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# Quantum gravity without gravitons as dark energy inflow

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## Abstract

It is assumed that dark energy (69.1% of what constitutes our Universe<sup>2</sup>) is quantized and behaves as a superfluid. We hypothesize that the flux described in Gauss's law for gravity is real and corresponds to dark energy absorption into massive particles, driven by spin. A quantum potential consequently arises from the pressure gradient around massive bodies, allowing a formula for quantum gravity without resorting to gravitons. The Newtonian gravitational constant disappears and Einstein field equations, along with their metrics, are presented in a modified form, highlighting the role of dark energy's fluid dynamics. In the approach of superfluid quantum gravity (SQG) any effect predicted in special and general relativity is allowed. We also analyze the consequences of light propagation through dark energy, we explain gravitational waves as negative pressure waves propagating through dark energy, and we show Lorentz factor as the rheogram of dark energy. Thus, considering the unifying and clarifying faculty of a dark energy-based approach to relativity and cosmology, it is suggested to proceed with proposed experimental verifications, with the aim of replacing Einstein's curved space-time with the hydrodynamics of dark energy, to unify relativity with quantum field theory.

**keywords:** gravity; dark energy; special and general relativity; photon; gravitational waves; Hubble's law.

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<sup>2</sup>data from the Planck Space Observatory, ESA.

## Introduction

We start from the hypothesis of a Universe full of superfluid, quantized dark energy, in which hydrodynamic perturbations would occur. In Sec. 1, gravity is described as absorption of dark energy's quanta into massive particles, driven by spin. We show how to obtain a formula for quantum gravity without resorting to gravitons, following the hydrodynamic approach, thanks to which the gravitational constant disappears. We derive then the quantum potential (§1.1) and we modify the Einstein field equations and their solutions (§1.2) without resorting to any constant, nor to the speed of light ( $c$ ), as it would depend on dark energy's density and isentropic compressibility. In fact, in section 2, since light propagates in a Universe full of dark energy, we wonder whether a photon could actually be a phonon propagating through dark energy and we show that this analogy is sufficiently strong to describe the speed of light as the speed of sound through dark energy (29) and the electromagnetic field of a photon as the periodic excitation of dark energy's quanta during the propagation of the phonon, due to its spin. The consequences of such an approach on the interpretation of Hubble's law are discussed (§2.2) and the recently detected gravitational waves are also described as pressure waves propagating through dark energy (§2.1). Einstein's energy-matter formula is observed putting in evidence the role of dark energy (§2.3). We proceed analyzing other consequences of dark energy fluid dynamics, showing that Lorentz factor could actually correspond to the rheogram of dark energy (§2.4). In section 3, we discuss a fluid equivalence principle which equates the gravitational field (as incoming flow of dark energy) to motion through dark energy, explaining time dilation of special relativity as a phenomenon actually caused by gravity, seen as the origin of any other relativistic effect. In Sec. 4, we eventually discuss the consequences of dark energy absorption into massive particles without provoking mass increase.

## 1 From classical gravity to quantum gravity without gravitons

Data from the Planck Space Observatory suggest that dark energy fills up the Universe, constituting 69.1% of its mass-energy. Since any form of energy has to be quantized, we suppose that also dark energy is and that this ubiquitous sea of dark quanta, partially (an additional 25.9%) condensed in dark matter, acts as a superfluid medium, producing fluid dynamic phenomena in the Universe and in the world of elementary particles. The most important would be gravity. Gauss's law for gravity,

$$\oiint_{\partial V} \mathbf{g} \cdot d\mathbf{A} = -4\pi GM, \quad (1)$$

describes the gravitational field as an incoming flux. We assume that this flux is real and caused by the absorption of superfluid dark energy into massive

particles, driven by their spin. Indeed, we believe that fundamental massive particles are superfluid vortices [3, 4, 5, 6] of dark energy's quanta and according to Salvatore Esposito [2], who cites Recami and Salesi [1], we think that the quantum potential

$$Q = -\frac{1}{2}m\vec{v}_S - \frac{1}{2}\nabla \cdot \vec{v}_S \quad (2)$$

of a particle totally arises from its internal motion  $\vec{v}_S \times \vec{s}$ , where

$$\vec{v}_S = \frac{1}{2m} \frac{1}{\rho} \nabla \rho = \frac{1}{2m} \frac{\nabla R^2}{R^2}, \quad (3)$$

putting  $\hbar = 1$ , and  $\vec{s}$  is the direction of spin. A superfluid horn-torus-shaped vortex evolving from a vortex ring would actually possess spin- $\frac{1}{2}$  as fermions and all the information of the particle would be contained on its surface, also explaining some instances of the holographic principle. Since even in superfluids viscosity is never exactly zero, the vortex would attract the surrounding quanta, causing pressure variation and gravitational acceleration in the environment. Below we show how the quantum potential in (3) connects with that of quantum gravity, indicating the spin as its source. Mass conservation despite energy absorption would be possible thanks to emission of virtual photons, as discussed in §4, marking the nexus between gravity and electromagnetism.

Let us analyze below the mechanism of SQG and its consequences.

If a body radially absorbed the fluid in which it is immersed, it would consequently attract other bodies around it, which are immersed in the same fluid, due to a force originating from a pressure gradient. A similar hypothesis of hydrodynamic gravity was proposed by Cahill [7], based on quantum foam absorption, a condition that we do not consider possible for several reasons<sup>3</sup>.

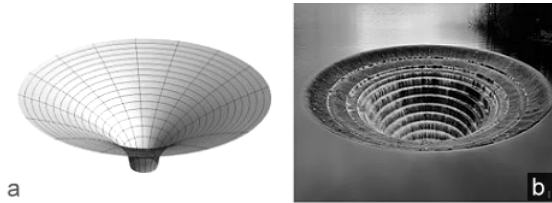


Figure 1: Analogy between curved space-time in a Flamm's paraboloid (a), corresponding to the Schwarzschild solution, and inflow of superfluid dark energy, represented as water flowing into a bell-mouth spillway (b). An object floating in the area around the spillway would be attracted toward the site of absorption because of a force generated by a pressure gradient in a *flat* space-time.

<sup>3</sup>particle-antiparticle pairs immediately annihilate. Though the absorption occurred before the annihilation, a fermion as an electron could not absorb another electron. Moreover, the free positron would annihilate with a third electron.

CFD simulations confirm that in the case of a fluid medium absorbed by a spherical body, a pressure gradient (Fig. 2) arises around it. The absorption provokes an attractive force which obeys Gauss's law for gravity and the Schwarzschild solution. Refinement of the computational grid and domain enlargement helped to reduce the curvature of the flow lines up to a virtually radial flow.

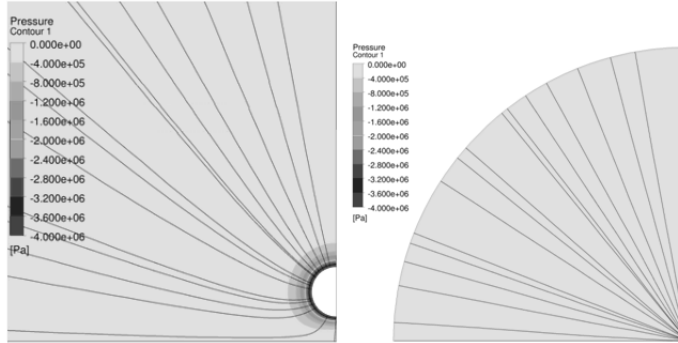


Figure 2: Pressure gradient around a spherical body absorbing the fluid in which it is immersed. As verified in CFD simulations, the consequent attractive force mathematically equals Gauss's and Newton's laws for gravity and is compatible with the Schwarzschild solution. Refining the grid (on the right) leads to a perfectly radial symmetry.

We know that a pressure gradient generates a force, whose acceleration is expressed as

$$\vec{a} = -\vec{\nabla} \frac{P}{\rho}. \quad (4)$$

In our case, (4) corresponds to the gravitational acceleration caused by dark energy absorption, then we have

$$\vec{g} = -\vec{\nabla} \frac{P_d}{\rho_d}, \quad (5)$$

where  $P_d$  and  $\rho_d$  are, respectively, pressure and density of dark energy.

By using (5) in Newton's second law, we can therefore write a hydrodynamic formula for universal gravitation, based on dark energy's fluid dynamics

$$\vec{F}_g = -m \vec{\nabla} \frac{P_d}{\rho_d}. \quad (6)$$

Since we assumed that dark energy is a quantized superfluid whose absorption into massive particles is driven by spin, (6) has to be the formula for quantum gravity. Below, we will derive the quantum potential.

In SQG, the classical gravitational potential ( $\varphi$ ) corresponds to the ratio pressure to density expressed in (5), as a hydrodynamic gravitational potential  $\varphi_h$ :

$$\varphi = -G \frac{M}{r} \left[ \frac{\text{m}^2}{\text{s}^2} \right] \iff \varphi_h = -\frac{P_d}{\rho_d} \left[ \frac{\text{m}^2}{\text{s}^2} \right], \quad (7)$$

where the gravitational constant  $G$  disappears. This is a good hint, since the role of the Newtonian constant is simply that of adjusting calculations and units of measure in a non-quantum formula. It is also interesting to note that the units correspond to Gray (Gy), i.e. to the unit used for energy absorption (J/kg). In this case, absorption of dark energy.

We see that the same hydrodynamic expression is used for the equation of state in cosmology:  $w = P/\rho$ . By considering a Universe full of superfluid dark energy, that approach acquires greater significance.

## 1.1 Deriving the quantum potential

Let us consider the gravitational acceleration, due to the absorption, of  $N$  dark energy's quanta (DEQ) contained in a unit volume.

Their mass will be  $m_V = mN$ , where  $m$  is the mass of a single quantum. We multiply (7) by  $m_V$ , in order to obtain for the system a hydrodynamic quantum potential in units of energy

$$Q_\varphi = -m_V \frac{P_d}{\rho_d}. \quad (8)$$

According to Fick's law, a flux of DEQ is directed toward the region of lower density (Fig.2) around the absorbing body. We can therefore express the pressure in (8) as  $P = J \cdot u$ , where

$$J = D \frac{d\rho}{dx} = \rho \cdot u \quad (9)$$

By also considering the De Broglie relations, we therefore observe the following identities

$$Q_\varphi = -m_V \frac{P_d}{\rho_d} = m_V \frac{J \cdot u}{\rho} = p \cdot u = -i\hbar \nabla u = -i\hbar \frac{\partial}{\partial t} = \hat{H} = -\frac{\hbar^2}{2m} \nabla^2 + \hat{U} \quad (10)$$

where  $p = mu = \hbar k = -i\hbar \nabla$  represents the momentum,  $m = m_V/N$  is the mass of a quantum and  $\hat{H}$  is the hamiltonian operator of the Schrödinger equation (SE), indicating the energy of the system. Both energy terms, kinetic,  $-(\hbar^2/2m)\nabla^2 = \hat{T}$ , and potential,  $\hat{U}$ , are expression of the same total gravitational quantum energy of the system, where potential energy gradually converts into kinetic energy as DEQ approach the absorption site. Let us observe the SE with its quantum potential. We define the probability density for unit volume

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

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 two coupled equations. That arising from the real part of the SE reads

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

where the quantum potential  $Q$  is expressed as kinetic energy. We can equate the Hamiltonian operator in (10) with that in (12) since in the considered system DEQ do not possess kinetic energy,  $(\nabla S)^2/2m$ , different from that due to the gravitational acceleration (seen as a quantum hydrodynamic phenomenon). We have

$$Q_\varphi = \hat{H} = - \left[ \hat{U} + \frac{\hbar^2}{2m} \frac{\nabla^2 \sqrt{\rho}}{\sqrt{\rho}} \right]. \quad (13)$$

When DEQ reach the absorption site, potential energy ( $\hat{U}$ ) has been totally converted into kinetic energy. In that case

$$Q_\varphi = - \frac{\hbar^2}{2m} \frac{\nabla^2 \sqrt{\rho}}{\sqrt{\rho}}. \quad (14)$$

This quantum potential is directly connected with that at the source of quantum gravity in (3). We therefore look at the spin of massive particles as at the engine of quantum gravity.

Eq.(14) has the same mathematical form of the quantum pressure tensor of Madelung equations [20].

In the case of a non-free body in a gravitational field, the energy, and our quantum potential, totally corresponds to potential energy. In fact, from (7), we observe

$$U = -m \frac{GM}{r} + k = -m \frac{P_d}{\rho_d} = Q_\varphi, \quad k = 0 \quad (15)$$

being  $U$  the gravitational potential energy of classical physics in its general formulation and putting  $k = 0$  for a point at infinity.

Having defined the quantum potential, a quantum force,  $\vec{F}_Q = -\vec{\nabla}Q_\varphi$ , exists, which brings back to (6), now seen as the formula for quantum gravity

$$\vec{F}_Q = -\vec{\nabla}Q_\varphi = -m \vec{\nabla} \frac{P_d}{\rho_d} = \vec{F}_{gQ}. \quad (16)$$

If we projected the Bohmian approach [21] onto a macroscopic level, we could state that the trajectory of an accelerated body along the lines (seen as a

quantum flux obeying Fick's law) of the gravitational field is analogous to that of a particle driven by its pilot-wave (we could wonder whether also a pilot wave could be a flow of DEQ).

It is now clear that in this approach we don't refer to curved space-time but to accelerated fluid space, due to dark energy's hydrodynamics, whose effects, as discussed below, are the same of those described in Einstein's relativity.

From (7), we see that the disappeared Newtonian gravitational constant now reads

$$G = \varphi \frac{r}{M} = -\frac{P_d}{\rho_d} \frac{r}{M} = Q_\varphi \frac{r}{m_\pi} = \text{const.} \quad (17)$$

where  $m_\pi = Mm$ .

The differential form of Gauss's law for gravity (i.e. Poisson's equation) becomes

$$\nabla^2 \frac{Q_\varphi}{m} = 4\pi Q_\varphi \frac{r}{m_\pi} \rho_m = \frac{3Q_\varphi}{mr^2} \quad (18)$$

where  $\rho_m = \frac{3}{4} \frac{M}{\pi r^3}$  is mass density. We don't write the minus sign at the beginning of each member since contained in  $Q_\varphi$  (8).

## 1.2 Einstein field equations and their solutions in SQG

Let us now consider Einstein's field equations (EFE)

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}. \quad (19)$$

In SQG the space-time curvature is substituted by dark energy's hydrodynamics but general relativity's differential geometry can still be a useful tool *as if space were curved*. Below, the EFE are shown in a modified form by replacing:

- a) the gravitational constant  $G$  from (17), considering a positive  $Q_\varphi$
- b) vacuum's density with dark energy's density when  $g \rightarrow 0$ , that is  $\rho_{vac} = \rho_{d0}$
- c) the identity  $\frac{1}{c^2} = \beta_d \rho_{d0} = \delta$ , from (29), §2, where  $\beta_d$  is dark energy isentropic compressibility,

therefore seeing that Einstein's constant becomes

$$\kappa = \frac{8\pi G}{c^4} = \frac{8\pi Q_\varphi r}{m_\pi} \delta^2$$

and the cosmological constant consequently reads



$$\Lambda = \rho_{d_0} \kappa = \frac{8\pi Q_\varphi r \delta^2 \rho_{d_0}}{m_\pi}. \quad (20)$$

The field equations assume then the following quantum form, dominated by dark energy's fluid dynamics

$$G_{\mu\nu} + 8\pi Q_\varphi \frac{r}{m_\pi} \delta^2 \rho_{d_0} g_{\mu\nu} = \frac{8\pi Q_\varphi r}{m_\pi} \delta^2 T_{\mu\nu}, \quad (21)$$

The role of dark energy was already present in the meaning of the cosmological constant but it is here extended to the whole meaning of the field equations. We note that the stress-energy tensor is fully compatible with a quantum fluid dynamic interpretation which considers dark energy, being  $T^{00}$  its density,  $\rho_{d_0} = \rho_{vac}$ ,  $T^{ii}$ , its pressure,  $P_d$ ,  $T^{0i} = T^{i0}$  the momentum density and being shear stress (cf. §2.4) and momentum flux the remaining components. As far as the metric tensor,  $g_{\mu\nu}$ , is concerned, though space-time would not be distorted but simply expressed by dark energy's fluid dynamics, it maintains its computational usefulness *as if space were distorted*. The same can be said for the other tensors in EFE, since both Ricci tensor,

$$R_{ij} = R^k_{ikj} = \partial_l \Gamma^l_{ji} - \partial_l \Gamma^l_{li} + \Gamma^l_{l\lambda} \Gamma^\lambda_{ji} - \Gamma^l_{j\lambda} \Gamma^\lambda_{li} \quad (22)$$

and Ricci scalar,

$$S = 2g^{ab} (\Gamma^c_{a[b,c]} + \Gamma^d_{a[b} \Gamma^c_{c]d}), \quad (23)$$

forming Einstein tensor,  $G_{\mu\nu}$ , are defined through Christoffel symbols, which are themselves expressed by the metric tensor, e.g.  $\Gamma_{cab} = \frac{1}{2}(\partial_b g_{ca} + \partial_a g_{cb} - \partial_c g_{ab})$ .

Now, by substituting  $G$  and  $c$  as above, we can rewrite the solutions to EFE in quantum hydrodynamic form. The line element for Schwarzschild metric will read

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu = (1 - 2Q_{\varphi_m} \delta)^{-1} dr^2 + r^2 (d\theta^2 + \sin^2 \theta d\phi^2) - \delta^{-1} + 2Q_{\varphi_m} dt^2, \quad (24)$$

where  $\theta, \phi$  are coordinates of colatitude and longitude and, for brevity,  $Q_{\varphi_m} = Q_\varphi/m$ , which corresponds to the gravitational potential in fluid dynamic form (7).

Kerr metric becomes:

$$\begin{aligned} \delta^{-1} d\tau^2 = & \left( \delta^{-1} - \frac{2Q_{\varphi_m} r^2}{\varrho^2} \right) dt^2 - \frac{\varrho^2}{\Delta} dr^2 - \varrho^2 d\theta^2 - \\ & \left( r^2 + \frac{\gamma^2}{\delta} + \frac{2Q_{\varphi_m} r^2}{\varrho^2} \gamma^2 \sin^2 \theta \right) \sin^2 \theta d\phi^2 + \frac{4Q_{\varphi_m} r^2}{\varrho^2} \gamma \sin^2 \theta dt d\phi, \end{aligned} \quad (25)$$

by defining for brevity  $\gamma = \frac{J}{Mc^2} = \frac{J\delta}{M}$ , being  $J$  the angular momentum;  $\varrho^2 = r^2 + \frac{\gamma^2}{\delta} \cos^2 \theta$  and  $\Delta = r^2 + \frac{\gamma^2}{\delta} - 2Q_{\varphi_m} r^2 \delta$ . We note that introducing dark energy's hydrodynamics, the Schwarzschild radius reads  $R_S = 2Q_{\varphi_m} r \delta$ .

Switching to Reissner-Nordström metric in spherical coordinates  $(t, r, \theta, \phi)$ , we see that

$$\delta^{-1}d\tau^2 = \left( \delta^{-1} - 2Q_{\varphi_m} + \frac{Q^2\delta Q_{\varphi}}{4\pi\epsilon_0 r m_{\pi}} \right) dt^2 - \left( \frac{1}{\delta^{-1} - 2Q_{\varphi_m} + \frac{Q^2\delta Q_{\varphi}}{4\pi\epsilon_0 r m_{\pi}}} \right) \delta^{-1}dr^2 - r^2 d\Omega^2, \quad (26)$$

where  $Q$  is the charge,  $\epsilon_0$  vacuum (dark energy) permittivity and  $d\Omega^2 = d\theta^2 + \sin^2\theta d\phi^2$ .

Finally, we see the line element of Kerr-Newman metric in Boyer-Lindquist coordinates as follows

$$\delta^{-1}d\tau^2 = - \left( \frac{dr^2}{\Delta} + d\theta^2 \right) \varrho \cos^2\theta + \left( \sqrt{\delta^{-1}}dt - \xi\sqrt{\delta}\sin^2\theta d\phi \right)^2 \frac{\Delta}{\varrho \cos^2\theta} - (\varrho d\phi - \xi dt)^2 \frac{\sin^2\theta}{\varrho \cos^2\theta} \quad (27)$$

where the following length-scales are introduced for brevity:  $\xi = \frac{J}{M}$ ;  $\varrho = r^2 + \delta\xi^2$  and  $\Delta = \varrho - 2Q_{\varphi_m}r^2\delta + \frac{Q^2Q_{\varphi}r\delta^2}{4\pi\epsilon_0 m_{\pi}}$ .

## 2 Light propagation through dark energy

Light doesn't travel through a real vacuum. We don't refer to quantum vacuum<sup>4</sup> [8, 9] or quantum foam [10] but to the fact that dark energy permeates the Universe. Light therefore propagates through dark energy. Equations show that a photon could actually be a special spin-1 phonon. A pulse propagating through superfluid dark energy. Waves existing in nature would reduce to only one type and photon's electromagnetic field could be interpreted as a periodic excitation of DEQ.

Let's 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

$$a = \frac{1}{\sqrt{\beta_S \rho}} \quad (28)$$

If we consider  $\beta_S = \beta_d$  as dark energy's isentropic compressibility,  $\rho_{d_0}$  as its density and  $c$  as the speed of the pulse, we get

$$c = \frac{1}{\sqrt{\beta_d \rho_{d_0}}} \quad (29)$$

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<sup>4</sup>where particle-antiparticle pairs continuously form and annihilate probably corresponding to stochastic fluid dynamic perturbations of superfluid dark energy, i.e. superfluid quantum vortices.

expressing the speed of a photon as a phonon through dark energy, mathematically analogous to  $c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$ , as resulting from Maxwell's equations.

This means that light's EM field would quantum mechanically arise from the periodic excitation of DEQ during the propagation of the phonon. This explains why the physical vacuum (a false vacuum) possesses a given permittivity ( $\epsilon_0$ ) and permeability ( $\mu_0$ ) as other materials. From (29), we see that the speed of light would simply be the speed of sound through dark energy, a *sound* that we perceive through our eyes. “*Wie? Hör' ich das Licht?*”, wondered Tristan<sup>5</sup>.

We also have to consider light propagation as a phenomenon of second sound through dark energy, as photons transmit thermal energy. After all, we know that phonons as well are bosons [11], have wave-particle duality [12, 13], obey the doppler effect, 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 of photons,  $p_{ph} \equiv \hbar k = \frac{h}{\lambda}$ , with  $k = \frac{2\pi}{\lambda}$ , can produce photoelectric effect and Compton scattering thanks to their momentum, can possess spin [14], can form squeezed coherent states and can interact via parametric down conversion [15]. 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  $\omega_k$  ( $k$  is the wave number) are:

$$E_n = \left(n + \frac{1}{2}\right) \hbar\omega_k \quad n = 1, 2, 3, \dots \quad (30)$$

If a photon is a pulse through superfluid dark energy and the gravitational field is an incoming flow of such medium, then light cannot have the same speed when travelling upward or downward parallel to the gravitational field. We need to vertically place a Michelson interferometer to verify that. Indeed, the original premise of the Michelson-Morley test was in this case wrong, since the ether is not stationary but radially directed toward the center of the Earth, independently of its motion about the Sun. The only influence on this flow comes from Earth's rotation and corresponds to the Lense-Thirring precession described in general relativity, in which the rotation of the planet bends the gravitational field (in this case the flow of dark energy), as a rotating garden sprinkler bends its jet of water. Tests with a vertically placed Michelson interferometer gave positive result [16]. We also suggest to measure the speed of light (through the time of flight) without reflexion, along a single trajectory parallel to the gravitational field ( $\vec{c} \parallel \vec{g}$ ), after having synchronized the clocks used to determine when the measurement begins and ends. In this case, the measured speed should be lower than  $c$  when the beam is directed upward or, vice versa, faster. In case of reflexion of the beam the discrepancies would be leveled.

Through other CFD simulations, we could verify that any other effect described in special and general relativity is explainable through the laws of fluid dynamics within a superfluid sea of dark energy, instead of resorting to a curved space-time. The word *dynamics* already contains time in itself.

<sup>5</sup>“What? Is it the light I hear?”, R.Wagner, Tristan und Isolde, Act 3, Scene 2.

For instance, the gravitational lensing would not be caused by curved space-time but by the fact that light travels through a flowing medium, since dark energy flows toward massive bodies (5)(16) as stars. We observe the same mechanism in classical fluid dynamics when the wind deflects a sound. The inflow of dark energy would also keep a body orbitating about another one.

## 2.1 Gravitational waves

Assuming gravity as absorption of superfluid dark energy, gravitational waves [17] arise as negative pressure waves generated by periodic ( $\Rightarrow$ quadrupole) variations in the absorption intensity oriented towards a given point (e.g. towards LIGO's mirrors [18]). Gravitational waves would be negative pressure waves propagating through dark energy. Again, no curved space-time is needed to explain what experimentally observed. Let us consider a supposed space-time deformation as a wave with polarization $\times$

$$h_{\times} = -\frac{1}{R} \frac{G^2}{c^4} \frac{4m_1 m_2}{r} (\cos \theta) \sin \left( 2\omega \left( t - \frac{R}{c} \right) \right). \quad (31)$$

By substituting from (17) and (29) we see that the gravitational wave is a pressure oscillation propagating through dark energy

$$h_{\times} = -\frac{1}{R} \left( 2 \frac{P_d}{\rho_d} \beta_d \rho_{d_0} \right)^2 r m_2 (\cos \theta) \sin \left( 2 \sqrt{\frac{1}{r^2} \frac{P_d}{\rho_d} \left( 1 + \frac{m_2}{m_1} \right)} \left( t - R \sqrt{\beta_d \rho_{d_0}} \right) \right) =$$

$$-\frac{1}{R} (2Q_{\varphi} \delta)^2 \frac{r}{m_1 m_2} (\cos \theta) \sin \left( 2 \sqrt{\frac{1}{r^2} Q_{\varphi} \frac{m_1 + m_2}{m_1 m_2}} \left( t - R \sqrt{\delta} \right) \right), \quad (32)$$

while the polarization  $h_+$  reads

$$h_+ = -\frac{1}{R} (Q_{\varphi} \delta)^2 \frac{2r}{m_1 m_2} (1 + \cos^2 \theta) \cos \left( 2 \sqrt{\frac{1}{r^2} Q_{\varphi} \frac{m_1 + m_2}{m_1 m_2}} \left( t - R \sqrt{\delta} \right) \right), \quad (33)$$

where  $R$  is the distance from the observer,  $t$  the elapsed time,  $\theta$  the angle between the perpendicular to the plane of the orbit and the line of sight of the observer,  $r$  the radius of the quadrupole,  $\sqrt{\frac{1}{r^2} Q_{\varphi} \frac{m_1 + m_2}{m_1 m_2}} = \omega$  the angular frequency of the quadrupole, obtained by using the identity (7) in the Newtonian formula for constant angular velocity of a circular orbit  $\sqrt{G(m_1 + m_2)/r^3}$ ,  $Q_{\varphi}$  is positive and  $\sqrt{\beta_d \rho_{d_0}} = \sqrt{\delta}$  corresponds to  $c^{-1}$  (29), which accounts for the speed of the gravitational wave as speed of light, since in both cases we observe a pressure wave through dark energy though, in the case of gravitational waves, with the distinction of a negative pulse whose frequency depends on the

quadrupole. As shown in (4)(5) the pressure variation corresponds to an acceleration, acting in this case on LIGO's test masses if we take into account the recent tests.

## 2.2 Hubble's law

Valid the analogy photon-phonon and taken into account that no superfluid has actually zero viscosity, Hubble's law in the form

$$z = \frac{H_0 D}{c} \quad (34)$$

or by highlighting dark energy's role,  $z = H_0 D \sqrt{\delta}$ , would be compatible with an energy loss ( $\Rightarrow$ redshift) of photons, due to the minimal viscosity of dark energy and proportional to the distance: the further a galaxy, the greater the detected redshift, without accelerated expansion of the Universe. According to  $E = \frac{hc}{\lambda}$ , the energy decrease would cause a greater wavelength, hence a redshift, while the speed of light would remain unaffected.

Lemaître's hypothesis,  $v \propto D$ , used to interpret the empirical Hubble's law, would not be, therefore, correct in attributing the cause of the observed redshift to the recessional velocity of the galaxies. This phenomenon is different from the theorization of tired light provided by Zwicky [19]. The known objections to tired light vanish in this approach, since a redshift due to a quasi-zero, uniform viscosity of dark energy throughout the cosmos: a) would not exhibit blurring, since no Compton scattering occurs in this hypothesis, b) for the same reason, it would admit the same measurement in any wavelength-band and c) it would follow the empirical Hubble's law. Moreover, we don't need to explain cosmological time-dilation, since it was introduced within a competing hypothesis (the expansion of the Universe). We have to add, that the observed redshift might arise as

$$z_{obs} = z_a + z_\mu \quad (35)$$

i.e. due to concomitant causes, where  $z_a$  is the redshift due to the expansion (in this case weaker as we think) of the Universe and  $z_\mu$  the component of redshift due to energy loss caused by dark energy's non-zero viscosity.

## 2.3 Mass-energy formula

By calculating the speed of light as described in Eq. (29) and by using for brevity  $\frac{1}{c^2} = \beta_d \rho_{d_0} = \delta$ , the mass-energy formula  $E = mc^2$  can be observed in the form

$$E = \frac{m}{\delta}, \quad (36)$$

To use a German expression, here dark energy appears as the *Urenergie* in the Universe. Whereas using the speed of light ( $c$ ) doesn't clarify the real meaning of the mass-energy formula, since such speed arises from more significant, fundamental parameters of dark energy, as its density and its isentropic compressibility (§2). If a certain mass were annihilated by a corresponding anti-mass, the total excitation of DEQ would correspond to a given number of photons, i.e. of phonons (§2) propagating through the superfluid sea of dark energy and occurring as a result of the destruction of superfluid vortices which possess conflicting spin (particle-antiparticle pair). The resulting thermal energy, propagated by the produced phonons, can be seen as second sound through dark energy.

## 2.4 Lorentz factor as the rheogram of dark energy

Dark energy's quanta which fill up the Universe as a suspension in space, would cause a non-newtonian, dilatant behavior of dark energy. However, given its extremely low density, the dilatancy of this granular, dark substance would be detectable only at drastically high shear stress. This would explain why particles which are accelerated in synchrotrons towards the speed of light encounter an increasing non-linear resistance (currently interpreted as relativistic mass increase), as indicated by Lorentz factor, where  $\beta = \frac{v}{c}$  is here described as the ratio between the total flow velocity of dark energy ( $u_{tot}$ ) which a body is subject to, as expressed in the fluid equivalence principle (38), and that of a pulse through dark energy,  $u_p = c = \sqrt{\delta^{-1}}$ , (29). Of course we assume it is not possible to exceed the speed of sound through a dilatant fluid.

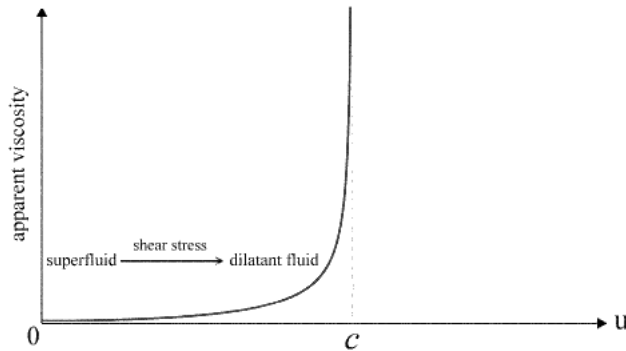


Figure 3: Lorentz factor as dark energy's rheogram.

The derivative of the arcsine indicates the impossibility of exceeding the speed of a pulse through dark energy because of its dilatant response as speed and shear stress increase

$$\gamma \equiv \arcsin' \left( \frac{u_{tot}}{u_p} \right) = \frac{1}{\sqrt{1 - \left( \frac{u_{tot}}{u_p} \right)^2}} = \frac{1}{\sqrt{1 - u_{tot}^2 \delta}} \quad (37)$$

where  $\delta = \frac{1}{c^2} = \beta_d \rho_{d0}$  represents the role of dark energy, as a quantum fluid, in Lorentz factor.

Known the velocity field related to dark energy absorption, if we used the total flow velocity  $u_{tot}$  (38), instead of the simple translational velocity, Eq. (37), in the form  $\Delta t' = \frac{\Delta t}{\sqrt{1 - \left( \frac{u_{tot}}{u_p} \right)^2}}$ , could also express gravitational time dilation, instead of  $\Delta t' = \frac{\Delta t}{\sqrt{1 - \frac{R_S}{r}}}$ , as discussed below.

### 3 Relativistic time dilation and fluid equivalence principle (FEP)

Special relativity (SR) tells us that velocity slows down clocks. General relativity (GR) asserts that also gravity slows them down. Something interesting happens when we remember that we have defined a gravitational field as an incoming flow of dark energy (§1). A body immersed in a gravitational field is subject to that flow. Now, a condition of equivalence arises when a body travels through a stationary fluid, since subject to an apparent flow. This is the reason why both velocity (SR) and gravity (GR) slow down clocks, as they are subject to a flow of dark energy which exerts a force (gravity). In SR we actually observe an apparent gravitational force opposite to the direction of motion (drag weight), which increases as the speed of sound through dark energy (i.e. the speed of light) is approached, because of dark energy's dilatancy at extreme shear stress (Fig. 3). We can therefore express a fluid equivalence principle which considers both (direct and apparent) gravitational flows as:

$$\mathbf{u}_{tot} = \mathbf{u}_\varphi + \mathbf{u} \quad (38)$$

where the total flow velocity  $\mathbf{u}_{tot}$  of dark energy, which a body is subject to, arises from the sum of the flow velocity of dark energy due to the gravitational absorption ( $\mathbf{u}_\varphi$ ) and the translational velocity of the body ( $\mathbf{u}$ ) through dark energy.

In this way, relativistic time dilation is reduced to the action of gravity also in SR. And since Lorentz-Fitzgerald contraction depends on time dilation, we can therefore demonstrate that all relativistic effects of SR and GR are ascribable in SQG to the sole action of gravity.

By equating the time dilation formulas of SR and GR we see that translational velocity in SR corresponds to a function of the hydrodynamic gravitational potential (7), as second cosmic velocity, which has to counterbalance the absorption velocity, demonstrating the FEP in Einstein's relativity:

$$\Delta t' = \frac{\Delta t}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{\Delta t}{\sqrt{1 - \frac{R_S}{r}}} \quad (39)$$

hence

$$\frac{v^2}{c^2} = \frac{R_S}{r} = \frac{2GM}{c^2 r} \implies v^2 = \frac{2GM}{r} \quad (40)$$

and

$$v = \sqrt{2rg} = \sqrt{2\varphi} \quad (41)$$

eventually from (7),

$$v = \sqrt{2 \frac{P_d}{\rho_d}}. \quad (42)$$

## 4 Mass conservation in SQG and prospect of fundamental interactions unification

The absorption of dark energy into massive particles would cause their mass to progressively increase. This doesn't occur. Since we assumed that the massive particles of the Standard Model are superfluid vortices in the superfluid sea of dark energy, according to Helmholtz's second theorem we consider an output for the absorbed energy and we believe it is 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 absorption process would push them to decay and we know in fact that unbound neutrons' mean lifetime is 881s. Dark energy absorption explains in this way the  $\beta$ -decay. On the contrary, bound neutrons in the nucleus can transfer the exceeding DEQ to protons and be stable: this transfer corresponds to the gluon flow and hydrodynamically explains the strong interaction. A prediction of SQG, for instance, would be that of a greater mass of 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.

Since the emission of virtual photons is quantized and we assume that each of them is made up of several DEQ, charged particles would briefly increase their mass before the emission of the following virtual photon obeying a sawtooth function. This energy loop 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 (dark energy, in our case).



## Conclusion

Considering gravity as the absorption of superfluid, quantized dark energy into massive particles, we have obtained a formula for quantum gravity (16) without resorting to gravitons. The Newtonian gravitational constant disappeared (7) and since the photon-phonon analogy (§2) seems sufficiently strong, we replaced all constants in Einstein's field equations and in their solutions with the corresponding, constituting quantities, showing the central role of dark energy, whose hydrodynamics replaces the idea of curved space-time. The recently detected gravitational waves are explained as negative pressure waves propagating through dark energy.

Thanks to a fluid equivalence principle, the cause of all relativistic phenomena is reduced to gravity as dark energy absorption.

Since light propagates through dark energy, it should change its speed if traveling parallel to a gravitational field, as probably observed in a test run by M. Grusenick [16] using a vertically placed Michelson interferometer. In fact, the premise of the standard Michelson-Morley test would be wrong, as in SQG the ether wind (the flux of dark energy) corresponds to the gravitational field and is independent of Earth's motion. The non-zero viscosity of dark energy would cause energy loss of light, avoiding the historical objections to the idea of tired light in explaining the empirical Hubble's law without accelerated expansion of the Universe.

Eventually, the issue of mass conservation in SQG suggests how to complete the unification of the fundamental interactions.

It seems therefore worthwhile to perform further tests to continue with the unifying approach of a superfluid Universe. For instance, a measurement of the speed of light (as time of flight) without reflexion, along a single trajectory parallel to the gravitational field lines ( $\vec{c} \parallel \vec{g}$ ), after having synchronized the clocks used to determine when the measurement begins and ends, should be done. The measured speed should be lower than  $c$  when the beam is directed upward or, vice versa, faster. In case of reflexion of the beam the theorized discrepancies would be otherwise leveled. On the side of particle physics, subtle mass-energy variations in neutral particles, just before they decay, should be investigated.

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