Quantum gravity without gravitons in a superfluid quantum space.

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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.*[1, 2, 3] We usually believe that quantum vacuum is populated by an enormous amount of particles pairs (*e.g.* couples e^-, e^+) 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 space's quanta (SQ, for which we use the symbol ς), probably arising as perturbations of the SQS through a process similar to that of a Kármán vortex street. Because of superfluidity these vortices can have an indeterminately long life. Vorticity is interpreted as spin and if conflicting they cause destruction of the vortices, justifying matter-antimatter annihilation. SQS would be an ubiquitous superfluid sea of SQ, before being a foam of particles pairs. Due to its non-zero viscosity, these vortices attract the surrounding quanta, pressure decreases and the consequent incoming flow radially directed toward the center of the massive particle let arise a gravitational potential. This is called fluid quantum gravity, whose *passive* quantum is the SQ and the quantum potential is triggered by the spin of any massive particles. We don't need gravitons in this model. We immediately notice that such a fluid model perfectly matches Gauss's law for gravity and this has been indeed proven through CFD simulations. Once comparing fluid quantum gravity with general relativity, it is evident how a hydrodynamic gravity can fully account for the relativistic effects due to spacetime distortion, where the space curvature is substituted by flows of space's quanta in the SQS.

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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 is a fundamental scalar field with quasi-zero 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 0-spin vortex of SQ (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-4 nanodroplets [8, 9]. It may be interesting to start from the analysis of vortices in Bose-Einstein condensates, for which the most simple model is the Gross-Pitaevskii equation [10]:

$$i\hbar\frac{\partial\psi(\mathbf{r},t)}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\psi(\mathbf{r},t) + \frac{4\pi\hbar^2 a_s}{m}\left|\psi(\mathbf{r},t)\right|^2\psi(\mathbf{r},t) + V_{ext}(\mathbf{r},t)\psi(\mathbf{r},t) \quad (1)$$

From (1) Proment, Onorato and Barenghi [11], elaborate the continuity and linear momentum conservation equations for an inviscid, barotropic, compressible and irrotational fluid:

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

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

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

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

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

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

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

to describe a fundamental particle as a superfluid vortex. In eq. 6 $\hat{H}$ corresponds to the quantum pressure tensor

$$\mathbf{P}_Q = -\left(\frac{\hbar}{2m} \right)^2 \rho \nabla \otimes \nabla \ln \rho \tag{7}$$

related to the Bohmian quantum potential discussed below (§3).

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[2] as a perturbative phenomenon similar to that described in a Kármán vortex street (fig. 1)

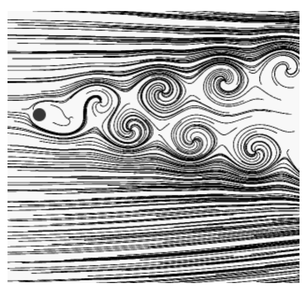

Figure 1: a computer simulation of a Kármán vortex street. Clumps of space's quanta (dark matter?) in a SQS might be responsible for the appearance of particle-antiparticle pairs as right- and left-handed superfluid vortices of space's quanta.

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

[2]Referring, for instance, to electron-positron pairs in the Casimir effect

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.

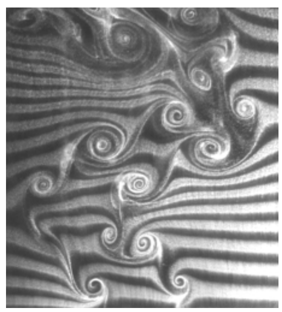

Figure 2: a possible analogy between vortex street phenomena [14] and perturbations in SQS might help us to understand how particles and interactions arise from a superfluid *false vacuum*.

1.1 Vacuum fluctuations as superfluid vortices.

It may be interesting to analyze whether what we usually call vacuum fluctuations are vortices in SQS. Let's consider the relationship:

$$\triangle E \triangle t \geq \frac{h}{2\pi} = \hbar \tag{8}$$

In natural units $\hbar = 1 E_P t_P$ and we know that $E_P = m_P c^2$. Within the photon-phonon analogy described in [4], we see that $c^2 = \frac{\Upsilon}{\rho_0}$, *i.e.* the ratio between the Young modulus (unidirectional compression) applied to SQS and its density. Hence $E_P = m_P \frac{\Upsilon}{\rho_0}$. Planck energy therefore corresponds to the maximum mass a single vortex which emits virtual photons (m_P) can have, multiplied by the ratio compressibility/density of SQS. We see that

$$\triangle E \triangle t \geq \frac{m_P \frac{\Upsilon}{\rho_0} t_P}{2\pi}. \tag{9}$$

Since 2π corresponds to a 360° turn, the reduced Planck constant is interpretable as the rotation a vortex with Planck mass can do within a Planck time, given a specific density and compressibility of the SQS. On the other hand, time arises as a chain of elementary hydrodynamic phenomena in SQS, where the rotation of the vortices is itself the generator of time. For this reason the hydrodynamics of the SQS can be sufficient for replacing Einstein's spacetime (§4). Once put (9) in (4) we have the circulation of SQ, Γ_ς, directly related to spin (fig.4, §3), in a vortex-particle expressed as

$$\Gamma_\varsigma = \oint_{C_{(t)}} \mathbf{v} \cdot d\mathbf{l} \equiv \frac{m_P}{m} \frac{\Upsilon}{\rho_0} n t_P \leq \frac{\triangle E \triangle t}{2\pi m} n, \tag{10}$$

which approximatively corresponds to n vacuum fluctuations each complete turn (2π), divided by the mass of the vortex-particle whose life corresponds to nt_P. Since vacuum fluctuations consist in annihilating particles pairs, we have to consider two symmetrical vortices which destroy each other when they come into contact in the way their circulations are not mechanically mutual. Also the phenomenon of annihilation would therefore occur on the basis of quantum hydrodynamics.

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

No superfluid has a real zero viscosity. Non-zero viscosity of SQS causes the attraction of the space's quanta surrounding the vortices into the vortices themselves (absorption, fig. 3). The result is a force gradient around the vortex which obeys the inverse-square law. 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].

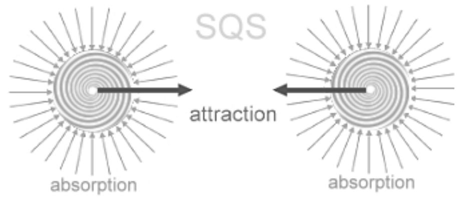

Figure 3: Two vortex-particles move the one toward the other since they're absorbing the fluid (SQS) which they're immersed in (here in a very simplified 2D reduction). This phenomenon is in direct agreement with Gauss's law for gravity: $\oiint_{\partial V} \mathbf{g} \cdot d\mathbf{A} = -4\pi GM$ and 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:

$$\frac{\partial(u_j)}{\partial x_j} = 0 \tag{11}$$

$$\frac{\partial(u_i u_j)}{\partial x_j} = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} + \frac{\mu}{\rho}\frac{\partial}{\partial x_j}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) \tag{12}$$

$$\frac{\partial((\rho E + p)u_j)}{\partial x_j} = -k\frac{\partial}{\partial x_j}\left(\frac{\partial T}{\partial x_j}\right) \tag{13}$$

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, where A corresponds to the surface of the inner sphere and $\vec{d}$ is the unit vector for the distance between the spheres, is represented by:

$$F_a = \int_A (p + \rho(\vec{u} \cdot \vec{n})(\vec{u} \cdot \vec{d}))d\vec{A} \cdot \vec{d} \tag{14}$$

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. 14, 15, 16 and 17 (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. 13).

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 quantum potential.

As far as the most appropriate vortex geometry is concerned, it is interesting to consider the evolution: vortex tube → vortex torus → horn torus (fig.4). Also Villois, Krstulovic et al. analyze vortex tubes evolving into vortex tori in superfluids [16], demonstrating the emergence of a non-trivial topology. The suggested geometry could be able to account for the main mechanism suggested in this work, *i.e.* the absorption of SQ (gravity) 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. Furthermore, referring to fig.4, if a space's quantum (dot in the figure) in the toroidal vortex needed the same time the vortex needs to complete two turns in the toroidal direction (σ_1 spin component) to return in the same position, while the vortex completes a single turn in the poloidal direction (σ_2), then the vortex would have spin$\frac{1}{2}$ (the system returns in the same state after a toroidal rotation of 720°, i.e. 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 between the two different rotations in the torus. In fact, we would obviously have:

$$\frac{1\sigma_2}{2\sigma_1} \Rightarrow spin\,\frac{1}{2};\ \frac{1\sigma_2}{1\sigma_1} \Rightarrow spin\,1;\ \frac{0\sigma_2}{1\sigma_1} \Rightarrow spin\,0 \tag{15}$$

The peculiar geometry of a toroidal vortex would also 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) 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 (i.e. phonons through SQS [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 a charged or neutral particle. It is however presumable that the torus geometry of a charged particle will have $r \to R$, instead of being an exact horn torus.

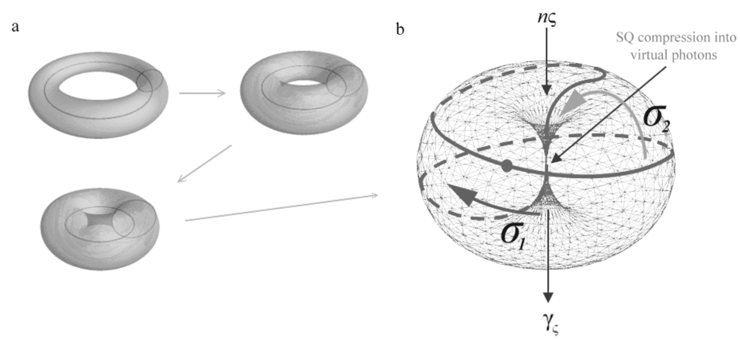

Figure 4: evolution of a torus vortex, from a vortex tube, into a horn torus. This might justify the compression of space's quanta (ς) into virtual photons (γ_ς) within the absorption-emission mechanism. On the right the possible mechanism corresponding to spin$\frac{1}{2}$, where the system returns in the same state after a rotation of 720° in the toroidal direction σ_1, while each space's quantum in the vortex flows along a Möbius strip. Such two-components model (σ_1, σ_2) may mechanically explain any other kind of spin as the ratio between the two rotations (15). In this case we have $\frac{1\sigma_2}{2\sigma_1} = spin\frac{1}{2}$.

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, *e.g.* dark matter?) of the flows occurring in SQS, as for instance gravitational flows or flows produced by the motion of other bodies

all three Helmholtz's theorems are respected.

Considering $\vec{v}_\theta$ as the poloidal tangential velocity associated with σ_2 and $\vec{v}_\varphi$ as the toroidal tangential velocity of σ_1, we can think of the continuity equation for the horn torus vortex:

$$\frac{\partial \rho}{\partial t} + \oiint_S \rho \mathbf{v}\, dS = 0 \tag{16}$$

where $\mathbf{v} = \vec{v}_\theta + \vec{v}_\varphi$, S denotes the surface of the torus as $S = 4\pi^2\varrho$, with $\varrho = Rr$ to impose the horn torus geometry and 0 on the right side accounts for having neither sources nor sinks of mass-energy or, to be more precise in our case, it accounts for an equilibrium between absorbed ($n\varsigma$) and emitted (γ_ς) quanta, which occurs through a quick sawtooth energy oscillation of the vortex-particle (fig.5), which reads

$$m_{eff(t)} = (t - \lfloor t \rfloor)k_a + m_0, \tag{17}$$

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).

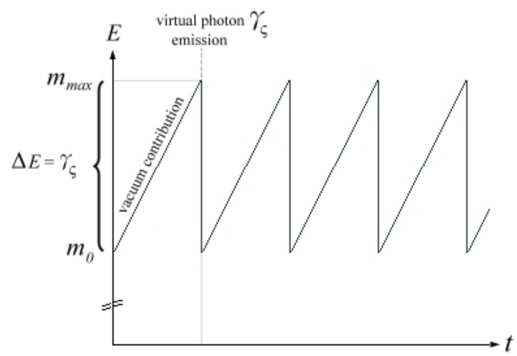

Figure 5: sawtooth electrogravitational oscillator for a charged particle expressing its rest mass variation while producing gravitational pull and electrostatic field. Vacuum contribution corresponds to the absorption of SQ in the vortex.

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 881s. 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. Moreover if neutrinos have a mass, since they're not bound to charged particles, they are due to decay.

As far as a suitable quantum Hamilton-Jacobi equation for the vortex geometry in fig.4 is concerned, it is first of all useful to 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. 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

$$Q = -\frac{1}{2} m \vec{v}_S - \frac{1}{2} \nabla \cdot \vec{v}_S \tag{18}$$

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 (18). The Bohmian term Q in the quantum Hamilton-Jacobi equation can be then justified by the spin, where in our case: $\vec{v}_S \times \hat{s} = \vec{v}_\theta + \vec{v}_\varphi$.

$$\frac{\partial S}{\partial t} = -\left[\frac{|\nabla S|^2}{2m} + V + \left(-\frac{1}{2}\left(m\vec{v}_S - \hbar \nabla \cdot \vec{v}_S\right)\right)\right]$$

Spin alone would not be however sufficient to justify the absorption mechanism, thus the non-zero viscosity of the medium in which the vortex takes shape is fundamental. The other main element in the mechanism of fluid quantum gravity is SQS pressure. Because of the SQ absorbed into the vortex-particle, pressure decreases around the object and this generates a flow directed toward the point of lower pressure, exactly as it happens in the atmosphere for wind. But in the SQS 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 sea of space's quanta, 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 again part of the play.

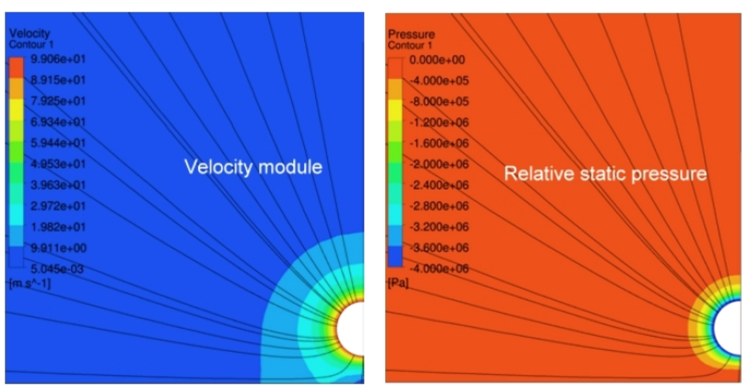

Figure 6: absorption velocity and pressure gradient from the performed CFD simulations.

We have

$$F_q = \nabla Q = \nabla \frac{P}{\rho} \tag{19}$$

as the quantum force in relation with quantum potential and pressure, where the gradient is positive since we consider the decrease of pressure and of its repulsive quantum force by approaching the massive particle. This determines what we call a gravitational potential. We can therefore reflect on the following relations (cascading gradients occurring in SQS and involved in quantum gravity):

$$v_{sq} = -\nabla\phi \Rightarrow \nabla P \Rightarrow F_q = \nabla Q \Rightarrow g = -\nabla V \tag{20}$$

where v_{sq} is the velocity of the space's quanta directed toward the attracting vortex-particle and ϕ is the velocity field or velocity potential (fig. 6 left), P is pressure of SQS, F_q the corresponding quantum force, Q the quantum potential, g the gravitational field and V the 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 as internal pressure of SQS.

We assume that the SQS is a compressible quantum superfluid, whose internal pressure may act as a repulsive force in the universe, having a role in its expansion. This would be 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 immersed in the SQS.

In fig. 7 we see the relationships (not in scale) among the four gradients involved in fluid quantum gravity. At the axis origin we have to image a massive particle. As a simplification the spherical gradients are depicted as 2D Gaussians. The velocity field and the gravitational potential decrease with distance from the particle, while pressure potential increases toward the value of SQS internal pressure at infinity. If we consider the repulsive quantum force due to SQS internal pressure, we see in the figure that also the quantum potential, which is proportional to pressure, increases with distance and becomes negative ($\Rightarrow$attraction) by approaching the axis of the vortex-particle.

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 pressure) becomes dominant.

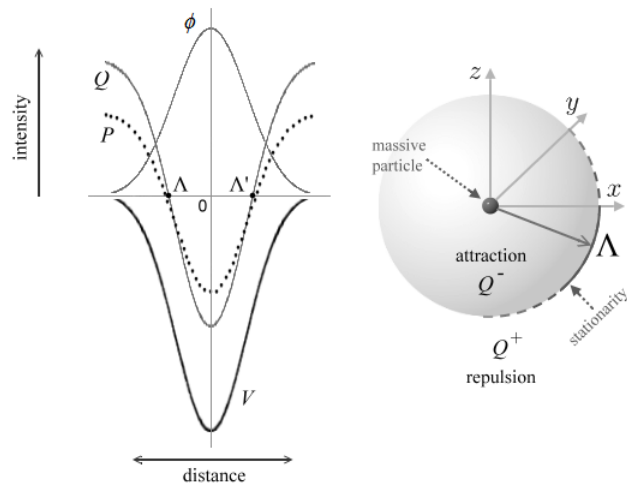

Figure 7: with a massive particle centered at the axis origin the four Gaussians (not in scale) represent in 2D, in causal order: the spherical gradient of absorption velocity (ϕ), of pressure (P), the quantum potential (Q) and the gravitational potential (V). Pressure and repulsive quantum potential (which are proportional) reach their maximal values with distance at infinity.

4 Fluid 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,

$$ds^2 = \left(1 - \frac{2Gm}{c^2 r}\right)^{-1} dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2) - c^2\left(1 - \frac{2Gm}{c^2 r}\right) dt^2 \quad (21)$$

suggesting that the metric tensor of GR may be expressed through fluid dynamic forces. Fluid quantum space whose hydrodynamics produces time and influences clocks through gravity (weight force), likewise described as a fluid phenomenon, instead of a deformable geometric spacetime (fig. 8, 9, 10).

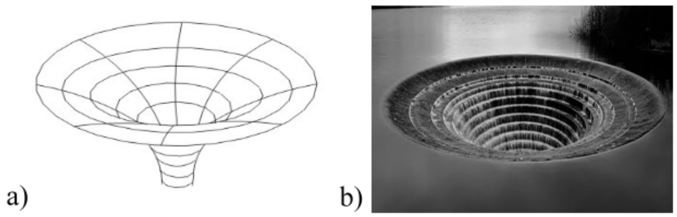

Figure 8: how the presence of a massive body curves spacetime (a) or absorbs fluid quantum space (b), here in analogy with a bell-mouth spillway.

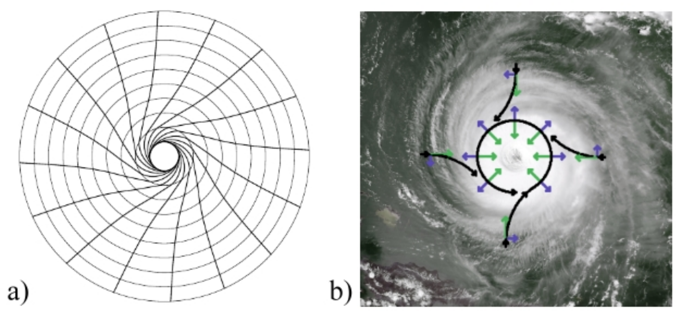

Figure 9: the Lense-Thirring effect according to Einstein's curved spacetime (a) and to fluid dynamics (b). Here as an analogy with the Coriolis effect in a cyclone.

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

$$B = -\frac{4}{5}\frac{m\omega R^2}{r^3}\cos\theta \tag{22}$$

and the Coriolis force can be written as:

$$F_C = -2m\omega(\omega R)\mathbf{u}_R. \tag{23}$$

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

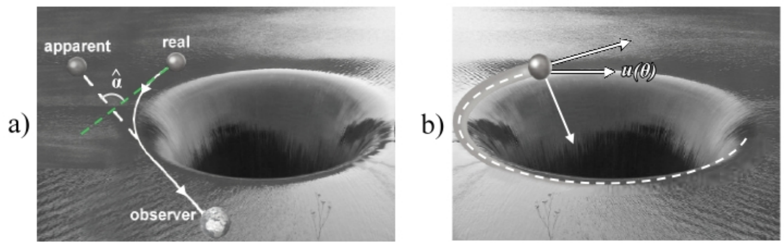

Figure 10: Gravitational lensing (a) and the motion of a satellite (b) according to SQS, still in analogy with a bell-mouth spillway representing the gravity of a star which curves space (in our case, which absorbs SQS).

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

$$\vec{\hat{\alpha}}(\vec{\xi}) = \frac{4G}{c^2} \int d^2\xi' \int dz \rho(\vec{\xi'}, z) \frac{\vec{b}}{|\vec{b}|^2} \tag{24}$$

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 (14), is given as

$$u(\theta) = \frac{\mu}{h^2} - A \cos(\theta - \theta_0) \tag{25}$$

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$\leftrightarrow$time, since time would arise from the hydrodynamics of SQS (10) and, also in our case, it wouldn't be absolute but influenced by gravity, which is *per se* a fluid phenomenon.

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

When considering gravity as 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 nonexistence of relative motion Earth-ether but not the absolute nonexistence of an ether, if we assume, within the hypothesis of fluid 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, while Earth's rotation would cause the Lense-Thirring effect by bending the incoming ether wind (fig.9), *i.e.* the gravitational field. Another effect caused by this kind of ether wind would be the gravitational lensing (fig.10). Several hints matching the predictions of general relativity which suggest to proceed with the hypothesis of a fluid space and of quantum gravity as absorption of SQ into vortex-particles. The consequences of a fluid space as far as the propagation of light is concerned are likewise interesting and have been 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. Moreover, the Michelson interferometer, though vertically positioned, would be inappropriate to prove this hypothesis because of the round trip of light occurring in it, while a Hanbury-Brown-Twiss interferometer could be suitable.

Furthermore, the existence of a fluid medium would compel us to reconsider the meaning of Hubble's law, since the fact that the redshift is greater for more distant galaxies could simply mean that light looses energy by traveling through the SQS because of its non-zero viscosity and that we are observing a sort of tired light. In this case the universe wouldn't be accelerating its expansion.

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

Other consequences of a SQS and of fluid quantum gravity would be:

- Quantum vacuum friction, which has for instance been considered in pulsars [23, 24, 25]: when energy loss is indeed only related to magnetic dipole radiation, we have $n = 3$ from the braking index $n = \frac{\omega\ddot{\omega}}{\dot{\omega}^2}$, in disagreement with observations which show that $n < 3$.

- Vacuum friction could also have played a role in the Pioneer anomaly [26].

- Gravitational waves, which would be defined as a periodic variation in SQS pressure caused by the variable position of a quadrupole in time (fig. 11) and corresponding to a variable rate in the absorption of SQ. In this case gravitational waves arise as negative pulses propagating through SQS. Since, as said, we think that also photons can be described as pulses (phonons) through the SQS [4], 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), can provide kinetic energy to a target (radiation pressure), exactly as for gravitational waves acting on LIGO's test masses where the pressure is however negative. Also in this case it would be a hydrodynamic quantum phenomenon and no deformation of a geometric spacetime would be necessary to explain gravitational waves.

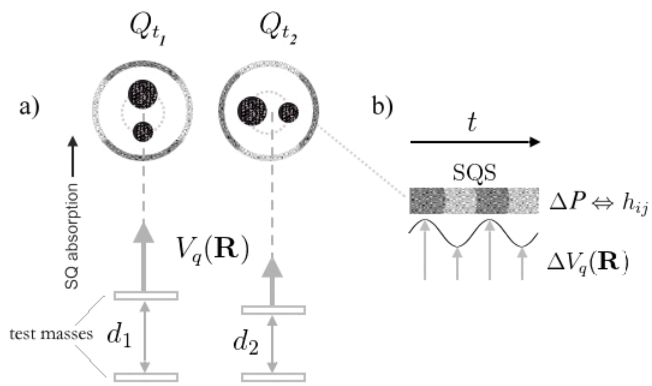

Figure 11: Gravitational waves according to fluid quantum gravity. Periodic variations in SQS pressure due to a likewise periodic variation of the absorption velocity ($\Rightarrow$ changing position of the quadrupole) may explain them as a hydrodynamic quantum phenomenon, without resorting to the concept of spacetime deformation. Depending on the alternating position of the quadrupole (Q_{t_1},Q_{t_2}) we have greater absorption (pressure decrease) or weaker absorption which correspond to a variation in the resulting gravitational potential (V_q). On the right, the periodicity of pressure variations is interpreted in time as a wave.

The changing rate in the absorption of space's quanta, occurring twice the orbital frequency ($2\omega_q$) , causes periodic decompressions (ΔP) in SQS (fig.11.b), currently interpreted as a deformation of spacetime (h_{ij}, in linear gravity: $g_{ij} = \eta_{ij}+h_{ij}$). 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].

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Annex.

Other images and charts from the performed CFD simulations.

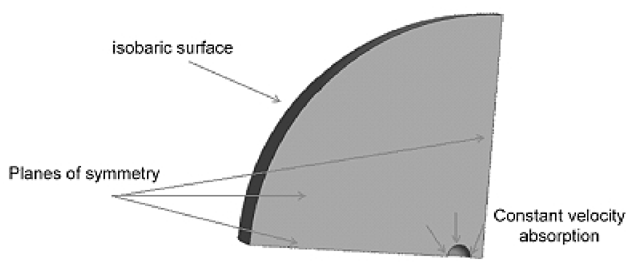


Figure 12: Simulation settings

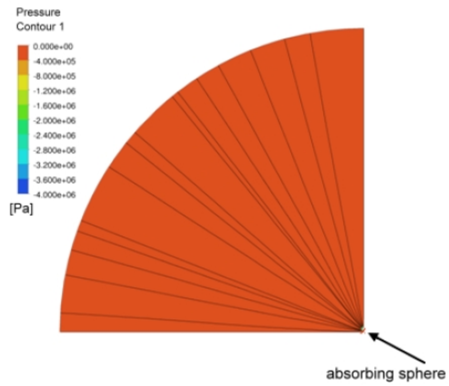


Figure 13: radial flow obtained in the simulations

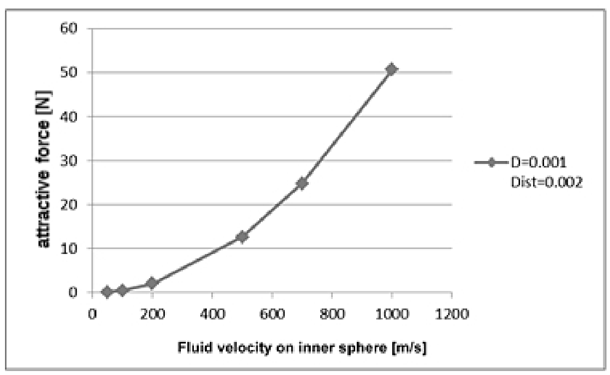


Figure 14: Test for force dependence on absorption velocity: sphere diameter 1mm, distance 2mm. Tested velocities: 50, 100, 200, 500, 700, 1000 m/s. Other tested conditions (50, 100, 200, 500 m/s) are shown in fig. 6 and 7.

Figure 15:

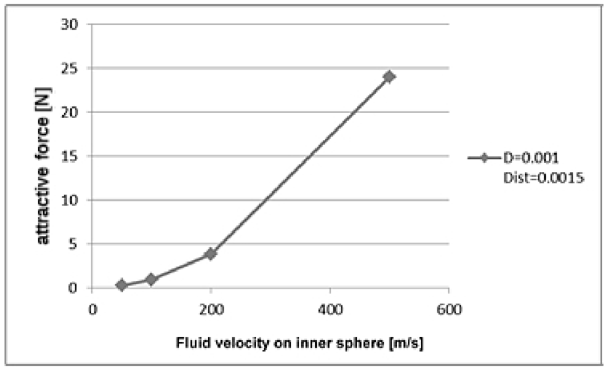
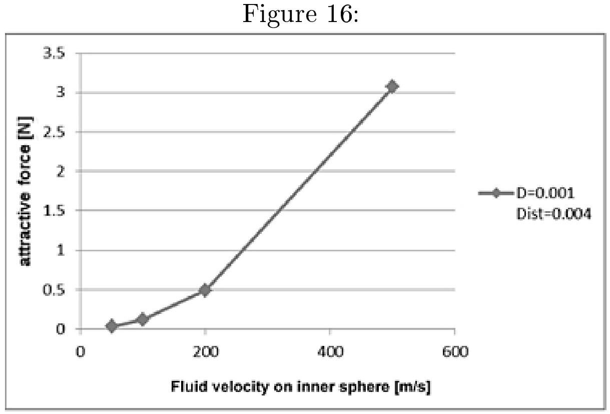


Figure 16:



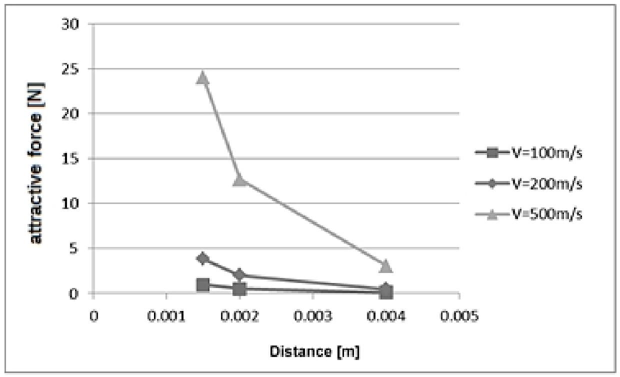


Figure 17: Test for force dependence according to the distance between the spheres.