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► **To cite this version:**

Marco Fedi. Special and General Relativity according to Superfluid Quantum Space. 2015. hal-01248015v2

**HAL Id: hal-01248015**

**<https://hal.science/hal-01248015v2>**

Preprint submitted on 27 Jan 2016 (v2), last revised 5 May 2017 (v6)

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# Special and general relativity according to superfluid quantum space.

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January 27, 2016

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## Abstract

by starting from the mathematically demonstrated quantum fluid dynamic reformulation of Newton's law of universal gravitation [1], it is shown how the principle of equivalence can be likewise reformulated according to fluid dynamics. From this, special and general relativity are incorporated in fluid quantum gravity, which also explains GR's curved spacetime. Moreover, if superfluid quantum space (SQS) replaces quantum vacuum, light propagates through it. Indeed, many clues and equations indicate how photons could be superfluid phonons of space's quanta, without contradicting the Michelson-Morley experiment. In this way, the unification of gravity and Einstein's relativity with QFT would be completed, without resorting to gravitons or string theory. It seems only necessary to reformulate the equations of relativity according to the fluid equivalence principle, whose theoretical framework simplifies relativity, *e.g.* showing that there is only a primary relativistic effect, the increase of mass, while time dilation and length contraction are respectively second and third-order effects. A minor correction in the classical formula of weight would be likewise necessary. Indications are given for experimental verification.

## 1 Fluid principle of equivalence and relativistic mass increase.

This work starts from the mathematically proved mechanism of fluid quantum gravity [1], which entails that Newton's law of universal gravitation may be fluid dynamically reproduced by placing the hypothesis that fermions absorb space's quanta (SQ), as they would be superfluid vortices (topological defects) in SQS:

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the fact that a subsequent expulsion of SQ, compacted into virtual photons (*cf.* also §5), may or may not occur and that the vortices can merge or annihilate themselves (duality matter-antimatter) according to their torque, is shown to be able to complete the unification of the fundamental interactions. From this point of view, a gravitational field is a flow of SQ directed toward the center of a massive body and the principle of equivalence (both in its weak and strong form), which plays an essential role in Einstein's relativity, is confirmed also in its fluid dynamic reformulation (fig. 1), which becomes a quantum fluid dynamic explanation, when referred to SQS:

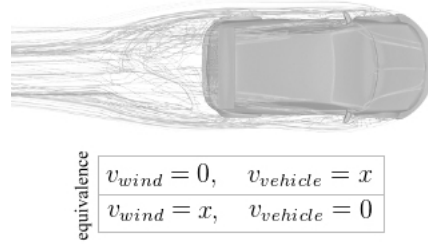


Figure 1: Fluid principle of equivalence: it is impossible to distinguish between the two equivalent situations of a body moving through a fluid and a fluid moving toward the body at the same velocity. The same would occur regarding SQS.

The fluid explanation of the weak equivalence principle (gravitational mass = inertial mass) and of Einstein's equivalence principle is easily demonstrated in fig. 1. since the total velocity of the fluid relative to the vehicle is  $\mathbf{v}(x) = \mathbf{v}_{wind} + \mathbf{v}_{vehicle}$  (in this case:  $v(x) = 0 + x = x + 0 = x$ , confirming the equivalence), which in fluid quantum gravity becomes:

$$\mathbf{v}_{\Phi} = \mathbf{v}_{sq} + \mathbf{v} \quad (1)$$

where  $\mathbf{v}_{\Phi}$  is the velocity of the flow relative to the moving body, resulting from the vector sum of the velocity at which the SQ are absorbed ( $\mathbf{v}_{sq}$ ) and the body's translational velocity ( $\mathbf{v}$ ). For instance, an acceleration of  $9.81\text{m/s}^2$  where all gravitational fields tend to zero, is therefore equivalent to being stationary in the Earth's gravitational field, also from a quantum point of view, since in both cases, it would be a matter of gravitational interaction. It is possible to mathematically demonstrate that gravity is the common cause of time dilation in special and general relativity, by showing how it corresponds, in both cases, to the flow velocity of the SQ:

$$t' = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - \frac{R_S}{r}}} \quad (2)$$

hence

$$\frac{v^2}{c^2} = \frac{R_S}{r} = \frac{2GM}{c^2 r} = v^2 \frac{1}{c^2} = \frac{2GM}{r} \frac{1}{c^2} \implies v^2 = \frac{2GM}{r} \quad (3)$$

and

$$v = \sqrt{2rg} = \sqrt{2V}. \quad (4)$$

where  $V$  is the gravitational potential and  $v$  corresponds to the SQ's drift velocity in the gravitational field (and, consequently, also to the escape velocity) while, without a sufficiently considerable gravitational field (when  $g \rightarrow 0$ ) it refers to the translational velocity of a body, according to the fluid equivalence principle (FEP)(1). For instance, since SQ's drift velocity in Earth's gravitational field is  $\sim 11180$  m/s (4), a body traveling at the same velocity where the field is irrelevant will undergo the same time dilation *and mass increase* (as discussed below) caused by Earth's gravitational field. It is thus demonstrated that the quantum FEP applies to special and general relativity and attributes the cause of time dilation to gravity. Also in special relativity then. It is moreover interesting to notice that the speed of light cancels in the calculations, leading to an equation that simply relates velocity to gravity (4). From it, we have:

$$g = \frac{v^2}{2r}. \quad (5)$$

Then the intensity of a gravitational field quadratically depends on the velocity at which a mass absorbs SQ. But this refers to the intensity of the field as described in fig. 3 case A (fall in the field), while if a body interacts with the flow of SQ (fig. 3, case B, and FEP) it is subject to an additional force in the direction of the flow, due to SQS's minimal viscosity (as no superfluid has real zero viscosity), which can be quantified by Lorentz factor and is the cause of relativistic mass increase. The derivation of (4) has already demonstrated how Lorentz factor actually refers to the increase of gravity opposite to motion. An additional reverse derivation is however obtained if we consider  $c$  as the distance travelled by light in one second, and in (5) we set  $r = 4.5 \cdot 10^{16}$  m, as the notable distance  $d_N$ . We have  $c = \sqrt{2d_N} \Rightarrow 2d_N = c^2$  and the identities:

$$g_N = \frac{\|\mathbf{v}_\Phi\|^2}{2d_N} = \frac{\|\mathbf{v}_\Phi\|^2}{c^2} \Leftarrow \frac{v^2}{c^2} = \beta^2 \quad (6)$$

where  $g_N$  is the value of  $g$  calculated by using  $d_N$ ,  $v_\Phi$  is the relative velocity of the flow (1) and  $\beta$  refers to its use in Lorentz factor. It is interesting to notice that  $\beta^2$ , or  $g_N$  in its fluid reformulation, can be described as a dimensionless expansion parameter of compressible<sup>1</sup> SQS, identical to that described for other compressible superfluids by Malmi-Kakkada, Valls and Dasgupta [23](left):

$$\left(\frac{v}{v_s}\right)^2 \Longrightarrow \left(\frac{\|\mathbf{v}_\Phi\|}{c}\right)^2 = g_N \quad (7)$$

where the speed of sound ( $v_s$ ) in the superfluid can be equated by analogy to that of light, when considering photon as a phonon through SQS (§5). According to (6), Lorentz factor (9), conformed to the FEP, follows as:

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<sup>1</sup>primordial inflation and the expansion of the universe suggest that compressibility is a physical property of SQS.

$$\vec{\gamma}_{\Phi} \equiv -\hat{v}_{\Phi} \arcsin' \sqrt{g_N} = -\hat{v}_{\Phi} \frac{1}{\sqrt{1-g_N}} = -\hat{v}_{\Phi} \frac{1}{\sqrt{1-\frac{\|\mathbf{v}_{\Phi}\|^2}{2d_N}}} = -\hat{v}_{\Phi} \frac{1}{\sqrt{1-\frac{\|\mathbf{v}_{\Phi}\|^2}{c^2}}} \quad (8)$$

where

$$\|\vec{\gamma}_{\Phi}\| \Leftarrow \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \quad (9)$$

(*q.v.* also (41) for  $\vec{\gamma}_{\Phi}$  as function of  $v_{\Phi}$  and SQS's density) where  $\gamma$  is derived as a mere function of gravity and is expressed as a vector, since it corresponds to an increase of gravity *in the opposite direction to motion* ( $-\hat{v}_{\Phi}$ ), clarifying the cause of relativistic mass increase from the point of view of QFT. Unlike current Lorentz factor, this formula, because of the way it has been derived, incorporates the FEP, which makes it more accurate in specific situations: the velocity used in the equation ( $v_{\Phi}$ ) indeed arises from the vector sum of SQ's drift velocity and the body's velocity (1), *i.e.* it is the SQ's relative velocity. Namely, neither time dilation nor mass increase would occur if the body was travelling in the same direction of the SQ and at their exact velocity (*e.g.* orthogonally at 11180 m/s toward Earth's surface (4)), while Lorentz factor, on the contrary, simply considers a body's scalar translational velocity and would predict such effects in any case. The importance of SQ's relative velocity (1) is also discussed in fig. 3 (correction of weight formula), by comparing the case a. with cases b./c., and emerges in the twin paradox, which can be easily solved (19) by resorting to  $v_{\Phi}$  (relative SQ's velocity) instead of the simple translational velocity used in Lorentz factor.

The peculiar mathematical increase of  $\gamma$  as the derivative of the arcsine of  $\sqrt{g_N}$  can be understood along with the physical properties of SQS. In fact, this implies that SQS acts as a non-newtonian dilatant fluid, showing apparent viscosity as a reaction to shear stress brought to relativistic velocities. Indeed, no superfluid has exact zero viscosity. SQS's minimal viscosity would play an important role, when shear stress increases toward the speed of light. The reason why exactly  $c$  is the asymptote is discussed below (fig.5)(§5, phonoton).

There's however no physical limit (Lorentz factor doesn't apply in this case) to the velocity of bodies which are falling in a gravitational field, as they fall *with* the SQ (fig. 3, case A) and don't undergo SQS's  $\gamma$ -increasing apparent viscosity.

Indeed, from (5) we see that the intensity of a gravitational field (in fig. 2 mass and radius are linked as density, similarly to Gauss's law for gravity) increases with the density of the attracting body, without any asymptote, allowing the absorption of SQ to occur at  $v_{sq} \geq c$ . It is assumed that this is the case of a black hole (BH).

A body could then have a velocity of fall into a BH  $v \geq c$  but, according to the FEP, on the surface - if there was one - it would be suddenly in the same situation of a body travelling at, or over, the speed of light. A case

forbidden both by Einstein's relativity and by this quantum fluid reformulation of it (8)(fig.4)(fig.5)(§5). Actually, the surface itself would be subject to an incoming flow of SQ moving at, or over, the speed of light.

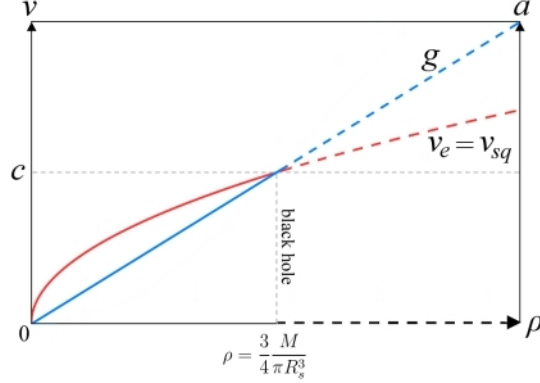


Figure 2: SQ-absorption velocity (= escape velocity) and intensity of a gravitational field according to density.

Either a BH has therefore no surface and is actually a singularity or the drift velocity of the SQ ( $v_{sq}$ ) in a BH's gravitational field is more truly  $\lesssim c$ . Light's speed and frequency would drop almost to zero and the celestial body would be, in any case, black. Fluid quantum gravity therefore agrees with Chapline [24] and Vachaspati, Stojkovic and Krauss [25], when it states that BHs' horizons can't form. This would mean that, at a certain point, no further matter can be added to a BH's mass (to avoid  $v_{sq} = \sqrt{2V} \geq c$ ), thus, once attracted until the surface, matter would be annihilated, perhaps decomposed into SQ, according to [1], which describes fermions as superfluid vortices of SQ. Matter decomposition into SQ would solve the BH information paradox and BHs would appear as a sort of recycling plants of the universe. In such circumstance, BHs' density couldn't be  $\geq 1.8517 \cdot 10^{19} \text{kg/m}^3$ , calculated through the formula:

$$\rho = \frac{3 M}{4 \pi R_s^3} \quad (10)$$

BHs wouldn't be gravitational singularities but massive spheroids (such as stars or planets), whose density provokes the absorption of SQ *almost* at the speed of light and matter conversion into SQ. Of course, as far as supermassive black holes are concerned, a greater mass doesn't necessarily correspond to a greater density and it is impossible to theoretically vary the mass and the radius of a celestial body to obtain  $v_{sq} \geq c$  (4) without falling in the case  $r \leq R_s$ . From (4), by putting  $v = c$ , we have:

$$c = \sqrt{\frac{2GM}{r}} \Rightarrow c^2 = \frac{2GM}{r} \Rightarrow r = \frac{2GM}{c^2} = R_s \quad (11)$$

hence (10) represent the universal asymptote of density in fluid quantum relativity.

As discussed so far, fluid quantum gravity requires an adjustment to the formula of weight.

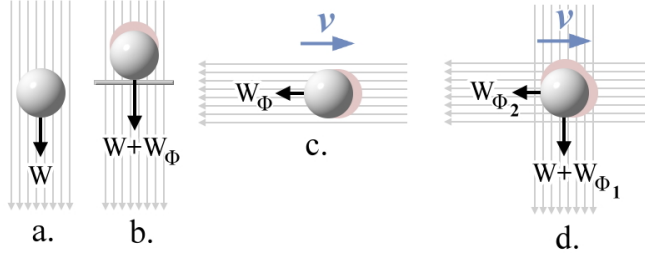


Figure 3: Weight in fluid quantum gravity: (a) normal weight (classical formula) for a body falling with SQ in a gravitational field; (b) if the body is in equilibrium in the field it undergoes SQ's apparent viscosity (pink halo) and, therefore, an additional force ( $\mathbf{W}_\Phi$ ) in the direction of the flow (of the order of  $10^{-10}$ kg per kilogram for a stationary body on Earth); (c) the same force acts on a body in motion outside of a gravitational field (FEP  $\Rightarrow$  apparent flow); (d) if a body is moving in a gravitational field all forces are combined.

Fig.3 shows the difference in the weight forces acting on a body, depending on whether it falls with the SQ in the field (a) or it remains in equilibrium (b) and on whether it moves outside of (c), or inside (d), a gravitational field. When a body undergoes SQ's apparent viscosity, which increases with velocity, an additional force ( $\mathbf{W}_\Phi$ ), depending on the fluid Lorentz factor (8), acts on it. Since near Earth's surface  $v_{sq} = v_e \approx 11180$  m/s, this effect isn't noticed, as it would produce a difference of only  $7 \cdot 10^{-10}$ kg per kilogram but it would become evident in synchrotrons for accelerated particles (as in fig. 3 case c, with  $\mathbf{W}_\Phi$  diverging as  $v \rightarrow c$ ).

This suggests to reconsider the formula of weight according to different situations:

	fall, $g>0$	eq., $g>0$	$v>0, g \rightarrow 0$	$v>0, g>0$	eq., $a>0, g \rightarrow 0$	$a>0, g>0$
$\mathbf{W}_{tot} = \mathbf{W} + \mathbf{W}_\Phi$	$mg$	$m(g + g_\Phi) \dagger$	$mg_\Phi$	$m(g + g_\Phi)$	$m(a + g_\Phi) \dagger$	$m(a + g_\Phi + g + g_\Phi)$
$\mathbf{F} \neq \mathbf{W}$						

where  $\mathbf{W}_{tot}$  is the vector sum of the gravitational forces acting on a body: normal weight,  $\mathbf{W}$ , and the relativistic drag weight<sup>2</sup>  $\mathbf{W}_\Phi = m\mathbf{g}_\Phi$ , concordant with the direction of the flow, where

$$\mathbf{g}_\Phi = \vec{\gamma}_\Phi - 1 \quad (12)$$

<sup>2</sup>in reference to the aerodynamic drag.

assessing the gamma-increase of gravity (8) in the direction of the flow and opposite to motion. The symbol † indicates equivalent situations if  $\mathbf{a} = \mathbf{g}$  (equivalence principle). The formula to express the total weight (also opposite to motion) in fluid quantum gravity is therefore:

$$\mathbf{W}_{\text{tot}} = m(\mathbf{g} + \mathbf{g}_{\Phi}) \quad (13)$$

in Earth's gravitational field, where  $\mathbf{g}_{\Phi} \approx 0$ , and at subrelativistic velocities, the classical formula applies. Fig. 4, shows the relativistic mass increase according to the reformulated Lorentz factor (8), which expresses the fluid properties of quantum space.

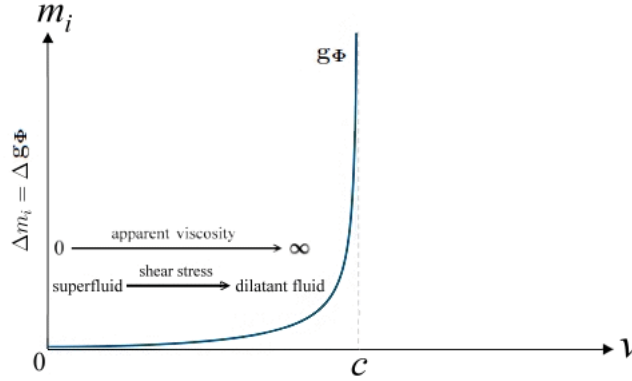


Figure 4: relativistic mass increase, where  $\Delta m_i$  corresponds to  $\Delta \mathbf{g}_{\Phi}$ . This graph can also be interpreted as a rheogram of quantum space. As shear rates and flow velocities move toward relativistic values, collisions among SQ intensify and viscosities, albeit initially near zero, critically increase.

This quantum fluid reformulation of relativity shows how mass increase can be considered the only fundamental relativistic effect, as discussed below (§2, 3).

Before concluding this section, it is important to point out the difference between SQ's drift velocity ( $\mathbf{v}_{sq}$ ) and the speed of action of gravity. The difference is analogous to that occurring between electrons' drift velocity along an electric wire (very slow, max  $\sim 6$  m/s in superconductors) and the speed of action of electricity (pulse). This theory assesses the velocity of action of gravity at  $c$ , for two reasons:

1. the absorption of SQ (drift velocity) can't occur at  $v_{sq} > c$  if a density limit for BHs applies, as discussed above.
2. the propagation speed of a pulse through SQS exactly corresponds to the speed of light when a photon is described as a phonon traveling through SQS (§5).



## 2 Relativistic time dilation.

Once it is clear, from a quantum point of view, why inertial mass *is* gravitational mass (1) and why it increases with gravity or velocity (4)(9)(13)(fig. 4), time dilation can be explained as a direct consequence of mass increase, in other words it would be a *secondary* relativistic effect. First of all, it has to be pointed out that time is never slowed down: only clocks are. And any clock works thanks to its mechanics, by means of energy and forces. For instance, when considering the case of a mechanical clock, a given amount of energy (from its battery, spiral mainspring *etc.*) produces a given force, which corresponds to a given movement, *e.g.* a tick of the second hand. When the same clock is situated in a stronger gravitational field, the gravitational mass of all its components increases and this means that a greater amount of energy would be necessary to produce greater forces and to keep the tempo. However, since the supplied energy remains the same and becomes insufficient, the clock slows down. This occurs also for caesium clocks since, once the atoms have been launched upwards by laser beams, they fall back down under gravity: they therefore mark time differently in different gravitational fields. The same happens for a pendulum:  $T_0 = 2\pi\sqrt{\frac{\ell}{g}}$ . Practically, every dynamic system (also biological), in which the gravitational mass increase of its components can slow its mechanical processes, can be considered a clock and is subject to time dilation. Moreover, also cosmic muons are influenced by gravity, thus, their relativistic velocity (provoking greater gravity, in agreement with the FEP) is able to lengthen their life, by slowing their quantum mechanical processes. In the formula

$$T_c = \frac{F_f + W}{F_c} = 1 \quad (14)$$

a clock is calibrated to have a period  $T_c = 1$ s, by counteracting internal friction ( $F_f$ ) and gravitational force ( $W$ ) by means of an equal force ( $F_c$ ). By cancelling energy mass, we express the accelerations acting on the clock:

$$T_c = \frac{\cancel{m}a_f}{\cancel{m}a_c} + \frac{\cancel{m}g}{\cancel{m}a_c} = \frac{a_f + g}{a_c} = 1 \quad (15)$$

However, when a clock moves through SQS, another gravitational acceleration, oriented in the opposite direction to motion and due to the FEP (1), starts to act according to (8)(fig.4). Therefore, in (15) we have to add drag acceleration  $g_\Phi$ , which remains unbalanced and slows down the clock (12):

$$T' = \frac{a_f + g}{a_c} + g_\Phi \geq 1 \quad (16)$$

(16) corresponds to (15) only if  $g_\Phi = 0$  (stationary clock), otherwise  $T'$  refers to the travelling clock's dilated period. Thus, time dilation reduces to the quantum relativistic increase of gravity  $g_\Phi$ . Below it's shown how the main hypothesis (14) actually corresponds to Lorentz factor. From (12) we know that:

$\gamma_\Phi = 1 + g_\Phi$ . Hence

$$T' = T_c + g_{\Phi} = 1 + g_{\Phi} = \gamma_{\Phi} \quad (17)$$

thus, we obtain below special relativity's formula for time dilation, now conformed to the FEP (use of  $v_{\Phi}$ ), which can be therefore used also for gravitational time dilation (*i.e.* in GR):

$$T' = \frac{1}{\sqrt{1 - \frac{v_{\Phi}^2}{c^2}}}. \quad (18)$$

The use of the further formula  $t' = \frac{1}{\sqrt{1 - \frac{R_S}{r}}}$  is then not necessary. Time dilation is thence a *secondary* relativistic effect, depending on the gravitational mass increase opposite to motion.

It is interesting to realize that, in fluid quantum relativity, the well-known twin paradox is solved by the fact that (18) uses the quantum relative velocity ( $\mathbf{v}_{\Phi}$ ) from (1) instead of the simple translational velocity of Lorentz factor. It then suffices to consider the two different velocities of the gravitational flows ( $v_{sq}$ ) which the twins are respectively subject to (that of Earth's gravitational field and that due to the rocket's motion through SQS) to see in which frame of reference time is more dilated. Although both twins are moving respect to one another, only the twin traveling in the high-speed rocket is indeed interacting with SQ because of his translational velocity, since  $v_{sq} = v_{rocket}$  (1), while the other is in apparent motion, only interacting with the SQ of Earth's gravitational field ( $v_{sq} = v_e \approx 11180$  m/s) and is therefore only subject to the time dilation caused by Earth's gravity. Thus, by applying (1) to calculate the difference  $v_{\Phi} = v_{rocket} - v_e$  of the gravitational flows which the twins are respectively subject to, the paradox is immediately solved, where (19) gives the variation in the period of the traveling twin's clock according to *both* points of view:

$$\Delta T_{rocket} = \frac{1}{\sqrt{1 - \frac{(v_{rocket} - v_e)^2}{c^2}}} \quad (19)$$

If the velocity of the rocket is therefore greater than the SQ's drift velocity in the gravitational field where the other twin is situated (let's say greater than the escape velocity in that field, since we know that  $v_{sq} = v_e$ ) then the travelling twin is subject to a greater time dilation, otherwise (*e.g.* in the case of a twin in a strong gravitational field and of a slow rocket) the clock in the rocket would tick faster. Thus, in fluid quantum gravity, time dilation is absolutely *not* reciprocal: it depends on the (direct or equivalent) gravitational flows acting onto clocks, and the paradox vanishes. The issue of acceleration is therefore not necessary and we also bypass Von Laue's and Halsbury's reasonings.

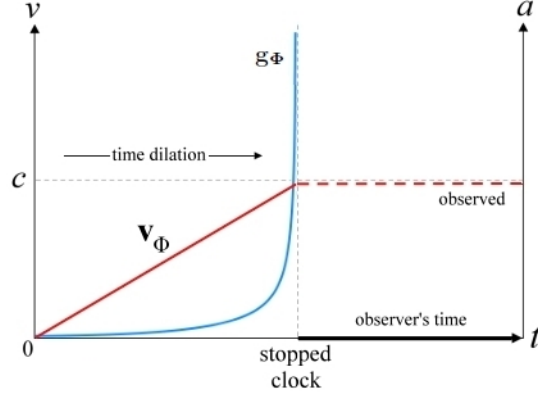


Figure 5: Gravitational mass increase opposite to motion (due to the increase of  $\mathbf{g}_\Phi$ ) for a moving body, conforming to the FEP and time dilation.

Fig. 5 shows how the asymptote at  $c$  can be explained through time dilation, which for its part depends on mass increase: when the mass of a clock's parts is critically high and the clock stops, further acceleration is impossible:

$$\mathbf{a} = \frac{d\mathbf{v}}{dt}, \text{ if } T \rightarrow \infty \Rightarrow dt \rightarrow \infty \Rightarrow \mathbf{a} \rightarrow 0.$$

Near the point of time freezing, clock's period ( $T$ ) diverges to infinity, as well as gravity opposite to motion ( $\mathbf{g}_\Phi$ ), acceleration stops and the translational velocity of the body undergoes an asymptote.

To conclude this section, also the relativistic phenomenon of gravitational redshift is explainable according to SQS within the effect of time dilation, since an observer's clock located in a weaker gravitational field ticks faster. This means that the observer will measure a longer period for light waves ( $\Rightarrow$ redshift). Therefore, the current formula

$$\omega_1 = \omega_0 \frac{\sqrt{1 - \frac{R_S}{r}}}{\sqrt{1 - \frac{R_S}{r'}}$$

where  $\omega_1$  is the observed frequency, is still valid in fluid quantum relativity but its quantum aspect emerges when it is expressed according to the FEP:

$$\omega_1 = \omega_0 \frac{\sqrt{1 - \left(\frac{v_\Phi}{c}\right)^2}}{\sqrt{1 - \left(\frac{v'_\Phi}{c}\right)^2}} \quad (20)$$

where  $v_\Phi$  is the SQ's drift velocity (calculated from (4)) where light is emitted and  $v'_\Phi$  that where the observer is situated.

### 3 Lorentz-FitzGerald contraction.

Relativistic length contraction is here treated as a *third-order* relativistic effect, in that it depends on time dilation which, for its part, depends on mass increase. It affects *measurements* taken in two different frames of reference in relative motion, when compared. Since depending on time dilation, this phenomenon can be reduced to what already discussed in §2 and is therefore explainable within the theoretical framework of fluid quantum gravity. Let's consider fig. 6:

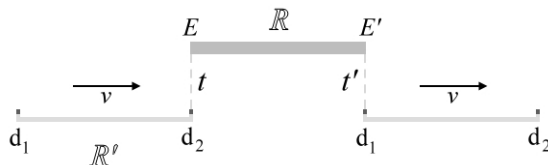


Figure 6: Relativistic length contraction. According to an inertial frame of reference ( $\mathbb{R}$ ), the length  $\overline{EE'}$ , detected in the frame  $\mathbb{R}'$ , is shorter when measured in that frame, since in a moving frame of reference Lorentz factor has to be considered:  $l_{\mathbb{R}'} = v \frac{\Delta t}{\sqrt{1 - \frac{v^2}{c^2}}}$ .

Be  $\mathbb{R}$  an inertial frame of reference and  $\mathbb{R}'$  a frame moving with velocity  $v$ . The length  $\overline{EE'}$  is measured in both frames by considering  $\Delta t$  as the difference  $t' - t$ , between the instants in which the detectors  $d_2$ ,  $d_1$  respectively align with  $E$ ,  $E'$ . The two measurements are determined by:

$$l_{\mathbb{R}} = v\Delta t \quad \text{and} \quad l_{\mathbb{R}'} = v \frac{\Delta t}{\sqrt{1 - \frac{v^2}{c^2}}}$$

and since  $\frac{\Delta t}{\sqrt{1 - \frac{v^2}{c^2}}} > \Delta t \implies l_{\mathbb{R}} > l_{\mathbb{R}'}$

Clocks tick slower in  $\mathbb{R}'$  then  $\Delta t$  is shorter in that frame, as well as the measured length  $\overline{EE'}$ .

From (8), we can now replace the standard form with the corresponding quantum formula:

$$\vec{l}_{\mathbb{R}'} = \mathbf{v}_{\Phi} \frac{\Delta t}{\sqrt{1 - \frac{\|\mathbf{v}_{\Phi}\|^2}{c^2}}} \quad (21)$$

which indicates the contraction of length in the direction of motion:  
 $\vec{l}_{\mathbb{R}'} = \hat{v}_{\Phi} l_{\mathbb{R}'}$ .

### 4 How superfluid quantum space can replace Einstein's curved spacetime.

It is discussed how the fluid dynamics of SQS (gravitational flows due to fermionic absorption of SQ [1], corresponding to the tidal forces of GR) is able to repro-

duce and justify GR's curved spacetime as a fluid space and to reproduce any relativistic effect Einstein's theory predicts. This means that tensors in GR have to correspond to the mathematical description of what occurs under the effect of such flows.

For instance, the Schwarzschild solution

$$ds^2 = \left(1 - \frac{2Gm}{c^2 r}\right)^{-1} dr^2 + r^2(d\theta^2 + \sin^2 \theta d\phi^2) - c^2 \left(1 - \frac{2Gm}{c^2 r}\right) dt^2 \quad (22)$$

may correspond to a sphere absorbing the fluid space in which it is immersed: the geodesic of a body situated in the attraction field of such sphere would be indeed identical. This is the simplest case but since both Ricci tensor, which expresses how riemannian metric differs from euclidean space, and the Christoffel symbols depend on a metric tensor  $g_{ij}$ ,

$$\begin{pmatrix} g_{00} & g_{01} & g_{02} & g_{03} \\ g_{10} & g_{11} & g_{12} & g_{13} \\ g_{20} & g_{21} & g_{22} & g_{23} \\ g_{30} & g_{31} & g_{32} & g_{33} \end{pmatrix}$$

which refers to how to compute the distance between any two points in a given space, Einstein's field equations can be roughly thought as an elegant tool by which the geometrical characteristics of a space can be *arithmetized* by way of introducing a sort of generalized coordinate system [3], which describes space and time depending on how mass-energy (the source of gravity) is distributed in it, as indicated by the energy-momentum tensor  $T_{\mu\nu}$ . Cauchy's tensor

$$\begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{pmatrix}$$

used in fluid dynamics to describe small deformations occurring in fluids, wouldn't be so different from the metric tensor  $g_{ij}$  if we added time. Below, we see that Einstein's tensor is defined as the interaction between the metric tensor and the scalar curvature expressed by Ricci tensor ( $R_{\mu\nu}$ ):

$$G_{\mu\nu} \equiv R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} \quad (23)$$

and the Christoffel symbols can be directly derived from the metric tensor:

$$\Gamma_{cab} = \frac{1}{2} \left( \frac{\partial g_{ca}}{\partial x^b} + \frac{\partial g_{cb}}{\partial x^a} - \frac{\partial g_{ab}}{\partial x^c} \right) \quad (24)$$

Also in fluid quantum gravity, the source of the attraction, discretized in GR by Christoffel symbols, is mass, where it doesn't curve space, however, but absorbs it, producing tidal forces. A discretization of space which, after all, is necessary also in the CFD simulations. But, albeit geometrically useful as a calculation tool, space deformation is not theoretically necessary in the

present approach: neither of Einstein's spacetime nor of superfluid quantum space, inasmuch what is rather able to replace spacetime's curvature is fluid dynamics itself: flows occurring in SQS, vortices *etc.*. In fact, from this point of view, gravity is only a flow of space quanta which transports what is immersed in SQS, as a floating object would be sucked into the spillway of fig. 7.b.

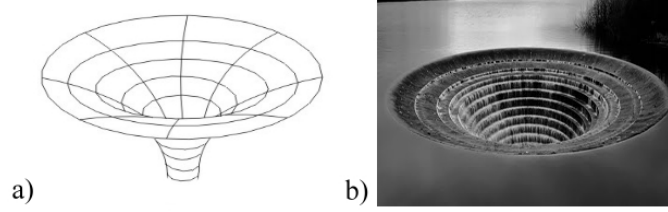


Figure 7: how the presence of a massive body curves spacetime (a) or absorbs it (b), here in analogy with a bell-mouth spillway.

In the following images, we see how fluid space can produce the same relativistic effects of general relativity.

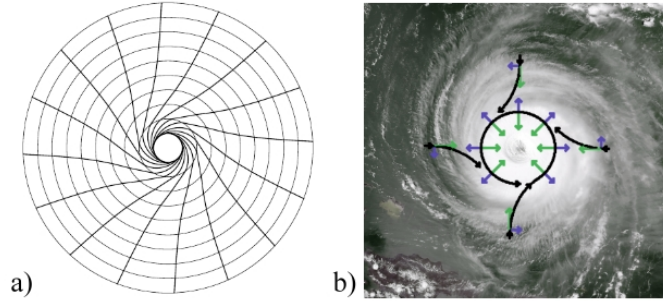


Figure 8: The Lense-Thirring effect according to Einstein's curved spacetime (a) and to fluid dynamics (b). Here as an analogy with the Coriolis effect in a cyclone.

Where the gravitomagnetic field related to the Lense-Thirring effect is expressed as

$$B = -\frac{4}{5} \frac{m\omega R^2}{r^3} \cos \theta \quad (25)$$

and the Coriolis force can be written, in some respects, in a similar form:

$$F_C = -2m\omega(\omega R)\mathbf{u}_R. \quad (26)$$

Other effects which can be described by fluid dynamics are, for instance, the gravitational lensing:

$$\vec{\hat{\alpha}}(\vec{\xi}) = \frac{4G}{c^2} \int d^2\xi' \int dz \rho(\vec{\xi}', z) \frac{\vec{b}}{|\vec{b}|^2} \quad (27)$$

with  $b \equiv \vec{\xi} - \vec{\xi}'$  where  $\xi, z$  are coordinates and  $\hat{\alpha}$  is the deflection angle, which in fig. 8.a is determined by vector interaction between light's and SQ's momenta. The absorption of SQ is here illustrated as water flowing into a spillway. By considering the photon as a special spin-1 phonon, as discussed in §5, SQS interestingly curves light as wind curves sound waves. In this case, gravitational lensing would rather mean that light is moving in a superfluid medium (SQS) where flows occur, not that space is curved. Equations in (§5) seem to confirm that.

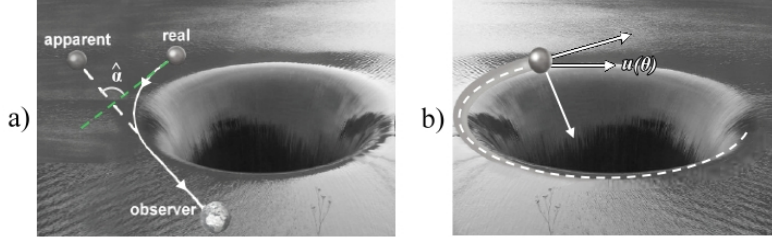


Figure 9: Gravitational lensing (a) and the motion of a satellite (b) according to SQS, here in analogy with a bell-mouth spillway.

Also orbital motion (fig. 9.b) is fluid dynamically explainable, when the description of angular velocity for *any* inverse square law, such as that found in the CFD simulations [1] is given as

$$u(\theta) = \frac{\mu}{h^2} - A \cos(\theta - \theta_0) \quad (28)$$

where  $A$  and  $\theta_0$  are arbitrary constants,  $h$  the angular momentum and  $\mu$  the standard gravitational parameter  $GM$ . Beyond this newtonian formula (28), relativistic effects which may occur along with orbital motion, as the aforementioned Lense-Thirring effect, can be likewise described by fluid dynamics, without resorting to curved spacetime.

## 5 Photon as phonon through superfluid quantum space.

The value of  $c$  is due to photon's interaction with vacuum. It is indeed derivable as:

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}. \quad (29)$$

By replacing the concept of vacuum with that of SQS,  $\varepsilon_0$  and  $\mu_0$  can be considered physical properties of the latter. Moreover, in the energy eigenvalue of any eigenstate  $\psi_n$ , expressed as

$$E_n = (n + \frac{1}{2})\hbar\omega \quad (30)$$

$\frac{1}{2}\hbar\omega$  (vacuum's energy contribution) may correspond to the energy from SQS. If quantum vacuum *is* SQS, then photons move through a superfluid. It is then interesting to make a comparison with the speed of sound in a fluid:

$$a = \sqrt{\frac{E}{\rho}} \quad (31)$$

where, by setting  $\sigma = 1$  in Young's modulus ( $E = \frac{\sigma}{\epsilon}$ ), we obtain  $a = \frac{1}{\sqrt{\epsilon\rho}}$ . When  $\epsilon$  is seen as quantum space's deformability and  $\rho$  as its density, we have

$$a = \frac{1}{\sqrt{\epsilon_0\rho_0}} \quad (32)$$

which is mathematically analogous to (29): this suggests that light can really move through a superfluid, whose quanta, like air's molecules, possess specific properties. Superfluidity would, for instance, account for photon's indefinite propagation, more extensively discussed below.

When travelling through a specific medium and at specific temperature, sound has constant speed just as light and the motion of a sound source only determines frequency shift, according to the Doppler-Fizeau effect which, for light, corresponds to redshift's formula:

$$z = \frac{f_{emit} - f_{obs}}{f_{obs}}$$

The photon-phonon analogy might, however, be questioned by pointing out that there are at least a couple of fundamental differences between sound and light. The latter doesn't move through a medium and the photon is also a particle. But there are actually no differences when the medium is, in our case, SQS (currently corresponding to quantum vacuum, zero-point field<sup>3</sup>) and the dual nature of photon actually matches that of phonon, which also has both wave and particles characteristics. Analogies with photons have also been encountered in plasmons [16]. Moreover, and this is of central importance, the disproof concerning the existence of a *luminiferous aether*, due to the Michelson-Morley experiment [4], doesn't confute the photon-phonon analogy since, in that case, the hypothesis was that of a stationary aether<sup>4</sup> and - as a result of Earth's

<sup>3</sup>Superfluid quantum space corresponds, in my opinion, to dark energy, whose negative pressure is due to SQS's expansion, which proceeds since primordial inflation. This would mean that ~68% of universe's energy is SQS itself.

<sup>4</sup>proposed by A.Fresnel in 1818



motion - of an aether wind which would have influenced light's speed in the experiment. While the present case is very different, as it assumes that Earth - since made up of fermions - absorbs SQ, whose flow shapes Earth's gravitational field. So, in our case, the aether simply corresponds to the gravitational field. For this reason, in the Michelson-Morley experiment, light had the same speed in both orthogonal directions. At most, when travelling parallel to Earth's surface, it slightly curves downward, according to general relativity<sup>5</sup>, albeit this effect becomes evident only on astronomical distances and for much greater gravitational fields. Thus, Michelson and Morley concluded that light doesn't need any medium to propagate. Now, SQS - along with the fact that fermions absorb it, producing gravity - might be, in a way, a plot twist. It is now clear that SQS doesn't need gravitons or other force carriers to explain gravity, since quantum gravity is reduced to SQ's dynamics, as well as ocean currents don't need anything else than water and fluid-thermodynamics to be described and understood.

Therefore, we could actually think of light as a collective, excited state of space quanta (phonon). By considering phonons in a quantum mechanical harmonic chain of  $N$  identical atoms (as they were space's quanta) whose positions are  $x_1, x_2, \dots$ , the potential energy is expressed as:

$$\frac{1}{2}m\omega^2 \sum_j (x_j - x_{j+1})^2 = \frac{1}{2} \sum_k m\omega_k^2 Q_k Q_{-k} \quad (33)$$

where  $Q_k$  is a set of  $N$  normal coordinates defined as discrete Fourier transforms of the conjugate momenta  $\Pi$  of  $x$  and  $N$ , corresponding to the Fourier transforms of the momentum operator  $p$

$$Q_k = \frac{1}{\sqrt{N}} \sum_l e^{ikal} x_l$$

$$\Pi_k = \frac{1}{\sqrt{N}} \sum_l e^{-ikal} p_l$$

$k_n$  is the wave number of the phonon and

$$\omega_k = \sqrt{2\omega^2 [1 - \cos(ka)]}.$$

The harmonic oscillator eigenvalues for the mode  $\omega_k$  are

$$E_n = (n + \frac{1}{2})\hbar\omega_k \quad n = 0, 1, 2, 3, \dots \quad (34)$$

with quantized levels at

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<sup>5</sup>where the angle of deflection is:  $\theta = \frac{4GM}{rc^2}$

$$\frac{1}{2}\hbar\omega, \quad \frac{3}{2}\hbar\omega, \quad \frac{5}{2}\hbar\omega \quad \dots$$

exactly matching (30), where  $\frac{1}{2}\hbar\omega$  is the zero-point energy for phonon and photon, *i.e.* SQS's energy. We know that phonons are bosons [13], just like photons, since they are symmetric under exchange  $|\alpha, \beta\rangle = |\beta, \alpha\rangle$  and any number of identical excitations can be created by repeatedly applying the creation operator  $b^\dagger$ . Phonon's hamiltonian (renormalized on the right by putting  $\frac{1}{2}\hbar\omega q_k = 0$ ) is:

$$\hat{H}_{ph} = \sum_k \hbar\omega_k \left( b_k^\dagger b_k + \frac{1}{2} \right), \quad \hat{H}_{ph} = \sum_k \hbar\omega_k b_k^\dagger b_k \quad (35)$$

and again a photon can be described as a phonon occurring in SQS, where the necessary collective excitation is satisfied by SQ: a discretized amount of these (as pulse), would form a photon. Other clues are that, as well as photons, phonons possess wave-particle duality [7][8], can form squeezed coherent states and they can interact via parametric down conversion [14]. Moreover, it would be now evident that light moves at the maximum, possible speed, since a phonon, as pulse, doesn't entail shear stress, while a body moving through SQS provokes, as velocity increases to relativistic values, intensifying collisions among SQ and apparent viscosity increase according to (8). While, then, in a newtonian fluid such as air, supersonic velocities are possible, this wouldn't occur in a dilatant space, where the speed of light can be considered as the speed of *sound* in SQS, whose quanta are not matter however, thus they actually transport discretized energy in form of photons. We could therefore state that light is *the sound of space*. So, for any object moving through SQS, we always have  $v < c$ . Because of superfluidity, a *phonoton* (a photon described as a special spin-1 phonon occurring in SQS) could indefinitely propagate - overcoming the limitations of a liquid space which would cause dissipation of light [17] - until it scatters, for instance, with an electron. The photoelectric effect and Compton scattering would be indeed still allowed, thanks to its momentum  $\frac{h}{\lambda}$ , which for analogy is also derivable from phonons' crystal momentum  $p_{crystal} \equiv \hbar k = \frac{h}{\lambda}$ , where  $k = \frac{2\pi}{\lambda}$ . Anyway a phonoton doesn't possess crystal momentum, since it doesn't pertain to solid-state physics, thus photon's momentum  $\frac{h}{\lambda}$  directly applies. Pair production is furthermore allowed and intelligible when electrons are described as vortices of space quanta [1], triggerable by scattering of discrete SQ's pulses such as phonotons. But how would the latters carry an electromagnetic field? In an ideal isotropic medium such as SQS, it is plausible that phonons may have spin=1, as the angular momentum transmitted by the emitting particles. Theoretically, since it has been demonstrated how sound waves may spin [19][20], also phonons moving through a superfluid medium might accordingly spin. This fact could trigger secondary compressive, elastic and harmonic phenomena - in addition to the main one occurring along the  $z$ -axis (fig. 10.b) - which might generate the field.

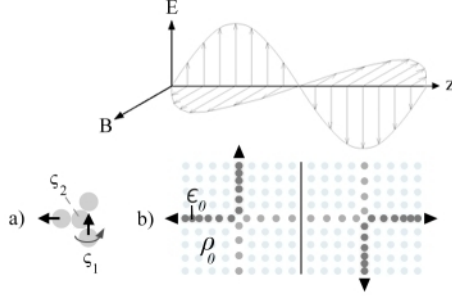


Figure 10: Density ( $\rho$ ) and deformability ( $\epsilon$ ) of SQS at the origin of photon's transverse EM field (b), whose oscillations are due to harmonic, orthogonal compressions of space quanta, while the main pulse (phonon) is moving along the  $z$ -axis. On the left (a) the probable quantum mechanism at the origin of transversality, due to compression and spin.

The EM field is generated according to vacuum's permittivity ( $\epsilon_0$ ) and permeability ( $\mu_0$ ), here represented as SQS's deformability ( $\epsilon_0$ ) and density ( $\rho_0$ ) when a photon is described as phonon.

As inferable from fig.10, the dimensionless equivalence  $\epsilon_0\rho_0 = \epsilon_0\mu_0$  is placed. Within this framework, SQS's density and deformability indeed determine phonon's speed ( $c$ ) in vacuum (*i.e.* in SQS) and (32) is equivalent to (29). To highlight the relationship between photon's electromagnetic field and its total angular momentum, we also see that the latter is related to  $\epsilon_0$ , that is - valid the equivalence - to SQS's deformability( $\epsilon_0$ ):

$$\mathbf{J} = \epsilon_0 \int \mathbf{r} \times (\mathbf{E} \times \mathbf{B}) d^3\mathbf{r} \quad (36)$$

and deformability is inevitably pertaining to how (mass-)energy ( $\Rightarrow$ SQ) is locally distributed, hence the field's oscillation, while a photon is travelling in the direction of propagation and its translational velocity is given as  $c = \lambda\nu$ . Light's EM field would be therefore created by superfluid scattering among the phonon and the adjacent space quanta, occurring in SQS: this would be the underlying quantum mechanism to equation (29). A harmonic perturbation mechanism without energy loss. And it wouldn't be an isolated case: metamaterials have been investigated, in which light moves without energy loss [18]; energy is also conserved in Rayleigh scattering and *a fortiori* when the scattering pertains to the zero-point field (SQS). Fig. 10.a shows the possible quantum mechanism at the origin of the transversality ( $E \perp B$ ). Space's quantum  $s_1$  moves upward against the overlying SQ and elastic scattering occurs: because of both compression and its spin, received from the phonon<sup>6</sup>, an orthogonal pulse is generated in the opposite direction to spin, harmonically rightward and leftward, according to the varying orientation of the phonon along the direc-

<sup>6</sup>It's assumed that SQ have no intrinsic spin.

tion of propagation. In some respects, a reference to the interaction among particles described in quantum billiards might be considered.

Phonotons as discrete pulses of SQ, along with gravity described as absorption of SQ, may also explain why photons, although massless, are subject to gravity. In both cases it's a matter of SQ's fluid dynamics. As a phonoton, it becomes also clear why a photon can't escape from a BH, as well as sound waves couldn't propagate if air was sucked more rapidly than sound's speed. Also equation (7) argues for photon as a phonon in SQS and, for its part, the concept of phonoton helps to justify the superfluid reformulation of Lorentz factor (8), by indicating  $c$  as the velocity of a pulse through SQS, obviously faster than any accelerated body, which would undergo nonlinear dilatancy by approaching that velocity.

It is finally questionable whether the assumed accelerating expansion of the universe, *i.e.* distant galaxies' acceleration inferred from the distance-dependent increase of redshift (Hubble's law), is really caused by acceleration or rather by light's energy dissipation, after phonotons have propagated through SQS for extremely long time/distances. Does Hubble's law actually represent distant galaxies' acceleration?

## 5.1 Speed of light in fluid quantum gravity.

If photon is a phonon of SQ, it follows that, in a gravitational field, its velocity is not constant in some circumstances, inasmuch it would also depend on the drift velocity of SQ (corresponding to the escape velocity in that field,  $v_{sq} = v_e$ ). Thus, when light travels upward in the field, its actual speed should be  $c - v_e = 299781278$  m/s in Earth's gravitational field, since  $v_e = 11180$  m/s, vice-versa  $c + v_e = 299803638$  m/s, when the beam travels downward. This phenomenon would be confirmed in black holes, where light can't leave the celestial body since, in that case,  $v_e = c \Rightarrow v_{light} = c - v_e = 0$ . In fact, the speed of any wave traveling through a medium is relative. We would consequently observe a slight redshift when in the field the source is situated lower than the observer and a blueshift when light travels downward. This effect is confirmed by Einstein's redshift (gravitational redshift) and it's then questionable whether it really depends on time dilation or on a different speed of light, or on both. It has to be pointed out that, when light travels round trip along a same path, the possible difference in velocity is cancelled. For this reason, a laser beam from Earth to Moon and back (or satellite communications) wouldn't show any aberration as far as light's speed is concerned and a vertically placed Michelson's interferometer wouldn't be useful to confirm different speeds of light. On the contrary, a Hanbury-Brown Twiss interferometer might be. The use of a specific interferometer to measure slight differences in light's speed would be then the simplest way to verify fluid quantum gravity and photon as phonoton.

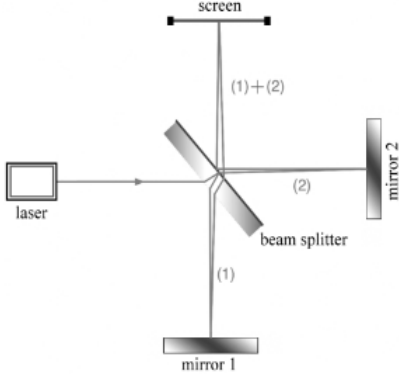


Figure 11: A vertically placed Michelson interferometer wouldn't be useful to detect fluctuations in light's speed when light travels in the same direction of the gravitational flow or in the opposite direction. Indeed, path (1) is round trip and would cancel the possible difference in velocity, nor a difference would arise from the joint path (1)+(2). A specific interferometer would be therefore necessary.

In this case, the value of the speed of light should be actually expressed as the scalar value of vector

$$\vec{c} = \frac{\hat{c}}{\sqrt{\epsilon_0 \mu_0}} + \vec{v}_e = \frac{\hat{c}}{\sqrt{\epsilon_0 \rho_0}} + \vec{v}_{sq} \quad (37)$$

where  $\hat{c}$  is a versor indicating light's direction of propagation.

## 6 Physical properties of Superfluid Quantum Space.

SQS's physical properties so far examined in this work are:

- quantum nature  $\Rightarrow$  SQ
- superfluidity / quasi-zero viscosity
- compressibility
- capacity to propagate light as phonons of space's quanta, depending on SQS's density ( $\rho_0$ ) and deformability ( $\epsilon_0$ ).
- dilatant behavior for extreme shear stress at velocities  $\rightarrow c$ , which determines mass increase and second-/third-order relativistic effects.

Compared to Einstein's spacetime, thought experiments which consider that spacetime can be bent to superimpose two distant points are not allowed in SQS. The only way to travel astronomical distances in a short time, would be overcoming the speed of light by cancelling SQS's minimal viscosity to avoid dilatancy.

Let's now consider the possibility of knowing some further numerical data concerning SQS's density, deformability, energy per cubic meter *etc.*

If we set a value of 1 kg for mass in the mass-energy relationship  $E = mc^2$ , we obtain, for this case:  $E = c^2$ .

Now,  $c$  refers to a velocity but it's also a value for a length: that traveled by light in one second. This consideration has been useful also about (6). We're then allowed to consider  $c^2$  as the size of an area, which might correspond to a layer of SQ. In this case the energy of the layer would be:

$$E = c^2 \approx 8.987551 \cdot 10^{16} \text{ J} \quad (38)$$

And the energy of a cubic portion of SQS with side equal to  $c$  would be:  $\sim 2.6944 \cdot 10^{25} \text{ J}$ . We'd consequently have that:

1. the energy per cubic meter of SQS is exactly 1 J. The upper limit of  $\Lambda$  gives a lower value of  $10^{-9} \text{ J}$  but it's necessary to consider that, in fluid quantum gravity, the energy of SQS doesn't directly deal with the gravitational interaction: only when SQ are set in motion by fermionic absorption we have gravitational flows. Thus, a higher value wouldn't disturb the Lambda-CDM model. If anything, a higher density of SQS (*e.g.* as it might have been in the primordial universe) would imply expansion, *i.e.* apparent negative gravity. But not accelerating expansion, which wouldn't occur, since Hubble's law is most likely explainable as photons' energy loss in function of distance.
2. the mass of  $1 \text{ m}^3$  is  $1.11265 \cdot 10^{-17} \text{ kg}$ . Implying that SQ are not massless: this agrees with [1], where fermions are made up of SQ, and with SQS's dilatant behavior at relativistic shear.
3. density,  $\rho_0$ , is  $1.11265 \cdot 10^{-17} \text{ kg/m}^3$
4. by considering only one space's quantum in a volume of  $\ell_p^3$ , the maximum number of SQ in one cubic meter is:  $6.187154 \cdot 10^{104}$ .
5. the mass of a single quantum is  $1.79404 \cdot 10^{-122} \text{ kg}$ , and its energy  $1.79404 \cdot 10^{-105} \text{ J}$ .
6. SQS must be the elementary scalar field (how is it related to Higgs field? Is Higgs boson a cluster of SQ or a topological defect of SQS? In both cases it would agree, then, with [1]).
7. the value of  $\epsilon_0 = \frac{1}{\rho_0 c^2}$  is 1 (dimensionless, matching  $\epsilon_0$  in Young's modulus).
8. the velocity of light is, then, essentially function of SQS's density:  $c = \frac{1}{\sqrt{\rho_0}}$ , confirming light as phonons in fluid quantum space. But then, to be accurate (37), we have

$$\vec{c} = \frac{\hat{c}}{\sqrt{\rho_0}} + \vec{v}_{sq} \Rightarrow c = \|\vec{c}\| \quad (39)$$

9. the equation  $E = mc^2$  corresponds to the relationship between the mass-energy of a body and the mass-energy (energy density) of quantum space. Indeed, from point 8. we have:

$$c^2 = \rho_0^{-1} \Rightarrow E = \frac{m}{\rho_0}. \quad (40)$$

and Lorentz factor (scalar form) appears as a function of the translational velocity through SQS and of its density:

$$\gamma_{\Phi} = \frac{1}{\sqrt{1 - \|\mathbf{v}_{\Phi}\|^2 \rho_0}} \quad (41)$$

where it's interesting to notice that, in absence of mass (6), only SQS's energy is able to cause an increase of gravitational interaction. That indeed occurs when considering a given energy corresponding to  $c^2$  (38).

## Conclusions and experimental verifications.

By hypothesizing the existence of a superfluid quantum space in place of what we call quantum vacuum or zero-point field, quantum gravity is obtained by starting from the Navier-Stokes equations without resorting to gravitons or string theory. In a previous work of mine [1], it has been shown how this approach would be able to unify gravity with the other fundamental interactions and in this paper it has been shown that it implies a fluid reformulation of the principle of equivalence, through which special and general relativity can be merged with fluid quantum gravity.

GR's curved spacetime may be replaced by the fluid dynamics of SQS, without discarding Einstein's equations but only adapting them to the fluid equivalence principle. A correction to the equations of weight is also necessary.

Moreover, equations give evidences for considering a photon as a phonon moving through superfluid quantum space, without violating the Michelson-Morley experiment. This would be, on its part, a confirmation to the existence of superfluid quantum space. In short, a virtuous circle that cannot be ignored and needs further investigations.

We can summarize as follows:

1. The fluid reformulation of the equivalence principle states that translational velocity produces gravitational interaction opposite to motion and this explains relativistic mass increase.
2. Mass increase is the only fundamental relativistic effect.
3. Time dilation is a secondary relativistic effect which depends on mass increase and length contraction a third-order effect depending on time dilation.

4. All relativistic effects described in general relativity (curved spacetime) are obtained and explained through the fluid dynamics of SQS, where the gravitational tidal forces of GR correspond to the flows of space's quanta occurring in SQS and due to fermionic absorption.
5. SQS is compressible, as primordial inflation and universe's expansion suggest, and its quasi-zero viscosity (superfluidity) increases and becomes critical for shear stress driven to relativistic velocities, determining an apparent dilatant behavior.
6. A photon can be mathematically described as a phonon of space's quanta. In this case,  $c$  refers to the speed of light through SQS. Light is the sound of space.

As far as fluid quantum relativity's verification is concerned, only a few experimental differences can be suggested if compared with Einstein's relativity. But firstly, the fact that it mathematically works and is able to unify gravity and relativity with QFT thanks to almost the same equations we already use, should be the strongest clue for its correctness. *Entia non sunt multiplicanda praeter necessitatem*. We probably don't need 26 dimensions<sup>7</sup> in the universe, nor a supergravity with 11 dimensions as in M-theory. Space's quanta may suffice to explain quantum gravity, quantum relativity, bosons, fermions and the fundamental interactions [1]: thus we need them and we shouldn't be surprised if one day the standard model will contain only one fundamental particle: the space quantum ( $\varsigma$ ). Experimental verifications of fluid quantum gravity and fluid quantum relativity could take place as follows:

1. Thanks to a specific interferometer which doesn't cancel possible discrepancies through round-trip trajectories (§5.1), it should be possible to demonstrate that light has a higher velocity (by measuring a higher frequency) when traveling downward perpendicular to a gravitational field and, on the contrary, a lower velocity when traveling upward in the field. The difference should exactly correspond to the escape velocity in that field. Since the observation of the interference fringes would occur where the gravitational field has a single, specific intensity (no comparison between two observers located at two different heights) Einstein's redshift due to time dilation would be excluded and the effect ascribed to different velocities of light, confirming that photon is a phonon in SQS and the gravitational field as the fluid dynamic effect of the absorption of SQ, effected by fermions [1].
2. when an object is in equilibrium in the Earth's gravitational field, its weight exceeds a  $\gamma$  factor that predicted by classical physics, where SQ's drift velocity ( $v = \sqrt{2rg}$ ) is considered in the calculation of  $\gamma$ . A specific ultra-sensitive balance would be however necessary.

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<sup>7</sup>from Polyakov's equation.



## References

- [1] Fedi M., (October 2015) Hypothetical role of quantum space superfluid dynamics in the physics of particles and fundamental interactions. <https://hal.archives-ouvertes.fr/hal-01223102>
- [2] Alonso, M.; Finn, E.J. (1968). *Fundamental University Physics Volume III: Quantum and Statistical Physics*. Addison-Wesley
- [3] Borisenko, A. I.; Tarapov, I. E. (1979), *Vector and Tensor Analysis with Applications*. New York: Dover Publications, Inc.
- [4] Michelson, Albert A.; Morley, Edward W. (1887). “On the Relative Motion of the Earth and the Luminiferous Ether”. *American Journal of Science* 34: 333–345
- [5] Mermin, D. (February 1984). “Relativity without light”. *American Journal of Physics* 52 (2): 119–124
- [6] Wilczek, Frank (2009). *The Lightness of Being: Mass, Ether, and the Unification of Forces*. Basic Books
- [7] Einstein, A. (1909). “Über die Entwicklung unserer Anschauungen über das Wesen und die Konstitution der Strahlung”. *Physikalische Zeitschrift*, 10: 817–825
- [8] Saleh, B. E. A. and Teich, M. C. (2007). *Fundamentals of Photonics*. Wiley
- [9] C. Burgess, G. Moore (2007), *The Standard Model. A Primer*, Cambridge University Press
- [10] Markus Pössel, (2010). “The equivalence principle and the deflection of light”, in: *Einstein Online Vol. 04*, 1020
- [11] Haugen, Mark P.; Lämmerzahl, Claus (2001). *Principles of Equivalence: Their Role in Gravitation Physics and Experiments that Test Them*. Springer
- [12] Mahan, G.D. (1981). *Many particle physics*. New York. Springer.
- [13] Feynman, Richard P. (1982). *Statistical Mechanics, A Set of Lectures*. Reading, Massachusetts: The Benjamin/Cummings Publishing Company, Inc. p. 159
- [14] Reiter, D E; et al. (2009). “Generation of squeezed phonon states by optical excitation of a quantum dot”, *J.Phys.: Conf. Ser.* 193 012121, Institute of Physics.
- [15] Naber, G.L. (2012), *The Geometry of Minkowski Spacetime, Applied Mathematical Sciences*, Springer.

- [16] Fakonas, J.S.; Lee, H. *et al.*, (2014). “Two-plasmon quantum interference”, *Nature Photonics*, 8 (4).
- [17] Liberati, S; Maccione, L. (April 2014), “Astrophysical Constraints on Planck Scale Dissipative Phenomena”, *Phys. Rev. Lett.* 112, 151301
- [18] Li, Y.; Kita, S.; Muñoz, P. *et al.*, (2015), “On-chip zero-index metamaterials”, *Nature Photonics* 9, 738–742.
- [19] Santillán, A.O.; Volke-Sepúlveda, K. (2009), “A demonstration of rotating sound waves in free space and the transfer of their angular momentum to matter”, *Am. J. Phys.* 77, 209
- [20] Jiang, X.; Liang, B. *et al.* (2014), “Broadband field rotator based on acoustic metamaterials”, *Appl. Phys. Lett.* 104, 083510
- [21] Maxwell, J. C. (1866). “On the viscosity or internal friction of air and other gases”. *Philosophical Transactions of the Royal Society of London* 156: 249–268.
- [22] Hall, H.E. (1981), “Superfluid compressibility in  $^3\text{He-B}$ ”, *Physica B+C*, Volume 108, issues 1–3, pages 1147-1148.
- [23] Malmi-Kakkada, A.N.; Valls, O.T.; Dasgupta, C., (2014) “Hydrodynamics of compressible superfluids in confined geometries”, *Journal of Physics. B, Atomic, Molecular and Optical Physics*; v. 47(5)
- [24] Chapline, George (July 1998). “The Black Hole Information Puzzle and Evidence for a Cosmological Constant”, [arXiv:hep-th/9807175](https://arxiv.org/abs/hep-th/9807175)
- [25] Vachaspati, Tanmay; Dejan Stojkovic; Lawrence M. Krauss (June 2007). “Observation of Incipient Black Holes and the Information Loss Problem”. *Phys. Rev. D* 76 (2)