A new approach to the quantum nature of spacetime

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General relativity and quantum theory are believed to be incompatible, but are they? Here it is revealed that there is a logical way for these theories to be extended to a unified theory. In a fresh approach, the graviton is defined as the quantum field particle that produces the dimensions of time and space, whereby gravitational effects are one consequence of this role. The concept is explained and evidence is revealed which supports the new direction. The approach leads to the derivation of the Einstein equation of general relativity and the unification equation, which predicts that the frequency of gravitons in the void is f_{X0}=1.48 × 10^{42} s^{-1}. Thus the graviton is a high-energy particle, quite the opposite to expectations of current particle theory, but in keeping with its role of producing: the dimensions of time and space, vacuum energy, expansion of the Universe, and gravitational effects. The predicted frequency is accurately supported by empirical data from cosmological measurements. Observations that have been attributed to dark matter and vacuum energy, are now explained by scattering of gravitons and diffraction patterns of gravitons. Diffraction minima have reduced energy density, thus producing microscopic regions of curvature of spacetime in galactic haloes. Based of these diffraction patterns, equations are derived which accurately predict the rapid speed of orbiting bodies and explain the flatness of rotation curves. The evidence supports the extension of quantum theory and general relativity to a general quantum theory.

Keywords: Graviton; curvature of spacetime; dark matter; scattering of gravitons; diffraction patterns of gravitons; energy density; vacuum energy; rotation curves; general quantum theory.

1. Defining the graviton

1.1. *Background*

The standard model of particle physics hypothesizes that the graviton should be a massless, spin-2 boson which travels at the speed of light. The energy of the graviton has been predicted to be infinitesimal and detection of the graviton is considered to be unlikely.[1–3] Also Einstein, as early as 1916, questioned quantum gravity, see Ref. 4, so although the graviton was predicted almost a century ago, it is not a significant part of the current models of particle physics and cosmology. Here a new approach is taken to the role of the graviton with ground-breaking results.

1.2. *The Basis of the Approach*

Rather than defining the graviton in terms of gravitational interactions, the paradigms of general relativity and quantum theory are combined to define the graviton as the quantum field particle of spacetime. As a result, gravitational interactions are one consequence of this role, albeit an important one. This change is more than semantics because it leads to profound outcomes as recent work reveals.[5–7] The new approach adds to the standard models of cosmology and particle physics because these theories lack a mechanism for the existence of time and space. The role of the graviton is introduced as follows.[5]

Proposition 1.1. *The dimensions of time and space are produced by gravitons, the quantum field particles of spacetime, which travel at the speed of light and carry the energy of other quantum particles in the time dimension.*

Accordingly any location in the Universe experience time and space because of the gravitons that are passing through it. Also every location in the Universe is teeming with gravitons that were created at a very early stage in the history of the Universe, i.e., the event at which spacetime began. It follows that photons, and all massless-particles, actually radiate at the speed of gravitons, which is universally known as the speed of light. This speed is not influenced by the motion of a body because it is a property of gravitons. This feature corresponds to the second postulate of special relativity.[8] Further, the new approach has been used to explain Young's two-slit interference experiment.[5] In essence, sets of synchronized gravitons carry a particle's energy in the time dimension, and every one of the gravitons in a set has an equal chance of carrying the energy of the particle. Subsets of gravitons pass through the slits and when they arrive at the detector, the energy of the particle is detected at a location in space. The phase of the particle is determined by the path-length of the carrier-graviton's journey. Accordingly, uncertainty is a consequence of sets of gravitons sharing in carrying a particle's energy in the time dimension, from the event of emission to the event of detection.

From special relativity, bodies with mass have energy, but what is the source of the energy-content of bodies? To answer, the following is proposed:[6,7]

Proposition 1.2. *Elastic encounters between incident gravitons and mass cause the emitted gravitons to be red-shifted and scattered. The energy-content of the mass is transferred from the gravitons during these on-going encounters.*

Thus the energy-content of special relativity, see Ref. 9, is energy that is transferred from gravitons (i.e., during Compton-like scattering). These proposals lead to predictions, some of which are tested in the work that follows.

2. The unification equation

Let a mass M be at rest in the void of space, such that all incident gravitons have a frequency of f_{X0} and wavenumber of k_{X0}, and all emitted gravitons have a frequency of f_{XE} and wavenumber of k_{XE}. Based on the propositions, the energy-content of the mass E_M can be found from the change in frequency and change in wavenumber of gravitons.[6,7] The energy per unit length E_X/l that is transferred from gravitons to the mass, is given by:

$$\frac{E_X}{l} = hf_{X0}k_{X0} - hf_{XE}k_{XE}. \tag{1}$$

Let the body have an energy-content E_M and an average radius of r with a surface area of $4\pi r^2$. As r increases, the surface area of the body increases and the number of incident gravitons increases accordingly. The energy-content remains constant but the red-shift caused by the mass is spread between a larger number of gravitons. When the average radius of the body tends to infinity (i.e., $r \to \infty$), the redshift of individual gravitons becomes insignificant (i.e., $f_{XE} \to f_{X0}$ and $k_{XE} \to k_{X0}$). In other words a change in the average radius dr causes a change in the energy transferred by gravitons $d(E_X/l)$ as follows:

$$\frac{d(E_X/l)}{dr} = \frac{E_M}{4\pi r^2}. \tag{2}$$

The value of E_X is obtained by using (1) and treating (2) as a separable equation, then integrating both sides from $r = R$ to $r = \infty$ to give:

$$(hf_{X0}k_{X0} - hf_{XE}k_{XE}) = \frac{E_M}{4\pi r^2}. \tag{3}$$

This equation is simplified by using the relationship between wavenumber and frequency ($f_X = ck_X$) to give:

$$\frac{f_{XE}}{f_{X0}} = (1 - \frac{E_M}{4\pi h f_{X0} k_{X0} R})^{\frac{1}{2}}. \tag{4}$$

Here in (4) is the equation which describes the red-shift in the frequency of gravitons caused by mass. Compared to the gravitational red-shift of photons of general relativity, we see that they are of equivalent form. Insert into (4) the relation of special relativity for energy-content of a mass, $E_M = Mc^2$, and equate the factors in brackets. As a result the following holds true:

$$\frac{Mc^2}{4\pi h f_{X0} k_{X0} R} = \frac{2GM}{c^2 R}. \tag{5}$$

This equation is simplified and Newtons gravitational constant G is made the subject:

$$G = \frac{c^4}{8\pi h f_{X0} k_{X0}}. \tag{6}$$

The unification equation (6) reveals the relationship between the fundamental constants that binds quantum theory and general relativity. By applying the values for the constants, the properties of the graviton in the void of space (i.e., in flat spacetime) are as follows: frequency of gravitons is $f_{X0} = 1.48 \times 10^{42}$ s^{-1}; wavenumber of gravitons is $k_{X0} = 4.92 \times 10^{33}$ m^{-1}; force of gravitons is $hf_{X0}k_{X0} = 4.85 \times 10^{42}$ J m^{-1}; and energy density of the void $hf_{X0}{k_{X0}}^3 = 1.17 \times 10^{110}$ J m^{-3}. The magnitudes of these values are comparable to those of the Planck scale, and this aspect is explored next.

3. The vacuum catastrophe

The so-called vacuum catastrophe arises because of the difference in magnitude between the energy density of the vacuum according to general relativity (approximately 10^{-26} kg m^{-3}), and the predicted value of the zero-point energy of quantum field theory (i.e., Planck density of 10^{96} kg m^{-3}). Based on our definition of the graviton, the energy density of the void is 1.17×10^{110} J m^{-3}, see above. According to general relativity, a Universe teeming with high-energy gravitons should collapse upon itself. But this claim needs to be reassessed because we have recognized that gravitons, acting as spacetime-particles, do not change their frequency or wavenumber in the void, given that the void is free of mass. So the presence of high-energy gravitons, in itself, does not produce curvature of spacetime. Indeed, curvature of spacetime occurs when gravitons are red-shifted by matter or Doppler shifted by motion. Incident gravitons cause gravitational effects through differences in intensity of gravitons (i.e., equivalent to effects of mass-energy-momentum $T_{\alpha\beta}$ on the Einstein curvature tensor $G_{\alpha\beta}$). It follows therefore that the vacuum catastrophe is based on a misunderstanding of the energy density and its origin. In general relativity, energy density refers to a net effect, i.e., the difference in the spacetime-interval of the stress-energy tensor. In contrast, the energy density of gravitons in the void refers to the absolute value of the energy density, not a difference.

The usefulness of the unification equation (6) is highlighted by the derivation of the Einstein equation of general relativity. Einstein's spacetime constant κ, see Ref. 10, is shown to be based on the quantum properties of gravitons (i.e., $hf_{X0}\,k_{X0}$) as shown here:

$$G_{\alpha\beta} = \frac{1}{hf_{X0}\,k_{X0}}\,T_{\alpha\beta}. \tag{7}$$

This new form of the Einstein equation reveals that the curvature of spacetime depends to changes in the frequency and wavenumber of gravitons. Also an important factor, which is not present in general relativity but which is predicted by our approach to the graviton, is the scattering of gravitons. This phenomenon has profound effects on the large-scale structure of the Universe and the next section summaries some recent findings.[7]

4. The scattering of gravitons and cosmology

4.1. *The scattering angle of gravitons*

The concept of scattering of gravitons can be understood in terms of Compton scattering, and the scattering angle ϕ of gravitons can be determined from (4) and (6).[7] Assuming a stellar body, like the Sun, is composed of hydrogen, the scattering of gravitons by atoms gives $\phi = 8.5 \times 10^{-32}$ radian while scattering by hydrogen nuclei gives $\phi = 1.8 \times 10^{-29}$ radian. The scattering angle is slightly greater for other elements. For example, suppose that a stellar body is made of iron, then the scattering angle increases to $\phi = 3.3 \times 10^{-30}$ radian for iron atoms and $\phi = 7.5 \times$

10^{-28} radian for iron nuclei. It is noted that the scattering angle is much greater for white dwarfs and neutron stars.[7]

It follows that scattering of gravitons produces diffraction patterns, but there are no effects on an orbiting body until it is far enough from a star for the interference minima to encompass entire atoms (or nuclei). Accordingly, an atom encompassed by a diffraction minimum experiences a decreased number of red-shifted gravitons coming from the direction of the stellar body, causing atoms to free-fall at a greater rate than if not for diffraction. Rotation curves reveal that at distances of 0.1 – 1 kpc (i.e., 3×10^{18} m to 3×10^{19} m), the orbital speed of bodies starts to deviate from the speed expected by general relativity. We call this point the critical distance and use this empirical data to determine that $\phi = 3 \times 10^{-29}$ – 3×10^{-30} radian. This range overlaps the range predicted above for scattering of gravitons by hydrogen atoms, 8.5×10^{-32} radian, and hydrogen nuclei, 1.8×10^{-29} radian. Also, diffraction patterns of gravitons should extend far beyond the stellar bodies of galaxies (i.e., beyond the galactic disk) and this prediction is consistent with the shape of galactic rotation curves and macro-lensing of galactic haloes.[7]

4.2. *The speed of bodies in the galactic halo*

Analysis of the effects of diffraction minima reveals that at galactic distances larger than the critical distance of 0.1 kpc, the energy density is half of that due to gravitational red-shift at the surface of a ponderous mass.[7] Also at distances larger than the critical distance, the speed of an atom in a diffraction minimum is $\sqrt{1/2}$ times the speed of a surface orbit. That is, at distances greater than 0.1 kpc the analysis predicts that atoms orbit Sun-like stars at 3.1×10^5 m s^{-1}, and that the speed is independent of distance. An analysis of 62 galactic rotation curves reveals that orbital speeds range from 0.1×10^5 m s^{-1} to 5.0×10^5 m s^{-1}, indicating that there is overlap in the ranges of predicted and observed orbital speeds.[7] From the cosmological evidence it is concluded that diffraction patterns of gravitons produce the observations that have been attributed to dark matter.

4.3. *Hubble expansion*

Typically scattering causes a spreading out of quantum particles, as typified by the expansion of a beam of photons by a diffraction grating. But the scattering of gravitons by stellar bodies has a significant point of difference to scattering of photons. According to our approach, gravitons propagate the dimensions of time and space, so when gravitons are scattered or spread apart there is an expansion of spacetime, which we claim is the mechanism producing the Hubble expansion of the Universe. For an observer in an expanding Universe, the cosmological red-shift of starlight is a predictable consequence of the increased path-length caused by scattering of gravitons. It also follows that an observer today, or at any point of time in the ageing Universe, finds that f_{X0} and k_{X0} are constants because of the

Doppler shift of expansion.[7] Thus the energy density of the void, which is given by $hf_{X0}k_{X0}{}^3$, is constant, even though the average mass density of the expanding Universe decreases with time. The rate of expansion depends on the scattering angle of gravitons, which depends on the density of the stellar bodies (i.e., M/R). Hence, the observed increase in the Hubble rate of expansion is consistent with the Universe's trend toward an increase in the density of stars and stellar bodies.

5. Conclusion

Starting from a proposition that the graviton is the field particle of spacetime, we find that the quantum nature of the graviton includes gravitational red-shift, Doppler shift, scattering, and diffraction patterns. These properties can be used to derive the Einstein equation and to account for cosmological observations that have been attributed to dark matter and vacuum energy. The approach leads to the unification equation that links relativity and quantum theory, as well as providing values for f_{X0} and k_{X0}, which are found to be fundamental constants.

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