A theory of gravity based on quantum clocks and moving space

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Abstract. A theory of gravity based on quantum clocks and moving space is proposed. The theory is based on the hypothesis of the quantum clock equivalence principle (QCEP): it is impossible for a locally isolated observer to distinguish between a red-shift in a moving inertial frame of reference and a red-shift in a reference frame that is at rest in a field of gravity, if the red-shift is all the information he has. This allows us to formulate a time-dilatation measurement based definition of the speed of space in a gravity field. The QCEP is then used to predict the frequency shift of a quantum clock at rest in a g-field, moving in a closed circular orbit and in free fall. The cosmological and quantum gravitational possibilities of the QCEP hypothesis are shortly mentioned.

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1. Mie's foundations for a theory of matter and Louis de Broglie's Harmony of the Phases.

In a paper published in this Journal in 2004 I compared the theory of gravity of Gustav Mie with Louis de Broglie's thesis concerning the Harmony of the Phases [1]. In 1912-1913 Gustav Mie published his "Grundlagen einer Theorie der Materie" in a series of three papers in "Annalen der Physik"[2],[3],[4]. In part III, Mie defined gravitational mass as

$$m_g = \frac{1}{\gamma} m_0. \tag{1}$$

and inertial mass as

$$m_i = \gamma m_0, \tag{2}$$

with

$$\frac{1}{\gamma} = \sqrt{1 - \frac{v^2}{c^2}}. \tag{3}$$

Ten years later, de Broglie's hypothesis of the existence of matter waves connected to particles with inertial mass started modern quantum mechanics. De Broglie began with the assumption that every quantum of energy E should be connected to a frequency ν according to $E = h\nu$ with h as Planck's constant [5],[6]. Because he assumed every quantum of energy to have an inertial mass m_o and an inertial energy $E_0 = m_0 c^2$ in its rest-system, he postulated

$$h\nu_0 = m_0 c^2. \tag{4}$$

De Broglie didn't restrict himself to one particular particle but considered a material moving object in general [5]. This object could be a photon, an electron, an atom or any other quantum of inertial energy. Thus de Broglie attributed two frequencies to every particle, their inertial-energy frequency ν_i and their inner-clock frequency ν_c. These frequencies were identical in a rest-system but fundamentally diverged in a moving frame according to

$$\nu_i = \gamma \nu_0 \tag{5}$$

$$\nu_c = \frac{1}{\gamma} \nu_0. \tag{6}$$

This constituted an apparent contradiction for de Broglie, but he could solve it by a theorem which he called "Harmony of the Phases". He assumed the inertial energy of the moving particle to behave as a wave-like phenomenon and postulated the phase of this wave-like phenomenon to be at all times equal to the phase of the inner clock-like phenomenon. Both inner-clock- and wave-phenomenon were associated to one and the same particle, for example an electron, a photon or an atom.

In 2004 I tried to connect Mie's theory to de Broglie's thesis. I proposed

$$h\nu_{gravity} = E_{gravity} = \frac{1}{\gamma} E_0 = \frac{1}{\gamma} h\nu_0 = h\nu_c \tag{7}$$

and

$$h\nu_{inertial} = E_{inertial=\gamma E_0} = h\nu_{wave}. \tag{8}$$

The mayor problem with this interpretation was the fact that Mie's definition of gravitational energy equals the negative of the standard Lagrangian energy of a moving free particle in empty space:

$$L = -\frac{1}{\gamma}E_0. \tag{9}$$

This Lagrangian doesn't normally lead to a theory of gravity, but to the approximation

$$L = -\frac{1}{\gamma}E_0 \approx E_k - E_0 \tag{10}$$

with E_k as the kinetic energy. If we wanted to have a theory of gravity that in its classical approximation leads to Newtonian gravity we should get

$$L = h\nu_g \approx E_k - E_p - E_0. \tag{11}$$

So the question of how to connect Louis de Broglie's clock-time of his quantum-clocks to a theory of gravity wasn't solved.

2. The Principle of Equivalence of velocity red-shift and gravitational red-shift of quantum-clocks

We consider a quantum-clock to be any object that contains an accurate time-device based on quantum mechanical processes. Present day atomic clocks used in the GPS network are examples of such clocks. Stationary quantum clocks (QC) in free space have a rest system frequency ν_0. When such a clock is set in motion it obtains a new clock-frequency ν_c for which the relativistic (STR) value is given by

$$\nu_c = \frac{1}{\gamma}\nu_0. \tag{12}$$

This phenomenon is called the velocity red-shift: moving clocks have a lower frequency compared to the same clock at rest. If the very same clock is placed at rest in a gravitational field ϕ it obtains a gravitational red-shift and a new frequency ν_ϕ which is lower than its free space frequency ν_0. This gravitational red-shift is a well a observed and measured fact of nature. In Einstein's GR it is explained as an effect of the curvature of space-time. But the existence of the gravitational red-shift was predicted by Einstein in 1907, well before the invention of GR and also before the discovery of Quantum Mechanics. We have the curious fact that prior to the advent of both GR and QM, the influence of gravity on quantum clocks, a quantum gravity phenomenon, was already pre-visioned. But a century later, a theory of Quantum Gravity is still wanted.

If we assume, only as part of a thought experiment, that Einstein's Theory of General Relativity (GR), with as its key ingredient the curvature of space-time, is ultimately the 'wrong' theory, then we couldn't use curvature to explain the gravitational red-shift of quantum clocks and we would still lack an explanation for this phenomenon.

In such a hypothetical world we would search for an explanation for the gravitational red-shift with as little assumptions as possible. In such a parallel universe curvature would not be imagined but the equivalence principle would be highly valued, especially as it was used by Einstein to correctly predict phenomena like the gravitational red-shift and the gravitational bending of light or photons. Einstein's elevator thought experiments would be valued and pushed to the limit of their usefulness.

Until that moment the principle of relative motion was applied only to material objects, never to space itself. The principle stated that it was impossible to determine wether an isolated object in space, an inertial system, was in constant motion or in rest. Ultimately this principle would be applied to space itself: for an isolated inertial observer it was impossible to determine wether space itself was at rest with him moving through space, or he was at rest with space moving through him. The principle of relative motion would dictate that an elevator moving through space would be indistinguishable from a situation where space moved through the elevator. In both cases there was a relative motion between space and elevator, resulting in a red-shift of quantum-clocks according to the laws of Special Relativity. In that parallel universe, quantum clocks became the only tool to determine the relative velocity between space and the observer. An isolated observer with a single quantum-clock would of course not be able to determine wether his clock was in rest-system frequency mode or if it was red-shifted. But an observer with an extended lattice of quantum-clocks available could obtain a lot more data concerning his situation vis a vis space.

It is in this context that we propose the quantum clock equivalence principle (QCEP): it is impossible for a locally isolated observer to distinguish between a red-shift in a moving inertial frame of reference and a red-shift in a reference frame that is at rest in a field of gravity, if the red-shift is all the information he has. So in both cases we can define $\nu_{shifted} = (1/\gamma)\nu_0$. Once this observer is allowed to gather more information he will soon be able to choose between the two. If for example his box is moving in free space and a rest-system clock is available as a gauge-value, he will decide that his box is moving with velocity v and he will assume

$$\nu_c = \frac{1}{\gamma}\nu_0. \tag{13}$$

If on the other hand he finds out that his box is resting on the surface of a planet and a rest-system clock in an extremely far orbit is available as a gauge-value, he will decide that space is moving through his box with velocity v_ϕ and he will assume

$$\nu_\phi = \frac{1}{\gamma_\phi}\nu_0. \tag{14}$$

The measurements of ν_ϕ and ν_0 will define v_ϕ through this formula. In such a way, the gravitational velocity of space, being based on standard measurements, is a well defined physical quantity.

In this context the Mie-de Broglie connection between gravitational energy and clock-frequency becomes a rational one. For a quantum particle at rest in a gravitational

velocity field we get

$$E_{gravity} = h\nu_{gravity} = h\nu_\phi = \frac{1}{\gamma_\phi}E_0 = \frac{1}{\gamma_\phi}h\nu_0. \tag{15}$$

And the gravitational frequency dilatation factor is

$$\frac{\nu_\phi}{\nu_0} = \frac{1}{\gamma_\phi} = \sqrt{1 - \frac{v_\phi^2}{c^2}}. \tag{16}$$

In our theory of gravity, we do not have a gravitational potential energy any more. Fields of gravity have become space velocity fields. In these space velocity fields we have a hidden kinetic energy. So what used to be the potential energy E_p becomes the hidden kinetic energy $E_{k\phi}$. If the potential energy is taken zero in infinity, the sign must be reversed because the kinetic energy should always be positive. This gives

$$E_p = -\frac{GMm_0}{R^2} = -\frac{1}{2}m_0v_\phi^2 = -E_{k\phi} \tag{17}$$

and

$$-2\frac{GM}{Rc^2} = \frac{v_\phi^2}{c^2} = 2\alpha. \tag{18}$$

The gravitational frequency dilatation factor for a quantum particle at rest in a gravitational velocity field can accordingly be written as

$$\frac{\nu_\phi}{\nu_0} = \sqrt{1 - 2\alpha}. \tag{19}$$

3. A quantum clock object in a closed circular planetary orbit

A quantum clock object in a closed circular orbit with orbital velocity v has $F_g = F_c$, so

$$\frac{mv^2}{R} = -\frac{GMm}{R^2} \tag{20}$$

and

$$\alpha = \frac{v^2}{c^2} = -\frac{GM}{Rc^2}. \tag{21}$$

Because we replace the gravitational potential energy by the hidden kinetic energy, we still have

$$\frac{v_\phi^2}{c^2} = 2\alpha = 2\frac{v^2}{c^2}. \tag{22}$$

So the space velocity field is central and must have a velocity (actually a speed) v_ϕ equal to twice the orbital velocity $2v$ in order to have a closed circular orbit. Because these two velocities are perpendicular he total velocity v_{total} of the quantum clock object relative to space is given by the Pythagorean sum

$$v_{total}^2 = v^2 + v_\phi^2. \tag{23}$$

In combination this leads to

$$v_{total}^2 = v^2 + v_\phi^2 = 3v^2 = 3\alpha c^2. \tag{24}$$

The resulting frequency dilatation factor for a quantum clock object in a closed circular orbit as it is caused by the total relative motion between the the object and space is

$$\frac{\nu_{total}}{\nu_0} = \frac{1}{\gamma_{total}} = \sqrt{1 - 3\frac{v_{total}^2}{c^2}} = \sqrt{1 - 3\alpha}. \tag{25}$$

This result was already obtained by Reginald Cahill by using a moving space theory of gravity in his *Quantum-Foam In-Flow Theory of Gravity* [7]. But the theory presented in this paper differs in a fundamental ways from Cahill's. Cahill uses an absolute background space, and thus a pre-*Special Theory of Relativity* context, to refer this moving space to [8]. The theory presented in this paper assumes the correctness of STR and uses an *Eich*-theory to determine the rest-system clock frequency ν_0. So in our theory of moving space and moving clocks, the rest-system clock frequency ν_0 is a chosen one and from then on used to refer or gauge all other clocks to. Because our theory of gravity is a local theory, the force of gravity is determined by the local divergences in ν_{clock}, so by $\overrightarrow{\nabla}\nu_{clock}$. In this way our force of gravity is gauge-independent, meaning that a different choice of rest-system value ν_0 will not influence the resulting gravitational force. So we don't need an Absolute Space. Another difference is the quantum foam concept used by Cahill. It implies that gravity is a quantum effect and thus assumes a certain hierarchy. This papers theory, based on the QCEP, is independent of the cause of the movement of space and is independent of assumptions of the being this or that of space. We nevertheless highly respect the daring contribution of Cahill to the progress of physics, his moving space theory was first.

If we go back to our own analysis, we can now relate the result to the Mie-de Broglie synthesis of the beginning of this paper. Because in a closed circular orbit the orbital kinetic energy equals half the potential energy, the total classic kinetic energy of the orbiting object, hidden plus manifest E_k, equals the classic Lagrangian energy, because

$$E_{k,total} = \frac{1}{2}mv_{total}^2 = \frac{1}{2}mv^2 + \frac{1}{2}mv_\phi^2 = 3E_k = E_k - E_p. \tag{26}$$

The connected relativistic value of the total kinetic energy then has to be

$$E_{k,total} = \frac{1}{\gamma_{total}}E_0 \approx E_{k,total} - E_0 = E_k + E_{k\phi} - E_0 = E_k - E_p - E_0. \tag{27}$$

This equals the relativistic Lagrangian and its Newtonian approximation for a moving particle in a potential field. This is exactly what we wanted to have in our Mie-de Broglie theory of quantum gravity, because it gives us

$$E_{k,total} = \frac{1}{\gamma_{total}}E_0 = \frac{1}{\gamma_{total}}h\nu_0 = h\nu_{clock} = L_{gravity}. \tag{28}$$

4. A quantum clock object in a vertical free fall

Lets study the frequency-shift of a quantum clock object in free fall from the higher starting position A, with velocity $v_A = 0$ and potential ϕ_A, to a lower passing by position B, with velocity v_B and potential ϕ_B. In A, our quantum clock has a frequency shift relative to its free space rest-system frequency determined by α_A. A clock in B,

being lower in the gravity field, will have a larger frequency shift. In terms of the space velocity field this means that space is moving faster in B, when compared to A. In free fall, the total energy of the falling quantum clock object must remain constant. This total energy can be expressed as the total kinetic energy relative to space

$$E_{k,total} = \frac{1}{2} m v_{relative}^2. \tag{29}$$

This total energy can only remain constant if $v_{relative}$ is constant during the free fall. In B, space is falling by with velocity $v_{\phi,B}$ and the object is falling by with free fall velocity v_{ff} in the same direction, so the relative velocity of the falling quantum clock object to space should be

$$v_{relative} = v_{\phi,B} - v_{ff} = v_{\phi,A} = constant. \tag{30}$$

The frequency shift of the free falling quantum clock object is given by its velocity relative to space, which is constant, so

$$\frac{\nu_{ff}}{\nu_0} = \frac{\nu_{relative}}{\nu_0} = \sqrt{1 - \frac{v_{relative}^2}{c^2}} = \sqrt{1 - 2\alpha_A}. \tag{31}$$

So a quantum clock in free fall should have a constant frequency and a constant frequency shift. Because the clock in B is red-shifted compared to the clock in the starting position A, an observer who compares the frequency of the free falling clock with clock B at the moment it passes by will observe a blue shift relative to B. This blue shift is caused by the fact that space is falling by faster in B as compared to the falling by of space in A.

We used the terms blue-shift and red-shift as analogies for clock anti-dilatation and clock-dilatation, but it shouldn't be just an analogy. If we send a photon with a specific frequency from A to B, the internal clock of the photon should give the same results as atomic clock objects in free fall. The velocity of light c relative to space must remain constant, otherwise we would not be able to apply the laws of Special Relativity in our QCEP. This implies that light in B has an apparent tachyon velocity $c + v_{ff}$ and thus still its original constant light velocity c relative to space itself.

Another conclusion that can be drawn is that a quantum clock object in free fall is normally not equivalent to that same quantum clock object at rest in infinity. The quantum clock object in free fall from starting position A is equivalent to that same quantum clock object moving with velocity $v_{\phi,A}$ in infinity. So the usual free fall is equivalent to an inertial motion, but not equivalent to a position at rest. Only a quantum clock object in a free fall with starting position at rest in infinity will be equivalent to that same object at rest in infinity.

In the logic of our QCEP, free falling objects are not being accelerated, the space around them in which they are moving with constant velocity is being accelerated during free fall.

5. Cosmological implications

It is modern cosmology that inspired me to think of space as dynamic. The Bing Bang theory has a dynamic expanding space. Recent observations lead astronomers to the conclusion that space expansion is even accelerating. An accelerating expansion of space is already assured when space itself is the active agent, when every portion of space creates its new portion of space, which can create in turn new portions of space.... If that would be the only active agent on space in the Universe, then space in between the sun and the earth should have been almost tripled during the billions of years that the earth is orbiting the sun. If that would have happened, life would not have been as it is, because the temperature on such an earth would not have been that constant. So, another active agent on space should exist. At the basis of the QCEP lies the hypothesis that mass is this second active agent and that it has the opposite effect on space, taking space away from space. If mass does this by contracting it into a black hole or by absorbing it and simply letting it disappear is not relevant to the QCEP. By either contracting or absorbing space, mass causes space dynamics. In such a dynamic cosmos, mass causes space to move, to accelerate and to pass by other masses.

6. Implications for Quantum Gravity

Quantum gravity is a theory that is missing in present day physics. We have the Standard Model and GR as the two fundamental theories. The Standard Model is based on Quantum Mechanics, especially the Dirac Equation, and on Special Relativity. GR uses space-time curvature as the determining factor, but how curvature influences the waves of elementary particles as they were postulated by de Broglie is an unsettled matter. So it is unclear how gravity through curvature influences QM-statistics and thus QM-measurements. In our QCEP theory of gravity-fields as space velocity fields, the gravitational potential can be translated into a space-velocity. Every quantum clock object moves relative to this space velocity field and it is relative to this space that Louis de Broglie's Harmony of the Phases should be applicable. So an electron at rest in a field of gravity is moving relative to space with velocity v_ϕ and thus has a momentum $p_\phi = mv_\phi$ and a wavelength defined by

$$p_\phi = \frac{h}{\lambda_\phi}. \tag{32}$$

Because we had for the quantum clock object at rest in a gravity field $v_\phi^2 = 2\alpha c^2$, we can write

$$p_\phi = \frac{h}{\lambda_\phi} = m_0 c\sqrt{2\alpha} \tag{33}$$

and

$$\lambda_\phi = \frac{h}{m_0 c}\frac{1}{\sqrt{2\alpha}} \tag{34}$$

as the gravitational contribution to the wavelength of a quantum particle. The gravitational space velocity on earth can be calculated as

$$v_\phi = c\sqrt{2\alpha} \approx 1.12 \cdot 10^3 \frac{m}{s} \tag{35}$$

resulting in a wavelength for an electron at rest in this g-field of approximately $650nm$ and a kinetic energy of $3.6\mu eV$. Such an electron kinetic energy probably disappears against the usual temperature background noise of electrons in ordinary matter. On the sun, this kinetic energy of an electron at rest at its surface would be approximately 1 electronvolt, still a factor 10 below its ionization energy. The main sequence stars all have an eV value in between 1 and 3. For a typical white dwarf, with 1.0 earth-radius and 0.6 sun-mass this becomes approximately $65eV$. This means that on the surface of a white dwarf, Hydrogen and Helium will be completely ionized and Carbon almost completely, in accordance with the standard knowledge of white dwarfs.

7. Electromagnetic implications for an H-atom at rest at the surface of a massive object

Due to the velocity of space at the surface of a planet or a star, charged particles will generate a magnetic field. We can use the Lorentz transformation to calculate the effect of this gravitationally induced magnetic field and the subsequent Lorentz Force in an Hydrogen atom. If we use the Bohr model of Hydrogen and concentrate on the situation where the orbit is perpendicular to v_ϕ, because it will produce the maximum Lorentz Force, we get the simplified equations, with proton magnetic field magnitude B_p and electric Coulomb field magnitude E_p:

$$B_p = \frac{1}{c^2} v_\phi E_p \tag{36}$$

and thus an extra Lorentz Force on the electron

$$F_L = J_\phi B = q v_\phi B = \frac{v_\phi^2}{c^2} v_\phi q E = 2\alpha F_{Coulomb}. \tag{37}$$

This extra Lorentz Force is repellent in the case of the Hydrogen atom and thus reduces the effect of the Coulomb Force. But on earth, $\alpha \approx 10^{-10}$ and on the sun $\alpha \approx 10^{-6}$, so the influence is minimal. Even for a white dwarf, this becomes only $\alpha \approx 10^{-4}$. The stability of the Hydrogen atom is thus not affected by the consequences of our theory of gravity, in conformity with reality.

8. Conclusion

Quantum Gravity research programs are to such a degree detached from experimental reality, because of QG's inherent complexity, that they compete with one another through the level of hope they can generate. The theory of QG based on the Quantum Clock Equivalence Principle as presented in this paper should be placed in that context. Can the QCEP-theory generate hope of bringing us a little bit closer in the direction of

a future theory of QG? Is it capable of generating hope that an experimental test might be a future possibility? If so, then the starting point was Louis de Broglie's observation regarding the two frequencies belonging to every quantum particle.

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