathbf{p}|}{E}e^{-ip^{\mu}x_{\mu}}=0\rightarrow\begin{pmatrix}E & -|\mathbf{p}|\\ -|\mathbf{p}| & E\end{pmatrix}\begin{pmatrix}a_{e,+}e^{-ip^{\mu}x_{\mu}}\\ a_{i,-}e^{-ip^{\mu}x_{\mu}}\end{pmatrix}=0$$

$$\rightarrow\begin{pmatrix}E & -\mathbf{s}\cdot\mathbf{p}\\ -\mathbf{s}\cdot\mathbf{p} & E\end{pmatrix}\begin{pmatrix}\mathrm{E}_{0e,+}e^{-ip^{\mu}x_{\mu}}\\ i\mathrm{B}_{0i,-}e^{-ip^{\mu}x_{\mu}}\end{pmatrix}=\begin{pmatrix}E & -\mathbf{s}\cdot\mathbf{p}\\ -\mathbf{s}\cdot\mathbf{p} & E\end{pmatrix}\begin{pmatrix}\mathbf{E}\\ i\mathbf{B}\end{pmatrix}=0$$

$$\rightarrow\begin{pmatrix}i\partial_t & i\mathbf{s}\cdot\nabla\\ i\mathbf{s}\cdot\nabla & i\partial_t\end{pmatrix}\begin{pmatrix}\mathbf{E}\\ i\mathbf{B}\end{pmatrix}=0\rightarrow\begin{pmatrix}\partial_t\mathbf{E}=\nabla\times\mathbf{B}\\ \partial_t\mathbf{B}=-\nabla\times\mathbf{E}\end{pmatrix} \tag{5.3}$$

where the relationship $\mathbf{S}\cdot(-i\nabla)=\nabla\times$ is used to derive the last set of equations which together with $\nabla\cdot\mathbf{E}=\mathbf{0}$ and $\nabla\cdot\mathbf{B}=\mathbf{0}$ are the Maxwell equations in the source-free vacuum.

Now, we ask what is quantum self-gravity (or self-quantum-entanglement) for the linear photon? The answer is that it is simply the interaction (relationship) between nonlocal objects **E** (electric field) and ***i*B** (magnetic field on imaginary axis) as external and internal gravitons respectively. Thus, electromagnetic field is self-quantum-entangled, that is, the quantum self-gravity of electromagnetic field is the interaction between electric field and magentic field on imaginary axis through Maxwell equations.

6. Quantum Gravity in the Principle of Existence [6]

In the principle of existence [6], quantum gravity is quantum entanglement (instantaneous interaction) across external and internal worlds (dual worlds) through prespacetime. Thus, there are two types of quantum gravity at play according to the principle of existence [6]. One is quantum self-gravity (self-entanglement) between the external object (external wave function) and internal object (internal wave function) of an elementary particle described above and the other is quantum gravity (quantum entanglement) between the external wave function of said elementary particle and the internal wave function of a second elementary particle or the collective internal wave functions of a particle assemble [6]. Thus, gravitational fields are just the collective internal and external wave functions themselves in the principle of existence.

In Ref. [6], three particular forms of gravitational fields were illustrated. One is timeless (zero energy) external and internal wave functions (self-fields) that play the role of timeless graviton, that is, they mediate time-independent interactions through space quantum entanglement. The second is spaceless external and internal wave functions (self-fields) that play the role of spaceless graviton, that is, they mediate space (distance) independent interactions through proper time (mass) entanglement. The third is massless external and internal wave functions (self-fields) that play the role of massless graviton, that is, they mediate mass (proper-time) independent interactions through massless energy entanglement.

As shown in Ref. [6], timeless quantum entanglement between two entities may account for Newtonian gravity. Spaceless and/or massless quantum entanglement between two entities may account for dark matter (Also see [5]). Importantly, gravitational components related to spinization may account for dark energy [5-6].

When E=0, we have (c= $\hbar$=1) [6]:

$$-m^2-\mathbf{p}^2=0 \quad \text{or} \quad m^2+\mathbf{p}^2=0 \tag{6.1}$$

One may regard expression (6.1) as a relationship governing the Machian quantum universe in which the total energy is zero. Classically, this may be seen as: (1) the rest mass m being comprised of imaginary momentum $\mathbf{P}=i\mathbf{P}_i$, or (2) momentum $\mathbf{P}$ being comprised of imaginary rest mass $m=im_i$.

As shown in [6], the timeless Matrix Law in Dirac and Weyl form is respectively the following:

$$\begin{pmatrix} -m & -|\mathbf{p}| \\ -|\mathbf{p}| & +m \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix} = L_M \tag{6.2}$$

$$\begin{pmatrix} -|\mathbf{p}| & -m \\ -m & +|\mathbf{p}| \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix} = L_M \tag{6.3}$$

Thus, the equations of the timeless wave functions (self-fields) are respectively as follows:

$$\begin{pmatrix} -m & -|\mathbf{p}| \\ -|\mathbf{p}| & +m \end{pmatrix} \begin{pmatrix} g_{D,e}e^{-iM} \\ g_{D,i}e^{-iM} \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix} \begin{pmatrix} V_{D,e} \\ V_{D,i} \end{pmatrix} = L_M V_D = 0 \tag{6.4}$$

and

$$\begin{pmatrix} -|\mathbf{p}| & -m \\ -m & +|\mathbf{p}| \end{pmatrix} \begin{pmatrix} g_{W,e}e^{-iM} \\ g_{W,i}e^{-iM} \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix} \begin{pmatrix} V_{W,e} \\ V_{W,i} \end{pmatrix} = L_M V_W = 0 \tag{6.5}$$

Equation (6.4) and (6.5) can be respectively rewritten as:

$$\begin{pmatrix} mV_{D,e} = -|\mathbf{p}|V_{D,i} \\ mV_{D,i} = |\mathbf{p}|V_{D,e} \end{pmatrix} \quad \text{or} \quad \begin{pmatrix} V_{D,e} = -\dfrac{|\mathbf{p}|}{m}V_{D,i} \\ V_{D,i} = \dfrac{|\mathbf{p}|}{m}V_{D,e} \end{pmatrix} \tag{6.6}$$

and

$$\begin{pmatrix} mV_{W,e} = |\mathbf{p}|V_{W,i} \\ mV_{W,i} = -|\mathbf{p}|V_{W,e} \end{pmatrix} \quad \text{or} \quad \begin{pmatrix} V_{W,e} = \dfrac{|\mathbf{p}|}{m}V_{W,i} \\ V_{W,i} = -\dfrac{|\mathbf{p}|}{m}V_{W,e} \end{pmatrix} \tag{6.7}$$

To see the coupling of external and internal wave functions (self-fields) in a different perspective we can rewrite (6.6) and (6.7) respectively as follows:

$$\begin{pmatrix} mmV_{D,e}V_{D,i} = \left(-|\mathbf{p}|V_{D,i}\right)\left(|\mathbf{p}|V_{D,e}\right) \\ \left(|\mathbf{p}|V_{D,e}\right)\left(mV_{D,e}\right) = \left(mV_{D,i}\right)\left(-|\mathbf{p}|V_{D,i}\right) \end{pmatrix} \tag{6.8}$$

and

$$\begin{pmatrix} mmV_{W,e}V_{W,i} = (|\mathbf{p}|V_{W,i})(-|\mathbf{p}|V_{W,e}) \\ (-|\mathbf{p}|V_{W,e})(mV_{W,e}) = (mV_{W,i})(-|\mathbf{p}|V_{W,i}) \end{pmatrix} \tag{6.9}$$

From expression (6.6), we can derive the following:

$$(m^2 + \mathbf{p}^2)V_{D,e} = 0 \quad \text{or} \quad (m^2 - \nabla^2)V_{D,e} = 0 \tag{6.10}$$

Equation (6.10) has radial solution in the form of Yukawa potential:

$$V_{D,e}(r) = \frac{1}{4\pi r}e^{-mr} \tag{6.11}$$

So in expression (6.4), M=-imr, that is, momentum is comprised of imaginary mass. The external timeless self-field in expression (6.11) has the form of Newton gravitational or Coulomb electric potential at large distance $r\to\infty$. We have from expression (6.6):

$$V_{D,i} = \frac{|\mathbf{p}|}{m}V_{D,e} = \frac{|\mathbf{p}|}{m}\frac{1}{4\pi r}e^{-mr} \to i\frac{1}{4\pi r}e^{-mr} \tag{6.12}$$

where we have utilized the following (for reasons to be discussed elsewhere):

$$|\mathbf{p}|V_{D,e} = \sqrt{-\nabla^2}\frac{1}{4\pi r}e^{-mr} \to im\frac{1}{4\pi r}e^{-mr} \tag{6.13}$$

The complete radial solution of equation (6.4) is then:

$$V_D(r) = \begin{pmatrix} V_{D,e} \\ V_{D,i} \end{pmatrix} = N\begin{pmatrix} \frac{1}{4\pi r}e^{-mr} \\ i\frac{1}{4\pi r}e^{-mr} \end{pmatrix} = N\begin{pmatrix} 1 \\ i \end{pmatrix}\frac{1}{4\pi r}e^{-mr} \tag{6.14}$$

where N is a normalization factor. Indeed, expression (6.7) can have same radial solution as expression (6.6):

$$V_W(r) = \begin{pmatrix} V_{W,e} \\ V_{W,i} \end{pmatrix} = N\begin{pmatrix} \frac{1}{4\pi r}e^{-mr} \\ i\frac{1}{4\pi r}e^{-mr} \end{pmatrix} = N\begin{pmatrix} 1 \\ i \end{pmatrix}\frac{1}{4\pi r}e^{-mr} \tag{6.15}$$

If we assume that the internal self-field $V_{D,i}$ (which is self-coupled to its external self-field $V_{D,e}$ through expression (6.4) or (6.8) also couples through timeless quantum entanglement with the external wave function ψ_e of another entity of test mass m_t (which is also self-coupled to its internal wave function ψ_i) as, for example:

$$i\kappa m V_{D,i} m_t \psi_e = i\kappa m i\frac{1}{4\pi r}e^{-mr}m_t\psi_e = -G\frac{m}{r}e^{-mr}m_t\psi_e \tag{6.16}$$

where $i\kappa$ is a coupling constant and $G=\kappa/4\pi$ is Newton's Gravitational Constant, we have gravitational potential at large distance $r\rightarrow\infty$ as:

$$V_g = -G\frac{m}{r} \tag{6.17}$$

When $|\mathbf{p}|=0$, we have($c=\hbar=1$) [6]:

$$E^2 - m^2 = 0 \tag{6.18}$$

One may regard expression (6.18) as a relationship governing a spaceless quantum universe. Classically, this may be seen as the rest mass m being comprised of time momentum (energy E). As shown in § 3, the spaceless Matrix Law in Dirac and Weyl form is respectively the following:

$$\begin{pmatrix} E-m & 0 \\ 0 & E+m \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix} = L_M \tag{6.19}$$

and

$$\begin{pmatrix} E & -m \\ -m & E \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix} = L_M \tag{6.20}$$

and the equation of spaceless wave functions (self- fields) are respectively the follows:

$$\begin{pmatrix} E-m & 0 \\ 0 & E+m \end{pmatrix}\begin{pmatrix} g_{D,e}e^{-imt} \\ g_{D,i}e^{-imt} \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix}\begin{pmatrix} V_{D,e} \\ V_{D,i} \end{pmatrix} = L_M V_D = 0 \tag{6.21}$$

and

$$\begin{pmatrix} E & -m \\ -m & E \end{pmatrix}\begin{pmatrix} g_{W,e}e^{-imt} \\ g_{W,i}e^{-imt} \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix}\begin{pmatrix} V_{W,e} \\ V_{W,i} \end{pmatrix} = L_M V_W = 0 \tag{6.22}$$

The external and internal (spaceless) wave functions $V_{D,e}$ and $V_{D,i}$ in equation (6.21) are decoupled from each other, but those in equation (6.22), $V_{W,e}$ and $V_{W,i}$, are coupled to each other:

$$\begin{pmatrix} EV_{D,e} = mV_{D,e} \\ EV_{D,i} = -mV_{D,i} \end{pmatrix} \text{ but } \begin{pmatrix} EV_{W,e} = mV_{W,i} \\ EV_{W,i} = mV_{W,e} \end{pmatrix} \tag{6.23}$$

It can be easily verified that the solutions to equation (6.21) are in forms of:

$$V_D = \begin{pmatrix} V_{D,e} \\ V_{D,i} \end{pmatrix} = N\begin{pmatrix} 1e^{-imt} \\ 0e^{-imt} \end{pmatrix} = N\begin{pmatrix} 1 \\ 0 \end{pmatrix}e^{-imt} \tag{6.24}$$

or

$$V_D = \begin{pmatrix} V_{D,e} \\ V_{D,i} \end{pmatrix} = N\begin{pmatrix} 0e^{imt} \\ 1e^{imt} \end{pmatrix} = N\begin{pmatrix} 0 \\ 1 \end{pmatrix} e^{imt} \tag{6.25}$$

but the solutions to equation (6.22) are in the forms of:

$$V_W = \begin{pmatrix} V_{W,e} \\ V_{W,i} \end{pmatrix} = N\begin{pmatrix} 1e^{-imt} \\ 1e^{-imt} \end{pmatrix} = N\begin{pmatrix} 1 \\ 1 \end{pmatrix} e^{-imt} \tag{6.26}$$

or

$$V_W = \begin{pmatrix} V_{W,e} \\ V_{W,i} \end{pmatrix} = N\begin{pmatrix} 1e^{imt} \\ 1e^{imt} \end{pmatrix} = N\begin{pmatrix} 1 \\ 1 \end{pmatrix} e^{imt} \tag{6.27}$$

As illustrated in [6], dark matter may be a manifestation of this non-Newtonian gravity or, at least, may have a contribution from spaceless quantum entanglement.

For simplicity, two masses m_1+m_p and m_2 respectively located at space points 1 and 2 were considered in [6]. Their respective spaceless wave functions can be written in Weyl form as follows:

$$V_{1W+} = \begin{pmatrix} g_{1W+,e}e^{-i(m_1+m_p)t} \\ g_{1W+,i}e^{-i(m_1+m_p)t} \end{pmatrix} \quad \text{and} \quad V_{2W-} = \begin{pmatrix} g_{2W-,e}e^{-im_2t} \\ g_{2W-,i}e^{-im_2t} \end{pmatrix} \tag{6.28}$$

which form product state $V_{1W+}V_{2W-}$. After m_p leaves V_{1W+} as an emitted particle and get absorbed by V_{2W-}, one may has the following two additional spaceless wave functions in Weyl form:

$$V_{1W-} = \begin{pmatrix} g_{1W-,e}e^{-im_1t} \\ g_{1W-,i}e^{-im_1t} \end{pmatrix} \quad \text{and} \quad V_{2W+} = \begin{pmatrix} g_{2W+,e}e^{-i(m_2+m_p)t} \\ g_{2W+,i}e^{-i(m_2+m_p)t} \end{pmatrix} \tag{6.29}$$

which form product state $V_{1W-}V_{2W+}$. The final spaceless quantum state may be written as follows:

$$V = \frac{1}{\sqrt{2}}\left(V_{1W+}V_{2W-} + V_{1W-}V_{2W+}\right) = \frac{1}{\sqrt{2}}\left(|1+\rangle|2-\rangle + |1-\rangle|2+\rangle\right) \tag{6.30}$$

In this joint spaceless wavefunction, m_1 and m_2 are quantum entangled due to interaction with and through m_p. It was suggested in [6] that this space (distance)-independent quantum entanglement (non-Newtonian gravity) between two entities is the cause of dark matter.

When m=0, we have (c= $\hbar$=1) [6]:

$$E^2 - \mathbf{p}^2 = 0 \tag{6.31}$$

We can regard expression (31) as a relationship governing the massless quantum universe in which the total rest mass (proper time) is zero. Classically, this may be seen as energy E being comprised of momentum **p**. As shown in [6], the massless Matrix Law in Dirac and Weyl form is respectively the following:

$$\begin{pmatrix} E & -|\mathbf{p}| \\ -|\mathbf{p}| & E \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix} = L_M \tag{6.32}$$

and

$$\begin{pmatrix} E-|\mathbf{p}| & 0 \\ 0 & E+|\mathbf{p}| \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix} = L_M \tag{6.33}$$

and the equations of massless wave functions (self-fields) are respectively the following:

$$\begin{pmatrix} E & -|\mathbf{p}| \\ -|\mathbf{p}| & E \end{pmatrix} \begin{pmatrix} g_{D,e} e^{-iM} \\ g_{D,i} e^{-iM} \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix} \begin{pmatrix} V_{D,e} \\ V_{D,i} \end{pmatrix} = L_M V_D = 0 \tag{6.34}$$

and

$$\begin{pmatrix} E-|\mathbf{p}| & 0 \\ 0 & E+|\mathbf{p}| \end{pmatrix} \begin{pmatrix} g_{W,e} e^{-iM} \\ g_{W,i} e^{-iM} \end{pmatrix} = \begin{pmatrix} L_{M,e} & L_{M,i} \end{pmatrix} \begin{pmatrix} V_{W,e} \\ V_{W,i} \end{pmatrix} = L_M V_W = 0 \tag{6.35}$$

Equations (6.34) and (6.35) have plane-wave solutions. The external and internal (masssless) wave functions $V_{D,e}$ and $V_{D,i}$ in equation (6.34) are coupled with each other, but those in equations (6.35),$V_{W,e}$ and $V_{W,i}$, are decoupled from each other:

$$\begin{pmatrix} EV_{D,e} = |\mathbf{p}| V_{D,i} \\ EV_{D,i} = |\mathbf{p}| V_{D,e} \end{pmatrix} \text{ but } \begin{pmatrix} EV_{W,e} = |\mathbf{p}| V_{W,e} \\ EV_{W,i} = -|\mathbf{p}| V_{W,i} \end{pmatrix} \tag{6.36}$$

For eigenstate of E and |**p**|, the solutions to equation (6.34) are in the forms of:

$$V_D = \begin{pmatrix} V_{D,e} \\ V_{D,i} \end{pmatrix} = N \begin{pmatrix} 1e^{-i(\omega t - \mathbf{k}\cdot\mathbf{x})} \\ \frac{|\mathbf{p}|}{E} e^{-i(\omega t - \mathbf{k}\cdot\mathbf{x})} \end{pmatrix} = N \begin{pmatrix} 1 \\ 1 \end{pmatrix} e^{-i(\omega t - \mathbf{k}\cdot\mathbf{x})} \tag{6.37}$$

or

$$V_D = \begin{pmatrix} V_{D,e} \\ V_{D,i} \end{pmatrix} = N \begin{pmatrix} \frac{|\mathbf{p}|}{E} e^{i(\omega t - \mathbf{k}\cdot\mathbf{x})} \\ 1e^{i(\omega t - \mathbf{k}\cdot\mathbf{x})} \end{pmatrix} = N \begin{pmatrix} 1 \\ 1 \end{pmatrix} e^{i(\omega t - \mathbf{k}\cdot\mathbf{x})} \tag{6.38}$$

but the solutions to equation (6.35) are in the forms of:

$$V_W = \begin{pmatrix} V_{W,e} \\ V_{w,i} \end{pmatrix} = N \begin{pmatrix} 1e^{-i(\omega t - \mathbf{k}\cdot\mathbf{x})} \\ 0e^{-i(\omega t - \mathbf{k}\cdot\mathbf{x})} \end{pmatrix} = N \begin{pmatrix} 1 \\ 0 \end{pmatrix} e^{-i(\omega t - \mathbf{k}\cdot\mathbf{x})} \tag{39}$$

or

$$V_W = \begin{pmatrix} V_{W,e} \\ V_{W,i} \end{pmatrix} = N \begin{pmatrix} 0e^{i(\omega t - \mathbf{k}\cdot\mathbf{x})} \\ 1e^{i(\omega t - \mathbf{k}\cdot\mathbf{x})} \end{pmatrix} = N \begin{pmatrix} 0 \\ 1 \end{pmatrix} e^{i(\omega t - \mathbf{k}\cdot\mathbf{x})} \tag{40}$$

Equations (6.34) and (6.35) describe the self-interaction of external and internal massless and spinless wave functions (self-fields). We can build a quantum-entangled state of two massless and spinless entities similar to that of two spaceless entities. It is suggested that this rest mass-independent quantum entanglement (non-Newtonian gravity) between two massless entities may also contribute to the cause of dark matter [5-6].

7. Transition from Quantum Gravity to General Relativity

To make the transition from quantum gravity to general relativity, it is theorized that: (1) Ricci scalar R and metric tensor $g_{\mu\nu}$ are originated from and determined by the collective internal and external wave functions of the matter present; (2) in the absence of nonlocal effect of remote matter through quantum entanglement, R and $g_{\mu\nu}$ are only correlated to momentum-energy tensor of the local matter; (3) in the presence of nonlocal effect of remote matter through quantum entanglement, R and $g_{\mu\nu}$ are also influenced by the nonlocal effect of the remote matter currently interpreted (or seen) as dark matter and/or dark energy.

Some of the important consequences of the above theory are the following: (1) gravitational fields (gravitons as nonlocal objects comprised of internal and external wave functions) may not carry localized or directly detectable momentum and energy; (2) there may be no gravitational wave since gravity is nonlocal and instantaneous.

General Relativity of Electromagnetic Field (Photon)

In the principle of existence [6], quantum self-gravity of photon is embodied in its quantum equation in which external wave-function **E** and internal wave-function $i\mathbf{B}$ are self-entangled through self-interaction/gravity ($c=\hbar=1$):

$$\begin{pmatrix} E & -\mathbf{s}\cdot\mathbf{p} \\ -\mathbf{s}\cdot\mathbf{p} & E \end{pmatrix}\begin{pmatrix} \mathbf{E} \\ i\mathbf{B} \end{pmatrix} = 0 \rightarrow \begin{pmatrix} i\partial_t & i\mathbf{s}\cdot\nabla \\ i\mathbf{s}\cdot\nabla & i\partial_t \end{pmatrix}\begin{pmatrix} \mathbf{E} \\ i\mathbf{B} \end{pmatrix} = 0 \rightarrow \begin{pmatrix} \partial_t\mathbf{E} = \nabla\times\mathbf{B} \\ \partial_t\mathbf{B} = -\nabla\times\mathbf{E} \end{pmatrix} \tag{7.1}$$

which together with $\nabla\cdot\mathbf{E}=\mathbf{0}$ and $\nabla\cdot\mathbf{B}=\mathbf{0}$ are the Maxwell equations in the source-free vacuum. The latter in turn can be written in the co-variant form:

$$\partial_\beta F^{\alpha\beta} = 0 \tag{7.2}$$

where

$$F^{\alpha\beta} = \begin{pmatrix} 0 & -E_x & -E_y & -E_z \\ E_x & 0 & -B_z & B_y \\ E_y & B_z & 0 & -B_x \\ E_z & -B_y & B_x & 0 \end{pmatrix} \tag{7.3}$$

The principle of existence [6] treats wave functions as real entities instead of mathematical symbolism for calculating probability only. In the case of electric field **E** and magnetic field on the imaginary axis i**B**, this is certainly true.

Using the action principle, we will now derive the well-known equations of motion for electromagnetic field (photons) under the *new understandings* of gravity and self-gravity respectively (c=G=μ_0=1):

The total action can be written as (this is well known):

$$S = \frac{1}{16\pi}\int R\sqrt{-g}\,dx^4 - \frac{1}{4}\int F_{\alpha\beta}\,F^{\alpha\beta}\sqrt{-g}dx^4 \tag{7.4}$$

Varying metric tensor $g^{\mu\nu}$, we have:

$$\delta S = \frac{1}{16\pi}\int \left(R_{\mu\nu} - \frac{1}{2}Rg^{\mu\nu}\right)(\delta g^{\mu\nu})\sqrt{-g}\,dx^4 \\ -\frac{1}{2}\int \left(F_{\mu\beta}F_{\nu}^{\beta} - \frac{1}{4}F_{\alpha\beta}F^{\alpha\beta}g_{\mu\nu}\right)(\delta g^{\mu\nu})\sqrt{-g}dx^4 \tag{7.5}$$

Thus, we get the following well known equation of motion for electromagnetic field under gravity:

$$R_{\mu\nu} - \frac{1}{2}Rg^{\mu\nu} = 8\pi\left(F_{\mu\beta}F_{\nu}^{\beta} - \frac{1}{4}F_{\alpha\beta}F^{\alpha\beta}g_{\mu\nu}\right) = 8\pi T^{\mu\nu} \tag{7.6}$$

Putting back c, G and μ_0, we have:

$$R_{\mu\nu} - \frac{1}{2}Rg^{\mu\nu} = \frac{8\pi G}{c^4}\frac{1}{\mu_0}\left(F_{\mu\beta}F_{\nu}^{\beta} - \frac{1}{4}F_{\alpha\beta}F^{\alpha\beta}g_{\mu\nu}\right) = \frac{8\pi G}{c^4}\frac{1}{\mu_0}T^{\mu\nu} \tag{7.7}$$

Varying electromagnetic four-potential A^{α}, we have:

$$\delta S = -\frac{1}{4}\delta\int F_{\alpha\beta}\,F^{\alpha\beta}\sqrt{-g}dx^4 = \int \partial_{\beta}\left(F^{\alpha\beta}\sqrt{-g}\right)(\delta A^{\alpha})dx^4 = \int \partial_{\beta}\left(F^{\alpha\beta}\right)(\delta A^{\alpha})\sqrt{-g}dx^4 \tag{7.8}$$

Thus, we get the following well-known Maxwell equations (7.2) of motion for electromagnetic field under the *new understanding* of self-gravity in the source-free vacuum:

$$\partial_{\beta}F^{\alpha\beta} = 0$$

Putting back c and μ_0, we have:

$$\frac{1}{\mu_0}\partial_\beta F^{\alpha\beta} = 0 \tag{7.9}$$

where

$$F^{\alpha\beta} = \begin{pmatrix} 0 & -E_x/c & -E_y/c & -E_z/c \\ E_x/c & 0 & -B_z & B_y \\ E_y/c & B_z & 0 & -B_x \\ E_z/c & -B_y & B_x & 0 \end{pmatrix} \tag{7.10}$$

Due to a recent result by Loinger and Marsico [25], it turns out that the above equation (7.6) or (7.7) for describing the gravitational field of electromagnetic field also implies Maxwell equations (7.1) or (7.2) which describe self-gravity (self-interactions) of **E** and *i***B**.

Therefore, in the case of electromagnetic field (photons), the unification of quantum self-gravity, quantum gravity and general relativity is successfully and consistently realized under the new understandings of gravity and self-gravity. In this case, the Ricci scalar R and metric tensor $g_{\mu\nu}$ are originated from and determined by the collective internal and external wave functions **E** and *i***B** of the electromagnetic fields.

General Relativity of Fermion, Massive Boson, Dark Matter and Dark Energy

Transitions from quantum gravity and self-gravity of fermions and massive bosons to general relativity, quantifications of dark matter and dark energy, and possible connections to other scholarly work are currently under investigations and formulations. New results will be reported in due course.

8. Some Related Work by Other Authors

Besides other authors' work already referenced in this article, we briefly list here some more related works by other authors. However, the list is undoubtedly incomplete.

Pope and Osborne [26] argued for the instantaneousness of gravity. Gibbs [27] explored quantum gravity based on the principle of event-symmetric space-time. Arcos and Pereira [28] attempted to connect Kerr-Newman solution to Dirac particle. Pitkanen [29] explored a TGD-based theory of gravitation. Fiscaletti and Amrit [30] explored gravitation in a timeless quantum space. Kyriakos [31] explored a Lorentz-invariant theory of gravitation based on the nonlinear theory of elementary particles. Kaufman [32] explored gravitation based on relational-matrix model. Crowell [33] explored gravitation based on unitarity, locality and spacetime geometry. Campbell [34] explored gravitation based on cosmic order.

In a series of articles stretching more than a decade, Loinger [35] argued against the existence of gravitational wave and the common explanation of binary pulsar PSR1913+16 (Hulse–Taylor binary pulsar)'s decaying orbit. Dalton [36] showed that Einstein's gravitational field has zero energy, momentum, and stress. Recently, Pusey *et al* [37] have argued that quantum state is physically real and Hehl [38] argued that nonlocal gravity simulates dark matter both of which support the herein authors' earlier propositions [3-6]. Kowall [39] explored quantum gravity based on the holographic principle.

9. Conclusions

In this article, the natures of quantum gravity and graviton have been reviewed and explored from the non-mainstream perspectives. It turns out that quantum gravity is likely manifestation of quantum entanglement and mediated by wave-functions of elementary particles as nonlocal objects. Thus, each elementary particle has its corresponding gravitons comprised of its external and internal wave-functions as nonlocal objects. This new understanding allows one to reconcile quantum mechanics with general relativity and explain dark matter and dark energy as nonlocal effects on the cosmic scales.

To make the transition from quantum gravity to general relativity, it is theorized that: (1) Ricci scalar R and metric tensor $g_{\mu\nu}$ are originated from and determined by the collective internal and external wave functions of the matter present; (2) in the absence of nonlocal effect of remote matter through quantum entanglement, R and $g_{\mu\nu}$ are only correlated to momentum-energy tensor of the local matter; (3) in the presence of nonlocal effect of remote matter through quantum entanglement, R and $g_{\mu\nu}$ are also influenced by the nonlocal effect of the remote matter currently interpreted or seen as dark matter and/or dark energy.

Some of the important consequences of the above theory are the following: (1) gravitational fields (gravitons as nonlocal objects comprised of internal and external wave functions) may not carry localized or directly detectable momentum and energy; and (2) there may be no gravitational wave since gravity is nonlocal and instantaneous.

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