Hydrodynamics of the dark superfluid: III. Superfluid Quantum Gravity

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Abstract Having described in previous articles dark energy, dark matter and quantum vacuum as different aspects of a dark superfluid which permeates the universe and having analyzed the fundamental massive particles as toroidal vortices in this superfluid, we reflect here on the Bernoulli pressure observed in quantum vortices, to propose it as the mechanism of quantum gravity. In this view, the dark superfluid surrounding a particle would be attracted toward it: a pressure gradient along with a velocity field would manifest around the particle and would be currently interpreted as the gravitational field. We call this hypothesis Superfluid Quantum Gravity. Here the hydrodynamics of the dark superfluid would replace the curved spacetime of general relativity, still respecting its observed predictions. Here the picture of gravity is that of an apparent force driven by spin. When this model is applied to a quadrupole dynamics, gravitational waves arise as negative pressure waves through the dark superfluid. Here the geometry of spacetime is indeed replaced by the hydrodynamics of the dark superfluid. A test is eventually suggested to confirm the gravitational field as an inflow of DS.

Keywords Quantum gravity · general relativity · dark energy · gravitational waves · analog gravity

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Introduction

In the first article on the hydrodynamics of the dark superfluid [1] we have provided reasons to interpret dark energy and dark matter as a dark superfluid (DS) whose quantum hydrodynamics produces both what we call *quantum vacuum* (as hydrodynamic fluctuations in the DS) and the massive particles of the Standard Model, as torus-shaped superfluid quantum vortices, where the ratio of the toroidal angular velocity to the poloidal one may hydrodynamically describe the spin. Furthermore, in [2] we have analyzed the theoretical possibilities that a photon be a transverse phonon propagating through the DS, concluding that there are good hints to consider light as "the sound of the dark superfluid", as all properties and behaviors of light can be observed within a quantum hydrodynamic approach. In this third paper, we return to fundamental particles as quantum vortices and we focus on the Bernoulli effect experimentally observed in superfluid vortices [25, 26, 28], suggesting that it can be the core mechanism of quantum gravity, which in turn is driven by spin [1] as a particle's internal, vorticous motion. In this model we do not resort to gravitons, since the quantum aspect of gravity is found in the quantized nature of the dark superfluid and in the attraction of its quanta into vortex-particles. Here Einstein's curved spacetime is replaced by the hydrodynamics of the dark superfluid and time itself arises from the dynamical aspect of this superfluid. All known phenomena attributed in general relativity to the Riemannian geometry of spacetime possess an equivalent explanation resorting to the hydrodynamics of the DS, from Lense-Thirring precession and gravitational lensing up to gravitational waves.

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1 Superfluid quantum gravity (SQG): Bernoulli pressure in the DS as the mechanism of quantum gravity

We refer here to the description of massive fundamental particles as torus-shaped quantum vortices in the DS [1], for which an hydrodynamic analogy with the fundamental entities introduced in Loop Quantum Gravity [9,10], where space is similarly granular and quantized, shall be reported for some aspects. From that, we focus on the Bernoulli force observed [25,26,29,28] when vortices form in superfluids. The formula reads [29]

$$\mathbf{F}_b = \int_S K(\mathbf{r})\mathbf{n}(\mathbf{r})dS \tag{1}$$

where $K(\mathbf{r}) = \rho v^2/2$ expresses the density of kinetic energy (which dominates on the vortex surface, while the density of the superfluid drops to zero within the so-called healing length [1]) and $\mathbf{n}(\mathbf{r})$ is a unit vector normal to the cylindrical surface S over which the integral is calculated. A schematical description of this force as superposition of the vortices' velocity fields obeying a $1/r$ function, which pressure fields are associated to, has been made in [29]. Due to Bernoulli pressure we see in Fig. 1 that particles of various sizes adhere onto the vortices, making them visible as filaments. The amazing analogy with the observed cosmic web of dark matter filaments showed in [1] is significant and tells us how the DS hydrodynamics may express both the cosmos of galaxies and the microcosm of particle physics. Also interesting is the appearance of attractive or repulsive (depending on the chirality) Bernoulli pressure between quantum vortices only in two-component superfluids [29], where we have a small amount of a "doping substance" (e.g. metallic atoms) scattered in a superfluid, such as superfluid ^{4}He. The analogy with a two-component DS in which a smaller amount of dark matter ($\sim 25\%$) is immersed in a vast ocean of superfluid dark energy ($\sim 70\%$) [1] is relevant. Thus, if macroscopic bodies were made up of vortex-particles in a two-component DS [1], they would show as well a pressure gradient around them and would exert (and be subject to) Bernoulli force. This pressure gradient is called "gravitational field". Fig. 2 represents the gravitational field as inflow of dark superfluid which consequently causes attraction between two or more bodies floating in it [16], while in Fig. 3 the pressure gradient causing attraction is shown through a set of CFD simulations. Here we can verify that the consequent attractive force mathematically equals Gauss's law for gravity

$$F_g = \oint_S \mathbf{g} \cdot \mathbf{n}(\mathbf{r})dS = -4\pi GM, \tag{2}$$

for which we consider a "real" incoming flow (in our case of DS), and is compatible with the Schwarzschild solution. Similarity with (1) is also evident. A similar hypothesis of hydrodynamic gravity was proposed by Cahill [17] and Kirkwood [18] previously thought of the gravitational field as an ether inflow, moving from the interpretation of the equivalence principle (also see Sect. 7) and analyzing this issue in terms of particle and light motion in a gravitational field. Also other efforts in the context of analog gravity, as those by Visser, Barcel, Consoli, have to be mentioned [19–21]. Finally, it is important to notice that Bernoulli pressure is

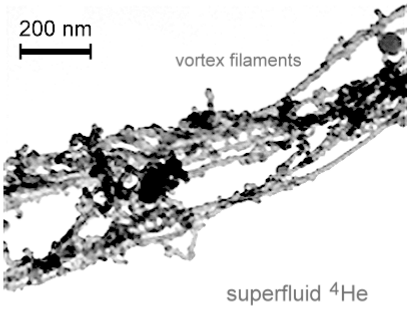

Fig. 1 Metallic nano-particles adhere onto vortex-filaments in superfluid ^{4}He making them visible, thanks to Bernoulli pressure [25,26]. The attraction of the surrounding quanta in the DS exerted by vortex-particles is by us indicated as the quantum mechanism of gravity.

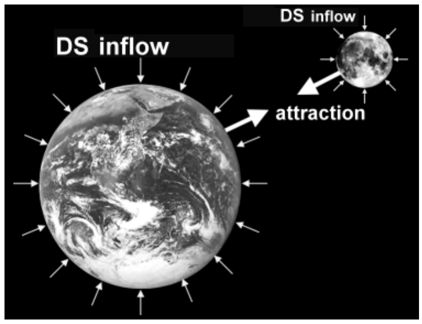

Fig. 2 Since macroscopic bodies consist of fundamental particles, they also produce a pressure gradient which becomes strong and evident around large celestial bodies and determines attraction. This is what we call "gravitational field". This hypothesis is nothing more than Gauss's law for gravity, however considering here a *real* flux of DS.

created by the action of spin, once this quantum number has been defined as the circulation of quanta in a superfluid vortex taking shape in the DS (see [1] Sect. 3). So the core mechanism of quantum gravity would be actually spin, described as vorticity of quanta in the DS.

2 From classical to quantum gravity without gravitons

We know that a pressure gradient generates a force, for which the acceleration is expressed as

$$\mathbf{a} = -\nabla \frac{P}{\rho}, \tag{3}$$

being P and ρ respectively pressure and density. In our case, (3) has to correspond to the gravitational acceleration caused by the attraction of dark superfluid quanta (DSQ) due to the Bernoulli effect (Fig. 1, 2), then we write

$$\mathbf{g} = -\nabla \frac{P_d}{\rho_d}, \tag{4}$$

where the subscript d refers to DS. By using (4) in Newton's second law, we can write a formula for universal gravitation,

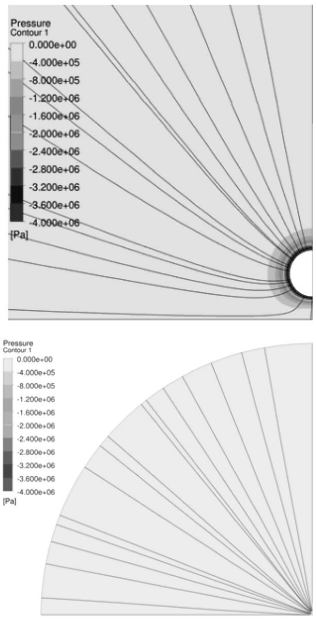

Fig. 3 CFD simulation putting in evidence the pressure gradient around a macroscopic spherical body absorbing the fluid in which it is immersed. The consequent $1/r^2$ attractive force mathematically equals Gauss's law for gravity and is compatible with the Schwarzschild solution. Refining the grid (on the right) leads to a perfect radial symmetry.

based on the hydrodynamics of the DS

$$\mathbf{F}_g = -m\nabla \frac{P_d}{\rho_d}. \tag{5}$$

Since we assumed that the DS is quantized as well as its absorption into vortex-particles [1], (5) would be the formula for quantum gravity. As we see, the superfluid approach generates a formula for quantum gravitation in two simple steps, without resorting to differential geometry, gravitons or strings. So far then, the Ockham razor seems to be in favor of the quantum hydrodynamic hypothesis for gravity. We proceed then with the analysis and below we will derive the quantum potential.

From (5) it emerges that in SQG, the classical gravitational potential φ corresponds to the ratio pressure to density expressed in (4), becoming a hydrodynamic gravitational potential φ_h:

$$\varphi = -G\frac{M}{r}\left[\frac{\mathrm{m}^2}{\mathrm{s}^2}\right] \Longleftrightarrow \varphi_h = -\frac{P_d}{\rho_d}\left[\frac{\mathrm{m}^2}{\mathrm{s}^2}\right], \tag{6}$$

where the gravitational constant G disappears. This is a good hint, since the role of the classical Newtonian constant is simply that of adjusting calculations and units of measure in a non-quantum formula. Measuring gravity through mass and distance does not refer to the quantum mechanism of gravity, in which other parameters have to be taken into consideration, i.e. local pressure and density of the DS. If we use mass and distance between bodies we have to use a scale and conversion factor and this is indeed the role assumed by G. It is also interesting to note that the units in (6) correspond to Gray (Gy), i.e. to the unit used for energy absorption (J/kg). In this case, absorption of DS (of dark energy), as hypothesized for SQG.

The Newtonian gravitational constant now would read

$$G = -\varphi_h \frac{r}{M} = \frac{P_d}{\rho_d}\frac{r}{M} = const. \tag{7}$$

So, its value and utility remain but it would now reveal the physical quantities and the relationships among them which produce that constant output on a quantum hydrodynamic basis. Furthermore, we see that the same hydrodynamic expression (6) is used for the equation of state of cosmology: $w = P/\rho$, that we already considered as the equation of state of the DS [1,8]. We also notice that by considering the gravitational field as an incoming flow of DS, light propagating parallel to it should show a frequency shift analogous to the gravitational redshift of general relativity. A differential test is proposed in Sect. 9. It is also important to notice that the negative pressure gradient around celestial bodies (the DS inflow) would obviously cancel the tiny braking action produced by the apparent viscosity (no superfluid has real zero viscosity) for bodies orbiting or traveling through the DS, in the case a strong enough absorption creates the condition

$$v_a \geq v \tag{8}$$

where v_a is the velocity at which the DS is attracted into a massive body (see Fig. 4, the velocity field coexisting with the pressure gradient shown in Fig. 3) and v the orbital or translational velocity of the body throgh the DS. The by us suggested mechanism for quantum gravity is therefore able to justify orbital stability of celestial bodies over indefinitly long times, as actually observed, despite their orbits occur in a superfluid medium with near-zero viscosity instead of in a real-zero viscosity Newtonian vacuum (which as regards quantum physics does not exist). Smaller and faster celestial bodies undergo however a greater interaction with the DS, as showed in (35) as regards the anomalous perihelion precession of Mercury, and several detected probes anomalies could be also due to the interaction with the DS, undergoing in this case (small objects) the unfavourable condition $v_a < v$ and a greater action of apparent viscosity. Following this approach we have speculated that also the anomalous deceleration of the Pioneer probes 10 and 11 [24] could depend on vacuum friction, obtaining the result of $a = -8.785 \times 10^{-10}\ \mathrm{m \cdot s^{-2}}$, without resorting to the still uncertain issue of thermal photons recoil.

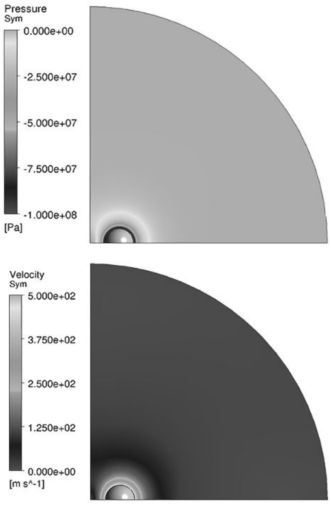

Fig. 4 CFD simulations showing the velocity field (on the right) causally associated with the pressure gradient around a vortex-particle attracting the DS. From it we can have an absorbtion velocity v_a in any point of the field.

3 Quantum potential

To consider (5) as the formula of quantum gravity the following identity has to be true

$$\mathbf{F}_{gQ} = -m\nabla\frac{P_d}{\rho_d} = -\nabla Q_\varphi \tag{9}$$

where $Q_\varphi = -m\left(P_d/\rho_d\right)$ is the quantum potential in units of energy. Being m the mass of a quantum of DS and taking into account the de Broglie relations, we observe the following simple identities

$$Q_\varphi = -m\frac{P_d}{\rho_d} = -\mathbf{p}\cdot\mathbf{u} = -i\hbar\nabla\mathbf{u} \Rightarrow -i\hbar\frac{\partial}{\partial t} = \mathscr{H} = -\frac{\hbar^2}{2m}\nabla^2 + U \tag{10}$$

where $\mathbf{p} = m\mathbf{u} = \hbar k \Rightarrow -i\hbar\nabla$ represents the momentum and $\mathscr{H}$ is the hamiltonian operator of the Schrödinger equation (SE). Both energy operators, kinetic, $-(\hbar^2/2m)\nabla^2$, and potential, U, are expressions of the same total gravitational quantum energy of the system, where potential energy gradually converts into kinetic energy as the quantum approaches the point of attraction (a vortex-particle). Let us observe the SE with its quantum potential. We define the probability density per unit volume

$$\rho(r,t) = R(r,t)^2 = |\Psi(r,t)|^2 = \Psi^*(\mathbf{r},t)\Psi(\mathbf{r},t) \tag{11}$$

being $R(r,t)$ the amplitude of the wavefunction $\Psi(r,t)$ and r the spatial coordinate. By rewriting the SE in polar form with $\psi = Re^{iS/\hbar}$ and $S/\hbar$ as the phase of the wavefunction, we obtain as known two coupled equations. That arising from the real part of the SE reads

$$\frac{\partial S}{\partial t} = -\left[\frac{(\nabla S)^2}{2m} + U + Q\right] = \mathscr{H} \tag{12}$$

where Q is the quantum potential. For the considered quantum, kinetic and potential energies are not determined by anything else than the gravitational acceleration as a hydrodynamic quantum phenomenon, thus $(\nabla S)^2/2m + U = 0$ and $\frac{\partial S}{\partial t} = \mathscr{H} = Q_\varphi$.

It may be useful to detail Q_φ by distinguishing between potential and kinetic aspects. We do that adopting Sbitnev's approach to quantum potential [3,4], which we already resorted to in [1]

$$Q = -\frac{\hbar^2}{2m}(\nabla S_Q)^2 + \frac{\hbar^2}{2m}\left(\nabla^2 S_Q\right) \tag{13}$$

where

$$S_Q = \frac{1}{2}\ln\rho_d \tag{14}$$

is the quantum entropy of the DS due to its hydrodynamic perturbation. Therefore, we have

$$\mathscr{H} = Q_\varphi = -\frac{\hbar^2}{2m}(\nabla S_Q)^2 + \frac{\hbar^2}{2m}\left(\nabla^2 S_Q\right) \tag{15}$$

Since the gravitational potential (6) used in (11) is determined by Bernoulli pressure at quantum level due to vortex-particles and verified the quantum potential (15), Eq. (9) can be the formula of quantum gravity, whose action is exerted on a body's reference frame. Therefore gravity is presented here as an apparent force. Indeed, Einstein himself considered gravity not as a real force but as an intrinsic property of spacetime.

The bridge to classical gravity is represented by the fact that gravity as a hydrodynamic phenomenon in the DS implies that vortices (e.g. fermions) or pulses (photons, see [2]) existing in such a reference frame are consequently accelerated as objects on a conveyor belt. This is for instance the reason why light is deflected by gravitational fields, as discussed below. We would not observe gravity, nor the existence of particles [1], without the presence of the DS. According to SQG, a black hole, for example, swallows up (superfluid) space along with the matter it contains, it does not directly attract matter. In this case it is therefore correct to refer to gravity as an apparent force, without active force carriers (no gravitons). In the case of a non-free body in a gravitational field, the quantum potential has to correspond to gravitational potential energy. In fact, from (6)

$$U = -m\frac{GM}{r} = -m\frac{P_d}{\rho_d} = Q_\varphi \tag{16}$$

We can now change the subscript in Eq. (6), $\varphi_h = \varphi_Q$, to refer to the quantum nature of the hydrodynamic gravitational potential. The differential form of Gauss's law for gravity (i.e. Poisson's equation) becomes

$$\nabla^2 \varphi_Q = 4\pi\varphi_Q \frac{\mathbf{r}}{M}\rho_m = \frac{3\varphi_Q}{\mathbf{r}^2} \tag{17}$$

where $\rho_m = \frac{3}{4}\frac{M}{\pi\mathbf{r}^3}$ is mass density.

It is now clear that this approach does not refer to curved spacetime but to the hydrodynamics of the DS, whose effects are the same as those described in Einstein's relativity. There is no curved spacetime but a superfluid space, whose hydrodynamics at Planck scale generates time itself (quantum vortices as fundamental clocks in nature?) and we are reminded of the de Broglie's idea about a sort of clock inside the fundamental particles [5–7] based on the Bohr-Sommerfeld relationship, $\oint_C \mathbf{p}\cdot dx = nh$. Putting $n = 1$ we see that the quantum of action is a complete turn of quanta in a vortex-particle. We believe that time itself may take shape from the simplest events on quantum hydrodynamic basis. Let us therefore consider Planck time. Since the classical constant G has been revealed in its constituent quantum hydrodynamic quantities (7) which give as output a constant value and having rewritten the formula for the speed of light [2] as

$$c = \frac{1}{\sqrt{\beta_d\rho_d}} \tag{18}$$

where the permittivity and permeability of vacuum have been translated into density and isentropic compressibility of the DS, we can rewrite Planck time only resorting to Planck constant (the quantum of "circulation") and the basic parameters of the DS, that is ρ_d and β_d. The expression for Planck time becomes

$$t_{P_d} \equiv \sqrt[8]{\hbar^2\beta_d^5\rho_d^3}. \tag{19}$$

It is evident that also the other Planck units can be rewritten using $\hbar$, ρ_d, β_d, all referring to the hydrodynamics of the DS.

4 Einstein field equations. From curved spacetime to the hydrodynamics of a superfluid space.

Since we here affirm that Einstein's spacetime is an elegant theoretical construct which quantitatively works in explaining gravity thanks to differential geometry but from a qualitative point of view it would actually correspond to the hydrodynamics of the DS in a *flat* space, we should express the gravitational forces only through pressure gradients arising in the superfluid quantum space. As opposed to Einstein's model, this quantum hydrodynamic description of space, time and gravity does not fail at short scale, since *it starts from short scale,* from the quantum nature of the physical vacuum (as DS), confirmed in quantum field theory and in recent tests [27].

Without regard, for the time being, to a complete quantum hydrodynamic reformulation of the Einstein field equation (EFE) with pressure accounting for the apparent curvatures of space, we begin by substituting what has been derived in these papers of ours about the hydrodynamics of the DS. From (7) and (18), [2], Einstein constant reads

$$\kappa = \frac{8\pi G}{c^4} \Rightarrow \kappa_h = 8\pi\varphi_Q \frac{r}{M}(\beta_d\rho_d)^2 = 8\pi\frac{r}{M}P_d\beta_d^2\rho_d \tag{20}$$

where the subscript h means hydrodynamic. The cosmological constant becomes

$$\Lambda_h = \rho_d\kappa_h = 8\pi\frac{r}{M}P_d(\beta_d\rho_d)^2 \tag{21}$$

where vacuum energy (commonly dark energy) density is expressed as that of the DS, $\rho_{vac} = \rho_d$, and in this case M and r respectively refer to the mass of baryon matter in the universe and to the radius of the visible universe. Thus, the EFE, $G_{\mu\nu} + \Lambda g_{\mu\nu} = \kappa T_{\mu\nu}$, would read

$$G_{\mu\nu} + 8\pi\frac{r}{M}P_d(\beta_d\rho_d)^2 g_{\mu\nu} = 8\pi\frac{r}{M}P_d\beta_d^2\rho_d T_{\mu\nu} \tag{22}$$

where resorting to the single-fluid (DS in our case) model of cosmological perturbation theory [8] and reducing to the simpler case of a perfect fluid, the stress-energy tensor is hydrodynamically defined as

$$T_{\mu\nu} = (P+\rho)\frac{u_\mu u_\nu}{c^2} - Pg_{\mu\nu} \Rightarrow (P_d+\rho_d)u_\mu u_\nu\beta_d\rho_d - P_d g_{\mu\nu}. \tag{23}$$

where u is the four-velocity. Here the EFE tells us that the apparent spacetime curvature is caused by the action of pressure forces in the DS, whose role (as that of dark energy) was already present in the cosmological constant and we see that also the stress-energy tensor is fully compatible with a quantum hydrodynamic interpretation which considers dark energy, being T^{00} its density, $\rho_0 = \rho_d$, T^{ii} its pressure, P_d, $T^{0i} = T^{i0}$ the momentum density and being shear stress and momentum flux the remaining components. As far as the metric tensor, $g_{\mu\nu}$, is concerned, though spacetime would not be distorted but simply expressed by the hydrodynamics of the DS, it can maintain for the moment a computational usefulness *as if space were distorted*. The same can be said for the other tensors in the EFE, since, as we know, both Ricci tensor

$$R_{ij} = R^k_{ikj} = \partial_l\Gamma^l_{ji} - \partial\Gamma^l_{li} + \Gamma^l_{l\lambda}\Gamma^\lambda_{ji} - \Gamma^l_{j\lambda}\Gamma^\lambda_{li} \tag{24}$$

and Ricci scalar

$$S = 2g^{ab}(\Gamma^c_{a[b,c]} + \Gamma^d_{a[b}\Gamma^c_{c]d}), \tag{25}$$

forming Einstein tensor, $G_{\mu\nu}$, are defined through Christoffel symbols, which are themselves expressed through the metric tensor, $\Gamma_{cab} = \frac{1}{2}(\partial_b g_{ca} + \partial_a g_{cb} - \partial_c g_{ab})$. Said that a spherical body absorbing the fluid in which it is immersed generates a pressure gradient and that this is analogous to the Schwarzschild solution, a body which rotates while absorbing DS would obviously correspond to Kerr metric and would express the Lense-Thirring precession. Also the gravitational lensing would be explained by the fact that photons (as phonons, see [2]) propagate in a DS where pressure forces act, so the deviation of light would be analogous to that of sound under the action of wind. In short, every effect attributed to curved spacetime in general relativity can be also explained resorting to the hydrodynamics of the DS.

5 Line elements for the metrics and relativistic effects.

The solutions to the EFE can be expressed in quantum hydrodynamic terms. The line element for the Schwarzschild metric with signature $(1,-1,-1,-1)$ reads

$$c^2 d\tau^2 = \left(1-\tfrac{r_S}{r}\right) c^2 dt^2 - \left(1-\tfrac{r_S}{r}\right)^{-1} dr^2 - r^2\left(d\theta^2+\sin^2\theta d\varphi^2\right) \tag{26}$$

where $r_S = 2GM/c^2$ is the Schwarzschild radius, which after quantum hydrodynamic substitutions reads

$$R_{S_Q} = 2rP_d\beta_d \tag{27}$$

Below, we similarly substitute the constants G and c with their equivalent quantum hydrodynamic expressions obtaining

$$(\beta_d\rho_d)^{-1} d\tau^2 = \left(\tfrac{1}{\beta_d\rho_d} - 2\varphi_Q\right) dt^2 - \tfrac{1}{1-2P_d\beta_d} dr^2 - r^2\left(d\theta^2+\sin^2\theta d\varphi^2\right) \tag{28}$$

Now we pass to the Kerr metric (in our approach a rotating spherical body absorbing the DS) in the form

$$c^2 d\tau^2 = \left(g_{tt} - \tfrac{g_{t\phi}^2}{g_{\phi\phi}}\right) dt^2 + g_{rr}dr^2 + g_{\theta\theta}d\theta^2 + g_{\phi\phi}\left(d\phi + \tfrac{g_{t\phi}}{g_{\phi\phi}}dt\right)^2 \tag{29}$$

equivalent to a co-rotating frame of reference with Killing horizon which reads

$$\Omega = -\frac{g_{t\phi}}{g_{\phi\phi}} = \frac{r_S r\alpha c}{\rho^2\left(r^2+\alpha^2\right) + r_S r\alpha^2\sin^2\theta} \tag{30}$$

where the following length-scales are introduced for brevity: $\rho^2 = r^2 + \alpha^2\cos^2\theta$ and $\alpha = J/Mc$, with M referring to a mass rotating with angular momentum J. The quantum hydrodynamic equivalent form of the Killing horizon expressing the Lense-Thirring precession is

$$\Omega = \frac{2r^2 P_d\beta_d J\sqrt{\beta_d\rho_d}}{M\sqrt{\beta_d\rho_d}\left(r^2+\beta_d\rho_d\left(\frac{J}{M}\right)^2\right)+2r^2P_d\beta_d^2\rho_d\left(\frac{J}{M}\right)^2\sin^2\theta} \tag{31}$$

and simplifying

$$\Omega = \left[\frac{J}{M^2}\left(\frac{M}{2}\left(\frac{M^2}{J^2\beta_d\rho_d} + r^{-2}\right) + \sqrt{\beta_d\rho_d}\sin^2\theta\right)\right]^{-1} \tag{32}$$

For brevity here we limit ourselves to the analysis of these metrics. As regards the gravitational lensing, the angle of deflection $\theta = 4GM/rc^2 = 2r_S/r$ has its quantum hydrodynamic equivalent from (7) and (18) as

$$\theta = 4P_d\beta_d. \tag{33}$$

evidencing the role of pressure in the DS in a simple formula, where light, as a pressure wave through the DS [2] is influenced by pressure gradients in the DS exerted by massive bodies.

As regards the anomalous perihelion precession of Mercury, in the relativistic formula for perihelia precessions calculated in Schwarzschild metric [30]

$$\Delta\phi = \frac{24\pi^3 a^2}{c^2 T^2\left(1-e^2\right)} \tag{34}$$

we can highlight the kinetic interaction planet-DS (from [2] we consider Lorentz factor as the rheogram of the DS), using the square ratio of the average orbital velocity, $v_o = 2\pi a/T$ (a is the semi-major axis and T the orbital period) to the speed of light (i.e. $\beta = v/c$ in special relativity)

$$\Delta\phi = \left(\frac{v_o}{c}\right)^2 \frac{6\pi}{1-e^2} = 5.018\times 10^{-7}\text{rad} \tag{35}$$

where $\Delta\phi$ expresses the relativistic contribution to Mercury's perihelion precession per revolution ($e = 0.205$ is orbital eccentricity), corresponding to the known value of 43" per century. In (35) we can better see the formula for the perihelion precession (34) as a function of orbital speed and orbital eccentricity. By substituting c with (18) we make also visible the basic parameters of the DS (within the identity $\beta_d\rho_d = \varepsilon_0\mu_0$ [2]) both in (35) and in the standard form (34)

$$\beta_d\rho_d v_o^2\frac{6\pi}{1-e^2} = \beta_d\rho_d\frac{24\pi^3a^2}{T^2\left(1-e^2\right)}. \tag{36}$$

The reason why the interaction planet-DS is more evident for Mercury is given by its smaller mass and its higher orbital velocity, along with its orbital eccentricity, compared with the other bodies of the solar system. Orbital eccentricity accounts for the speed variations during the revolution, causing a varying interaction with the DS and, in our opinion, the precession, also in a flat spacetime (that is in a superfluid quantum space). For precise calculations of Mercury's anomalous perihelium precession in a flat superfluid space we defer to a further study.

6 Gravitational waves as pressure waves through the DS.

Observing gravity as absorption of DSQ into masses, gravitational waves [14] arise as negative pressure waves generated by periodic variations in the absorption magnitude measured from a given point (e.g. LIGO mirrors [15]), due in this case to a quadrupole dynamics. Gravitational waves would be negative pressure waves propagating through the DS, which impart at a certain frequency (2ω, where ω is the orbital frequency of the quadrupole) a negative gravitational acceleration to a test mass. Again, invoking spacetime deformation is not necessary to explain what experimentally observed, which may obey quantum hydrodynamics.
Let us consider a supposed spacetime deformation as a wave with polarization $\times$

$$h_{\times} = -\frac{1}{R}\frac{G^2}{c^4}\frac{4m_1m_2}{r}(\cos\theta)\sin\left(2\omega\left(t-\frac{R}{c}\right)\right). \tag{37}$$

where R is the distance from the observer, t the elapsed time, θ the angle between the perpendicular to the plane of the orbit and the line of sight of the observer and r the radius of the quadrupole. The expression for a pressure wave in a fluid medium with orientation given by θ is $P = P_{max}(\cos\theta)\sin(\omega t - kx)$. Being $k = \omega/v_p$ where v_p is phase velocity, putting $x = R$ and considering a gravitational pressure wave in the DS (P_{GW}) propagating at the speed of light (both according to general relativity and to our approach [2]), $v_p = \lambda/T = c$, we multiply the frequency by 2 to due to the quadrupole dynamics and the equation reads $P_{GW} = P_{qmax}(\cos\theta)\sin\left(2\omega\left(t-\frac{R}{c}\right)\right)$, where P_{qmax} refers to the maximum gravitational negative pressure exerted by the quadrupole twice its orbital frequency, whose origin is in SQG (4), (5). Finally, to look at a complete quantum hydrodynamic formula describing gravitational waves in the DS, we substitute c with (18)

$$P_{GW} = P_{qmax}(\cos\theta)\sin\left(2\omega\left(t-R\sqrt{\beta_d\rho_d}\right)\right). \tag{38}$$

Thus, both in the case of light [2] and gravitational waves, we observe pressure waves through the DS which can impart acceleration (radiation pressure in the case of photons), although, in the case of gravitational waves, with the difference of negative waves whose frequency depends on the rotation of the binary system (quadrupole). As shown in (3) and (4) the pressure variation corresponds to an acceleration, acting in this case on LIGO's test masses, if we take into account the recent tests. Laughlin [22] reflects that: "there is compelling evidence that light and gravity are linked and probably both collective in nature". Indeed, from our point of view, both arise in the DS, being collective hydrodynamic manifestations of its quanta (pressure waves). Quantum-like gravity waves, but in a classical fluid, have been investigated by Nottale [23].

7 Fluid equivalent principle and new light shed on relativistic mass increase.

If a gravitational field is an incoming flow of DS as discussed above, we deduce that a body travelling with velocity v through the DS where the gravitational field tends to zero, is in the analogous situation of a body which is stationary in a gravitational field and the incoming flow of DS in that specific point of the field has exactly the same velocity v. We can express this equivalence as a fluid equivalence principle (FEP)

$$\mathbf{v}_{DSQ} = \mathbf{v}_a + \mathbf{v} \tag{39}$$

where $\mathbf{v}_{DSQ}$ is the velocity of the total resultant flow of DSQ acting on the body, determined by both translational motion through the DS ($\mathbf{v}$), i.e. the apparent velocity of DSQ, and by the flow of DSQ due to the gravitational field ($\mathbf{v}_a$). This means that in special relativity what is interpreted as mass increase is actually a sort of "drag weight", a braking force acting in the opposite direction to motion. By also considering Lorentz factor as the rheogram of the DS [2], the clues to reinterpret the relativistic mass increase in this direction are strong. The FEP can be demonstrated by equating the formulas of time dilation of special and general relativity, that is comparing the action of translational speed to that of gravity

$$\Delta t' = \frac{\Delta t}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{\Delta t}{\sqrt{1-\frac{R_S}{r}}} \tag{40}$$

hence $\frac{v^2}{c^2} = \frac{R_S}{r} \Longrightarrow v^2 = \frac{2GM}{r}$ thus $v = \sqrt{2rg} = \sqrt{2\varphi}$. Eventually from (6) using now the subscript Q

$$v = \sqrt{2\frac{P_d}{\rho_d}} = \sqrt{2\varphi_Q} \tag{41}$$

where we see that the action of gravity is equated to that of translational motion, via the second cosmic velocity. We realize that through the FEP it is possible to overcome the difference between the two formulas for time dilation used in special and general relativity, by attributing to gravity also the effects of special relativity and also in absence of a gravitational field (as we have in this case an "apparent" gravitational field due to acceleration through the DS). From here we reflect whether – as far as relativistic mass increase is concerned – the official theory make a dimensional mistake, swapping kgf with kg, *i.e.* interpreting a weight force pointing in the opposite direction to the supplied acceleration as a mass increase (the brace in Eq. 42 indicates the hypothesized misconstruction). In SQG, this phenomenon is actually due to a "drag weight", i.e to a gravitational force acting in the opposite direction to motion. Indeed, if drag weight grew according to Lorentz factor (see [2], Lorentz factor as the rheogram of the DS: a dilatant behavior of the DS in relativistic regime due to its granular, quantum nature) this could be the cause of the so-called relativistic mass increase leaving mass actually unchanged

$$\mathbf{a} = \frac{\mathbf{F}}{m \underbrace{+\mathbf{W}_{\Phi}}} \Rightarrow \frac{\mathbf{F} - \mathbf{W}_{drag}}{m}. \quad (42)$$

The new equation expressing the total weight of a body in SQG would then be:

$$\mathbf{W}_{\text{tot}} = m(\mathbf{g} + \mathbf{g}_{\varphi}) \quad (43)$$

where the accelerations g and g_{φ} (that due to drag weight) may point in different directions, according to the presence of a gravitational field and of translational motion for velocities in relativistic regime.

8 Gravity-electromagnetism unification via energy balance in SQG.

The attraction of DSQ into massive particles as quantum vortices exerting Bernoulli pressure, would cause their mass to progressively increase. This doesn't occur. We consider then an output for the absorbed quanta and we believe they are packed, and emitted, into amounts known as virtual photons, which generate the electrostatic field of charged particles. This mechanism would connect gravity with electromagnetism. In the case of unbound neutral particles, as neutrons, the absence of energy output would push them to decay and we know that unbound neutrons' mean lifetime is ~ 881 s. DS absorption would explain in this way the β-decay as energy imbalance. On the contrary, bound neutrons in the nucleus can transfer the exceeding DSQ to protons and be stable: this transfer corresponds to the gluon flow and would hydrodynamically explain the strong interaction [1,16]. Another prediction of SQG is a greater mass for isolated neutrons before they decay, if compared with the mass of bound neutrons in a nucleus, as well as a faster decay of neutral pions ($8.4 \cdot 10^{-17}$s) if compared with charged pions ($2.6 \cdot 10^{-8}$s), as it actually occurs. The decay of a charged particle might be then due to imbalance between absorbed and emitted vacuum energy (i.e. DSQ). We observe decay in the case $\varepsilon_{abs}(t) - \varepsilon_{emit}(t) > 0$ or stability if $\varepsilon_{abs}(t) - \varepsilon_{emit}(t) = 0$.

Since the emission of virtual photons is quantized and we assume that each of them is made up of several DSQ, charged particles would briefly increase their mass before the emission of the following virtual photon obeying a sawtooth function [16]. This trembling mass fluctuation would explain the hypothesized phenomenon of Zitterbewegung. Not by chance, stochastic electrodynamics explains Zitterbewegung as the interaction of a charged particle with the zero-point field (with the DS in our case). The amplitude of Zitterbewegung equals the Compton wavelength $\lambda_c = h/m_0c$, which refers to mass-energy conversion. In our case the conversion of the exceeding mass into virtual photons. Finally, DSQ "packaging"sheds light on the magnitude discrepancy between gravity and electromagnetism. An implication, which is different from the current model, would be the non-radiality of the electrostatic field of point particles and the unidirectional emission of virtual photons after a reorientation of the point charge (a vortex-particle in this approach [1]) when interacting with another one, as it happens for magnets. This issue is discussed in [16]. This should not be excluded, since we can know the geometry of the electrostatic field of a single free charge only when we observe it interacting with another charge. As an experimental evidence of this within our hydrodynamic analogy, we know that when in superfluids vortex lines approach, they reorient themselves [25]. The reorientation would occur through the interaction of the field lines (as (pilot-)waves in the DS), both in electromagnetism and as regards the dynamics of vortices, with in the latter Bernoulli pressure still playing a central role.

9 Verification

SQG may be difficult to verify since its predictions seem to completely coincide with those of general relativity, of which it would be the quantum hydrodynamic foundation. Room for tests on secondary co-hypothetical aspects of the theory may exist in particle physics (*a*. unbound neutrons increase their mass before decaying; *b*. point charges reorient themselves in space, as magnets, when approached to each other). However, the most important test would be that for demonstrating the gravitational field as inflow of DS, practically a radial, incoming ether wind called gravitational field, undetectable via a classic Michelson-Morley interferometric test, being the ether wind the gravitational field, not influenced by the Earth's orbital motion. This could be achieved by measuring the frequency of a laser beam when it travels parallel to the gravitational field without reflections (nor during the detection of frequency, unless the final direction of the beam is the same as at the origin): the result should match that predicted in general relativity for gravitational redshift but it should persist when the source and the frequency detector are synchronized with the same clock, excluding in this way the contribution from Einstein redshift. In short, SQG asserts that the frequency of light is directly affected by gravity, not simply changed because of time dilation affecting the instruments which measure it when located in different points of a gravitational field as theorized in general relativity.

Conclusion

By describing fundamental massive particles as quantized torus-shaped vortices in the DS [1], we have discussed how Bernoulli pressure, observed when vortices form in superfluids, can be the mechanism of quantum gravity by attracting the surrounding quanta and generating a pressure gradient aroung the particle. This means that gravity would be an apparent quantum hydrodynamic force which acts without gravitons. All effects predicted in general relativity seem to be predictable also in SQG, from gravitational lensing and Lense-Thirring precession up to gravitational redshift, letting appear SQG as the quantum hydrodynamic explanation of the global general relativity picture (and also of special relativity as discussed in [2]), thanks to considering the physical vacuum as a superfluid, which coincides with dark energy and dark matter: a “dark superfluid” [1]. Explaining the gravitational field as an incoming flow of DS would also justify the increase of inertia experienced in special relativity when a body is accelerated through the DS, showing an equivalent situation (fluid equivalence principle) in which the mass increase would be actually an increasing “gravitational” force (drag weight) acting in the opposite direction to motion. Eventually, the DSQ inflow requires an energy balance which may directly lead to the unification gravity-electromagnetism and to a general superfluid theory of fundamental forces. In short, we believe it is worth to study in deep and test the quantum hydrodynamic model called SQG as an alternative to the graviton picture and to the pure official differential-geometric approach to space and time which is still lacking quantum features.

References

1. Fedi, M.:*Hydrodynamics of the dark superfluid: I. Genesis of fundamental particles*, HAL-archives, CCSD, France, https://hal.archives-ouvertes.fr/hal-01549082
2. Fedi, M.:*Hydrodynamics of the dark superfluid: II. photon-phonon analogy*, HAL-archives, CCSD, France https://hal.archives-ouvertes.fr/hal-01532718
3. Sbitnev, V.I.: *split of the Schrödinger equation onto two equations describing evolution of real functions*, Kvantovaya Magiya, **5** (1), 1101-1111.
URL: http://quantmagic.narod.ru/volumes/VOL512008/p1101.html (2008)
4. Sbitnev, V.I.: *Bohmian traectories and the path integral paradigm. Complexified Lagrangian mechanics*, Int. J. Bifurcat. Chaos **19** (7), 2335-2346 (2009)
5. de Broglie, L.: *Une interpretation causale et non linéare de la mécanique ondulatoire: la théorie de la double solution*, Gauthier-Villars, Paris (1956)
6. de Broglie, L.:*The reinterpretation of quantum mechanics*, Found. Phys 1, 5 (1970)
7. Licata, I., Fiscaletti, D.:*Quantum potential: physics, geometry and algebra*, Springer briefs in physics, Springer, Cham Heidelberg New York Dordrecht London (2014)
8. Amendola, L., Tsujikawa, S.:*Dark Energy - Theory and Observations*, Cambridge University Press, 2010, p.46-51
9. Ashtekar, A., Pullin, J.:*Loop Quantum Gravity*, World Scientific, 2017
10. Rovelli, C., Vidotto, F.:*Covariant Loop Quantum Gravity: An Elementary Introduction to Quantum Gravity and Spinfoam Theory*, Cambridge University Press, 2014
11. Francisco, F., Bertolami, O., Gil, P. J. S. and Páramos, J.:*Modelling the reflective thermal contribution to the acceleration of the pioneer spacecraft*, (2012), URL https://arxiv.org/abs/1103.5222.
12. Toth, V. T.:*Study of the pioneer anomaly: A scientific detective story*, 2009, URL https://arxiv.org/abs/0903.0075
13. Rievers, B., Lämmerzahl, C., List, M., Bremer, S. and Dittus, H., New J. Phys. 11, 113032 (2009).
14. Einstein, A.:*Über Gravitationswellen*. Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften Berlin (1918)
15. Abbott, B.P. (LIGO Scientific Collaboration and Virgo Collaboration) et al.:*Observation of Gravitational Waves from a Binary Black Hole Merger*, Phys. Rev. Lett. **116** (6): 061102. arXiv:1602.03837 (2016)
16. Fedi, M.:*A Superfluid Theory of Everything?*, v.4, 2017, HAL-Archives, CCSD, France, URL: http://hal.archives-ouvertes.fr/hal-01312579
17. Cahill, R.T.:*Gravity as quantum foam in-flow*. URL: https://arxiv.org/abs/physics/0307003
18. Kirkwood, R.L.:*The Physical Basis of Gravitation*, Phys. Rev. **92**, 1557 (1953)
19. Visser, M., Barcel, C., Liberati, S.:*Analogue models of and for gravity*, General Relativity and Gravitation, **34** (10): 17191734 (2002).
20. Barcel, C., Liberati, S., Visser, M.:*Analogue Gravity*, Living Reviews in Relativity. **14** (3), 2011
21. Consoli, M., Pappalardo, L.:*Emergent gravity and ether-drift experiments*, arXiv:0912.0103
22. Laughlin, R.B.:*A Different Universe: Reinventing Physics from the Bottom Down*, NY, NY: Basic Books (2005)
23. Nottale, L.:*Quantum-like gravity waves and vortices in a classical fluid*, arXiv:0901.1270v1 (2009)
24. Sbitnev, V.I., Fedi, M.:*Superfluid quantum space and evolution of the universe*. In: Capistrano de Souza, A. J. (ed.), Trends in Modern Cosmology, InTech, Rijeka (2017)
25. Huang, K.:*A Superfluid Universe*. World Scientific, Singapore (2016)
26. Lebedev, V., Moroshkin, P., Grobey, B., Weis, A.: J. Low Temp. Phys. **165**, 166 (2011)
27. Amelino-Camelia, G., D´Amico, G., Rosati, G. and Loret, N.: *In vacuo dispersion features for gamma-ray-burst neutrinos and photons*, Nature Astronomy 1, Article number: 0139 (2017)
28. Dominici, L., Carretero-González, R., Cuevas-Maraver, J., Gianfrate, A. et al.: *Interactions and scattering of quantum vortices in a polariton condensate*, arXiv:1706.00143v1 (2017)
29. Pshenichnyuk, I.A.: *Pair interactions of heavy vortices in quantum fluids*, arXiv:1705.10072v1 (2017)
30. Gignoux, C., Silvestre-Brac, B.: *Solved Problems in Lagrangian and Hamiltonian Mechanics*, Springer Science and Business Media (2009)