Gravity as a fluid dynamic phenomenon in a superfluid quantum space.

Superfluid quantum gravity and relativity.

revised May 05, 2017 (v6)

Marco Fedi[1]

Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR), Italy

Abstract

This hypothesis starts from considering the physical vacuum as a superfluid quantum medium, that we call superfluid quantum space (SQS), close to the previous concepts of quantum vacuum, quantum foam, superfluid vacuum etc. We usually believe that quantum vacuum is populated by an enormous amount of particle-antiparticle pairs whose life is extremely short, in a continuous foaming of formation and annihilation. Here we move further and we hypothesize that these particles are superfluid symmetric vortices of those quanta constituting the cosmic superfluid (probably dark energy). Because of superfluidity, these vortices can have an indeterminately long life. Vorticity is interpreted as spin (a particle's internal motion). Due to non-zero, positive viscosity of the SQS, and to Bernoulli pressure, these vortices attract the surrounding quanta, pressure decreases and the consequent incoming flow of quanta lets arise a gravitational potential. This is called superfluid quantum gravity. In this model we don't resort to gravitons. Once comparing superfluid quantum gravity with general relativity, it is evident how a hydrodynamic gravity could fully account for the relativistic effects attributed to spacetime distortion, where the space curvature is substituted by flows of quanta. Also special relativity can be merged in the hydrodynamics of a SQS and we obtain a general simplification of Einstein's relativity under the single effect of superfluid quantum gravity.

[1]marco.fedi@istruzione.it; marco.fedi.caruso@gmail.com

1 Massive particles as vortices in a superfluid quantum space (SQS)

The particles of the Standard Model could form as dynamic topological defects (superfluid vortices) or pulses in a SQS [4]. In this view, the superfluid vacuum [1, 2, 3, 21] is a fundamental scalar field with quasi-zero, positive viscosity which gives mass to particles through the kinetic energy of its quanta, once perturbations occur. There are therefore several analogies with the Higgs field, while Higgs boson would be a spin-0 vortex of space's quanta (SQ), i.e. a single vortex, then an elementary particle, whose remarkable mass, given the low density and viscosity of SQS, would make it unstable and would compel it to a quick decay into smaller vortices (lighter particles) and pulses. Sbitnev [5, 6] considers quantum vacuum as a superfluid and applies quantum considerations to Navier Stokes equations to describe vortex objects (vortex balls) which, unlike Hill's spherical vortices, show intersected streamlines and seem to satisfactorily reproduce fermions' spin by varying their orientation at each revolution. Also Volovik [7] accurately discusses the possible topology of quantum vacuum and the appearence of vortices. Huang [19] affirms that quantum turbulence (chaotic vorticity) in the early universe was able to create all the matter in the universe.

We know that quantum vortices occur in other superfluids such as those observed in helium nanodroplets [8, 9]. It may be interesting to start from the analysis of vortices in a Bose-Einstein condensate ($\psi(\mathbf{r},t)$), for whose time-depending evolution the most simple model is the Gross-Pitaevskii equation [10]:

$$i\hbar\frac{\partial\psi(\mathbf{r},t)}{\partial t} = \left[-\frac{\hbar^2}{2m}\vec{\nabla}^2 + V_{ext}(\mathbf{r},t) + g\,|\psi(\mathbf{r},t)|^2\right]\psi(\mathbf{r},t) \tag{1}$$

Where $V_{ext}(\mathbf{r},t)$ is an external potential and $g = 4\pi\hbar^2 a_s/m$ (with a_s scattering length) is the coupling constant. From (1), Proment, Onorato and Barenghi [11] elaborate the continuity and linear momentum conservation equations for an inviscid, barotropic, compressible and irrotational fluid:

$$\frac{\partial\rho}{\partial t} + \nabla\cdot(\rho\mathbf{v}) = 0, \tag{2}$$

$$\frac{\partial\mathbf{v}}{\partial t} + (\mathbf{v}\cdot\nabla)\mathbf{v} = -\frac{\nabla\rho}{2} + \nabla\left(\frac{\nabla^2\sqrt{\rho}}{2\sqrt{\rho}}\right) \tag{3}$$

where the last term in (3) is the quantum stress tensor, which represents an important difference from the classical Euler equation. Albeit the superfluid is irrotational, quantized vortices can appear, with a quantized circulation which is analogous to that described in the Bohr model, as the wavefunction must return to its same value after an integral number of turns

$$\oint_{C_{(t)}} \mathbf{v}\cdot d\mathbf{l} \equiv \frac{2\pi\hbar}{m}n. \tag{4}$$

where m is the mass of the superfluid particle and $2\pi n$ the phase difference around the vortex. Eq. (4) is also the additional condition to impose to the Madelung equations

$$\partial_t \rho + \nabla \cdot (\rho \mathbf{v}) = 0, \tag{5}$$

$$\partial_t \mathbf{v} + \mathbf{v} \cdot \nabla \mathbf{v} = -\frac{1}{\mathrm{m}} \nabla \left(\frac{1}{\sqrt{\rho_{\mathrm{m}}}} \hat{H} \sqrt{\rho_{\mathrm{m}}} \right) \tag{6}$$

where $\rho_m = m\rho$ is mass density, to describe a fundamental particle as a superfluid vortex. These vortices behave as gaps in the medium where superfluidity breaks down and the presence of a topological structure where pressure and density go to zero, would suggest the non-necessity of renormalization, since no ultraviolet divergence would occur. The use of hydrodynamic equations of vortices applied to SQS to describe the fundamental particles and their force fields would be advantageous under different aspects. We could for instance explain the appearance of particle-antiparticle pairs from quantum vacuum as a perturbative phenomenon similar to that described in a Kármán vortex street (Fig. 1)

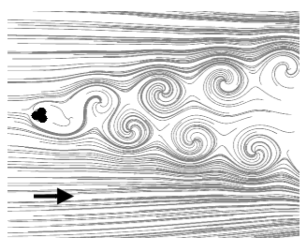


Figure 1: a computer simulation of a Kármán vortex street. Clumps of space's quanta (dark matter?) in a SQS might be responsible for the appearance of particle-antiparticle pairs as superfluid vortices of space's quanta.

where pairs formed by a right- and a left-handed vortex occur due to a perturbation of the flow. In our case the flow may be represented by hydrodynamic gravitational fields in the SQS produced by other bodies and the perturbation elements by other particles [12] or clumps of space's quanta (a possible explanation for dark matter and its role in creating/aggregating ordinary matter?) or any stochastic perturbation of the SQS (do we interpret this originary disturbance as the Big Bang? Has it been a cascading perturbation of a pre-existing SQS?). The self-sustainability of the vortices would be possibile thanks to superfluidity. The wave functions of particle-antiparticle pairs might then emerge from the perturbation of SQS. Avdeenkov and Zloshchastiev discuss self-sustainability and emergence of spatial extenta in quantum Bose liquids [13].

The trigger to the formation of vortex-antivortex pairs in fluid quantum space, corresponding to matter-antimatter within our analogy, might besides be a phase transition similar to the Kosterlitz-Thouless transition, where bound vortex-antivortex pairs get unpaired at some critical temperature, what could have occurred at a certain point in the history of the universe. Also the mathematics of Lamb-Chaplygin dipoles is interesting for describing the dynamics of symmetric vortices. We suggest however a different geometry for a vortex-particle in SQS, compatible with the fermionic spin$\frac{1}{2}$, and described in §3.

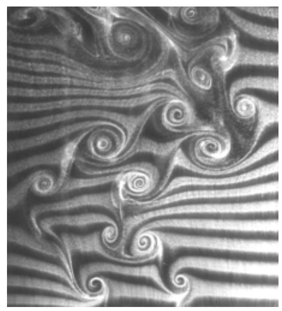


Figure 2: a possible analogy between Kármán vortex street phenomena [14] and perturbations in SQS might help us to understand how particles and interactions arise from a superfluid quantum vacuum.

If fundamental particles are vortices of the quanta which form the SQS, then also vacuum fluctuations should arise from their circulation. The fluctuations of the zero-point field are expressed as

$$\triangle E \triangle t \geq \frac{h}{2\pi} = \hbar. \tag{7}$$

In our case it refers to the energy fluctuations in time of the SQS. By considering the Bohm-Sommerfeld relation

$$\oint_C \mathbf{p} \cdot dx = nh \tag{8}$$

for $n = 1$ we see that the Planck constant refers to mass circulating along a closed loop in a given time, i.e. to kinetic energy confined in time (that necessary to complete one turn), having h unit of $[\mathrm{J} \cdot \mathrm{s}]$. With respect with the mass-energy of stationary SQ, this kinetic energy adds energy to the system while the turn is performed, so we understand the meaning of $\triangle E \triangle t$. Thus, in (7) we ascertain that the variation of energy $\triangle E$ which occurs in the time $\triangle t$ is of kinetic nature and corresponds to a mass circulation in a quantum vortex.

Vacuum fluctuations may therefore be vortices which manifest in the SQS. The so-called quantum foam of virtual particle-antiparticle pairs does not correspond to the scalar field itself but to a manifestation of the underlying fundamental scalar field (dark energy), that is to its continuous hydrodynamic fluctuation. Since vacuum fluctuations consist in particle-antiparticle pairs, we have to consider two symmetrical vortices which destroy each other when they come in contact in the way their circulations are not mechanically mutual (circulation of opposite sense). Also the phenomenon of annihilation would therefore occur on the basis of quantum hydrodynamics.

2 The engine of quantum gravity: spin, pressure and non-zero viscosity of SQS.

No superfluid has a real zero viscosity. Non-zero viscosity of SQS, along with Bernoulli pressure, would cause the attraction of the space's quanta surrounding the vortices into the vortices themselves and this would reflect onto macroscopic bodies (Fig. 3) which are constituted of vortex-particles. The result is a force gradient around the vortex which obeys the inverse-square law. Thus, we proclaim that quantum gravity can be described without resorting to gravitons, where space's quanta (dark energy quanta?) are the passive carriers of gravity, which occurs around massive particles as an apparent force mediated by a negative pressure gradient, due to quanta absorption. CFD simulations using Navier-Stokes equations have been performed (considering for simplification a newtonian fluid like water), with a positive result, and details are collected in the annex. We see in the simulation that a spherical geometry of the attracting object would exactly correspond to Gauss's law for gravity, which is directly connected with Newton's law of universal gravitation. Below (§3) we suggest a horn-torus-vortex geometry, which seems able to justify fermions' spin-$\frac{1}{2}$ and the link gravity-electromagnetism. Also Consoli and Pappalardo investigated the possibility that gravity can emerge from a superfluid vacuum [15].

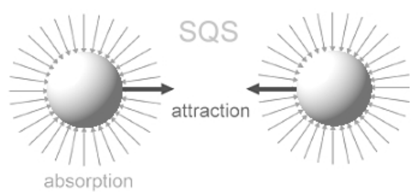


Figure 3: Two spherical macroscopic bodies move the one toward the other since they're absorbing the fluid (SQS) which they're immersed in. This phenomenon is in direct agreement with Gauss's law for gravity: $\oiint_{\partial V} \mathbf{g} \cdot d\mathbf{A} = -4\pi GM$ and has been proven through CFD simulations. The result is an apparent attractive force due a pressure gradient (Fig. 6) that we interprete as gravity.

Navier-Stokes equations representing mass, momentum and energy have been used:

$$\frac{\partial(u_j)}{\partial x_j} = 0 \tag{9}$$

$$\frac{\partial(u_i u_j)}{\partial x_j} = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} + \frac{\mu}{\rho}\frac{\partial}{\partial x_j}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) \tag{10}$$

$$\frac{\partial((\rho E + p)u_j)}{\partial x_j} = -k\frac{\partial}{\partial x_j}\left(\frac{\partial T}{\partial x_j}\right) \tag{11}$$

The condition of two stationary spheres immersed in an incompressible fluid was set and the pressure integral of the forces acting on them was calculated. The analysis took into account the response to absorption velocity and to distance between the spheres. To simplify the simulations, the system was reduced as showed in Fig. 12 (annex).

The attractive force produced by pressure forces and momentum is represented by:

$$F_a = \int_A (p + \rho(\vec{u}\cdot\vec{n})(\vec{u}\cdot\vec{d}))d\vec{A}\cdot\vec{d} \tag{12}$$

where A corresponds to the surface of the inner sphere, $\vec{n}$ is the normal unit vector to the sphere's surface (if the absorption velocity is perfectly radially aligned we have $\vec{u}\cdot\vec{n} = |\vec{u}|$), and $\vec{d}$ is the unit vector for the distance between the spheres. The analysis of velocity and pressure, with respect to the distance (radius) from the absorbing sphere is illustrated in Fig. 6 and the diagrams in Fig. 18, 19, 20 and 21 (annex) show an inverse quadratic dependence on distance and a quadratic dependence on the flow velocity.

Refinement of computational grid and domain enlargement helped to reduce the curvature of the flow lines, up to a virtually radial flow (Fig. 17).

The behavior of the attractive force shown by this analysis is concordant with Newton's law of universal gravitation, since the attractive force decreases with distance (radius) according to an inverse square law and quadratically grows according to the velocity of the flux. Two equal absorbing spheres have been considered, corresponding to equal masses in Newton's law.

3 Vortex geometry and emergence of spin and quantum potential.

As far as the most appropriate vortex geometry to hydrodynamically explain the spin is concerned, it is interesting to consider the simple evolution: vortex tube $\rightarrow$ vortex ring $\rightarrow$ horn-torus-shaped vortex (Fig. 4). Also Villois, Krstulovic *et al.* analyze vortex tubes evolving into vortex tori in superfluids [16] and demonstrate the emergence of non-trivial topology. This geometry seems to well account for the spin of fundamental particles. In the case a quantum of superfluid space flowing in the torus vortex needed the same time the vortex needs to complete two turns in the toroidal direction to return in the same position after having completed one turn in the poloidal direction, then the vortex would have spin-$\frac{1}{2}$ (fermion), i.e. the system returns in the same state after a toroidal rotation of 720°, after each quantum forming the vortex has moved along a Möbius-strip path. It is interesting to notice that a two-components spin can explain in mechanical terms any other type of spin as the ratio of the number of toroidal rotations to poloidal rotations. Putting ω_1, ω_2 as the angular velocities for the respectively considered directions, the spin angular momentum would be determined by the ratio

$$\frac{\omega_1}{\omega_2} = \frac{n}{2} = S \tag{13}$$

so, one rotation in the poloidal direction each two in the toroidal direction corresponds to spin $1/2$ (fermions).

The case of spin 0 may be determined by further evolution of the horn torus into a spheroidal vortex or correspond to simple, rotating clumps of SQ (or to spinning phonons §4.5). The suggested geometry could be able to account for the main mechanism suggested in this work, *i.e.* the attraction of SQ (gravity), due to Bernoulli pressure, and the consequent emission of virtual photons, which accounts for Coulomb's force and is necessary to maintain energy balance in spite of the absorption. The peculiar geometry of the toroidal vortex would then account for the charge of the particle: neutral if the vortex is a ring torus, as there cannot be genesis of virtual photons and charged in the case of a horn torus.

The theoretical mainstream describes the electrostatic field of charged fermions as the emission and reabsorption of virtual photons. In the hypothesis of gravity as absorption of SQ occurring in fermions (§2) we have first absorption and a subsequent emission to maintain energy balance. If we then hypothesize the emission of virtual photons as discrete packets of compressed SQ (Fig.4 right, red arrow) we would start seeing how gravity can be related to electromagnetism. Unlike normal photons, virtual photons can have a mass, since they're packets of SQ not simple pulses [4]. The strenght of their momentum is for instance evident when trying to bring together two magnets that repel each other. Therefore, the vortex geometry (horn torus or ring torus) would be the deciding factor for having respectively a charged or a neutral particle.

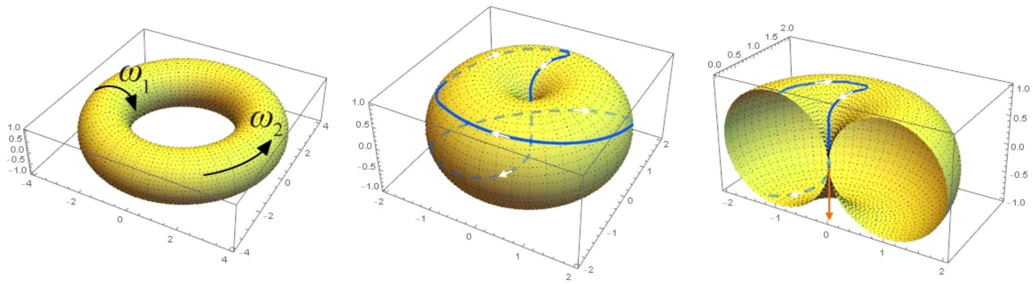


Figure 4: evolution of a vortex tube into a horn torus vortex. This might justify the compression of the quanta of the SQS into virtual photons (red arrow, on the right) within the absorption-emission mechanism. In the center, the possible mechanism corresponding to spin$\frac{1}{2}$, where the system returns in the same state after a toroidal rotation of 720° and a poloidal rotation of 360°, after each quantum has flowed along a Möbius-strip path. Such two-components model (ω_1, ω_2) may quantum mechanically explain any other kind of spin as the ratio between the two rotations.

Since the vortex

1. is a closed path with constant strenght along its filaments.
2. may be triggered by the perturbation (clumps of space's quanta $\Rightarrow$ dark matter?) of the flows occurring in the SQS, as for instance gravitational flows or flows produced by the motion of other bodies

all three Helmholtz's theorems are respected.

A continuity equation for the vortex has in our case to account for an equilibrium between absorbed and emitted quanta (emitted virtual photons), which occurs through a quick sawtooth energy oscillation of the vortex-particle (Fig.5), which reads

$$m_{eff(t)} = (t - \lfloor t \rfloor) k_a + m_0, \tag{14}$$

where $m_{eff(t)}$ is the time-depending effective mass of the particle, which would rapidly oscillate between two values $(m_{0,} m_{max})$, and k_a is a costant of mass-energy absorption expressed in kg/s, whose value is $k_a = m_{\gamma_\varsigma}/t_{emission}$, *i.e.* the ratio between the mass of a virtual photon and the necessary time to emit it from the vortex. The proper mass of a charged fermion would therefore minimally oscillate and this fact would agree with the indeterminacy of quantum mechanics. The oscillatory behavior of superfluid vortices shown in Fig.5, might also account for the phenomenon of *Zitterbewegung* (trembling motion), as an interaction of the particle with the zero-point field of quantum vacuum.

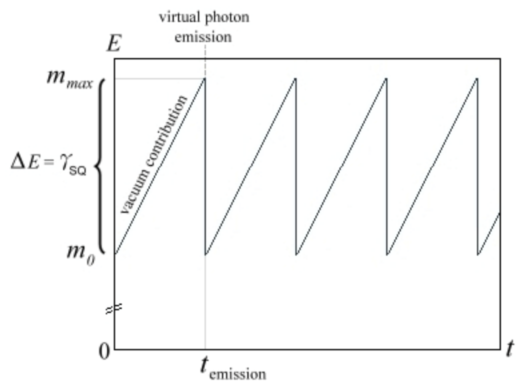


Figure 5: sawtooth electro-gravitational oscillator for a charged particle expressing its rest mass variation while producing gravitational pull and electrostatic field. Vacuum contribution corresponds to the absorption of SQ in the vortex.

It may be inferred that if no emission of virtual photons occurs (charge neutrality) a particle would be compelled to decay, because of the increase of its internal energy due to absorption of SQ. But this only has to occur in unbound neutral particles, i.e. where no exchange of SQ with adjacent vortices occurs. We indeed observe decay in unbound neutral particles such as isolated neutrons, whose mean lifetime is 881 s. A prediction of this theory would be a greater mass of isolated neutrons before they decay, if compared with the mass of bound neutrons in a nucleus and, for instance, also that of a faster decay of neutral pions (indeed $8.4 \cdot 10^{-17}$s) if compared with charged pions ($2.6 \cdot 10^{-8}$s), as it actually occurs. Different is the case of the neutrino. Since it is a neutral particle, a ring-torus vortex geometry would be suggested but this is incompatible with the fact neutrinos are stable, albeit some studies suggest it can decay [38]. A simple explanation to this apparent violation is that a neutrino possesses a horn-torus geometry but its mass is too small to pack SQ into virtual photons, so they are directionally re-emitted as smaller, trivial amounts or single quanta. Thus, we assume that a neutrino is the smallest possible horn-torus vortex and its mass, as for every other mass-endowed particle, arises from the SQ circulating in its superfluid structure.

To justify spin as vortex geometry, we also cite Recami, Salesi, Esposito and Bogan, who underline how the internal kinetic energy of a particle associated with spin can be identified as the quantum potential of Bohmian mechanics.

Recami and Salesi [17] reflect on the fact that fermions' spin can be the source of quantum potential. Salvatore Esposito [18], citing Recami and Salesi, defines two velocity fields related to a quantum particle, one external, $\vec{v}_B = \frac{1}{m}\nabla S$, with S as the phase of the function ψ of the Schrödinger equation ($i\frac{\partial\psi}{\partial t} = \psi H$), and $\vec{v}_S = \frac{1}{2m}\frac{1}{\rho}\nabla\rho = \frac{1}{2m}\frac{\nabla R^2}{R^2}$ as the internal velocity, with $\hbar = 1$. Since we can know the external initial conditions but not the initial conditions of internal motion, and since quantum mechanics is based on a probabilistic formulation which comes into play exactly when we deal with incognizable parameters, he asserts that the quantum potential of the particle is totally determined by its internal motion $\vec{v}_S \times \vec{s}$, where $\vec{s}$ is the direction of spin. From [18] we have

$$Q = -\frac{1}{2} m \vec{v}_S^2 - \frac{1}{2} \nabla \cdot \vec{v}_S \tag{15}$$

and we see here that the quantum potential of a fermion may be determined by the rotation itself of the vortex. Also Bogan [19], citing Esposito, indicates the internal kinetic energy of a fermion as the spin itself (15). Spin alone would not be however sufficient to justify the absorption mechanism, thus the non-zero, positive viscosity of the medium in which the vortex takes shape and the mechanism of Bernoulli pressure are fundamental. The main output of the absorption mechanism is a pressure gradient around the vortex-particles. Because of the SQ absorbed into the vortex, pressure decreases around a massive object and this generates a velocity field pointing toward the equipotential surface of lowest pressure. This flow is the gravitational field.

Indeed, we see (Fig.6) from the performed CFD simulations, that gravity is an apparent force mediated by a pressure gradient in the SQS, produced by the absorption process. On the left we have a velocity potential, causally linked to a pressure potential (right). Since we are talking about pressure in SQS, also a quantum potential is part of the play.

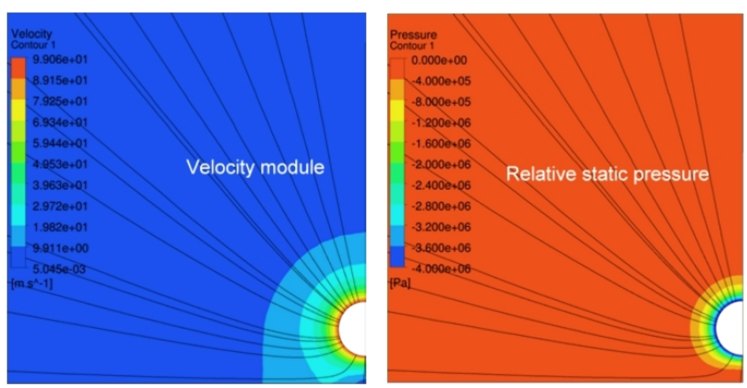


Figure 6: absorption velocity and pressure gradient from the performed CFD simulations.

By substituting the known hydrodynamic acceleration due to the pressure gradient, $\vec{a} = -\vec{\nabla}(P/\rho)$, into Newton's second law we have

$$\vec{F}_q = -m\vec{\nabla}\frac{P}{\rho} = -\vec{\nabla}Q \tag{16}$$

as the quantum force related to the pressure/density ratio, P/ρ, which replaces the classical gravitational potential V. This formula (16) may therefore correspond to that of quantum gravity. Indeed, $-\vec{\nabla}\frac{P}{\rho} = \mathbf{g}$ expresses the gravitational acceleration. We can therefore reflect on the following relations (cascading gradients occurring in SQS and involved in quantum gravity):

$$-\nabla P \Rightarrow -\nabla\phi,\ g = -\nabla V = -\nabla\frac{P}{\rho} \Rightarrow F_q = -\nabla Q. \tag{17}$$

where ϕ is the velocity field or velocity potential (Fig. 6 left), P is the local pressure in the SQS, F_q the corresponding quantum force, Q the quantum potential, g the gravitational acceleration and V the classical gravitational potential. With a different reasoning, also Volovik [20] discusses osmotic relationships between pressure of the superfluid vacuum and pressure in matter.

3.1 Dark energy repulsive action as internal pressure of SQS.

We assume that the SQS is a quantum superfluid, whose internal pressure may act as a repulsive force in the universe, having a role in its expansion. Or in simply balancing the action of gravity. This would be the effect of what we call *dark energy.* We agree with Huang [21] who states that dark energy is the energy density of the cosmic superfluid, and dark matter arises from local fluctuations of the superfluid density. In points of space where gravitational fields are irrelevant, SQS internal pressure shifts toward its maximal value. On the contrary, within a gravitational field, pressure decreases because of the absorption of SQ and may assume negative values. In this case the quantum force acts in the direction of the center of the massive body, causing the reciprocal attraction (⇒gravity) of the bodies which are immersed in the SQS.

In Fig. 7 we see the relationships (not in scale) among the four gradients involved in fluid quantum gravity and in the fact that the universe expands or be static. At the axis origin we have to image a test mass. As a simplification the spherical gradients are depicted as 2D Gaussians. The velocity field and the gravitational potential decrease with distance from the central massive body, while pressure potential increases toward the value of SQS internal (repulsive) pressure at infinity. If we consider the internal pressure, we see in the figure that also the quantum potential, which is proportional to pressure, increases with distance and becomes negative (⇒attraction) by approaching the mass.

Where the curve of the quantum potential intersects the x-axis (points Λ, Λ' in Fig. 7) the total quantum force acting on a body at that distance from the mass centered at the axis origin is zero, similarly to a Lagrange point. Here the gravitational quantum force is balanced by the quantum force of SQS internal pressure and a lighter body would be stationary with respect to the considered massive particle. Outward past the lambda boundary (Fig. 7 right) the repulsive force of dark energy (⇒ SQS internal pressure) becomes dominant.

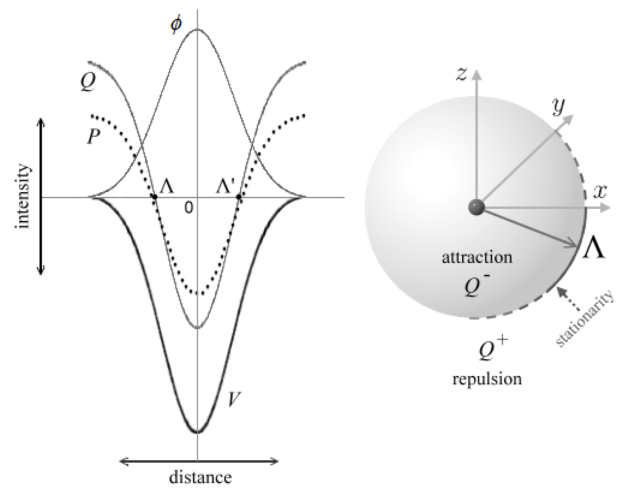


Figure 7: with a test mass centered at the axis origin, the four Gaussians (not in scale with respect to each other) represent in 2D, in causal order: the spherical gradient of absorption velocity (ϕ), of pressure (P), the quantum potential (Q) and the gravitational potential (V). Intrinsic pressure and repulsive quantum potential (which are proportional) reach their maximal values with distance at infinity. On the right, the spherical surface of equilibrium between the two opposite potentials (Q^-, Q^+) attractive and repulsive, analogous to the concept of Lagrange point.

4 Superfluid quantum gravity in general relativity.

We immediately notice that a sphere absorbing the fluid in which it is immersed generates a radial attraction field (as that generated by a vortex-particle in our hypothesis) equal to the Schwarzschild solution,

$$ds^2 = \left(1 - \frac{2Gm}{c^2 r}\right)^{-1} dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2) - c^2\left(1 - \frac{2Gm}{c^2 r}\right) dt^2 \quad (18)$$

suggesting that the metric tensor of GR may be expressed through fluid dynamic forces. Superfluid quantum space whose hydrodynamics produces time (Planck time as the time a quantized vortex needs to complete a rotation) and influences clocks through gravity, the latter described as a fluid phenomenon itself, instead of deformable geometric space-time (Fig. 8, 9, 10).

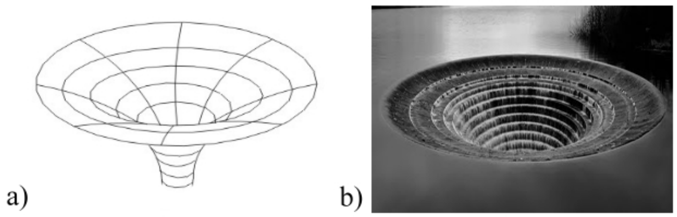


Figure 8: how the presence of a massive body curves spacetime (a) or absorbs fluid quantum space (b), here in analogy with a bell-mouth spillway.

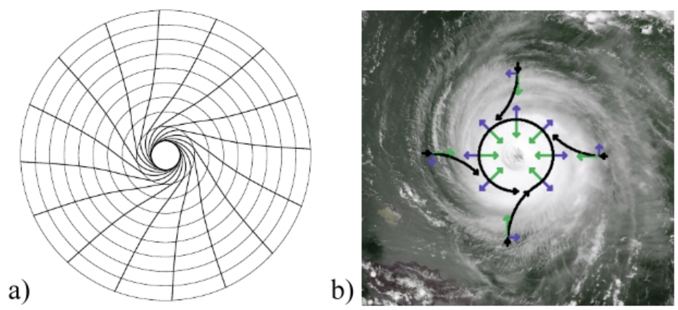


Figure 9: the Lense-Thirring effect according to Einstein's curved spacetime (a) and to fluid dynamics (b). Here as an analogy with the Coriolis effect in a cyclone.

Fig. 9 describes the strong hydrodynamic analogy with a cyclone (⇒Coriolis effect), where the gravitomagnetic field related to the Lense-Thirring effect is expressed as

$$B = -\frac{4}{5}\frac{m\omega R^2}{r^3}\cos\theta \tag{19}$$

and the Coriolis force can be written as:

$$F_C = -2m\omega(\omega R)\mathbf{u}_R. \tag{20}$$

where the difference between a 3D (gravitomagnetic field) and a 2D (Coriolis) model has to be however considered.

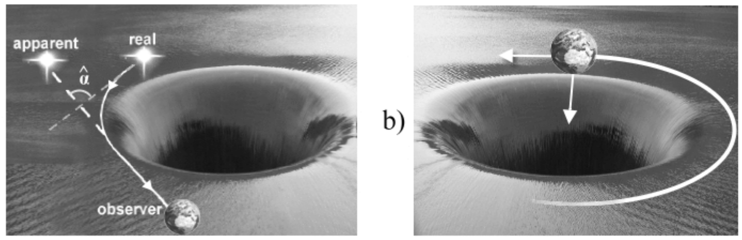


Figure 10: Gravitational lensing (a) and the motion of a satellite (b) according to SQS, still in analogy with a bell-mouth spillway representing the gravity of a star which curves space (in our case, which absorbs SQS).

Other effects which can be described by the hydrodynamics of SQS are the gravitational lensing:

$$\vec{\hat{\alpha}}(\vec{\xi}) = \frac{4G}{c^2} \int d^2\xi' \int dz \rho(\vec{\xi}', z) \frac{\vec{b}}{|\vec{b}|^2} \tag{21}$$

with $b \equiv \vec{\xi} - \vec{\xi}'$, where ξ, z are coordinates and $\vec{\hat{\alpha}}$ is the deflection angle, which in Fig. 10.a is determined by vector interaction between light's and space quanta's momenta (gravitational flow), and their absorption is illustrated as water flowing into a spillway (acting here as an interposed star).

While in Fig. 10.b SQS's hydrodynamics describes orbital motion, since the angular velocity for any inverse square law, such as Gauss's law for gravity and (12), is given as

$$u(\theta) = \frac{\mu}{h^2} - A\cos(\theta - \theta_0) \tag{22}$$

where A and θ_0 are arbitrary constants, h the angular momentum and μ the standard gravitational parameter.

All this suggests that the found solutions to Einstein's field equations could be fully replaced by hydrodynamic solutions based on modified quantum Navier Stokes equations. Einstein's spacetime as a single interwoven continuum is here described by the interdependence space↔time, since time would arise from the hydrodynamics of the SQS and, also in our case, it wouldn't be absolute but influenced by gravity, which in our framework is *per se* a superfluid phenomenon.

4.1 The Michelson-Morley test: does the ether wind correspond to the gravitational field?

When look at gravity as the absorption of SQ (§2), a gravitational field corresponds then to a flow of SQ moving toward the center of the absorbing mass. This fact motivates us to reconsider what the Michelson-Morley experiment [22] has actually demonstrated and to conclude that:

- the MM-test has only demonstrated the non-existence of relative motion Earth-ether but not the absolute non-existence of an ether, if we assume, within the hypothesis of superfluid quantum gravity, that the ether wind corresponds to the gravitational field.

In this case the ether wind wouldn't be dependent on Earth's orbital motion. Moreover the rotation of a celestial body about its axis could hydrodynamically cause the Lense-Thirring effect by bending the incoming ether wind (Fig.9), *i.e.* by bending the gravitational field. Another effect caused by such a kind of (radial) ether wind would be the gravitational lensing (Fig.10). These are several hints matching the predictions of general relativity which therefore suggest to proceed with the hypothesis of a superfluid space and of quantum gravity as absorption of SQ into vortex-particles. The consequences of a liquid space as far as the propagation of light is concerned are likewise interesting and have been better discussed in [4], suggesting the analogy photon = spinning phonon through the SQS.

In the MM-experiment the ether wind would have therefore been investigated in an erroneous way. A test by M.Grusenick using a differently oriented Michelson interferometer seems to have detected a radial ether wind [37].

Furthermore, the existence of a fluid medium would compel us to reconsider the meaning of Hubble's law [4, 40], since the fact that the redshift is greater for more distant galaxies could simply mean that light loses energy by traveling through the SQS because of its non-zero viscosity and that we are observing a sort of tired light, though different from the phenomenon hypothesized by Zwicky. In this case the universe would not be accelerating its expansion and probably it would be not even expanding, freeing us from the necessity of producing and explaining several paradoxes of modern cosmology, such as the cosmic inflation and the accelerated expansion.

4.2 Gravitational waves as periodic pressure variations propagating through a SQS.

Gravitational waves may be defined as a periodic (negative) pressure waves in the SQS caused by the variable position of a quadrupole in time and therefore corresponding to a variable pace in the absorption of SQ. In this case gravitational waves arise as negative pulses propagating through SQS and not as space-time deformations. Since, as said, we think that also photons can be described as pulses (phonons) through the SQS (see §4.5) it is obvious that gravitational waves travel at the speed of light. And, not surprisingly, also photons, as positive pulses that carry energy (like sound does), can provide kinetic energy to a target (radiation pressure), exactly as for gravitational waves acting on LIGO's test masses, where the pressure is in this case negative. Again, it would be a hydrodynamic quantum phenomenon and no deformation of a geometric spacetime would be necessary to explain gravitational waves.

The changing pace in the absorption of space's quanta, occurring twice the orbital frequency, causes periodic decompressions in SQS, currently interpreted as a deformation of space-time. Also in this case the quantum potential arises from pressure variations. Quantum-like gravity waves but in a classical fluid have been investigated by Nottale [27].

Simplifying the theory of relativity. Special relativity according to a superfluid quantum space: gravity as the sole cause of all relativistic effects.

4.3 Fluid principle of equivalence: is relativistic mass increase rather a matter of *drag weight?*

Because of the presence of SQS and according to the mechanism of superfluid quantum gravity, also translational motion would put a moving body in the condition of being subject to a gravitational field, as an apparent flow, which in this case acts in the opposite direction to motion. We could call it *drag weight.* We can express that as a fluid equivalence principle (FEP) (Fig. 11).

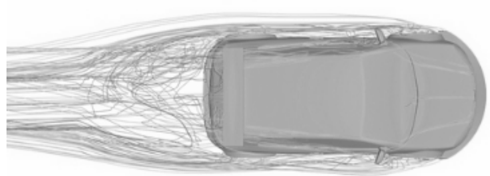


Figure 11: Fluid equivalence principle: it is impossible to distinguish between the two equivalent situations of a body moving at a given velocity through a stationary fluid and a fluid flowing toward a stationary body at the same velocity. This would also occur as far as a body interacting with the SQS is concerned, where the equivalence is between being stationary in a gravitational field (being subject to an ether wind having a given velocity in a given point of the field) or moving through the SQS at the same velocity, *i.e.* being subject to a gravitational field induced by motion which increases according to Lorentz factor.

Which obtains as:

$$\mathbf{v}_\Phi = \mathbf{v}_{sq} + \mathbf{v} \tag{23}$$

where $\mathbf{v}_\Phi$ is the velocity of the total resultant flow acting on the moving body, determined by the vector sum of the velocity at which SQ are absorbed ($\mathbf{v}_{sq}$, drift velocity of SQ) in the point of the gravitational field where the body is located at a given instant and of the body's translational velocity ($\mathbf{v}$) through the fluid space. According to the FEP, any translational velocity therefore provokes an apparent gravitational field (g_Φ) acting on the accelerated body and detected as a weight force opposite to motion (drag weight,$\mathbf{W}_\Phi$), Fig.12. Other cases of quantum vacuum friction have been discussed by several authors [23, 24, 28] and also Higgs field is said to possess a certain viscosity: potential relationships between these fields, or a possible correspondence, should be then investigated.

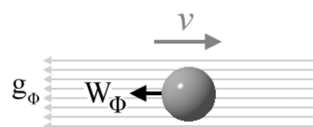


Figure 12: Weight acting in the opposite direction to motion (drag weight, $\mathbf{W}_\Phi$) due to the apparent gravitational field caused by motion through SQS. At low, everyday speeds this effect wouldn't be noticed, since SQS's viscosity is quasi-zero, as for any superfluid, but the effect of apparent viscosity would play a key role at relativistic velocities (extreme shear stress), increasingly opposing acceleration.

This is in agreement with the relativistic effect of mass increase, which would actually be a resistance to acceleration due to an increasing gravitational force acting in the opposite direction to motion. This issue is clear if we suppose that, when dealing with accelerated particles in synchrotrons, we make a dimensional mistake, swapping kgf with kg, *i.e.* interpreting a weight force ($\mathbf{W}_\Phi$) pointing in the opposite direction to the supplied acceleration as a mass increase (red color in Eq. 24 expresses the hypothesized misconstruction of current physics). If drag weight grew according to Lorentz factor (§4.5.1), (35), it could be the cause of the so-called relativistic mass increase:

$$a = \frac{F}{m + W_\Phi}. \tag{24}$$

The new equation expressing the total weight of a body in fluid quantum gravity would be:

$$\mathbf{W}_{\text{tot}} = m(\mathbf{g} + \mathbf{g}_{\mathbf{\Phi}}) \tag{25}$$

where the accelerations g and g_Φ may point in different directions, according to the presence of a gravitational field and/or translational motion.

It is possible to proof the FEP in Einstein's relativity by equating the cause of time dilation in special relativity (velocity) to that in general relativity (gravity):

$$\Delta t' = \frac{\Delta t}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{\Delta t}{\sqrt{1 - \frac{R_S}{r}}} \tag{26}$$

hence

$$\frac{v^2}{c^2} = \frac{R_S}{r} = \frac{2GM}{c^2 r} \Longrightarrow v^2 = \frac{2GM}{r} \tag{27}$$

and

$$v = \sqrt{2rg} = \sqrt{2\Phi}, \tag{28}$$

where (28) relates velocity and gravity (as gravitational potential Φ) in the formula of the second cosmic velocity, also meaning that a given velocity in SR corresponds to a certain gravity (drag weight), equivalent to that of a gravitational field g in a point where the absorption of SQ occurs at the same velocity. Fig. 13 indeed shows how a gravitational field corresponds to an absorption velocity field (velocity potential) analogous to that of Fig. 6 from the CFD simulations (absorption of SQ $\Rightarrow$ sink at the origin) and, on the right, the equivalence between translational velocity and absorption velocity of a gravitational field, which explains the relativistic phenomenon of illusory mass increase as drag weight (24) and unifies the cause of time dilation of SR and GR (gravity in both cases).

- *All* relativistic effects could be therefore explained *through the sole action of gravity*, described as a hydrodynamic force occurring in SQS. Besides what described in Fig. 8, 9, 10, also mass increase (or better, what would be the current interpretation of drag weight), time dilation and consequently Lorentz-Fitzgerald contraction, which depends on time dilation and does not need to be discussed. What is *relative* in superfluid quantum relativity is SQ's velocity ($\mathbf{v}_\Phi$) with respect to a frame of reference: it produces or varies the gravitational force acting in the frame, also modifying time, as discussed below.

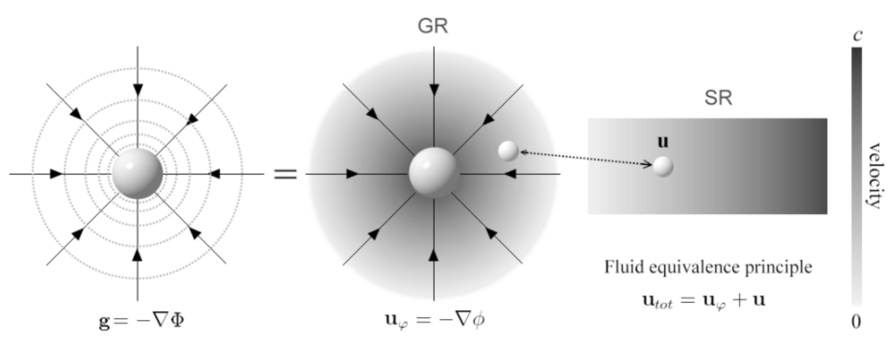


Figure 13: equivalence of a gravitational field (left) and a velocity field (center), where the latter corresponds to the absorption velocity (v_{sq}). In both cases we have sink at the origin and equipotential surfaces. On the right, a given translational velocity (SR) through SQS corresponds to being in a point of a gravitational field (GR) where space's quanta are absorbed at the same velocity.

4.4 Time dilation and length contraction in superfluid relativity.

Absolute time cannot exist. Indeed, according to which clock would it exist if any clock (also atomic, biological etc.) functions in a precise environment, where different parameters (e.g. temperature) and forces (such as gravity) act on it? Time exists in physics if a clock in a reference system can measure it and different measurements produce different time scales. Absolute time may perhaps exist in philosophy or in religion but that's a different story. Also in our superfluid approach to nature, gravity exists and acts onto clocks. As every physicist knows, the right locution should not be "time dilation" but "clocks retardation". Since we will replace Einstein's curved space-time with the hydrodynamics of SDE, this approach only considers a "flat" universe (according to observations) in which pressure forces (Fig. 6, 8-10) mime the effects of a curved space-time and can account for all relativistic effects of GR. But also locally, space-time is flat. We can say that the superfluid universe is Minkowskian.

The reason why time dilation occurs also in our approach is the increasingly viscous environment in which clocks, considered in their (quantum) mechanical dynamics, have to work by approaching the speed of sound in the SQS (Fig. 15). Not by chance then, clocks retardation follows the same curve of apparent viscosity that we can see in that figure. As a simple metaphore we could imagine an athlete who has to run through a more and more viscous medium. Thus, no wonder if up on a certain point gravity is also able to stop the clock. The reason why also gravity, besides velocity (which, as seen, provokes apparent viscosity), cause in GR clock retardation is clearly explained in the fluid equivalence principle (23).

According to the mainstream, Lorentz-Fitzgerald contraction (relativistic length contraction) depends on time dilation and consequently on gravity. This effect therefore exists in this superfluid approach too. It affects *measurements* taken in two different frames of reference which are in relative motion, when compared. Let us observe Fig. 14.

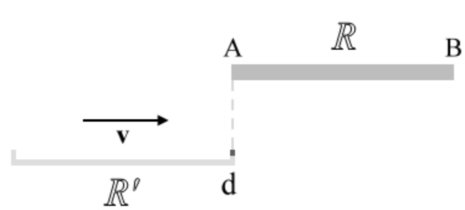


Figure 14: Relativistic length contraction. According to an inertial frame of reference ($\mathbb{R}$), the length $\overline{\mathrm{AB}}$ measured in the frame $\mathbb{R}'$ is shorter, since it is measured as $\ell = \overline{\mathrm{AB}} = v(t' - t)$ but being clocks retarded by motion (by the apparent viscosity of dark energy, for which Lorentz factor applies, $\ell = v\left(\Delta t/\sqrt{1-(v/c)^2}\right)$) the$\Delta t$ will be different in the two frames, as well as the measured length. The letter d refers to a detector (e.g. a photocell) which registers the instants (t, t') in which it is aligned with A and B.

Be $\mathbb{R}$ an inertial frame of reference and $\mathbb{R}'$ a frame moving with velocity v. It is a relative velocity, since according to $\mathbb{R}'$it is the other frame to travel at that velocity. The length $\ell = \overline{\mathrm{AB}}$ is measured in both frames by the formula

$$\ell = v\Delta t \tag{29}$$

being $\Delta t = t' - t$ the difference between the instant in which the detector d is aligned with B and that in which it is aligned with A. We know that, since motion always occurs through dark energy, Lorentz factor actually affects (29), so we have to write

$$\ell = v\frac{\Delta t}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{30}$$

Since $\mathbb{R}$ does not move through dark energy (30) becomes (29), thus we have

$$\Delta t(\mathbb{R}) > \Delta t(\mathbb{R}') \implies \ell_{\mathbb{R}} > \ell_{\mathbb{R}'} \tag{31}$$

Clocks tick slower in $\mathbb{R}'$ then Δt is shorter in that frame, as well as the measured length.

There is often a mistaken belief about the relativistic phenomenon of length contraction. Indeed, as demonstrated above, no actual shortening occurs, only measurements are affected due to time dilation. Also the extended mean life of cosmic muons is therefore due to clocks retardation. To conclude, special relativity holds also in the superfluid approach, which moreover explains why no physical body in the universe can exceed the speed of light (Fig. 15).

4.5 Photon as a phonon through a superfluid quantum space.

If space is (filled with a) superfluid then light has to propagate through it. We hypothesize here that photons are pulses through the SQS, i.e. that a photon is actually a special spin-1 phonon propagating through the SQS, we could say through dark energy. Let us remember that the basis assumption of the Michelson-Morley experiment, which affirms that light propagates without a medium, changes when we consider quantum vacuum (quantum field theory) and the mechanism suggested for superfluid quantum gravity, according to which the ether wind is radial and coincides with the gravitational field. Thus, once established that the MM-experiment has not actually (i.e. if we consider a radial incoming ether wind) disproved the existence of a luminiferous ether and since we think light propagates in a superfluid universe, full of dark energy, we see that light could be nothing more than "the sound of dark energy" and c the speed of sound thorough dark energy. A sound that we perceive through our eyes. "*Wie? Hör' ich das Licht?*", wondered Tristan[2]. Waves existing in nature would reduce to only one type (medium-dependent) and photon electromagnetic field could be interpreted as a periodic excitation of dark energy's quanta, producing a

[2]"*What? Is it the light I hear?*", R.Wagner, Tristan und Isolde, Act 3, Scene 2.

transversal wave due to spin [29, 30] and dark energy dilatancy (Fig. 15), in agreement with Stokes' theory of light propagation.

Let us then consider the formula indicating the speed of a mechanical wave through a fluid, $a = \sqrt{\frac{K}{\rho}}$, in which K is the bulk modulus, referring in our case to dark energy compressibility. By putting $\beta_S = \frac{1}{K}$ as isentropic compressibility, we see

$$a = \frac{1}{\sqrt{\beta_S \rho}} \tag{32}$$

If we consider $\beta_S = \beta_d$ as dark energy's isentropic compressibility, ρ_d as its density, c as the speed of sound in dark energy and we equate $\beta_d \rho_d = \epsilon_0 \mu_0$, we get

$$c = \frac{1}{\sqrt{\beta_d \rho_d}} \tag{33}$$

expressing the speed of a photon as that of a phonon through superfluid dark energy (through the SQS), mathematically analogous to $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$, as resulting from Maxwell's equations. Maxwell himself derived the expressions for the dielectric constant (ε_0) and the magnetic permeability (μ_0) of "vacuum" in terms of transverse elasticity and density of the ether. We now say of dark energy.

We also have to observe light propagation as a phenomenon of second sound through dark energy, as in superfluids energy is dissipated as heat at small scales by phonon radiation [39] and we know that bodies radiate heat through the emission of photons (e.g. infrared light). After all, we know that both photons and phonons

- are bosons [31]
- have wave-particle duality [32, 33]
- obey the doppler effect $z = \frac{f_{emit} - f_{obs}}{f_{obs}}$
- are symmetric under exchange,$|\alpha, \beta\rangle = |\beta, \alpha\rangle$
- can be created by repeatedly applying the creation operator, $b^\dagger$
- share the same momentum, where that of the phonon is $p_{ph} \equiv \hbar k = \frac{h}{\lambda}$,with $k = \frac{2\pi}{\lambda}$. Hence the parallelism: radiation pressure $\Leftrightarrow$sound pressure.
- can produce photoelectric effect and Compton scattering thanks to their momentum
- can possess spin [29, 30]
- can form squeezed coherent states [34]
- can interact via parametric down conversion.

Both for photons and phonons, $\frac{1}{2}\hbar\omega$ is vacuum's (we say dark energy's) contribution, where the harmonic oscillator eigenvalues for the mode ω_k (k is the wave number) are:

$$E_n = \left(n + \frac{1}{2}\right)\hbar\omega_k \quad n = 1, 2, 3, ... \tag{34}$$

To confirm a "false vacuum" we see in (34) that also for $n = 0$ the energy is not zero. This means that what we think to be the vacuum actually contains energy and according to $E = mc^2$ energy implies a certain mass density. There is a medium throughout the universe owning density $\rho \neq 0$ which light propagates through. In other words and according to quantum physics, light *does not* propagate in the vacuum.

It is also important to point out that light is a transverse wave and transverse sound waves usually propagate in solids, not in fluids. However, the quantum (granular) nature of the SQS would confer it a dilatant response under very high shear stress and this recalls Stokes' theory of light propagation, whereby the ether is fluid at lower speeds but becomes rigid at higher frequencies, being then able to support light propagation without interfering with the motion of the celestial bodies. In §4.5.1, we resort to the dilatancy of the SQS under extreme shear stress also to explain Lorentz factor, seen as the rheogram of the SQS (of dark energy), that is to explain the fact that the speed of light is the upper speed limit in the universe.

According to the photon-phonon analogy, we see that the speed of light is not constant in the universe if the background parameters of dark energy, i.e. its density and therefore its compressibility vary.

We cannot directly detect dark energy in the same way we cannot detect any sound until it is emitted by a source. Also, it would be in this case more correct to say that a particle provokes or produces a photon (dark energy phonon) not that it is emitted by the particle. So, to conclude we should reflect on the fact that dark energy (if excited) might be not dark at all.

4.5.1 Reinterpretation of Lorentz factor, mass-energy equivalence and Hubble's law.

If the SQS acted as a non-newtonian, dilatant fluid under extreme shear stress (bodies accelerated through SQS at relativistic velocities), this fact would justify the asymptote at c to translational velocity. Being moreover a dilatant fluid would confirm the granular [35] (quantum) nature of space, or at least of what fills up the physical space, constituting the 69% of the energy in the Universe.

When a photon is a phonon of space's quanta through the SQS, the parameter β in Lorentz factor becomes intelligible as the ratio between the speed of a body and that of sound through the SQS. Let us say the speed of sound through dark energy. It is assumed that the speed of sound is the maximum speed reachable through dilatant fluids. Indeed, the ratio $\left(\frac{v^2}{c^2}\right)$ is expressed as an adimensional parameter analogous to the ratio between the speed of a body and of sound (v_s) through other superfluids [36]: $\left(\frac{v}{v_s}\right)^2 \Longrightarrow \left(\frac{v}{c}\right)^2 \equiv \beta^2$.

- Within SQS, Lorentz factor is then hydrodynamically interpretable as

$$\gamma \equiv \operatorname{arcsin}' \frac{v_\Phi}{v_s} = \frac{1}{\sqrt{1-\left(\frac{v_\Phi}{v_s}\right)^2}} \tag{35}$$

indicating the asymptote at $v_s = c$, where v_s, is the speed of sound through the fluid space and v_Φ (23) is the relative velocity of SQ in a given frame of reference. By approaching $v_\Phi = v_s$ (*i.e.* $v = c$, if in the FEP formula $v_{sq} = 0$), fluid space's dilatancy would play more and more a strategic role in preventing further acceleration.

Valid the analogy photon-phonon, c^2 corresponds then to the square of the sound velocity $c^2 = v_s^2 = \frac{1}{\rho_0 \epsilon_0}$. We note the similarity with $v_s^2 \equiv \frac{1}{\rho_a \kappa}$ in [36].

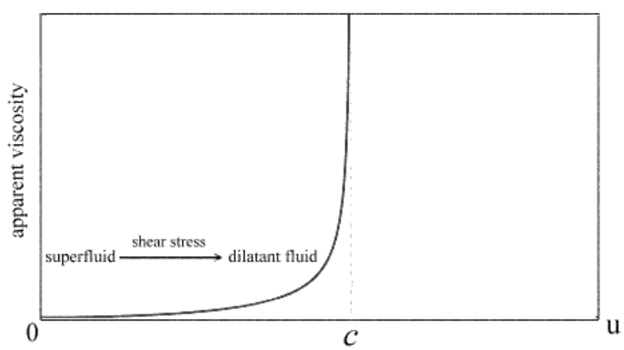


Figure 15: Lorentz factor as the rheogram of the superfluid quantum space (dark energy). Because of its quantum, granular nature, the SQS would behave as a dilatant fluid under extreme shear stress. This implies that the so-called relativistic mass increase is actually the effect of the apparent viscosity (we call it "drag weight"). It is easy to understand that the speed of sound through the dilatant fluid is the maximum speed possible. This would explain the limit to acceleration verified in synchrotrons.

By calculating the speed of light as in (33), we see that the expression $1/c^2$ corresponds to the product of the fundamental parameters of dark energy

$$\frac{1}{c^2} = \beta_d \rho_d \tag{36}$$

so the mass-energy formula $E = mc^2$ becomes

$$E = \frac{m}{D} \tag{37}$$

where $D = \beta_d \rho_d$. We see that dark energy density divides mass, which in our view is indeed a hydrodynamic manifestation of SDE (⇒vortex-particles). In short, the energy of a given mass can be measured in relationship to dark energy density per unit volume and to its compressibility. In other words, Einstein's mass-energy equation would indicate how much energy from SQS is entrapped in a body of mass m, given a specific density and compressibility of the SQS (of dark energy).

Now Lorentz factor can be rewritten in the (still adimensional) form:

$$\gamma \equiv \arcsin' \frac{v_\Phi}{v_{sd}} = \frac{1}{\sqrt{1 - \left(\frac{v_\Phi}{v_{sd}}\right)^2}} = \frac{1}{\sqrt{1 - v_\Phi^2 \beta_d \rho_d}}. \tag{38}$$

where v_Φ expresses the FEP in the considered frame of reference. It means that (38) could be used also in place of $\frac{1}{\sqrt{1-\frac{R_s}{r}}}$ if we knew the velocity of the flow of SQ in a given point of a gravitational field (Fig. 13).

Conclusion

If the single hypothesis of massive particles as vortices of space's quanta in a superfluid quantum vacuum, which obey Gauss's law for gravity (incoming flux ⇒ attraction of space's quanta determining a simple formula for quantum gravity as expressed in (16)) generates a series of consequences which range from describing and simplifying special and general relativity, up to letting us better understand what a fundamental particle can actually be (a quantized vortex, not a dimensionless point) and linking gravity to electromagnetism, it should be then considered for mathematical and experimental in-depth analysis. Furthermore, the hypothesis of SQ attraction into massive particle (thus, also towards the center of the Earth) solves the incompatibility of a fluid space (of an ether) with the outcome of the Michelson-Morley experiment, since an ether wind corresponding to the gravitational field conforms to the known experimental evidences, such as light beams deflection and gravitational redshift. Finally, the description of photons as spinning phonons (spinning since produced by vortices) propagating through a superfluid space would reduce waves which exist in nature to only one type (medium-dependent). Indeed, according to QFT a real vacuum does not exist and the eigenvalue of the harmonic oscillator (for photons and phonons) for $n = 0$ is not zero. We could therefore state that *entia non sunt multiplicanda praeter necessitatem,* as it seems that a superfluid approach may be able to explain nature without extra dimensions, strings, gravitons, cosmic inflation [4] or other *dei ex machina.* Nothing appears to be really fundamental but space's quanta, or better those quanta that fill up the whole space, probably corresponding to that 69% of mass-energy necessary to avoid the gravitational collapse of the universe (expressed by the cosmological constant Λ of Einstein field equations) called dark energy. Space may be full of dark energy quanta, whose hydrodynamics explains special and general relativity and tells us what particles and light are.

References

[1] Milonni P.W., (1994) The Quantum Vacuum. Academic Press, San Diego.

[2] Wheeler J.A., Ford K. (1995), Geons, Black Holes and Quantum Foam. Norton & Co.

[3] Milton K. A., (2001) The Casimir Effect. World Scientific, Singapore.

[4] Fedi M., (2016) A Superfluid Theory of Everything?, hal.archives-ouvertes.fr/hal-01312579

[5] Sbitnev V.I., Hydrodynamics of the physical vacuum: I. Scalar Quantum Sector, Found Phys (2016) 46:606–619

[6] Sbitnev V.I., Hydrodynamics of the physical vacuum: II. Vorticity dynamics, arxiv.org/abs/1603.03069

[7] Volovik G.E., Topology of Quantum Vacuum, arXiv:1111.4627v6

[8] Gomez L.F., Ferguson K.R., Cryan J.P. et al., Shapes and vorticities of superfluid helium nanodroplets, Science, Vol. 345 n. 6199 pp. 906-909

[9] Volovik G. E., The Universe in a helium droplet, Int. Ser. Monogr. Phys. 117 (2003) 1-507.

[10] Pitaevskii L., Stringari S. (2003), Bose-Einstein Condensation., vol. 116. Oxford University Press, USA.

[11] Proment D., Onorato M., Barenghi C.F., Torus quantum vortex knots in the Gross-Pitaevskii model for Bose-Einstein condensates. Journal of Physics, Conference Series 544 (2014) 012022

[12] Pinsker F., Berloff N.G. (2014), Transitions and excitations in a superfluid stream passing small impurities, arXiv:1401.1517v2 [cond-mat.supr-con]

[13] Avdeenkov A. V., Zloshchastiev K. G., Quantum Bose liquids with logarithmic nonlinearity: Self-sustainability and emergence of spatial extent, J. Phys. B: At. Mol. Opt. Phys. 44 (2011) 195303

[14] Boschitsch B., Dewey P., Smits A., The Buddy System. Dept. of mechanical and aerospace engineering, Art of science: 2010 online gallery, Princeton university.

[15] Consoli M., Pappalardo L., Emergent gravity and ether-drift experiments, arXiv:0912.0103

[16] Villois A., Krstulovic G., Proment D., Salman H. (2016), A Vortex Filament Tracking Method for the Gross–Pitaevskii Model of a Superfluid, arXiv:1604.03595v2.

[17] Recami E., Salesi G., Phys. Rev. A57 (1998) 98

[18] Esposito S. (1999), On the Role of Spin in Quantum Mechanics, arXiv:quant-ph/9902019v1

[19] Bogan J., (2002). Spin: the classical to quantum connection. arXiv:quant-ph/0212110

[20] Volovik G.E., Osmotic pressure of matter and vacuum energy, arXiv:0909.1044

[21] Huang K., Dark Energy and Dark Matter in a Superfluid Universe, arXiv:1309.5707

[22] 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

[23] Coelho J.G., Pereira J.P., De Araujo J.C.N. (2016), The influence of quantum vacuum friction on pulsars, arXiv:1604.00430v1

[24] Xiong X.Y., Gao C.Y., Xu R.X., Spindown of Magnetars: Quantum Vacuum Friction?, arXiv:1504.02204

[25] Dupays A., Rizzo C., Bakalov D., Bignami G.F., Quantum Vacuum Friction in Highly Magnetized Neutron Stars, arXiv:0804.1841

[26] Nieto M.M.; Turyshev S.G. (2004). "Finding the Origin of the Pioneer Anomaly". Classical and Quantum Gravity. 21 (17): 4005–4024.

[27] Nottale L., (2009). Quantum-like gravity waves and vortices in a classical fluid, arXiv:0901.1270v1 [physics.gen-ph]

[28] Dupays A., Rizzo C., Bakalov D., Bignami G.F., Quantum Vacuum Friction in Highly Magnetized Neutron Stars, arXiv:0804.1841

[29] 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

[30] Jiang, X.; Liang, B. *et al.* (2014), "Broadband field rotator based on acoustic metamaterials", Appl. Phys. Lett. 104, 083510

[31] Feynman, Richard P. (1982). Statistical Mechanics, A Set of Lectures. Reading, Massachusetts: The Benjamin/Cummings Publishing Company.

[32] Einstein, A. (1909). "Über die Entwicklung unserer Anschauungen über das Wesen und die Konstitution der Strahlung". Physikalische Zeitschrift, 10: 817–825

[33] Saleh, B. E. A. and Teich, M. C. (2007). Fundamentals of Photonics. Wiley

[34] 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.

[35] Eichler, D., Searching for granularity of the vacuum, arXiv:astro-ph/9811020v3 22 Mar 1999

[36] 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)

[37] Grusenick M. (2009), Extended Michelson-Morley interferometer experiment. URL (25.03.2017):
https://www.youtube.com/watch?v=7T0d7o8X2-E

[38] Barger V., Learned J. G., Pakvasa S. and Weiler T. J., Phys. Rev. Lett. **82**, 2640

[39] Vinen W. F. and Niemela J. J., Journal Low Temp. Phys. **128**, 167 (2002).

[40] V.I. Sbitnev, M. Fedi, *Superfluid quantum space and evolution of the universe*. In: Capistrano A., editor. Cosmology. InTech, Rijeka (2017) [to be published soon]

Annex.

Other images and charts from the performed CFD simulations.

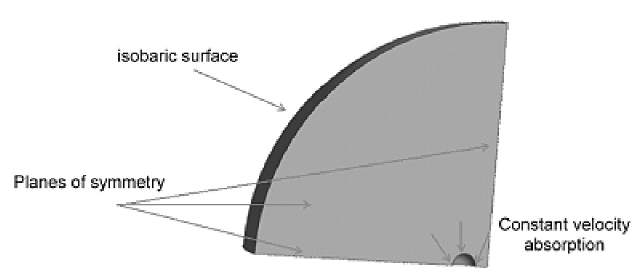


Figure 16: Simulation settings

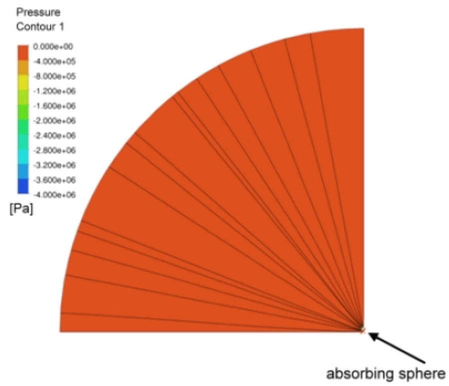


Figure 17: radial flow obtained in the simulations

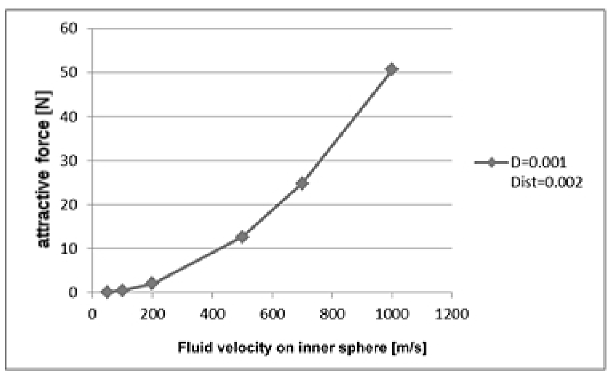


Figure 18: Test for force dependence on absorption velocity: sphere diameter 1mm, distance 2mm. Tested velocities: 50, 100, 200, 500, 700, 1000 m/s. Other tested conditions (50, 100, 200, 500 m/s) are shown in Fig. 6 and 7.

Figure 19:

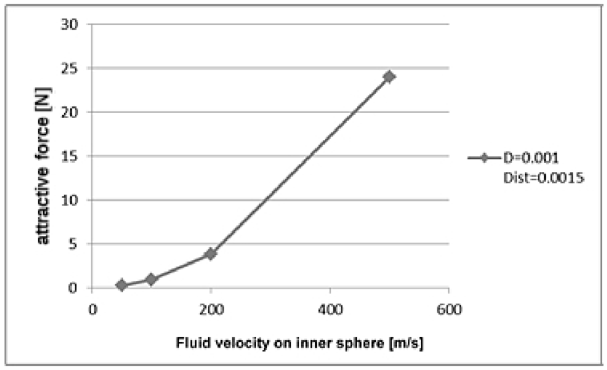
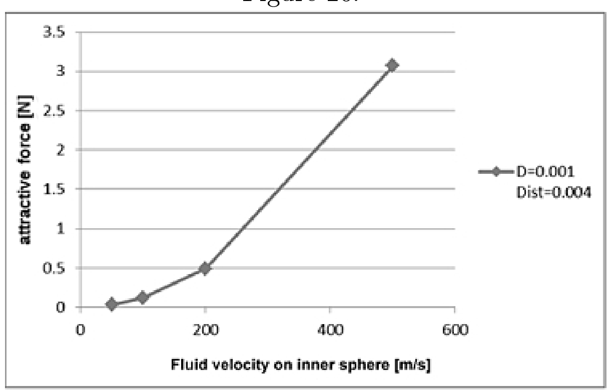


Figure 20:



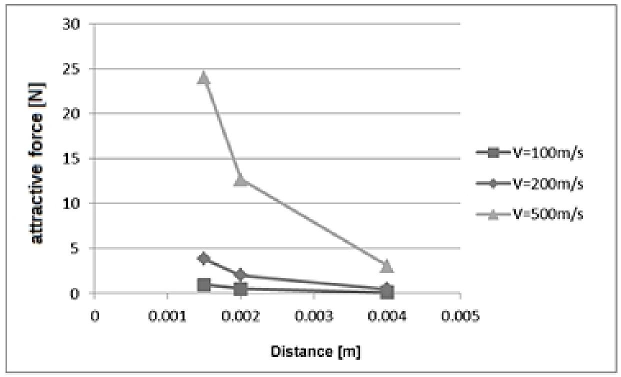


Figure 21: Test for force dependence according to the distance between the spheres.