A superfluid Theory of Everything?

Marco Fedi

A superfluid Theory of Everything?

May 3, 2017

Marco Fedi[1]

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

Abstract

We describe dark energy as a quantized, fundamental and ubiquitous scalar field possessing superfluid features, whose intrinsic pressure opposes the gravitation of matter in the universe and whose local density increase is by us detected as dark matter. Following the approach of Kerson Huang at MIT we aim to demonstrate that the hydrodynamics of this superfluid field can produce our universe, from fundamental particles and forces up to galaxies organization, also releasing modern cosmology from many open questions. In relation to previous research, we arrive to more extensive conclusions, showing for instance that light, gravity and general relativity may themselves arise as quantum hydrodynamic phenomena in superfluid dark energy.

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

Contents

1 Introduction

The universe exists and functions thanks to many laws, particles, forces, that we can still not completely understand and predict. To complicate the rich and odd framework of nature there are moreover quantum mechanics (QM) and quantum field theory (QFT), territories where the physical laws merge with probability and Heisenberg uncertainty principle prevents us from knowing all we would like. Not only. Modern cosmology by accepting the redshift observed by Lemaître in 1927 as due to the recessional velocity of galaxies, has paved the way to several paradoxes, father of which is the Big Bang theory and its singularity, given that physics usually eschewes any divergence. These are well-known: the homogeneity problem, the flatness problem, the magnetic monopoles problem. To solve the issues rising from the Big Bang model, cosmologists resorted to a *deus ex machina* which is not less mysterious than the Big Bang itself, i.e. the theory of cosmic inflation, thanks to which the universe would have instantly expanded from the singularity existing at the beginning of the Big Bang up to a certain size, to continue, slower, its expansion up to the present days and beyond. Furthermore, we should not forget the baryon asimmetry: another dilemma bound to the origin of the universe as we currently explain it. Where is indeed all the antimatter (§5.1.1) of the universe? Several questions arise. But the elegant and obvious hypothesis of the recessional velocity is worth. Or not? Well, that hypothesis itself does not actually hold water since, from the moment we observed the type Ia supernovae, we took note that the most distant galaxies do not respect the linear Hubble law but seem to escape from us at a much higher rate. And again, we solved a mistery with another enigma, by creating a sort of mysterious "dark" energy which saves Lemaître's hypothesis of an expanding universe and forcefully pushes the most distant galaxies far away. After all, Einstein himself understood that, to avoid a gravitational collapse of all matter in the universe, his field equation had to contain another addend, $\Lambda g_{\mu\nu}$, where Λ is called the cosmological constant, a huge (necessary, as much as inscrutable) energy-mass spread all over the universe, which balances the gravitational pull exerted by baryon matter. As a matter of fact, we know that after the redshift issue was formalized in 1929 through the contribution of E. Hubble, Einstein retracted the cosmological constant and his view of a static universe. But nowadays that constant is still useful and by many observed as the famous "dark energy", thought as the source of the repulsive force which causes the acceleration of galaxies. The energy of vacuum. The same energy which QM and QFT, one of the most elegant and precise theories of modern physics, need for their equations. However, the problems do not end here. The Voyager probes reported a value for vacuum energy density far below that predicted by

QFT. This issue is known as the vacuum catastrophe and is solved through a mathematical expedient called renormalization. Provided that this is enough to actually resolve the problem, to be wrong, or better meaningless, could instead be the measurements done by the probes. In fact, in physics the meaning of the observations is bound to that of the hypothesis. And we currently believe in the reciprocal logical implication mass $\Leftrightarrow$ gravity. In this work we want however to show (§4, superfluid quantum gravity) that mass, as summation of dark energy quanta, exerts gravitational pull only when it self-organizes into vortex-particles (e.g. into fermions, §§3, 3.1) and consequently attracts other quanta from the surrounding superfluid space, generating a gravitational field as a flow of dark energy quanta. In the above-questioned case then, the hydrodynamically unexcited mass of superfluid dark energy would not be responsible for balancing gravity and causing the acceleration of distant galaxies. Moreover, as R. Penrose observes [33], gravity is attractive not repulsive, so the issue of dark energy is open. The equilibrium with gravity could be more simply achieved thanks to dark energy internal pressure and the vacuum catastrophe could be solved in favor of QFT prediction (§5.3). On the other hand, the acceleration of galaxies might not exist at all and this directly goes back to the main issue of Hubble's redshift interpretation, that is a step back to the origin of the cosmological dilemmas of our age, which the superfluid approach can cast fresh light on. Furthermore, by describing quantum gravity (whose "passive" quantum is that of dark energy, not the graviton) as a hydrodynamic phenomenon arising in superfluid dark energy, general relativity curved space-time is not necessary anymore, as the observed relativistic phenomena (gravitational lensing, Lense-Thirring precession, gravitational waves §4.5, etc.) can be produced by the hydrodynamics of dark energy. After all, recent observations have confirmed that even the universe as a whole is flat ($k = 0$ in Robertson-Walker metric). In practice, a superfluid space can replace the idea of curved space-time, where about time, it is itself expressed by dark energy fluid dynamics, from Planck scale up. In our view, the quantum of action (h) corresponds to a complete turn (2π) of a vortex-particle according to de Broglie, who proposed that inside a particle there was a periodic process similar to a clock [1, 2, 3] and by analyzing the way this "clock" remains in phase, he came to the Bohm-Sommerfeld relationship $\oint \vec{p}\cdot dx = nh$, which, divided by mass, becomes the equation expressing the circulation in a superfluid quantized vortex, $\oint_C \mathbf{v} \cdot d\mathbf{l} = nh/m$. Given a suitable geometry (horn-torus vortex, §3.1, which renders the spin-$\frac{1}{2}$) a superfluid vortex of dark energy quanta may correspond to a fermion.

Moving from the approach of vorticity in superfluids (then also in superfluid dark energy) we notice a common thread binding different fields of physics, from the atom up to cosmology, from the creation and the structure of matter till the fundamental interactions, a thread which is unrolled along the path of the universe evolution by the hand of dark energy self-organization.

2 Dark energy and a superfluid quantum space.

2.1 The ether taboo.

The superfluid approach to the world of fundamental particles and especially to cosmology, based on the hydrodynamics of a superfluid quantum medium which fills up the universe, including the superfluid vacuum (or BEC vacuum) theory, is currently not a mainstream but has been however recently pursued with interest by several physicists, among them V. Sbitnev [4, 5, 6, 7, 8, 9], G.E. Volovik [10, 11] and K. Huang at MIT [12, 13, 14]. Such an approach would allow us to solve many open issues of modern physics and to eliminate some long-standing paradoxes, which make us clash with divergences and odd phenomena (singularities, accelerated expansion of the Universe, cosmological inflation, the problem of quantum gravity and of the complete unification of fundamental interactions etc.) solved with mathematical artifice (e.g. the renormalization in the case of infrared and ultraviolet divergences) or, mostly, still unsolved. The main problem for the superfluid approach to be accepted as the most convenient route modern physics should take, is basically the fact that a cosmos filled with a superfluid medium would imply the existence of an ether and this concept is associated to pre-Einsteinian physics, to obsolete models of the nineteenth century, when all physicists believed in the necessity of that invisible substance to justify the natural phenomena which they were observing.

The Michelson-Morley experiment, run in 1887 at the Case Western Reserve University [16], excluded the existence of a luminiferous ether, which Maxwell himself believed in. Nevertheless, for the following decades, many eminent physicists, including Lorentz and Einstein themselves [17, 18], still invoked the ether as the most logic explanation even to that new relativistic physics which was emerging. What the Michelson-Morley test has actually demonstrated and what not is discussed in §4.7, in the light of the suggested mechanism of superfluid quantum gravity (Bernoulli pressure exerted by vortex-particles producing the gravitational field as inflow of superfluid dark energy).

2.1.1 From Maxwell to Higgs.

We wish to briefly report what the main actors of the history of physics thought of the ether, and what we think today, to illustrate that the (still present) necessity of such a "dark" substance is not a trivial thought. Furthermore, from the rise of quantum mechanics (QM) and quantum field theory (QFT) it seems we're even witnessing a new inexorable rise of the ether.

First of all, it is interesting to remember that Maxwell derived the expressions for the dielectric constant and the magnetic permeability of "vacuum" in terms of transverse elasticity and density of the ether. Also Lorentz believed in the existence of an ubiquitous ether. His ether theory (LET) [17] has made it possible to theorize the Lorentz transformations, which along with several other aspects of LET have been used in Einstein's theory of special relativity (SR). The concept of preferred frame of reference, in which time dilation and length contraction occur, plays in it, for instance, the same role of the immobile ether in LET, allowing a complete Lorentz transformation. It is interesting to notice that an experimental distinction between SR and LET is impossible. Einstein himself actually believed [18] that the existence of an ether filling all space was necessary for his theory of general relativity (GR) and this is surprising, since a basic assumption of SR is that no ether exists. He said: "according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an aether. According to the general theory of relativity space without aether is unthinkable". This is exactly what we think today in developing this superfluid model. Indeed, we will see that the hydrodynamics of a superfluid space is able to justify the effects attributed to curved spacetime, without the necessity that such a geometrical construct really exists. After all, only a solid substance or a pure geometrical entity (not physical) can be "curved" and it is therefore hard to think that the vacuum is curved. It has been for instance demonstrated, thanks to various experimental data (WMAP, BOOMERanG, Planck space observatory), that the universe is flat [19, 20] with a 0.4% margin of error. Moving on to gravity, albeit the differential geometry used in GR is technically useful and predictive, it is not the only working theoretical explanation to what we observe, as I aim to demonstrate throughout this work. The hydrodynamics of a superfluid space is indeed able to replace Einstein's curved space-time and to explain what still remains unsolved as the reason why nothing can exceed the speed of light (adopted as a matter of fact by Einstein), §3.2.2, or the quantum nature of gravity.

With the development of QM and QFT, the ether assumes again a central role, although nowadays we prefer to simply call it "(quantum) vacuum". Which is not actually empty, since its energy is not zero. In 1951 Dirac stated [21]: "If one examines the question in the light of present-day knowledge, one finds that the aether is no longer ruled out by relativity and good reasons can now be advanced for postulating an aether". In his opinion the theory of electrodynamics, which implies a vacuum filled with virtual particles, forces us to consider the existence of an ether. His ether model was based on stochastic covariant distribution of subquantum motion, generating a vacuum that is dominated by stochastic fluctuations, where particle-antiparticle pairs rapidly appear and annihilate. This was the modern equivalent of the old concept of ether. As Hilbert elucidated, Dirac sea, although filled, can contain new, unpaired particles, since it has an infinite extent, and this allows the existence of our material world. De Broglie, stated: “Any particle, even isolated, has to be imagined as in continuous energetic contact with a hidden medium” [22]. And about de Broglie’s quantum theory of pilot wave, later developed by Bohmian mechanics, Petroni and Vigier state : “One can deduce the de Broglie waves as real collective Markov processes on the top of Dirac’s aether” [23]. From the point of view of a fluid approach, the de Broglie-Bohm’s pilot-wave could perhaps be explained as an ether wave, a special fluid which shows analogies with tests performed on a macroscopical scale by using silicon oil as vibrating fluid [24]. Bohm’s quantum potential, also seen as an information potential which for instance reaches and influences the particles involved in a double-slit experiment and determines the tunneling effect or the entanglement, has to be rooted in the environment, i.e. in the superfluid quantum space (superfluid dark energy? §2.2) which connects everything. Indeed, in his 1952 papers [25, 26], Bohm’s view on the quantum potential suggests a universal interconnection of all things that can no longer be questioned.

Max Planck, talking on the features of quantum mechanics (the discretization of energy), also invokes the role of the ether. He states: “The exchange of energy between the matter and the ether — or rather between ordinary matter and the small resonators whose vibrations furnish the light of incandescent matter — can take place only intermittently”. [27].

Bringing things up to date, Robert Betts Laughlin, Nobel Laureate for the fractional quantum Hall effect, in his work *A Different Universe: Reinventing Physics from the Bottom Down* [28], states: “relativity actually says nothing about the existence or nonexistence of matter pervading the universe, only that any such matter must have relativistic symmetry”, and also: “The word ’ether’ has extremely negative connotations in theoretical physics because of its past association with opposition to relativity. This is unfortunate because, stripped of these connotations, it rather nicely captures the way most physicists actually think about the vacuum. [...] Studies with large particle accelerators have now led us to understand that space is more like a piece of window glass (see §3.2.2) than ideal Newtonian emptiness. It is filled with ’stuff’ that is normally transparent but can be made visible by hitting it sufficiently hard to knock out a part. The modern concept of the vacuum of space, confirmed every day by experiments, is a relativistic ether. But we do not call it this because it is taboo”. We agree and we could remark that relativity, on the contrary, says something about the existence of invisible matter-energy pervading the universe, since the cosmological constant has been introduced [32].

Laughlin also tells us that this false vacuum can be treated with the laws of fluid dynamics as we intend to do in the present work: "About the time relativity was becoming accepted, studies of radioactivity began showing that the empty space had spectroscopic structure similar to that of ordinary quantum solids and fluids".

Finally, it is worth to wonder whether the Higgs field itself could not be observed as a sort of ether pervading the Universe. It is indeed an ubiquitous fundamental scalar field, which possesses non-zero viscosity and is able to give mass to particles. Huang thinks that what gives the whole universe a superfluid behavior is indeed the Higgs field [12] but he also reflects on the role of dark energy. We argue that Higgs field may coincide with the that of superfluid dark energy, whose intrinsic pressure avoids the gravitational collapse of matter in the universe (§5.2). Also the Higgs question can be therefore enumerated among those physical realities which are incompatible with the existence of a real zero-energy vacuum.

Some known effects due to vacuum energy are for instance the Lamb shift, the Casimir effect, the Unruh effect, the stability of classical electron on Rydberg's classical orbits, the anomalous magnetic moment and vacuum birefringence [87]. A photon is said to propagate in the vacuum but the eigenvalue for $n = 0$ is not zero (§3.2), meaning it propagates through a field whose energy is not zero. In conclusion, in a real zero-energy vacuum the laws of quantum physics would not work.

If, as we think, this cosmic scalar field corresponds to dark energy, how can we then say that dark energy does not interact with our world? It would interact by exchanging energy in almost all processes of quantum physics and, through the quantum-classical link represented by atomic physics, with our material world. In this work we discuss that it could be about much more than interaction. Dark energy hydrodynamics might have created our universe, from electrons to galaxies.

2.2 A superfluid universe due to dark energy?

It is quite common among physicists to think of the vacuum, from the point of view of QFT, as something still very close to what hypothesized by Dirac, i.e. to an infinite sea of particle-antiparticle pairs which stochastically appear and immediately annihilate as engaged in a perpetual dance. Not by chance, John Wheeler coined the expression "quantum foam" [29]. Several approaches tend to treat this lively vacuum as a Bose-Einsten Condensate (BEC), mathematically starting its description from the Gross-Pitaevskii equation, which refers to a quantum system of identical bosons through the pseudopotential interaction model and the Hartree-Fox approximation.

However, since in this work we describe the fundamental particles of the Standard Model as vortices, or pulses, of those quanta which fill up the whole space, I think it is not correct to refer to a superfluid quantum space (SQS) by thinking of its quanta as particles and antiparticles which appear and annihilate in it. For instance, supposing that these are electron-positron pairs, it would be odd that they can aggregate into vortices that correspond to other leptons. What I think, is that the quantum foam is only a hydrodynamic manifestation of the underlying fundamental scalar field that pervades the cosmos and not the field itself.

So, physically speaking, the question is now shifted to a more elementary level: "what is this fundamental scalar field which produces a boiling vacuum?". One candidate could be the Higgs field [30]. But we think that the quantum excitation of that field, the Higgs boson, cannot be the fundamental quantum we need, being rather an unstable vortex probably constituted by the *most* elementary particles we are looking for in this work, i.e. the quanta filling the SQS, which do not undergo decay and do not possess spin, since below we describe spin and decay as features emerging from superfluid vortices of those same quanta.

Also, it is in my opinion not correct to speak of space's quanta and is rather more appropriate to speak of quanta which fill up the whole physical space.

As the most probable candidate to represent the SQS, as a single-fluid scalar field, I suggest dark energy. This expression was put in print for the first time in 1999, in a paper by Heuterer and Turner [31] and albeit we know it exists, we still don't know what this expression exactly refers to. Data from the Planck Space Observatory of the ESA indicate that it constitutes ~69.1% of the mass-energy in our universe. If we describe dark matter as higher-density (as a sort of condensed) dark energy, we come to consider a further ~25.9%. Ordinary baryon matter and EM radiation constitute the remaining 5%, most of which corresponds to gas and dust.

It is therefore very likely that this small fraction of baryon matter which forms *inter alia* our planet and our bodies, has originated from this boundless and nourishing fundamental soup still present everywhere in the cosmos, with a superfluid temperature of about 2°K, currently interpreted as a cosmic microwave background radiation due to the Big Bang events (§§5.2, 5.1.1).

Our knowledge of QFT, would say that also dark energy is quantized. At this point we could define the SQS as a superfluid sea of quantized dark energy. We said that nobody knows yet what dark energy nor dark matter actually are, but for sure it has not to be simply intended as a repulsive force which provokes the (supposed) accelerated expansion of the Universe. If we think it is represented by the cosmological constant $\mathit{\Lambda}$ Einstein introduced in his field equation [32] to avoid a gravitational collapse (he believed in a static Universe), we see it is energy and within the mass-energy formula $E = mc^2$ (see also §3.2.1) it has a matter density ρ_0 expressed in the stress-energy tensor of the field equation as T^{00}. Indeed the cosmological constant, $\Lambda = k\rho_0$, where $k = 8\pi G/c^4$ is the Einstein constant, at first judged by Einstein as his greatest blunder when E. Hubble formalized an apparently expanding Universe due to the observed redshift of galaxies out of the Local Group, is now considered as a useful parameter in cosmology. Roger Penrose [33], is doubtful about the nature of dark energy mass density since in our present knowledge any mass produces gravitational attraction while dark energy has to be repulsive. But in the present work this apparent paradox is solved by explaining the repulsive behavior of dark energy as its intrinsic pressure, i.e. as the internal pressure of the SQS. Moreover, we said that to observe gravity, we need the formation of vortex structures in dark energy (§§3, 3.1, 4). Thus, low-entropy dark energy (a sea of unperturbed dark energy quanta) can possess a mass density without exerting gravitational pull and the paradox of repulsive mass is solved. Huang [12] agrees that dark energy is simply the energy density of the cosmic superfluid. We say "it is" the cosmic superfuid.

The fact its intrinsic pressure may determine a static universe by balancing the action of gravity or it can cause the accelerated expansion of the universe is in our opinion still debatable and will be discussed below (§§ 5.1, 5.2). Since dark energy is the predominant component of the universe, let us take into account the equation of state of cosmology for a single component, $w = P/\rho$, and let us replace it with the equation of state of dark energy as suggested by Amendola and Tsujikawa [34], i.e.

$$w_d = \frac{P_d}{\rho_d} \tag{1}$$

In this work we use the simpler subscript d instead of DE to refer to dark energy. We have however to point out that the specific, current interpretation of the cosmological redshift also influences the estimate and the equation of state of dark energy. In fact, in [34], for a flat universe (flat according to observations[2], which agree with the assumptions of the present work) where the contribution

[2]observational bound on the cosmic curvature is $-0.0175 < \Omega_k^{(0)} < 0.0085$ [35]

of radiation is negligible, the equation depends on the redshift (z) and reads

$$w_d(z) = \frac{(1+z)(E^2(z))' - 3E^2(z)}{3\left[E^2(z) - \Omega_m^{(0)}(1+z)^3\right]} \tag{2}$$

where $\Omega_m^{(0)} = 8\pi G\rho_m^{(0)}/3H_0^2$ (H is the Hubble parameter) and

$$E(z) = \frac{c}{H_0}\left[\frac{\mathrm{d}}{\mathrm{d}z}\left(\frac{d_L(z)}{1+z}\right)\right]^{-1} \tag{3}$$

with $d_L(z)$ as the empirically measured luminosity distance.

The theoretical framework and the calculations deriving from the observations might therefore change under a different interpretation of Hubble's redshift, as the existence of a SQS indeed suggests (§5.1).

3 Fundamental particles from superfluid dark energy (SDE)

We speculate whether fundamental particles can arise as vortices (or phonons §3.2) from SDE. We know that quantum vortices form in superfluids, such as those observed in ^{4}He nanodroplets [11, 36]. Sbitnev [5, 8] has considered the 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. Sbitnev adopted the definition "superfluid quantum space" [4, 15] and agrees [74] with a torus-shaped vortex model for fermions (§3.1) reproducing the spin-$\frac{1}{2}$. Also Volovik [10, 11] accurately discusses the possible topology of quantum vacuum and the appearence of vortices. Huang [12] affirms that quantum turbulence (chaotic vorticity; vortex tangle sustained by vortex reconnection) in the early universe was able to create all the matter in the universe.

These vortices behave as gaps in the medium where superfluidity breaks down and their structure (see healing distance in Fig. 1) would suggest the non-necessity of renormalization, since no ultraviolet divergence occurs. By considering the superfluid ocean of quantized dark energy as a BEC, we can start to describe its behavior from the Gross-Pitaevskii equation (GPE) [37]

$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{h^2}{2m}\nabla^2\psi + g\psi\left|\psi\right|^2 - \psi\mu_0 \tag{4}$$

where ψ is the condensate wave function, with m as the mass of a quantum, μ_0 the chemical potential and $g = 4\pi a\hbar^2/m$ a low-energy parameter, where

a refers to the scattering length between quanta. In the phase representation $\psi = \sqrt{\rho}e^{i\varphi}$, ρ is the density of the superfluid.

From (4) we can write the hydrodynamic equations, i.e. the continuity equation and the analogue of the Euler equation

$$\frac{\partial \rho_d}{\partial t} + \nabla \cdot (\rho_d \mathbf{v}_S) = 0 \tag{5}$$

$$m\left(\frac{\partial \rho_d}{\partial t} + \mathbf{v}_S \cdot \nabla\right)\mathbf{v}_S = \nabla\left(\mu_0 - g\rho_d + \frac{\hbar^2}{2m}\frac{\nabla^2\sqrt{\rho_d}}{\sqrt{\rho_d}}\right) \tag{6}$$

where $\mathbf{v}_S = \frac{\hbar}{m}\nabla\varphi$ is the superfluid velocity and $\frac{\hbar^2}{2m}\frac{\nabla^2\sqrt{\rho_d}}{\sqrt{\rho_d}}$ represents the quantum potential. Since the condensate must be a continuous function in space, its phase has continuous modulo 2π. We define then the quantized circulation (Γ) by the line integral

$$\oint_C d\mathbf{x} \cdot \mathbf{v}_S = \frac{2\pi\hbar}{m} n \equiv \Gamma \quad (n = 0, \pm 1, \pm 2, ...) \tag{7}$$

in which C is a close loop in space that must encircle a vortex line where $\psi = 0$ and the superfluid density vanishes. According to Helmoltz's second theorem, the vortex line, if it does not end on a boundary, must form a closed loop and it will indeed form a vortex ring.

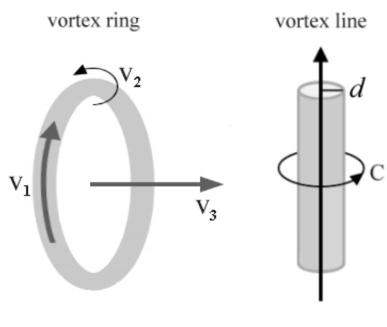

Figure 1: On the right a vortex ring, actually a torus, where v_1 is the toroidal velocity, v_2 the poloidal velocity and v_3 the translational velocity of the ring. On the right a vortex line with healing distance d.

It is interesting to notice that the healing distance d (Fig. 1) corresponds to half the radius of a fundamental particle (for instance an electron) if described as a horn-torus-shaped vortex in dark energy (§3.1). This solves the problem of ultraviolet divergence and of the radius of the fundamental particles. These would not be adimensional point-particles, as believed in the current theoretical framework, but toroidal vortices of dark energy's quanta (DEQ). Moreover, the velocities v_1 and v_2 (Fig. 1) might correspond to the spin-$\frac{1}{2}$ of fermions, as discussed below (§3.1). Albeit the simple Bohr model described in (7) is just a rough approximation of the full solution to the Schrödinger equation in a central $1/r$ potential, it alone can account for several correct results concerning atomic physics:

- Bohr radius, $a_0 \equiv \frac{4\pi\epsilon_0\hbar^2}{m_e e^2} \simeq 0.53\text{Å}$
- Rydberg constant, $\frac{e^2}{(4\pi\epsilon_0)2a_0} \simeq 13.6\,\text{eV}$
- Energy, $E_n = -\frac{Z^2}{n^2}\frac{e^2}{2a_0}$
- Angular momentum, $L = n\hbar$
- Fine structure constant, $\alpha = \frac{e^2}{\hbar c} \simeq \frac{1}{137}$
- Relativistic effects, $\frac{v_n}{c} = \frac{Z}{n}\alpha$
- Bohr magneton, $\frac{e\hbar}{2mc} \simeq 9.3 \cdot 10^{-21}\text{erg/G}$
- Magnetic dipole moment, $\mu = n\mu_B$

There are at least other two interesting facts about the possibility that fundamental fermions are superfluid vortices. First, the phenomenon of vortex reconnection as suggested by Feynman [38], which could explain the decay of a particle into other ones.

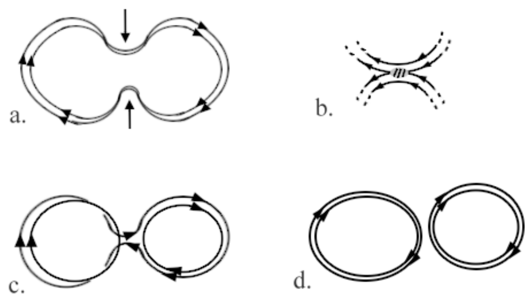

Figure 2: Vortex reconnection according to Feynman, as a suggested mechanism to explain particles decay. In grey (b) a region where vorticity cancels during the reconnection.

In Fig. 2(a) a vortex ring undergoes reconnection when it shrinks to a critical distance, which is estimated by Schwarz [39] to be

$$\delta \approx 2R \ln \frac{R}{c_0 R_0} \tag{8}$$

where c_0 and R_0 are constants. The reconnection process has been experimentally observed by Bewley, Paoletti *et al.* [70] and numerically analyzed using the GPE by Koplik and Levine [40] and by Kivotides, Barenghi, Samuels [41].

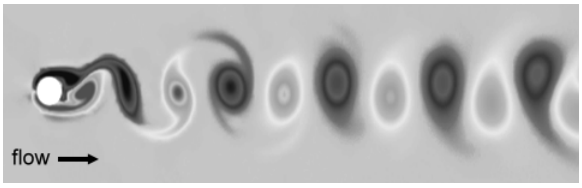

Figure 3: A computer simulation of a Kármán vortex street. Clumps of DEQ (dark matter?) along a flow of superfluid dark energy might be responsible for the appearance of particle-antiparticle pairs as anti-symmetric vortices of DEQ.

The second other hydrodynamic phenomenon that is useful to describe the world of fundamental particles is the Kármán vortex street (Fig. 3)[42]. The presence of an obstacle situated in a flow produces a series of anti-symmetric vortices, whose various appearance depends on the Reynolds number (9). In our superfluid analogy of particles physics this phenomenon could account for the particle-antiparticle simultaneous formation, appearing as the possible hydrodynamic basis for CP simmetry. The conflicting vorticity of each pair of vortices would explain the phenomenon of matter-antimatter annihilation. The vortices decompose into DEQ producing phonons which propagate through SDE and are observed as photons (§3.2).

The passage from laminar to turbolent flow in the vortex street phenomenon is predicted by using the Reynolds number

$$Re_L = UL\frac{\rho_0}{\mu_0} \tag{9}$$

where U is the free stream flow speed, L a characteristic length parameter of the obstacle or of the channel, ρ_0 the fluid density and μ_0 the dynamic viscosity of the stream, which also in superfluids is never exactly zero and could increase as apparent viscosity due to the possible dilatant behavior of dark energy under very high shear stress, as discussed in (§3.2.2). Within the understanding of particle decay as vortex reconnection, Fig. 4 shows an analogy between the particle shower induced by a cosmic ray (a proton, in this case) and a Richardson cascade, which in a superfluid and for wave number $k < 2\pi/\ell$, may be sustained by vortex reconnection. For $k > 2\pi/\ell$ the process gives way to a Kelvin-wave cascade, which ends with phonon emission (see also the analogy in §3.2).

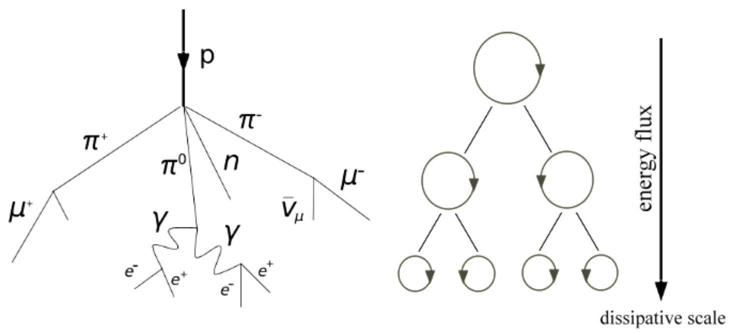

Figure 4: A particle shower (left) compared to a Richardson energy cascade (right) in a superfluid, for wave number $k < 2\pi/\ell$, sustained by vortex reconnection, here simplified to a few eddies.

3.1 Spin as vortex geometry.

According to Salvatore Esposito [43], who cites Recami and Salesi [44], we think that the quantum potential of a particle

$$Q = -\frac{1}{2}m\vec{v}_S^2 - \frac{1}{2}\nabla \cdot \vec{v}_S \tag{10}$$

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

$$\vec{v}_S = \frac{1}{2m}\frac{1}{\rho}\nabla\rho = \frac{1}{2m}\frac{\nabla R^2}{R^2}, \tag{11}$$

putting $\hbar = 1$, and being $\vec{s}$ is the direction of spin. By looking at a particle's spin as internal motion, the link with the concept of vortex-particle is quite immediate. Vorticity has however to explain the specific spin of any particle. As far as the most appropriate vortex geometry to hydrodynamically explain the spin is concerned, it is interesting to consider the simple evolution: vortex tube $\rightarrow$ vortex ring $\rightarrow$ horn-torus-shaped vortex (Fig. 5). Also Villois, Krstulovic *et al.* analyze vortex tubes evolving into vortex tori in superfluids [45] and demonstrate the emergence of non-trivial topology. This geometry seems to well account for the spin of fundamental particles. In the case a quantum of dark energy flowing in the torus vortex needed the same time the vortex needs to complete two turns in the toroidal direction to return in the same position after having completed one turn in the poloidal direction, then the vortex would have spin-$\frac{1}{2}$ (fermion), i.e. the system returns in the same state after a toroidal rotation of 720°, after each quantum forming the vortex has moved along a Möbius-strip path. It is interesting to notice that a two-components spin can explain in mechanical terms any other type of spin as the ratio of the number of toroidal rotations to poloidal rotations. Putting ω_1, ω_2 as the angular velocities for the respectively considered directions, the spin angular momentum would be determined by the ratio

$$\frac{\omega_1}{\omega_2} = \frac{n}{2} = S \tag{12}$$

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

The case of spin 0 may be determined by further evolution of the horn torus into a spheroidal vortex or correspond to simple, rotating clumps of DEQ (or to spinning phonons §3.2).

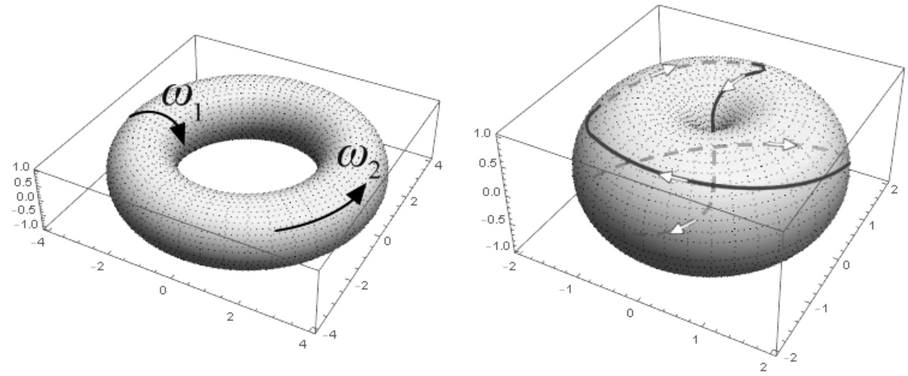

Figure 5: Evolution of a vortex ring into a vortex torus (horn torus). The ratio of the toroidal angular velocity to the poloidal one may determine the spin of a particle. Each quantum forming the torus vortex flows along a Möbius-strip trajectory. Given the ratio 1/2 of the poloidal angular velocity to the toroidal angular velocity, each quantum returns in its starting position after a 720° rotation of the particle.

3.1.1 Are vacuum fluctuations vortices of DEQ?

If fundamental particles are vortices of DEQ, then also vacuum fluctuations, being virtual particles, should arise from DEQ circulation. The fluctuations of the zero-point field are expressed as

$$\triangle E \triangle t \geq \frac{h}{2\pi} = \hbar. \tag{13}$$

Since in our case we are considering the fundamental scalar field of SDE, (13) refers to dark energy fluctuation in time. We recall the equation of quatized circulation (7)

$$\oint_C d\mathbf{x} \cdot \mathbf{v}_S = \frac{h}{m} n \tag{14}$$

where $n \in \mathbb{Z}$. Since m is the mass of the particle (we say of a quantum of dark energy) and$n$ refers to the number of turns, we see that the circulation is expressed by the Planck constant alone, where the quantum of action therefore corresponds to one turn along a close loop C. Even better, considering the Bohm-Sommerfeld relation, i.e. without dividing (14) by mass

$$\oint_C \mathbf{p} \cdot dx = nh \tag{15}$$

for $n = 1$ we see that the Planck constant refers to mass circulating along a closed loop in a given time, i.e. to kinetic energy confined in time (that necessary to complete one turn), having h unit of $[\mathrm{J} \cdot \mathrm{s}]$. With respect with the mass-energy of stationary DEQ, this kinetic energy adds energy to the system while the turn is performed, so we understand the meaning of $\triangle E \triangle t$. Thus, in (13) we ascertain that the variation of energy $\triangle E$ which occurs in the time $\triangle t$ is of kinetic nature and corresponds to a mass circulation in a quantum vortex.

Vacuum fluctuations may therefore be vortices which manifest in the SDE. The so-called quantum foam of virtual particle-antiparticle pairs does not correspond to the scalar field itself but to a manifestation (an order parameter variation) of the underlying fundamental scalar field (dark energy), that is to its continuous hydrodynamic fluctuation.

Similarly, also the Higgs boson could be described as a hydrodynamic fluctuation (⇒excitation) of the Higgs field. Since in this approach we consider a non-trivial (non-thermal) excitation as a vortex, we deduce that the Higgs boson (should we call it Higgs vortex?) could be composed of smaller particles which coincide with DEQ. In short, there are reasons to consider the Higgs field as the fundamental scalar field of SDE itself. For this reason the single-fluid model of vacuum (1) could work. This would agree with the fact that dark energy hydrodynamics gives any particle its mass and its features, as the Higgs field does. Undergoing reconnections (Fig. 2), Higgs boson would decay into smaller, more stable particles, also producing phonons (i.e. photons, §3.2).

3.2 Photons as phonons through dark energy?

If dark energy fills up the cosmos, light has to propagate through it. We hypothesize here that photons are pulses through the SDE, i.e. that a photon is actually a special spin-1 phonon propagating through dark energy. Let us say that the basis assumption of the Michelson-Morley experiment, which affirms that light propagates without a medium, changes when we consider the mechanism suggested for superfluid quantum gravity (SQG), according to which the ether wind is radial and coincides with the gravitational field. This issue is discussed in §4.7, after having presented SQG in §4. Thus, once established that the MM-experiment has not actually (i.e. if we consider a radial incoming ether wind) disproved the existence of a luminiferous ether and since light is forced to propagate in a superfluid universe, full of dark energy, we see that light could be nothing more than "the sound of dark energy" and c the speed of sound thorough dark energy. A sound that we perceive through our eyes. "*Wie? Hör' ich das Licht?*", wondered Tristan[3]. Waves existing in nature would reduce to only one type (medium-dependent) and photon electromagnetic field could be interpreted as a periodic excitation of dark energy's quanta, thanks to a mechanism that might resemble that depicted in Fig. 6, producing a transversal wave due to spin [49, 50] (see Fig. 6a) and dark energy dilatancy (see §3.2.2, Fig. 7), in agreement with Stokes' theory of light propagation.

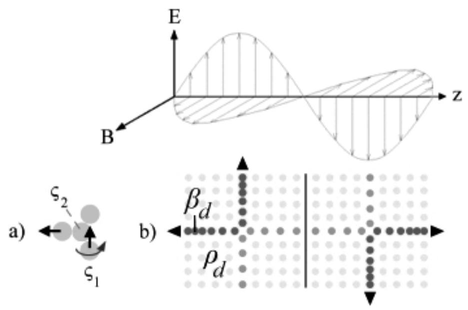

Figure 6: Density (ρ_d) and compressibility (β_d) of dark energy at the origin of photon's transverse EM field (b), whose oscillations are due to harmonic, orthogonal compressions of space's quanta, while the main pulse propagates along the $z-$axis. On the left (a), the probable quantum mechanism at the origin of transversality, due to compression and intrinsic angular momentum of DEQ imparted to them by the rotation of the vortex particle which generates the pulse (e.g. an electron emitting a photon).

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

$$a = \frac{1}{\sqrt{\beta_S \rho}} \tag{16}$$

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

$$c = \frac{1}{\sqrt{\beta_d \rho_d}} \tag{17}$$

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

expressing the speed of a photon as that of a phonon through SDE, mathematically analogous to $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$, as resulting from Maxwell's equations. We have already said (§2) that Maxwell himself derived the expressions for the dielectric constant (ε_0) and the magnetic permeability (μ_0) of "vacuum" in terms of transverse elasticity and density of the ether. We now say of dark energy.

We also have to observe light propagation as a phenomenon of second sound through dark energy, as in superfluids energy is dissipated as heat at small scales by phonon radiation [71] and we know that bodies radiate heat through the emission of photons (e.g. infrared light). After all, we know that both photons and phonons

- are bosons [46]
- have wave-particle duality [47, 48]
- obey the doppler effect $z = \frac{f_{emit} - f_{obs}}{f_{obs}}$
- are symmetric under exchange,$|\alpha, \beta\rangle = |\beta, \alpha\rangle$
- can be created by repeatedly applying the creation operator, $b^\dagger$
- share the same momentum, where that of the phonon is $p_{ph} \equiv \hbar k = \frac{h}{\lambda}$,with $k = \frac{2\pi}{\lambda}$
- can produce photoelectric effect and Compton scattering thanks to their momentum
- can possess spin [49, 50]
- can form squeezed coherent states [51]
- can interact via parametric down conversion.

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

$$E_n = \left(n + \frac{1}{2}\right)\hbar\omega_k \quad n = 1, 2, 3, ... \tag{18}$$

To confirm a "false vacuum" we see in (18) that also for $n = 0$ the energy is not zero. This means that what we think to be the vacuum actually contains energy and according to $E = mc^2$ (§3.2.1) energy implies a certain mass density. There is a medium throughout the universe owning density $\rho \neq 0$ which light propagates through. In other words and according to quantum physics, light *does not* propagate in the vacuum.

It is also important to point out that light is a transverse wave and transverse sound waves usually propagate in solids, not in fluids. However, the quantum (granular) nature of the SQS would confer it a dilatant response under very high shear stress and this recalls Stokes' theory of light propagation, whereby the ether is fluid at lower speeds but becomes rigid at higher frequencies, being then able to support light propagation without interfering with the motion of the celestial bodies. In §3.2.2, we resort to the dilatancy of the SQS under extreme shear stress also to explain Lorentz factor, seen as the rheogram of the SQS (of dark energy), i.e. to explain the fact that the speed of light is the upper speed limit in the universe.

Amendola and Tsujikawa [34], writing the perturbed energy-momentum tensor for a perfect fluid applied to cosmology, also resort to the speed of sound through the fluid as adiabatic sound speed

$$c_{s(a)} \equiv \sqrt{\frac{\dot{P}}{\dot{\rho}}} \tag{19}$$

The same authors, introducing the speed of sound through a ultra-light scalar field ϕ state that it is the key parameter to understand the (background) dynamics of such a field. They define the speed as

$$c_{s,\phi} = \sqrt{\frac{\delta P_\phi}{\delta \rho_\phi}} = \sqrt{\frac{H^2(\phi'\varphi' - \phi'^2\Psi) - V_{,\phi}\varphi}{H^2(\phi'\varphi' - \phi'^2\Psi) + V_{,\phi}\varphi}}. \tag{20}$$

From (20) we see that when the potential of the field is very flat, $V_{,\phi} \to 0$, we may have the speed of sound through the field coinciding with that of light (they put $c = 1$).

According to the photon-phonon analogy, we see that the speed of light is not constant in the universe if the background parameters of dark energy, i.e. its density and therefore its compressibility vary. As we will see below (§5.1) this fact may explain the apparent accelerated expansion of the universe which might be an illusion due to a stronger redshift caused by a lower density of SDE (as it were diluted by approaching the boundaries of the universe?).

We cannot directly detect dark energy in the same way we cannot detect any sound until it is emitted by a source. Also, it would be in this case more correct to say that a particle provokes or produces a photon (phonon) not that it is emitted by the particle.

To conclude we should reflect on the fact that dark energy could be not dark at all but it could be perceived as the most luminous thing we know. Light itself.

3.2.1 Mass-energy formula.

By calculating the speed of light as in (17), we see that the often used expression $1/c^2$ corresponds to the product of the fundamental parameters of dark energy

$$\frac{1}{c^2} = \beta_d \rho_d \tag{21}$$

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

$$E = \frac{m}{D} \tag{22}$$

where $D = \beta_d \rho_d$. We see that dark energy density divides mass, which in our view (§3) is indeed a hydrodynamic manifestation of SDE. In short, the energy of a given mass can be measured in relationship to dark energy density per unit volume and to its compressibility. Thus, to use a German expression, dark energy appears to us as the *Urenergie* in the universe and mass manifests as something taking shape from it and whose energy can be measured through that of dark energy. Indeed, 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 (§3.2), propagating through the superfluid sea of dark energy and occurring as the result of the destruction of superfluid vortices which possess conflicting spin (particle-antiparticle). On the contrary, the use of the speed of light (c) doesn't clarify the real meaning of the mass-energy formula, while expressing that speed through the parameters of the medium (dark energy) which determine it, makes the formula more meaningful, being the energy released as phonons in matter-antimatter annihilation dependent on their speed through the medium, $E = hc/\lambda$.

3.2.2 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, the dilatancy of this granular, dark substance would be detectable only at high shear stress, i.e. for acceleration occurring in relativistic regime, while at non-relativistic speeds it behaves as a superfluid. 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 but, in our case, that phenomenon would be actually caused by the apparent viscosity acting as a counterforce in the opposite direction to motion (§4.8.2) - as indicated by Lorentz factor, where $\beta = v/c$ is here described as the ratio v/v_{sd} of the velocity of a body through dark energy to the speed of sound in dark energy (we write v_{sd} instead of c to remark that we describe the speed of light as speed of sound in dark energy, §3.2)

$$\gamma \equiv \arcsin' \frac{v}{v_{sd}} = \frac{1}{\sqrt{1 - \left(\frac{v}{v_{sd}}\right)^2}} = \frac{1}{\sqrt{1 - v^2 \beta_d \rho_d}}. \tag{23}$$

In (23) the derivative of the arcsine specifies that it is not possible to exceed the speed of sound through a dilatant fluid, unless to crack it.

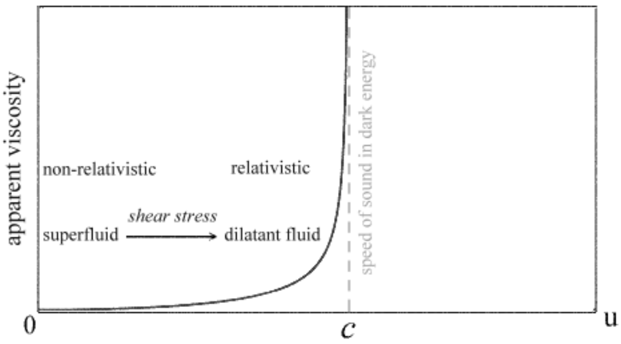

Figure 7: Lorentz factor as the rheogram of dark energy. Because of its quantum, granular nature, superfluid dark energy should behave as a dilatant fluid when shear stress enters into a relativistic regime, that is when the body velocity approaches the speed of sound in dark energy. This would imply that the so-called relativistic mass increase is actually the effect of apparent viscosity, which acts as a force in the opposite direction to acceleration, §4.8.2) . Assumed that the speed of sound in a dilatant fluid can't be exceeded without cracking it, this would explain the upper limit to acceleration experienced in synchrotrons.

Lorentz factor as the rheogram of dark energy, along with the detected phenomenon of mass increase (actually a viscous non-Newtonian resistence to acceleration) would also confirm that particles are not dimensionless points but have a spatial extent as vortices. We remember the already cited Laughlin's words about the false vacuum [28]: "It is filled with *stuff* that is normally transparent but can be made visible by hitting it sufficiently hard to knock out a part". The dilatant behavior of dark energy would be at the basis of the relativistic effects of special relativity and, through the fluid equivalence principle (§4.8.1), it would also cause time dilation in general relativity. An important difference is that in this approach, which considers dark energy as a quantum field, Einstein's relativity becomes a quantum theory. We call it "superfluid relativity".

3.2.3 Time dilation and length contraction in superfluid relativity.

Absolute time cannot exist. Indeed, according to which clock would it exist if any clock (also atomic, biological etc.) functions in a precise environment, where different parameters (e.g. temperature) and forces (such as gravity) act on it? Time exists in physics if a clock in a reference system can measure it and different measurements produce different time scales. Absolute time may perhaps exist in philosophy or in religion but that's a different story. Also in our superfluid approach to nature, gravity exists (§4) and acts onto clocks. As every physicist knows, the right locution should not be "time dilation" but "clocks retardation". Since we will replace Einstein's curved space-time with the hydrodynamics of SDE, this approach only considers a "flat" universe (according to observations) in which pressure forces (§§4, 4.1, 4.4) mime the effects of a curved space-time and can account for all relativistic effects of GR. But also locally, space-time is flat. We can say that the superfluid universe is Minkowskian.

The reason why time dilation occurs also in our approach is the increasingly viscous environment in which clocks, considered in their (quantum) mechanical dynamics, have to work by approaching the speed of sound in dark energy (Fig. 7). Not by chance then, clocks retardation follows the same curve of apparent viscosity that we can see in that figure. As a simple metaphore we could imagine an athlete who has to run through a more and more viscous medium. Thus, no wonder if up on a certain point gravity is also able to stop the clock. The reason why also gravity, besides velocity (which, as seen, provokes apparent viscosity), cause in GR clock retardation is clearly explained in the fluid equivalence principle (§4.8.1), after having introduced the mechanism of Superfluid Quantum Gravity (§4).

According to the mainstream, Lorentz-Fitzgerald contraction (relativistic length contraction) depends on time dilation and consequently on gravity (see also §4.8.1). This effect therefore exists in this superfluid approach too. It affects *measurements* taken in two different frames of reference which are in relative motion, when compared. Let us observe Fig. 8.

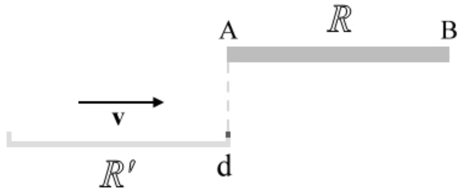

Figure 8: Relativistic length contraction. According to an inertial frame of reference ($\mathbb{R}$), the length $\overline{\mathrm{AB}}$ measured in the frame $\mathbb{R}'$ is shorter, since it is measured as $\ell = \overline{\mathrm{AB}} = v(t' - t)$ but being clocks retarded by motion (by the apparent vicosity of dark energy, for which Lorentz factor applies, $\ell = v\left(\Delta t/\sqrt{1-(v/c)^2}\right)$) the$\Delta t$ will be different in the two frames, as well as the measured length. The letter d refers to a detector (e.g. a photocell) which registers the instants (t, t') in which it is aligned with A and B.

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

$$\ell = v\Delta t \tag{24}$$

being $\Delta t = t' - t$ the difference between the instant in which the detector d is aligned with B and that in which it is aligned with A. We know that, since motion always occurs through dark energy, Lorentz factor actually affects (24), so we have to write

$$\ell = v\frac{\Delta t}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{25}$$

Since $\mathbb{R}$ does not move through dark energy (25) becomes (24), thus we have

$$\Delta t(\mathbb{R}) > \Delta t(\mathbb{R}') \implies \ell_{\mathbb{R}} > \ell_{\mathbb{R}'} \tag{26}$$

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

There is often a mistaken belief about the relativistic phenomenon of length contraction. Indeed, as demonstrated above, no actual shortening occurs, only measurements are affected due to time dilation. Also the extended mean life of cosmic muons is therefore due to clocks retardation. To conclude, special relativity holds also in the superfluid approach, which moreover explains why no physical body in the universe can exceed the speed of light. To look at the length contraction formula in superfluid relativity, we should however substitute the speed of light with that of sound in dark energy (17) and the translational velocity with the velocity expressing the fluid equivalence principle (§4.8.1). The formula is given in (71).

3.2.4 Cyclotron and Synchrotron radiation. Rindler photons and the acoustic hypothesis.

When a charged particle is radially accelerated but non-relativistic, it produces cyclotron radiation, while for a relativistic particle the phenomenon is called synchrotron radiation (SynR). In our view, the distinction between non-relativistic and relativistic depends on how close a particle speed is to the speed of sound in dark energy (Fig. 7) and, consequently, on how much the particle will undergo the apparent viscosity of "vacuum" due to dark energy dilatancy, which will non-linearly increase the resistence to further acceleration. This kind of electromagnetic radiation possesses high intensity and collimation, a broad spectrum, submicron source stability, circular and linear polarization and a pulsed time structure. The first observation of synchrotron light occurred in 1947, one year after the first synchrotron was built in Woolwich (UK). SynR is the brightest artificial source of X-rays and is used to study the structure of protein and DNA. In 2009 Ramakrishnan, Steitz and Yonath won the Nobel Prize in Chemistry for revealing the structure of the ribosome by using synchrotron light. Synchrotron radiation is also useful in materials science and is studied in astronomy, as pulsar wind nebulae (e.g. the Crab Nebula) and supermassive black holes (Fig. 19) produce SynR.

SynR is described according to SR but not in the usual way, since the frame of the accelerated particle is not at rest nor equivalent to a frame at rest, as a particle in circular motion undergoes acceleration. Let us bypass the reason why SR is anyway applied to explain SynR and let us point out that, since SR is not a quantum theory yet (it would pass under quantum physics by accepting Lorentz factor as the rheogram of dark energy, §3.2.2), SynR still needs to be well conciliated with QFT. In our superfluid approach we have described Lorentz factor as the rheogram of dark energy. And we have hypothesized that a photon is a phonon in dark energy. So, let us discuss the origin of SynR as energy coming from the zero-point field, i.e. from the SDE. This would be moreover a further confirmation to the existence of the fundamental scalar field we are talking about in this work.

Let us start from the Unruh effect, described in 1976 by William Unruh at the University of British Columbia. Any quantized field has an Hamiltonian based on local conditions, time included. Now, since time is not absolute, two observers in different reference frames will see a different energy for the field. In simple words, a particle accelerating through a quantized scalar field will undergo a heat-bath, i.e. will see a warmer field. This fact is broadly accepted in the scientific community [83]. Still discussed is, on the contrary, the possibility that the photons radiated from a particle which is accelerated in a synchrotron be due to the Unruh effect. Primarily, since it is a thermal effect, while SynR is not thermal. And we have to point out that in QFT the thermal state of the field has to be described as a Kubo-Martin-Schwinger (KMS) state, whose link with the Unruh effect has been for instance investigated by Sewell [80]. The answer for a non-thermal effect (SynR) coming from a thermal effect (Unruh) could belong to a rapidly developing branch of physics called thermoacoustics. In fact, we know that sound may produce temperature variations and it can be produced by heat. After all, we have described photons as phonons (sound) through dark energy (the currently called zero-point field). So, we have all the elements for putting the Unruh effect at the basis of SynR, at least in the superfluid approach.

First of all, let us see the way several authors [77, 78, 79] have investigated SynR in the light of the Unruh effect. The detected photons of SynR are Minkowskian photons (inertial detector). They shifted the detection into Rindler coordinates by considering a co-accelerating reference frame. Photons in this frame are called Rindler photons. Since the Rindler frame is subject to the Fulling-Davies-Unruh thermal bath, we believe Rindler photons are due to the interaction (energy absorption-emission) with the zero-point field (dark energy) and are detected as Minkowskian photons. This hypothesized identity (Rindler photons are Minkowskian photons) is shown in the following equation [75, 81, 82]as energy emission probability

$$\left.\frac{d\mathcal{P}(E)}{Td^2\mathbf{k}}\right|_{Mink,\,Emission} = \Theta(E)\left[\frac{1}{e^{2\pi E/a}-1}\right]\left.\frac{d\mathcal{P}(E)}{Td^2\mathbf{k}}\right|_{Rind,\,Absorption} + \Theta(-E)\left[1+\frac{1}{e^{2\pi|E|/a}-1}\right]\left.\frac{d\mathcal{P}(E)}{Td^2\mathbf{k}}\right|_{Rind,\,Emission} \tag{27}$$

where the emission (and the consequent detection) of a photon in the Minkowskian frame corresponds to the emission of a photon in the Rindler frame, which derives from the absorption of dark energy (Rindler absorption) due to the Unruh thermal-bath. In (27) we have

$$\mathcal{P}(E) = \left|\langle\varepsilon\,|m(0)|\,0\rangle\right|^2 \mathcal{F}(E) \tag{28}$$

as the lowest order in perturbation theory, where $E = \pm\varepsilon$ is the energy difference between the final and initial state of the detector (a negative value corresponds to de-excitation) and

$$\mathcal{F}(E) \equiv \int_{-\infty}^{\infty} d\tau \int_{-\infty}^{\infty} d\tau' e^{iE(\tau-\tau')} D^+\left[x(\tau),\, x(\tau')\right] \tag{29}$$

is the Fourier transform of the positive-frequency Wightman function of the field, with τ proper time and

$$D^+\left[x,\, x'\right] = \langle 0_M\,|\phi(x)\phi(x')|\,0_M\rangle = \int \frac{d^3\mathbf{p}}{16\pi^3\omega_p} e^{-ip(x-x')} \tag{30}$$

is the Wightman function using the standard plane wave expansion of the field, where $x^\mu \equiv (t, \mathbf{x})$, $p^\mu \equiv (\omega_p, \mathbf{p})$, $\omega_p = |\mathbf{p}|$.

Fig. 9 shows an analogy between the tangential emission of synchrotron radiation whose energy comes from the superfluid sea of dark energy, with a surfer in a curve trajectory who perturbs the water, analogously causing a tangential flow. Indeed, another hypothesis we can form on SynR is that the accelerated particle does not absorb energy from the SDE sea, as in (27), and re-emits it as a Minkowskian photon but directly produces phonons in SDE due to its circular motion in condition of high apparent viscosity (what we could call an acoustic hypothesis on SynR), which are detected as photons (§3.2).

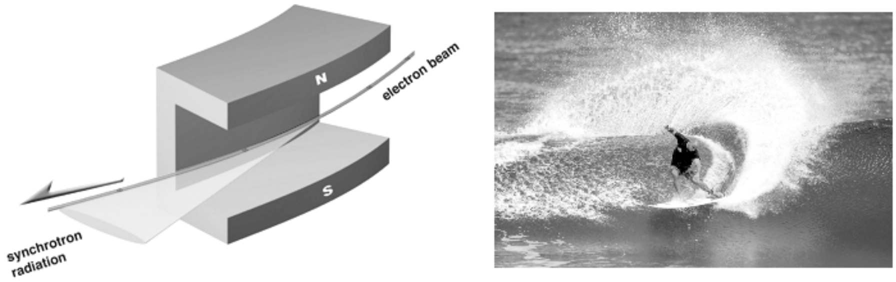

Figure 9: Synchrotron radiation as a hydrodynamic phenomenon in superfluid dark energy. Since the trajectory of the accelerated particle is curved and the fluid is dilatant in the relativistic regime (§3.2.2), this might provoke a directional, intense, sound emission in dark energy (acoustic hypothesis on SynR, within the photon-phonon analogy, §3.2), detected as synchrotron light. On the right side the curved path of the surf perturbs the water causing a tangential flow. In both cases the emission would occur on hydrodynamic basis.

3.3 Entropy and quantum potential in SDE.

When a system in our world or in the universe passes to a higher degree of disorder we say its entropy has increased. An interpretation of the disorder is the decrease, or loss, of local structuring. As when a particle and its antiparticle annihilate, which in our framework correspond to two vortices with conflicting spin that destroy each other and return to be destructured DEQ, producing phonons (light, §3.2) in the sea of SDE. But what does it happen from the point of view of dark energy? Its state of minimum entropy corresponds to the (quasi-)absence of perturbation. We say "quasi" since nothing can reach the absolute zero Kelvin. The formation of a vortex in SDE is a loss of order in the system, while, from our point of view, something with a higher order parameter emerged, acquired a structure. Our order is dark energy's disorder and vice versa. We can say that

$$S_{universe} = S_d + S_{struct.} = const. \tag{31}$$

that is the entropy of the universe is constant, since that of superfluid dark energy, S_d, and the entropy of all hydrodynamically structured systems ($S_{struct.}$) in the universe (from particles to galaxies) are inversely proportional. In other terms, when we apply a wave function to dark energy, to describe a particle, we perturb it and its entropy increases. The wave function acts on the local density of the superfluid, determining a modification in the geometry of the configuration space [3], following the logarithmic function

$$S_Q = \frac{1}{2} \ln \rho_d. \tag{32}$$

and describing the degree of order/chaos of dark energy. Agreement with Sbitnev [52, 53] is expressed about the fact that the quantum entropy which describes the configuration space order degree produced by the density of the particles associated to the wave function, is the source of the quantum potential. In other words, the hydrodynamic of SDE, the rupture of dark energy spatial homogeneity, determines its entropy degree and the quantum potential, which in turn acts as a pilot-wave, by virtue of space modifications due to density and kinetics of DEQ.

Sbitnev shows that by introducing the quantum Hamilton-Jacobi equation (in the momentum p representation)

$$\frac{\partial S_p}{\partial t} + \frac{p^2}{2m} + \frac{k}{2}\left(\frac{\partial S_p}{\partial p}\right)^2 - \frac{k}{2R_p}\left(\frac{\partial^2 R_p}{\partial p^2}\right) = 0 \tag{33}$$

the quantum potential for a one-body system can be expressed as follows

$$Q = -\frac{\hbar^2}{2m}\left(\nabla S_Q\right)^2 + \frac{\hbar^2}{2m}\left(\nabla^2 S_Q\right) \tag{34}$$

and the related Bohm's quantum Hamilton-Jacobi equation associated with the wave function $\psi(\vec{x}, t)$ reads

$$\frac{|\nabla S|^2}{2m} - \frac{\hbar^2}{2m}\left(\nabla S_Q\right)^2 + V + \frac{\hbar^2}{2m}\left(\nabla^2 S_Q\right) = -\frac{\partial S}{\partial t}, \tag{35}$$

where $-\frac{\hbar^2}{2m}\left(\nabla S_Q\right)^2$ represents the quantum correction of the kinetic energy $\frac{|\nabla S|^2}{2m}$, while $\frac{\hbar^2}{2m}\left(\nabla^2 S_Q\right)$ of the potential energy V, both conditioned by the degree of order/chaos of dark energy (32). Thus, the quantum entropy S_Q(32) determines the quantum correctors which allow the energy of the system to be conserved and its variation in time balances the flow of information that determines a particle's behavior.

4 Quantum gravity without gravitons: Superfluid Quantum Gravity (SQG).

Gauss's law for gravity, $\oiint_{\partial V} \mathbf{g} \cdot d\mathbf{A} = -4\pi GM$, describes the gravitational field as an incoming flux. We assume that this flux be real and caused by the absorption of SDE into massive particles, driven by their spin and due to Bernoulli pressure. This, taking into account the description of fundamental particles as toroidal vortices in dark energy (§3.1). 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. The attractive force exerted by the vortex-particles would be due to Bernoulli pressure. DEQ circulating about the vortex, at a small radius r from the vortex axis, possess a tangential velocity with constant magnitude [37]

$$v = 2\pi\hbar n/mr \tag{36}$$

where the $1/r$ behavior generates an attractive Bernoulli pressure. This phenomenon, also occurring in vortex-particles (e.g. fermions), would be the microscopic mechanism at the basis of quantum gravity. It is made experimentally evident when impurities in a superfluid, as nano-size metallic particles, tend to stick to the vortex tube (Fig. 10). Being formed by vortex-particles, also macroscopic bodies attract each other (Fig. 11) and the quantum behavior reflects onto the macroscopic world.

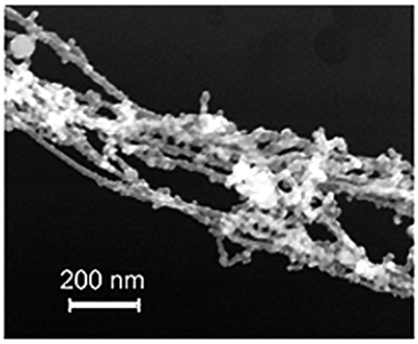

Figure 10: Nano-size metallic dust adheres to the surface of superfluid vortices due to Bernoulli pressure. From [84]

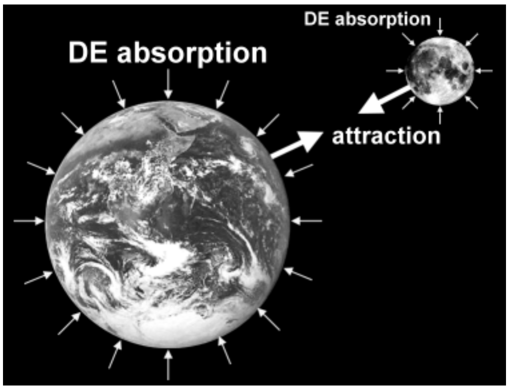

Figure 11: Dark energy absorption into vortex-particles reflects onto the macroscopic bodies they form. Pressure gradients arise around the absorbing bodies and gravity manifests as an apparent attractive force. We describe the superfluid and the absorption mechanism as quantized and we therefore observe quantum gravity without gravitons, as a quantum hydrodynamic phenomenon.

Mass conservation despite energy absorption would be possible thanks to the balancing emission of virtual photons, as discussed in §6.1, marking in this way the possible 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, as they 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 [54], here we move however from different premises and we elaborate the issue in a different way. Still in a different way, also Kirkwood [55] previously thought of the gravitational field as an ether inflow, moving from the interpretation of the equivalence principle (see §4.8.1) and analyzing this issue in terms of particle and light motion in a gravitational field. Also other efforts in the context of analog gravity are noteworthy [85, 86].

Coming to our approach, CFD simulations confirm that in the case of a body absorbing a fluid medium, a pressure gradient (Fig. 12) 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.

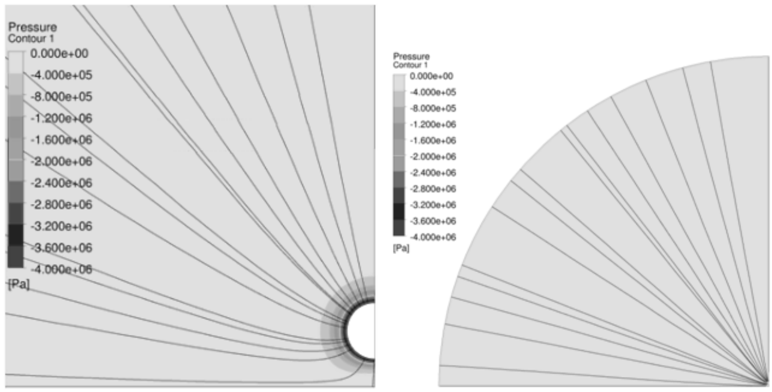

Figure 12: Pressure gradient around a spherical body absorbing the fluid in which it is immersed. As verified in CFD simulations, the consequent attractive force mathematically equals Gauss's and Newton's laws for gravity and is compatible with the Schwarzschild solution. Refining the grid (on the right) leads to a perfectly radial simmetry. For a rotating body, compatibility with the Lense-Thirring precession occurs.

4.1 The formula of quantum gravity and the disappearance of the Newtonian classical gravitational constant.

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

$$\vec{a} = -\vec{\nabla}\frac{P}{\rho}, \tag{37}$$

In our case, (37) corresponds to the gravitational acceleration caused by the attraction of DEQ due to the Bernoulli effect (Fig. 10-12 and Eq. (36)), then we have

$$\vec{g} = -\vec{\nabla}\frac{P_d}{\rho_d}, \tag{38}$$

By using (38) in Newton's second law, we can therefore write a hydrodynamic formula for universal gravitation, based on dark energy's fluid dynamics

$$\vec{F}_g = -m\vec{\nabla}\frac{P_d}{\rho_d}. \tag{39}$$

Since we assumed that dark energy is a quantized superfluid, whose absorption into massive particles is driven by spin, (39) has to 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 extra dimensions of space. Below (§4.1.1), we will derive the quantum potential.

In SQG, the classical gravitational potential φ corresponds to the ratio pressure to density expressed in (38), becoming a hydrodynamic gravitational potential φ_h:

$$\varphi = -G\frac{M}{r}\left[\frac{\mathrm{m}^2}{\mathrm{s}^2}\right] \Longleftrightarrow \varphi_h = -\frac{P_d}{\rho_d}\left[\frac{\mathrm{m}^2}{\mathrm{s}^2}\right], \tag{40}$$

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, as hypothesized (Fig. 11).

Furthermore, we see that the same hydrodynamic expression is used for the equation of state in cosmology: $w = P/\rho$, that we already considered as the equation of state of dark energy in Eq. (1).

4.1.1 Quantum potential

To consider (39) as the formula of quantum gravity the following identity has to be true

$$\vec{F}_g = -m\vec{\nabla}\frac{P_d}{\rho_d} = -\vec{\nabla}Q_\varphi \tag{41}$$

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

$$Q_\varphi = -m\frac{P_d}{\rho_d} = -\mathbf{p}\cdot\mathbf{u} = -i\hbar\nabla\mathbf{u} \Rightarrow -i\hbar\frac{\partial}{\partial t} = H = -\frac{\hbar^2}{2m}\nabla^2 + U \tag{42}$$

where $\mathbf{p} = m\mathbf{u} = \hbar k \Rightarrow -i\hbar\nabla$ represents the momentum and 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 approach the absorption site. Let us observe the SE with its quantum potential. We define the probability density for unit volume

$$\rho(r,t) = R(r,t)^2 = |\Psi(r,t)|^2 = \Psi^*(\mathbf{r},t)\Psi(\mathbf{r},t) \tag{43}$$

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

$$\frac{\partial S}{\partial t} = -\left[\frac{(\nabla S)^2}{2m} + U + Q\right] = H \tag{44}$$

where Q is the quantum potential. For the considered quantum, kinetic and potential energies are not those of baryon matter and are not determined by anything different than the gravitational acceleration as a hydrodynamic quantum phenomenon, thus$(\nabla S)^2/2m + U = 0$. The kinetic and potential energy of DEQ in a gravitational flow (⇒gravitational field) coincide with the quantum potential as expressed in (34). Therefore, we have

$$H = Q_\varphi = -\frac{\hbar^2}{2m}(\nabla S_Q)^2 + \frac{\hbar^2}{2m}\left(\nabla^2 S_Q\right) \tag{45}$$

Since the gravitational potential (40) used in (42) is determined by the Bernoulli effect at quantum level (⇒vortex-particles) and verified the quantum potential (45), Eq. (41) can be the formula of quantum gravity, whose action is exerted on the superfluid space, on a body's frame of reference. The bridge to classical gravity is represented by the fact that gravity as a hydrodynamic phenomenon in SDE implies that vortices (e.g. fermions) or pulses (photons, §3.2) existing in such a frame of reference (SDE) are consequently accelerated by an apparent force, as an object on a conveyor belt. Gravity is produced by massive bodies but does not directly act on them, as a vacuum cleaner does not directly attract dust but the air in which dust is present and without which it would not function, as we would not observe gravity without dark energy. For instance, a black hole swallows up (superfluid) space, with the matter it contains.

In the case of a non-free body in a gravitational field, the quantum potential has to correspond to potential energy. In fact, from (40)

$$U = -m\frac{GM}{r} = -m\frac{P_d}{\rho_d} = Q_\varphi \tag{46}$$

It is now clear that this superfluid approach does not refer to curved space-time but to dark energy hydrodynamics, whose effects are the same of those described in Einstein's relativity. There is no curved space-time but a superfluid space, whose dynamics at Planck scale generates time itself (quantum vortex as the fundamental clock in nature) and we are reminded of the de Broglie's idea about a sort of clock inside the fundamental particles [1, 2, 3] based on the Bohm-Sommerfeld relationship (15).

From (40), we see that the disappeared Newtonian gravitational constant now would read

$$G = -\varphi_h \frac{r}{M} = \frac{P_d}{\rho_d}\frac{r}{M} = const. \tag{47}$$

where φ_h is the hydrodynamic gravitational potential (40).

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

$$\vec{\nabla}^2 \varphi_h = 4\pi \varphi_h \rho_m = \frac{3Q_\varphi}{r^3} \tag{48}$$

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

4.2 Planck units rewritten using dark energy fundamental parameters.

Since in our hydrodynamic equations the gravitational constant G has dissolved (40) and since we have defined the speed of light c as the speed of sound in SDE (17), we can now use ρ_d, β_d, $\hbar$ instead of G, c, $\hbar$ to define Planck units. We see that the fundamental parameters of SDE and the Planck constant are sufficient to define

$$\ell_{P_d} \equiv \sqrt[8]{\frac{\beta_d \hbar^2}{\rho_d}} \tag{49}$$

$$m_{P_d} \equiv \sqrt[12]{\hbar^9 \beta_d^4 \rho_d^8} \tag{50}$$

$$t_{P_d} \equiv \sqrt[8]{\hbar^2 \beta_d^5 \rho_d^3} \tag{51}$$

$$T_{P_d} \equiv \frac{1}{k_B} \sqrt[12]{\frac{\hbar^9}{\beta_d^8 \rho_d^4}} \tag{52}$$

$$q_{P_d} \equiv \sqrt[4]{\frac{16\pi^2 \hbar^2 f_c \beta_d}{\rho_d}}. \tag{53}$$

Where the subscript d to Planck units refers to the use of dark energy parameters in calculations. We notice that we cannot be sure that these Planck units are invariant everywhere in the universe, since we see that if somewhere in the universe the density of dark energy ρ_d changed, Planck units would assume different values. In (53) f_c is a conversion factor having unit $\left[\mathrm{m}^4/\mathrm{s}^2\mathrm{A}^2\right]$ to allow the use of β_d instead of ϵ_0, within the equivalence $\beta_d \rho_d = \epsilon_0 \mu_0$ seen in §3.2.

4.3 Einstein field equations.

Since we affirm that Einstein's curved space-time is a theoretical construct which quantitatively works explaining gravity thanks to differential geometry but from a qualitative point of view it actually corresponds in nature to the hydrodynamics of SDE, we should eliminate all tensors (pressure is a scalar, not a tensor) and express the gravitational forces only through the interacting acceleratons due to the pressure gradients arising in the superfluid quantum space because of the presence of masses (seen as summation of vortex-particles which attract DEQ). Gravity is a macroscopic Bernoulli pressure which arises as the summation of pressure phenomena at a subatomic level (Bernoulli effect in quantum vortex-particles). In this context, Fig. 13 shows that two bodies accelerate the one toward the other in a superfluid "flat" space, due to the action of pressure. When we also consider SDE internal pressure (P_h in Fig. 13) we see that also a repulsing force comes into play [4]. This repulsive force becomes important on cosmic scale due to the small percentage of baryon matter ($\sim 5\%$) with respect to the superfluid dark energy along with the more condensed part of it, i.e. dark matter ($95 \sim \%$). SDE internal pressure has been incorporated into Einstein's field equations (EFE) in the form of the cosmological constant, adding $\Lambda g_{\mu\nu}$ to Einstein's tensor.

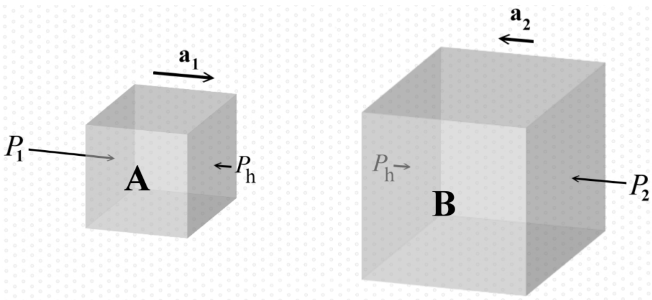

Figure 13: Hydrodynamic representation of gravity in a superfluid *flat* space. Two bodies attract each other since the vortex-particles which they are constituted of absorb DEQ. The resulting Bernoulli pressures (P_1, P_2) accelerate A and B the one toward the other, while P_h refers to the homeostatic (internal) pressure of SDE tending to distance all bodies in the SQS (corresponding to $\Lambda g_{\mu\nu}$ in Einstein's field equations).

Without regard, for the time being, to a complete quantum hydrodynamic reformulation of the EFE without tensors and curvature, we begin by substituting what has been derived in this work. From (47) and (17), Einstein constant reads

$$\kappa = \frac{8\pi G}{c^4} \Rightarrow \kappa_h = 8\pi\varphi_h \frac{r}{M} \left(\beta_d \rho_d\right)^2 = 8\pi \frac{r}{M} P_d \beta_d \rho_d \tag{54}$$

where the subscript h means hydrodynamic and the cosmological constant becomes

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

where vacuum energy density is expressed as dark energy density $\rho_d = \rho_{vac}$. Thus, the EFE, $G_{\mu\nu} + \Lambda g_{\mu\nu} = \kappa T_{\mu\nu}$, reads

$$G_{\mu\nu} + \rho_d \kappa_h g_{\mu\nu} = \kappa_h T_{\mu\nu}. \tag{55}$$

We see that the role of dark energy was implicitly already present in the cosmological constant and we note that also the stress-energy tensor is fully compatible with a quantum fluid dynamic interpretation which considers dark energy, being T^{00} its density, T^{ii} its pressure, P_d, $T^{0i} = T^{i0}$ the momentum density and being shear stress (see also §3.2.2) 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 can maintain for the moment its computational usefulness *as if space were distorted*. The same can be said for the other tensors in EFE, since both Ricci tensor,

$$R_{ij} = R^k_{ikj} = \partial_l \Gamma^l_{ji} - \partial \Gamma^l_{li} + \Gamma^l_{l\lambda} \Gamma^\lambda_{ji} - \Gamma^l_{j\lambda} \Gamma^\lambda_{li} \tag{56}$$

and Ricci scalar,

$$S = 2g^{ab}(\Gamma^c_{a[b,c]} + \Gamma^d_{a[b} \Gamma^c_{c]d}), \tag{57}$$

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

4.4 Superfluid representations of general relativity.

Let us observe below some hydrodynamic analogies with curved space-time. Fig. 14 represents a Flamm's paraboloid (corresponding to Schwarzschild metric), as a bell-mouth spillway, where attraction occurs without curved space-time due to a pressure gradient that pushes all bodies floating in the flat fluid space (b) toward the site of absorption. If the absorption site rotates about its axis, we automatically pass to a hydrodinamic description of Kerr metric (Fig. 15).

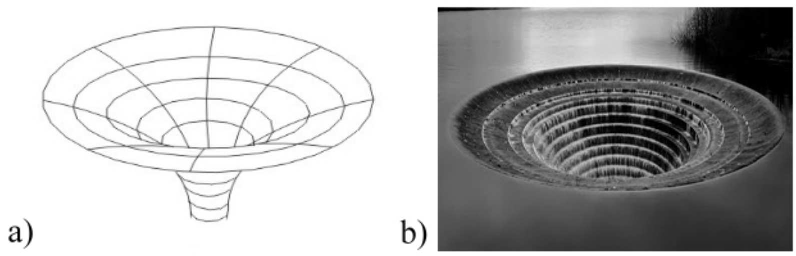

Figure 14: Analogy between (static) curved space-time in a Flamm's paraboloid (a), corresponding to the Schwarzschild solution, and (dynamic) inflow of superfluid dark energy, represented as water flowing into a bell-mouth spillway (b). Being a "dynamic" process time is *per se* included, so we do not refer to a space-time as an interwoven continuum but to a superfluid quantum space. 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" fluid space.

Substituting (17) and (47) in Schwarzschild radius, its hydrodynamic equivalent is

$$R_{S_h} = -2\varphi_h r \beta_d \rho_d \tag{58}$$

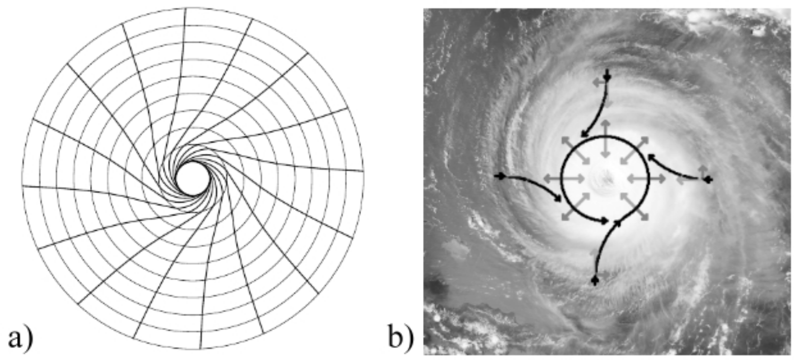

Figure 15: Lense-Thirring effect according to Einstein's curved spacetime (a) and to fluid dynamics (b). Here as an analogy with the Coriolis effect in a cyclone.

Fig. 15 describes the hydrodynamic analogy between a cyclone (⇒Coriolis effect) and the Lense-Thirring precession, where the gravitomagnetic field related to the relativistic effect is expressed as

$$B = -\frac{4}{5}\frac{m\omega R^2}{r^3}\cos\theta \tag{59}$$

and the Coriolis force can be written as follows

$$F_C = -2m\omega(\omega R)\mathbf{u}_R, \tag{60}$$

where the difference between a 3D (gravitomagnetic field) and a 2D (Coriolis) model has to be taken into account. An even simpler hydrodynamic analogy of the Lense-Thirring effect is a rotating garden sprinkler, whose jets of water are bent in the opposite sense to rotation (Fig. 16).

Figure 16: A rotating sprinkler representing a repulsive Lense-Thirring effect on hydrodynamic basis.

If the device were underwater and water were absorbed instead of emitted, the bending of the flow lines would still occur, within a negative pressure field. This is exactly the case of Lense-Thirring precession in SQG, produced by a rotating body that absorbs the SDE in which it is immersed.

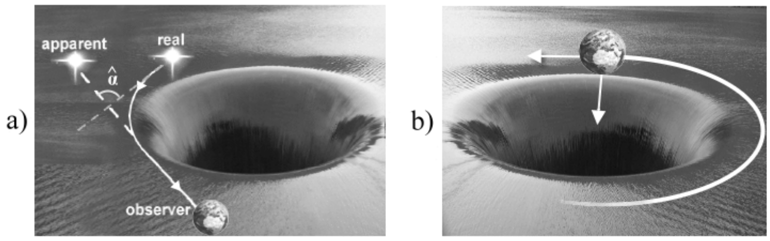

Figure 17: Gravitational lensing (a) and orbital motion (b) according to SQG, again in analogy with a bell-mouth spillway. Around the spillway the space is *flat* and the attraction is simply determined by a pressure gradient. In (a) light (as phonons through SDE, §3.2) is bend exactly as sound by wind, without resorting to curved space-time. In our case the wind is the inflow of DEQ corresponding to the gravitational field.

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

$$\vec{\hat{\alpha}}(\vec{\xi}) = \frac{4G}{c^2} \int d^2\xi' \int dz \rho(\vec{\xi'}, z) \frac{\vec{b}}{|\vec{b}|^2} \tag{61}$$

with $b \equiv \vec{\xi} - \vec{\xi'}$, where ξ, z are coordinates and $\hat{\vec{\alpha}}$ is the deflection angle, which in Fig. 17.a is determined by vector interaction between the momenta of light (of phonons) and of DEQ (gravitational flow), where their absorption is illustrated as water flowing into a spillway, acting in Fig. 17.a as an interposed star.

While in Fig. 17.b the hydrodynamics of SDE describes orbital motion, with orbital speed $u = 2\pi r/T$.

4.5 Gravitational waves as negative pressure waves through SDE.

Assuming gravity as absorption of SDE, gravitational waves [55] arise as negative pressure waves generated by periodic ($\Rightarrow$ quadrupole) variations in the absorption intensity oriented toward a given point (e.g. toward LIGO's mirrors [56]). 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 $\times$

$$h_\times = -\frac{1}{R}\frac{G^2}{c^4}\frac{4m_1m_2}{r}(\cos\theta)\sin\left(2\omega\left(t-\frac{R}{c}\right)\right). \tag{62}$$

By substituting from (47), where $M = m_1 + m_2$ and (17) we see that the gravitational wave is a pressure oscillation propagating through dark energy

$$h_\times = -\frac{r}{R}\left(2P_d\beta_d\right)^2\left(m_1+m_2\right)^{-1}(\cos\theta)\sin\left(2\frac{\sqrt{h_\varphi}}{r}\left(t-R\sqrt{\beta_d\rho_d}\right)\right) = \tag{63}$$

while the polarization h_+ reads

$$h_+ = -2\frac{r}{R}\left(P_d\beta_d\right)^2\left(m_1+m_2\right)^{-1}\left(1+\cos^2\theta\right)\cos\left(2\frac{\sqrt{h_\varphi}}{r}\left(t-R\sqrt{\beta_d\rho_d}\right)\right), \tag{64}$$

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, r the radius of the quadrupole, $\sqrt{h_\varphi}/r = \omega$ its angular frequency obtained resorting to the identity (40) in the Newtonian formula for constant angular velocity of a circular orbit $\sqrt{G(m_1+m_2)/r^3}$ and $\sqrt{\beta_d\rho_d}$ corresponds to c^{-1} (17), 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, although, in the case of gravitational waves, with the difference of a negative pulse whose frequency depends on the rotation of the binary system. As shown in (37) and (38) the pressure variation corresponds to an acceleration, acting in this case on LIGO's test masses if we take into account the recent tests.

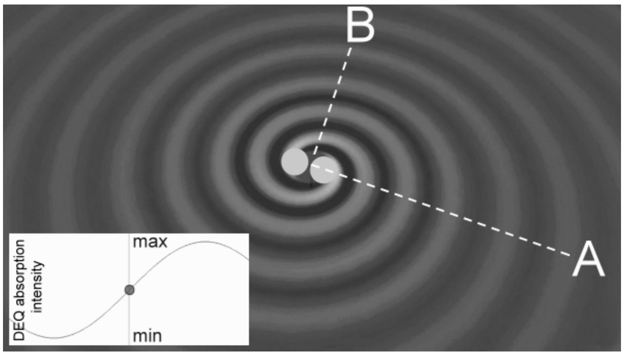

Figure 18: Two black holes of the same mass rotating in a circular orbit (quadrupole). At an instant t, the absorption is maximum toward the observer A and minimum toward the observer B. Since the binary system rotates, each observer detects a periodic variation in the absorption of DEQ, corresponding to a gravitational pull which variates between a minimum and a maximum. To respect the experimental evidences without resorting to curved space-time, gravitational waves can be pressure waves propagating through dark energy at the speed of light (since they are in both cases pressure waves in SDE, §3.2).

4.6 Black holes.

There is sufficient consensus that every galaxy contains at its center a massive black hole and that such dark objects have moreover been the reason itself for the formation of galaxies (Fig. 29). In SQG black holes can exist as celestial bodies that absorb DEQ (§4) at a pace faster than the speed of sound in dark energy, i.e. faster than light (§3.2). This is possible since shear stress (§3.2.2) does not occur in this case, as nothing is traveling through dark energy. Faster than c is only the current of DEQ directed toward the black hole. But even if a material body were attracted in the faster-than-c DEQ flow, shear stress, also in this case, would not occur, as the fluid space falls *with* the body toward the black hole.

We could consider black holes as black stars, not as singularities. Physics does not like divergences and a dimensionless point exists in mathematics but not in nature, as it would hit quantum physics. The superfluid approach tells us that if particles are vortices and a vortex has always a core with a healing length, then they cannot be dimensionless points. If a single particle cannot be that, *a fortiori*, a black hole does not possess a singularity. We agree with Lathrop's hypothesis as regards the formation dynamics of black holes (Fig. 29, [68]). In particular, we believe that a black hole could be a single, ultradense, giant vortex of DEQ.

Up on a certain point the density of the black vortex would be however so high that the emission of strong acoustic pulses (electromagnetic radiation, §3.2) occurs. In this case, the extreme pressure can produce jets of DEQ which are faster than sound in dark energy (i.e. faster than light, perhaps cracking the dilating dark energy, §3.2.2, as a bullet penetrates and cracks a dilatant fluid) able to leave the black hole and to produce phonons (photons) which proceed propagating at the speed of light. This could be the case of the Hawking radiation. This emission keeps the black hole in equilibrium, between the absorbed matter and the radiated energy, otherwise the pressure would increase more and more, bringing the dark body to evaporation (during which it probably decomposes into DEQ). It is indeed questionable whether a smaller black hole would evaporate more easily or not, depending on the fact that a lower energy absorption (but consequently also a lower emission) or an excessive mass-energy incorporation that breaks the absorption-emission equilibrium could accelerate the evaporation. It is indeed possible that total evaporation occurs when black holes reach a point of no return as regards their density, as their vortex structure becomes not able to sustain itself anymore and the collapse of the macroscopic wave function occurs. Indirect observation data about black holes are still not sufficient to let us build a more comprehensive and plausible theoretical framework, so speculation still prevails.

Finally, as far as the paradox of information is concerned, we can analyze different scenarios. If we accept that a black hole can behave (as also a BEC) as a single macroscopic quantum entity, the wave functions of the single absorbed particles merge with that of the giant black vortex and Hawking radiation might be of acoustic nature (§3.2), perhaps also producing heterogeneous components due to possible hydrodynamic interactions between the jet of DEQ and impurities (dark matter clumps or fermions) as it occurs in a Kármán vortex street (Fig. 3). On the contrary, if a black hole were a black star, whose density were greater than that of a neutron star but it preserved the vortex-structure of the single absorbed particles, then the information would be simply stored in the black hole and the outward radiation could again be of electromagnetic (acoustic, §3.2) nature along with re-emitted fermions (neutrinos, electrons etc.).

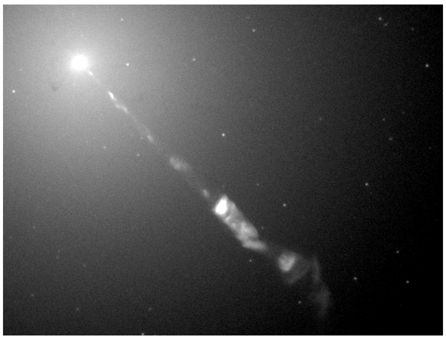

Figure 19: Jet containing gravitationally accelerated ions from the supermassive black hole in Messier 87 (image from the Hubble Space Telescope).

4.7 The Michelson-Morley test and the verification of SQG.

If a photon is a pulse through SDE 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 lines. We need to vertically place a Michelson interferometer to verify that. Indeed, in our case the original premise of the Michelson-Morley test was wrong, since the ether (dark energy) 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 may come from a celestial body's rotation and corresponds to the Lense-Thirring precession described in general relativity, in which the rotation of the body bends the gravitational field (Fig. 15). Tests with a vertically placed Michelson interferometer gave positive result [57], analogous experiences should be therefore repeated and confirmed.

We also suggest to measure the speed of light (via time of flight) without reflexion, along a single trajectory parallel to the gravitational field ($\hat{c}\,||\,\hat{g}$), after having synchronized the clocks used to determine when the measurement begins and ends. In this case, the measured speed should be lower when the beam is directed upward or, vice versa, faster.

It is important to notice that in case of reflexion of the beam the possible discrepancies in the time of flight would be leveled. For this reason in satellite communications the detected speed of the signal would be in any case c.

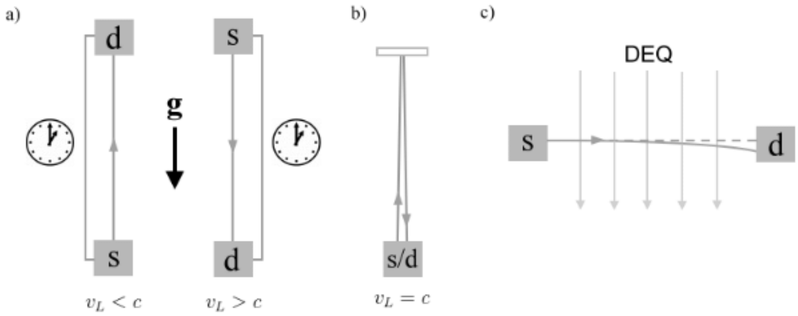

Figure 20: Possible test for verifying superfluid quantum gravity and the photon as a phonon through dark energy. The clocks of source and detector are synchronized to exclude the contribution of gravitational time dilation and the speed of light (or its frequency or wavelength) is measured while it travels up/downward with respect to the gravitational field (a). A slightly lower speed should be detected while light travels upward and, vice versa, light should be faster. The two opposite effects would be balanced in a round trip of light (b) giving $v_L = c$. On the right (c) SQG too predicts the effect of gravitational lensing due to the gravitational field as a flow of DEQ and to photon as a phonon through dark energy (in the same way wind deflects sound), without resorting to curved space-time.

4.8 Simplifying Einstein's relativity: gravity as the sole cause of all relativistic phenomena.

4.8.1 Fluid equivalence principle.

Because of the dark energy scalar field and according to the mechanism of SQG, also translational motion would put a moving body in the condition of being subject to a gravitational field, as an apparent flow of DEQ, which in this case acts in the opposite direction to motion. We say *drag weight* (interpreted as relativistic mass increase, §4.8.2) and we can express it as a fluid equivalence principle (FEP), Fig. 21.

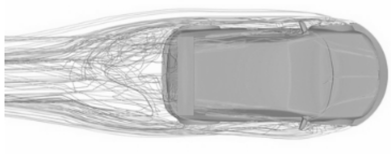

Figure 21: Fluid equivalence principle: it is impossible to distinguish between the two equivalent situations of a body traveling at a given velocity through a stationary fluid and of a fluid flowing against a stationary body at the same velocity.

Which obtains as:

$$\mathbf{v}_\Phi = \mathbf{v}_{\text{DEQ}} + \mathbf{v} \tag{65}$$

where $\mathbf{v}_\Phi$ is the velocity of the total resultant flow acting on the body, determined by the sum of the velocity at which DEQ are absorbed ($\mathbf{v}_{\mathrm{DEQ}}$, drift velocity of DEQ) in the point of the gravitational field where the body is located at a given instant and of the body translational velocity ($\mathbf{v}$) through the SDE. The FEP explains the action of translational velocity in special relativity as a gravitational action due to the apparent gravitational field produced by motion, that obeys Lorentz factor (§3.2.2). Which in its superfluid form with the FEP reads

$$\gamma \equiv \arcsin' \frac{v_\Phi}{v_{sd}} = \frac{1}{\sqrt{1-\left(\frac{v_\Phi}{v_{sd}}\right)^2}} = \frac{1}{\sqrt{1-v_\Phi^2 \beta_d \rho_d}}, \tag{66}$$

specifying that we have to take into account not the simply translational velocity of a body but that of the DEQ flow, i.e. the velocity v_Φ as it results from the FEP, which in the superfluid Lorentz factor is divided by the speed of sound in dark energy ($v_{sd} = c$).

In this way, relativistic time dilation is reduced to the action of gravity also in SR. And since relativistic mass increase is actually a gravitational force in the opposite direction to motion (§4.8.2) and Lorentz-Fitzgerald contraction (§3.2.3) depends on time dilation, we can therefore demonstrate that all relativistic effects of SR and GR are ascribable, in the framework of 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 (40), as second cosmic velocity (which has indeed to counterbalance the absorption velocity), demonstrating the FEP in Einstein's relativity:

$$\Delta t' = \frac{\Delta t}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{\Delta t}{\sqrt{1-\frac{R_S}{r}}} \tag{67}$$

hence

$$\frac{v^2}{c^2} = \frac{R_S}{r} = \frac{2GM}{c^2 r} \Longrightarrow v^2 = \frac{2GM}{r} \tag{68}$$

and

$$v = \sqrt{2rg} = \sqrt{2\varphi} \tag{69}$$

eventually from (40),

$$v = \sqrt{2\frac{P_d}{\rho_d}}. \tag{70}$$

Substituting (65) and into 66), we have also the length contraction formula for superfluid relativity

$$\ell = v_\Phi \frac{\Delta t}{\sqrt{1-\left(\frac{v_\Phi}{v_{sd}}\right)^2}} = \quad (71)$$

where v_{sd} is the speed of photons as phonons in dark energy and v_Φ refers to the FEP. The formula indicates the contraction of the measured length in the direction of motion (§3.2.3).

We realize that through the FEP it is possible to overcome the difference between the two formulas for time dilation used in SR and GR, respectively $\Delta t' = \Delta t/\sqrt{1-v^2/c^2}$ and $\Delta t' = \Delta t/\sqrt{1-R_S/r}$.

4.8.2 Relativistic mass increase or weight force opposite to the direction of motion?

According to the FEP, any translational velocity provokes an apparent gravitational field ($\mathbf{g}_\Phi$) acting on the accelerated body and detected as a weight force opposite to the direction of motion (drag weight,$\mathbf{W}_\Phi$), as in Fig. 22, which is currently interpreted as relativistic mass increase. Other cases of quantum vacuum friction have been discussed by several authors [58, 59, 60], also to explain the Pioneer anomaly [4], and also Higgs field is said to possess a certain viscosity: potential relationships between these fields, or a possible correspondence, should be then investigated.

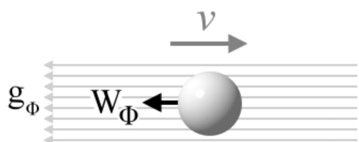

Figure 22: Weight acting in the opposite direction to motion (drag weight, $\mathbf{W}_\Phi$) due to the apparent gravitational field ($\mathbf{g}_\Phi$) and caused by motion through dark energy scalar field. At low, everyday's velocities this effect would not be noticed, since dark energy is superfluid within a non-relativistic boundary, while the effect of apparent viscosity would play a key role at relativistic velocities, increasingly opposing acceleration. according to Lorentz factor (Fig. 7).

This is in agreement with the relativistic effect of mass increase, which would actually be a resistance to acceleration due to an increasing gravitational force acting in the opposite direction to motion. This issue is clear if we suppose that, when dealing with accelerated particles in synchrotrons, we make a dimensional mistake, swapping kgf with kg, *i.e.* interpreting a weight force ($\mathbf{W}_\Phi$) pointing in the opposite direction to the supplied acceleration as a mass increase (the brace in Eq. 72 indicates the hypothesized misconstruction of current physics). If drag weight grew according to Lorentz factor (66), this could be the cause of the so-called relativistic mass increase:

$$a = \frac{F}{m \underbrace{+W_\Phi}}. \tag{72}$$

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

$$\mathbf{W}_{\text{tot}} = m(\mathbf{g} + \mathbf{g}_{\boldsymbol{\Phi}}) \tag{73}$$

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

5 Cosmological implications

5.1 Reinterpreting Hubble's law.

We reflected that the interpretation of Hubble's redshift as due to the recessional velocity of galaxies has generated a chain of problems which science still deal with after decades (§§1, 2.1). Valid the analogy photon-phonon and taken into account that no superfluid has actually zero viscosity, Hubble's law in the form

$$z = \frac{H_0 D}{c} \tag{74}$$

or by highlighting dark energy's role, $z = H_0 D\sqrt{\beta_d \rho_d}$, would be compatible with a loss of energy (⇒redshift) of photons, due to the minimal viscosity of dark energy and proportional to the traveled distance: the further a galaxy, the greater the detected redshift, without 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. Unless variations in dark energy density occur: this is the case we discuss below to explain the apparent accelerated expansion of the universe.

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. Anyway, the phenomenon we are talking about is different from the theorization of tired light provided by Zwicky [61]. 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 with free electrons occurs in this hypothesis, b) for the same reason, the same measurement in any wavelength-band would be admitted and c) would obey 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 however to add, that the observed redshift might arise as

$$z_{obs} = z_a + z_\mu \tag{75}$$

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_μ the component of redshift due to energy loss caused by dark energy's non-zero viscosity. But in this case we should accept the Big Bang, along with the problems and paradoxes it generates, that have been already discussed before. We therefore prefer to think (§5.2 and [4]) of a static universe where the redshift is only due to a slow energy loss while our photons-phonons travel in a superfluid quantum space.

Dark energy density, $\rho_d = |\psi|^2$, could tell us something interesting also as far as the deviation of Type Ia supernovae redshift from Hubble's law is concerned. The light grey curve in Fig. 23, indeed, tells us that if the medium which light travels through (SDE) decreased its density with distance, the redshift law would not be linear anymore. This would be compatible with the observations of the most distant objects at present time, i.e. of galaxy GN-z11, showing a redshift of $z = 11.09$.

This would mean that our universe is like a bubble of dark energy which fades out with distance (Fig. 24).

If in an ancient cosmic time this bubble also rotated about a center, the formation of matter (particles as superfluid vortices of DEQ, §3) would be justified as a phenomenon already known to happen in rotating containers of superfluid helium, where a vortex lattice forms [9]. This hypothesis could also explain the left-handed bias of our universe, which extends from particles up to galaxies, since a statistically relevant number of spiral galaxies rotates leftward with respect to their outward-bound paths in the supposedly expanding universe. Furthermore, such a formation of particles and galaxies in a previously rotating superfluid universe, would even explain the uniformity of galaxies in the universe without the need for cosmic inflation, that is of an inexplicable *deus ex machina* which is necessary to save the Big Bang theory.

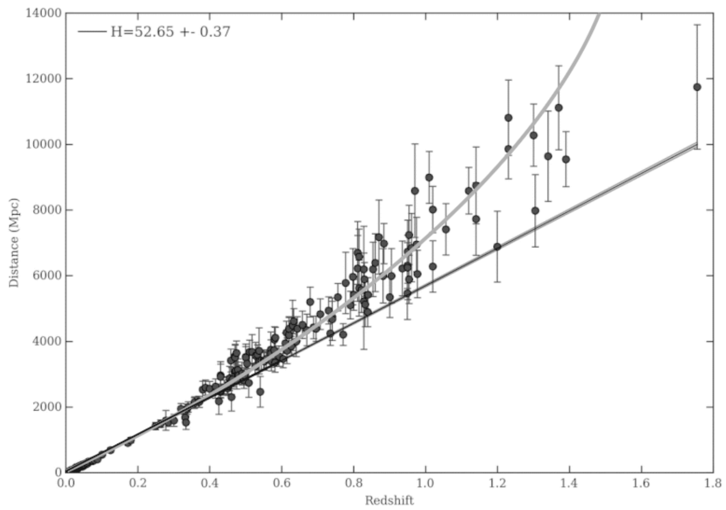

Figure 23: Redshift according to the projection of Hubble's law (straight line) and to the non-linear effect of dark energy density decrease with distance (light grey curve).

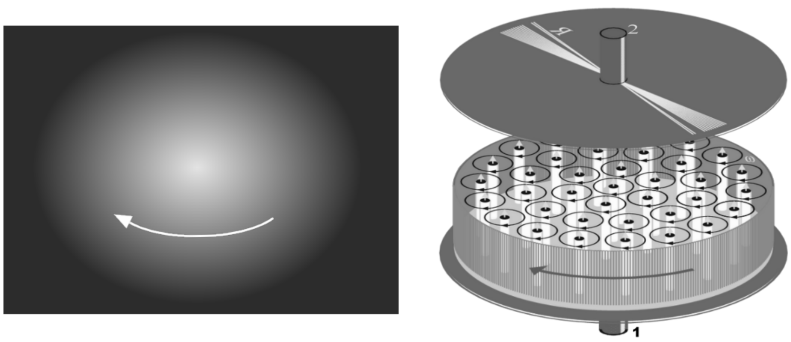

Figure 24: The observation of redshift suggests a non-linear effect on light due to dark energy density decreasing with distance. In this case the distribution of dark energy in the universe would appear as in the image on the left, as a fading bubble of superfluid dark energy. The possible rotation of this dark energy bubble in the early universe could have been the reason why fundamental particles have formed as vortices, in a similar way to that observed in superfluid helium, where vortices arise and rotate in the same direction of the container. This might be the *raison d'être* of the left-handed bias of our universe, from particles up to galaxies.

5.1.1 Baryon asymmetry: has antimatter never been there?

The decay of B mesons is predicted to favor the production of matter over antimatter but not enough to explain the huge preponderance of matter in the present universe. Recent tests at the LHCb [62] showed that baryons too seem to violate the CP symmetry by following different decay paths but stronger data are necessary and this phenomenon is maybe too rare in nature. Thus, with our present knowledge, baryon asymmetry remains a mystery. In this superfluid framework it could be however explained by the fact that a primordial universe as a left-handed bubble of SDE could have produced only left-handed matter particles, exactly as all quantum vortices in superfluid helium assume the same nature and orientation and follow the direction of rotation of the container (see Fig. 24). This seems to be the simplest reason why we do not observe matter-antimatter interactions in the universe.

As far as the cosmic microwave background radiation (CMB) is concerned, since a temperature of zero Kelvin is not possible (in our superfluid approach of vortex-particles we would say because a vortex has to rotate to exist and this preserves a minimum entropy), it can be seen as the temperature of the SDE when its order parameter is in the lowest-energy state (minimal entropy $\Leftrightarrow$ minimal quanta excitation $\Leftrightarrow$ lowest temperature). Therefore, the CMB would not be the relic of the hot, dense, early phase of the Big Bang but the average temperature of the SDE throughout the universe. According to Huang [12], matter was created in a vortex tangle due to quantum turbolence, whose lifetime has been that of cosmic inflation. On the contrary, we believe that the superfluid model does not need to conform to the problematic Big Bang + inflation framework, as it seems to give more simple reasons for the existence of the universe as we observe it. Moreover, the turbolent tangle scenario does not account for the existence of antimatter nor for the baryon asymmetry.

Still Huang takes into account the Higgs field, aware of the fact that the cosmic superfluid might be an overlapping of more, different superfluids, such as dark energy. On the contrary, in this work we consider a single-fluid model based on SDE only, thinking that the Higgs field be a manifestation of dark energy and Higgs boson a vortex of DEQ, i.e. a hydrodynamic excitation of the fundamental scalar field. Huang defines the lowest-energy order parameter of the cosmic superfluid as

$$\phi(x) = F_0 \tag{76}$$

where F_0 is a phenomenological parameter and he demonstrates that in a three-dimensional space (76) has long-ranged validity. He adds thermal fluctuations

$$\phi(x) = F_0 + u(x) \tag{77}$$

then by expanding the fluctuations in normal modes we get

$$u(x) = \sum_n \int d^D k e^{ik\cdot x} q_n(k) \tag{78}$$

where n refers to the types of modes and D defines the dimensions of space. The energy is equal to $k_B T$ and that present in a normal mode reads

$$E_n(k) = \frac{1}{2}\omega_n(k)\,|q_n(k)|^2$$

where ω_n is the normal frequency. The dominant contribution comes from the smallest $\omega_n(k)$, with $\omega_n(k) = ck$, corresponding to fluctuations in the long-wavelength Goldstone mode

$$\langle u^2 \rangle \sim \int dk \frac{k^{D-1}}{k^2} = \int dk\, k^{D-3} \tag{79}$$

We see that if $D > 2$, then also in our three-dimensional space, the long-ranged order of the field (76) is not destroyed and this may in our opinion account for the uniformity of the CMB.

5.2 Out of the paradoxes: is the universe static?

As outlined above, (a) if Hubble's redshift is not due to the recessional velocity of galaxies, (b) if the apparent accelerated expansion can be explained with the joint action of viscosity and decreasing density of dark energy and (c) if the formation of matter can have occurred without a Big Bang, we solve then at once the paradoxes of modern cosmology.

The currently accepted Big Bang model stands for several aspects in contrast with observations. According to it, the universe should not be homogeneous and isotropic as it is, for instance showing a cosmic microwave background radiation (CMB) at the same temperature in all directions. Second, the universe should not be flat, as we observe it is, since this is possibile only for a very fine-tuned critical density of matter and energy in the early universe, which moreover should not have changed during the cosmic time of the universe evolution. Third, at the extremely high temperatures of the primordial universe, the Grand Unified Theories predict the formation of magnetic monopoles. But such objects have been never observed (normally every magnet, or piece of magnet, has two poles), so, as far as we know, they do not exist. As we saw, these three problems are theoretically solved in modern cosmology by introducing cosmic inflation, which is however another brain teaser. So the question arises, do we have to believe that the Big Bang model is true despite the questions it lets arise, not least that of an adimensional point (singularity) which is however able to contain all the mass-energy of the universe and is in contrast to quantum physics, only because we observe a redshifted light of galaxies and we think the only explanation is an expanding universe? And so, by mentally reversing this phenomenon, we come back to a moment, where everything was concentrated in a single dimensionless point? In this work we have tried to differently explain Hubble's redshift and the present universe, without Big Bang, inflation and accelerated expansion. Analogous conclusions have been presented in [4].

Thus, it is opportune to wonder: maybe the universe is static, as Einstein believed before Hubble's observations? There may be a substantial equilibrium between gravity (dark energy absorption) and repulsion (dark energy intrinsic pressure). The intrinsic pressure would arise on homeostatic basis, if toward the boundaries of the universe dark energy density were lower, as we have hypothesized also to explain the apparent acceleration of distant galaxies. This is perhaps more plausible than the Big Bang theory and the paradoxes it produces. Eventually, back to the CMB, it would not be the echo of the Big Bang, as commonly said, but simply the minimal hydrodynamic (so also thermal) fluctuation of dark energy. Indeed nothing can be at 0°K, so the 2.725°K temperature of the CMB would be absolutely normal in the superfluid approach (^{4}He becomes superfluid at $T_\lambda \approx 2$K) and would be observed as the minimal possible entropy of dark energy (see also §3.3). Thus the homogeneity of the CMB throughout the universe would not be a problem to solve anymore and we do not need to resort to cosmic inflation. In Fig. 25, we see a Mollweide projection of the minimal oscillations ($\pm 2 \cdot 10^{-4}$Kelvin) in the CMB.

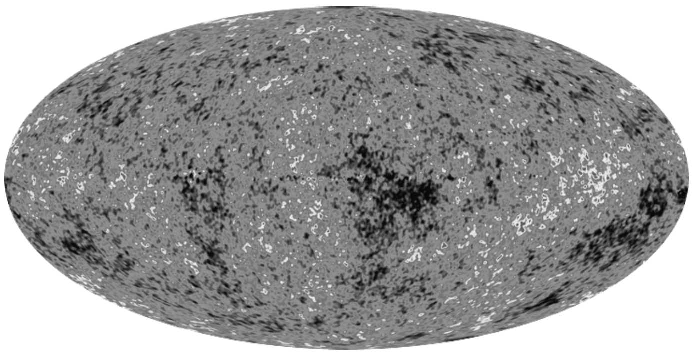

Figure 25: Cosmic Microwave Background temperature fluctuations (seen as the temperature fluctuations of superfluid dark energy) from the 7-year Wilkinson Microwave Anisotropy Probe (WMAP) data seen over the full sky. This image is a Mollweide projection of the temperature variations over the celestial sphere.The average temperature is 2.725 Kelvin degrees above absolute zero. Light regions are warmer and dark regions are colder by about 0.0002 degrees. This map is the ILC (Internal Linear Combination) map, which attempts to subtract out noise from the galaxy and other sources. In the superfluid approach to cosmology, we look at this map as the expected minimal, intrinsic thermal fluctuation of superfluid dark energy (zero-point temperature), without Big Bang. (Image adapted from: http://wmap.gsfc.nasa.gov/media/101080).

5.3 Vacuum catastrophe.

QFT is one of the most accurate theories of modern physics. It predicts a value for the energy of the vacuum, i.e. for the zero-point energy (but we say for dark energy density) which is very high, about 10^{113}J per cubic meter. This energy should exert gravitational effects (negative gravity as indicated by $\Lambda g_{\mu\nu}$ in the EFE) and was measured by the Voyager probes. But the result was far too low, i.e. 10^{-9}J/m^3, with respect to that predicted by QFT. However, there is always a mathematical expedient to solve any problem in physics, if one wants, so we apply a renormalization cutoff to the value obtained in QFT. There can be anyway a different answer coming from this superfluid approach, a solution which recalls the fact that dark energy *per se*, albeit possessing density $\rho_d \neq 0$, is not enough to produce gravitational pull. Vortices have to form (see SQG, §4). So, the answer to the so-called vacuum catastrophe could be that dark energy can actually possess the high energy density predicted by QFT and, nevertheless, do not exert a mass-related gravitational effect but simply a repulsion due to its internal pressure, as we discussed above. Thus, measuring the energy density of vacuum by observing mass-related gravitational effects would be a wrong approach of the space agencies.

Projecting the vacuum-catastrophe problem onto Einstein field equation, we have to point out that the cosmological constant $\Lambda = k\rho_0$ should not therefore refer to the density of dark energy but to its intrinsic pressure (repulsive force), able to balance gravity and to avoid a gravitational collapse of the universe.

We should finally reflect on the fact that an elementary particle of our baryon world does not contain more energy than that surrounding it as "vacuum" energy. On the contrary, the energy density falls in a vortex-particle and tends to its maximum with distance from it. As a conceptual example, albeit for different reaons, in Fig. 26 water density is zero inside the bubbles, as we know that $\rho \to 0$ in the vortex core (Fig.1), allowing no violation of Kelvin's circulation theorem. In Fig. 26 we look at the bubbles and the rest seems a dark nothing, but from the point of view of the fluid, *the bubbles* are nothing. The very high value for vacuum (we should not use anymore this word to refer to the zero-point field) energy density, deriving from QFT could be then plausible without any cutoff, meaning that what we consider to be "vacuum" owns a much higher energy density than baryon matter itself, albeit it does not interacting with standard matter, inasmuch it is superfluid and as long as it is not perturbed. Light, as phonons (§3.2), is for example a form of dark energy perturbation we can observe, so it is not correct to state that dark energy does not interact with baryon matter. Within our vortex picture, it "is" baryon matter. Thus, we observe interactions between vortices of dark energy, and this is the field of atomic physics and chemistry, but not between unperturbed DEQ and baryon matter, simply because these dark quanta cannot interact in a way we can observe until they assume a dynamic structure (pulse or vortex). Modern physics is at the moment focusing on the possible different kind of particles (e.g. the hypothetical WIMP) but, in my opinion, the key for understanding the difference and the communication channels between the dark world and the baryon world (and to understand the growing particle zoo itself) is the hydrodynamics of dark energy. Everything might be dark energy and we say we do not know what it is. Seen from a near future, this could be quite embarrasing for the physics of nowadays, if we do not start considering dark energy as a ubiquitous superfluid possessing high energy density.

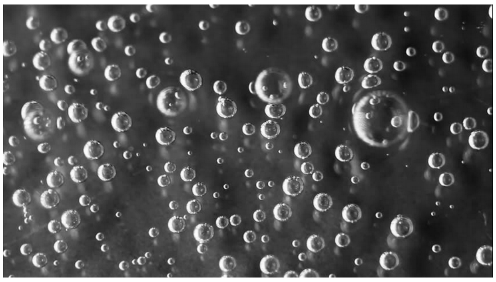

Figure 26: CO_2 bubbles in water representing the concept according to which matter particles, as superfluid vortices in dark energy, create regions where density falls, so the surrounding medium possesses much greater density. The very high value for vacuum energy density deriving from QFT could be then plausible without any cutoff, meaning that what we consider to be "vacuum" owns a much higher energy density than baryon matter itself, albeit not interacting with it as long as the superfluid remains unperturbed.

5.4 Vortex filaments of dark energy and the structure of the universe.

Galaxies in the universe appear to be distributed along cosmic filaments, resembling the cytoskeleton of a living cell. The mainstream believes they are filaments of dark matter, which acted as a scaffold for the distribution of ordinary matter in the universe. We believe dark matter arises from density variations in the superfluid ocean of dark energy. It would be a sort of condensed dark energy, probably involved in particular hydrodynamic behaviors, as macroscopic vortex tubes. Also Huang agrees about considering dark matter as a form of higher-density dark energy ([12] p.101). A demonstration of this would be the fact that galaxies acquire their dark matter halos (responsible for the flat-profile of the orbital speed) by dragging and condensing the dark superfluid which they move and rotate through (Fig. 28). It is particularly interesting to compare the formation of vortex filaments in superfluid helium with the galactic filaments observable in our universe (Fig. 27).

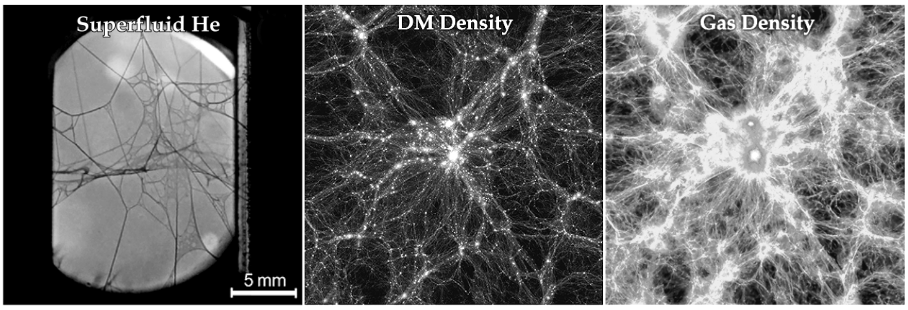

Figure 27: Left [67]: Metal atoms trapped in superfluid helium vortices highlight a structure of vortex filaments; at the center and on the right [66], galactic filaments of dark matter which galaxies aggregate on and the same image putting in evidence the distribution of gas accreting onto the filaments.

Such a similarity appears as a valid explanation to why galaxies in our universe are organized along filaments. During the genesis of our universe, baryon matter would have been attracted toward the vortices because of the same hydrodynamic mechanism (Bernoulli pressure) which lets the metal atoms adhere to the vortex surface in superfluid helium. We have indeed defined superfluid quantum gravity (§4) by starting from this mechanism.

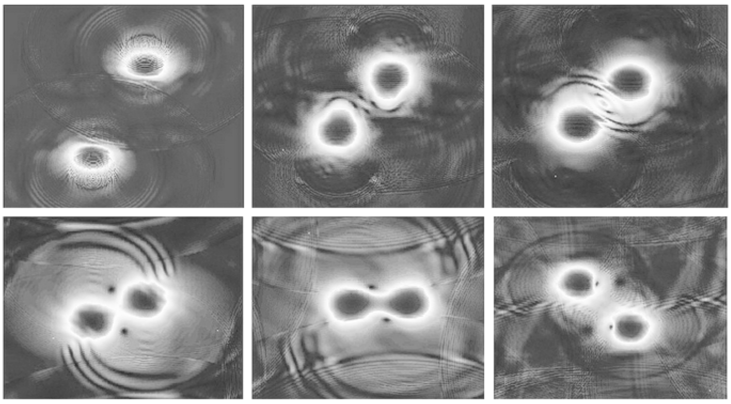

Figure 28: 2D simulation of a collision between two galaxies, where their galactic halos (dark matter, as dragged and condensed dark energy) flow in accordance with superfluid hydrodynamics. From [12].

According to a speculation of Lathrop [68], dust particles adhere to giant vortex rings existing in the superfluid cosmos, until they accrete into bigger clumps and collapse toward the center of the ring due to gravitation, generating the black hole at the center of any galaxy and letting the ring assume the form of a spiral galaxy (Fig. 29).

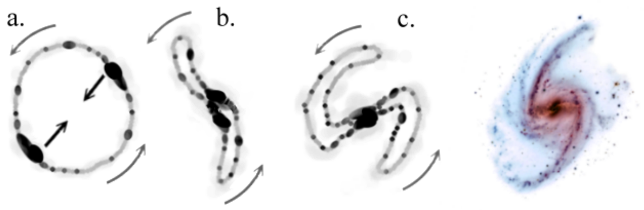

Figure 29: Lathrop hypothesis on Galaxy formation through accretion of dust particles on a vortex ring (a), which gravitate and clump (b) giving the ring a spiral shape (c) and creating the gravitational conditions for the formation of a black hole.

6 Unification of the fundamental forces.

6.1 Gravity-electromagnetism unification.

By describing quantum gravity as absorption of dark energy into vortex-particles, we have to account for the energy equilibrium of such systems, as we know that protons and electrons are, for instance, stable particles and their mass does not increase with time. We have then to suppose that a counterbalancing emission of DEQ occurs. If these quanta were packed into discrete amounts while circulating in the vortex and directionally re-emitted, we could not only justify the energy balance in the vortex-particle but also build a bridge between gravity and electromagnetism, by saying that these emitted packets are exactly those virtual photons of QED, responsible for the electrostatic field of charged particles. Within this hypothesis, neutral particles should on the contrary decay because of energy disequilibrium and indeed we know that isolated neutrons decay, having a mean lifetime of 881 s. Only when neutrons are bound to protons in the nucleus they are stable. The electric charge (the electrostatic field) of a particle would therefore act as a compensation mechanism for the absorbed DEQ. In Fig. 30 (arrow down) we see that the horn-torus geometry of the vortex justifies the compression and the directional emission of virtual photons as packets of DEQ.

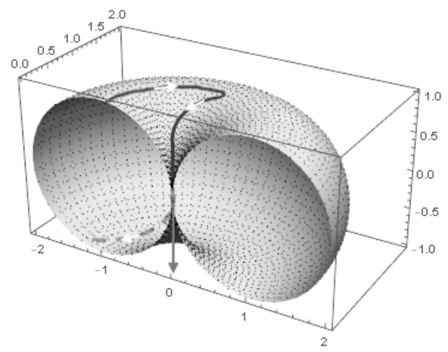

Figure 30: ejection mechanism of DEQ packets (virtual photons) from horn-torus-shaped vortex-particles (see also Fig. 5), causing the electrostatic interaction.

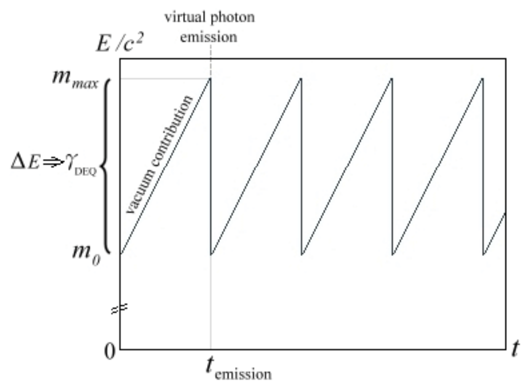

Figure 31: Sawtooth electro-gravitational oscillator for a charged particle expressing its rest mass variation while producing gravitational pull and electrostatic field. Dark energy contribution (vacuum contribution) corresponds to the absorption of DEQ into the vortex-particle and goes back to the m_0 level as soon as a virtual photon is emitted as a packet of DEQ (γ_{DEQ}).

From the sawtooth behavior described in Fig. 31 it follows

$$m_{eff(t)} = (t - \lfloor t \rfloor)k_a + m_0, \tag{80}$$

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 $k_a = m_{\gamma_{\mathrm{DEQ}}}/t_{emission}$, *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. This fact would agree with the indeterminacy of quantum mechanics and also account for the phenomenon of *Zitterbewegung* (trembling motion) [63, 64].

Starting from the Dirac equation in natural units, the equations of motion in the Heisenberg picture are given by

$$\frac{d}{dt}A(t) = i\left[\mathcal{H}, A(t)\right] + e^{i\mathcal{H}t}\left(\frac{\partial A(t)}{\partial t}\right)e^{-i\mathcal{H}t}. \tag{81}$$

where A is the observable and $\mathcal{H}$ the Dirac Hamiltonian. When applied to $\mathcal{H}$, we obtain the system

$$\begin{cases} \frac{d\vec{x}}{dt} = \vec{\alpha} \\ \frac{d^2\vec{x}}{dt^2} = 2i\vec{p} - 2i\vec{\alpha}\mathcal{H} \\ \vec{p} = -i\vec{\nabla} \end{cases} \tag{82}$$

Being $\vec{p}$ and $\mathcal{H}$ time independent we can integrate, obtaining two components of motion. A constant velocity

$$\vec{v}(t) = \frac{\vec{p}}{\mathcal{H}} + \left(\vec{\alpha}(0) - \frac{\vec{p}}{\mathcal{H}}\right)e^{i\omega t} \tag{83}$$

and an oscillation term (Zitterbewegung) whose frequency is

$$\omega_Z = 2\mathcal{H} = \frac{2mc^2}{h} \tag{84}$$

and whose amplitude equals the Compton wavelength $\lambda_c = h/m_0c$, which refers to mass-energy conversion. In our framework this conversion matches the positive and negative energy components of Zitterbewegung and corresponds to the absorption-emission mechanism described above, where the mass of some DEQ which have been attracted into the vortex is transformed into virtual photons by the vortex dynamics.

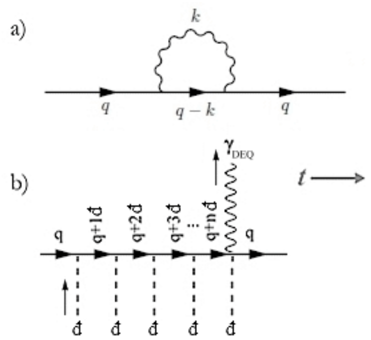

Figure 32: Current (a) and suggested (b) Feynman diagram describing a charged particle's self-energy, where đ indicates a quantum of dark energy and γ_{DEQ} a virtual photon as a discrete packet of dark energy quanta.

In Fig. 32 we see that the difference with the mainstream would be the fact that isolated charges do not emit and re-absorb virtual photons (a way to keep energy equilibrium in the current theory) but, on the contrary, they would first absorb DEQ and then re-emit them as virtual photons. Hence we suggest the Feynman diagram in Fig. 32 (b).

6.1.1 Coulomb's force.

To describe the dynamics of the electrostatic force, an anisotropic interaction between superfluid vortices, instead of the exchange of virtual photons in isotropic conditions (radial electrostatic field), could explain both attraction and repulsion between two charges as a mechanism driven by recoil (Fig. 33). On the contrary, the current isotropic model based on virtual photons exchange is weak in clarifying the mechanism of attraction.

The configuration of two same charges in Fig. 33 (bottom) shows Pauli exclusion principle (antisymmetric spins), which accounts for the validity of the anisotropic hypothesis for the electrostatic interaction. The orientation of a charge with respect to another would generate the illusion of a radial electrostatic force when two charges interact. Such a reorientation mechanism (which does not occur in atoms, since they are neutral but could be useful in the theory of molecular geometry) would also be valid for the electrostatic interactions occurring in more-particles systems. The compression of a given amount of absorbed DEQ into a single virtual photon which is directionally emitted, could account for the reason why the electrostatic interaction is 39 orders of magnitude stronger than gravity.

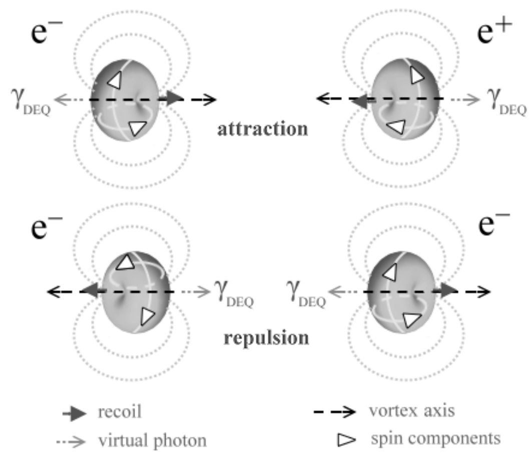

Figure 33: Electrostatic attraction and repulsion both due to the recoil caused by the emission of virtual photons ($\gamma_{\rm DEQ}$) from superfluid horn-torus-shaped vortex-particles.

The reorientation of particles (anisotropic electrostatic interaction) according to their charge would occur on hydrodynamic basis via information exchange in SDE and the emitted virtual photons are not exchanged but disperse obeying an inverse-square law, according to Coulomb's law. The analogy with ferromagnetism is very strong and interesting and may be in favor of the anisotropic hypothesis, since also within that phenomenon a reorientation (magnetization) of the particles occurs when the spin of the electrons, as the vortex axis in Fig. 33, changes its position under the external influence of a magnetic field. The magnetic field corresponds to the needed hydrodynamic information exchange (DEQ flow) between vortex-particles.

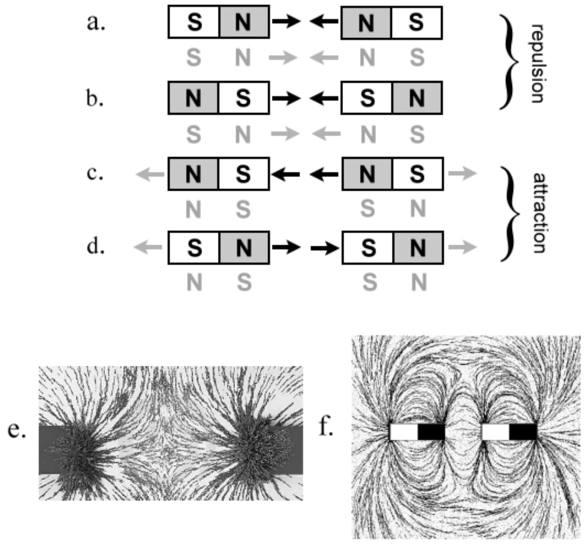

Figure 34: Force interactions in magnets. Black arrows (limited to the poles opposite one another) show the mainstream, while grey arrows refer to the suggested direction of virtual photon, whose recoil would cause repulsion or attraction after a spin reorientation has occurred. In (e) the opposite exiting flows of virtual photons are made visible and in (f) we observe the paradox of different poles having the same behavior, whose solution might be described by the grey letters and arrows in (c) and (d), that is a reorientation of the spins and a consequent inversion of the poles.

Trying to approach two magnets having same poles opposite one another lets us experience the power of a quantum phenomenon in our macroscopic world. Within our approach it means we are trying to defeat the force of the two opposite jets of virtual photons and of the repulsive recoil they cause. In Fig. 34 (a., b., c., d.), force interactions between magnets are shown. Black arrows indicate the direction of the field lines in the current theory (the image is simplified by considering only the arrows related to each couple of counterposed poles). Why do the fields lines remain the same after a rotation of 180° in both magnets has occurred? And why should an entering flux Fig. 34(c)(d) cause attraction? Taking into account the hypothesis of reorientation things become simpler. In (b) we see (grey letters) that the poles have actually switched and the field lines (grey arrows) now remain coherent, indicating the direction of the virtual photons and explaining the repulsion due to recoil. To undergo inversion would be actually the spins and consequently the poles. Moreover, in (c) and (d) different poles (as different charges in Fig. 33) determine the emission of virtual photons as indicated by the grey arrows and we see that in this case the recoil causes attraction. In (e) the opposite exiting flows of virtual photons are made visible by metal particles interacting with the field and in (f) we visualize the paradox of different poles having the same behavior (from one north pole the fields lines are exiting and into the other entering. The same happens to the south poles), whose solution can be again the riorientation of the spins, described by the grey letters and arrows in (c) and (d). In effect, though we can paint with different colors the north and south poles of a magnet, thinking that they always remain unvaried, all we notice is that different poles attract but we can't know if the fields lines remain the same albeit we perform a rotation of 180° (poles inversion) or if the poles switch, i.e. the spins reorient themselves. As a matter of fact, we know that an inversion of the poles has sometimes occurred in the Earth's magnetic field.

A similar reorientation (of the vortex lines) into an antiparallel configuration is known to happen just before the phenomenon of vortex reconnection (Fig. 2, Eq.8, [39]). Also the charge symmetry between matter and antimatter would then be due to the fact that antiparticles re-orient themselves in the opposite way with respect to matter.

6.1.2 Fine-structure constant.

The fine-structure constant represents the strength of the electromagnetic interaction. In all its equivalent formulations it is a dimensionless quantity. Let us observe it in the form

$$\alpha = \frac{k_e e^2}{\hbar c}. \tag{85}$$

By substituting $c = 1/\sqrt{\beta_d \rho_d}$ (§3.2) it reads

$$\alpha = \frac{k_e e^2}{\frac{h}{2\pi\sqrt{\beta_d \rho_d}}} \approx \frac{1}{137}. \tag{86}$$

In this form we observe a ratio where the numerator refers to the electrostatic interaction and the denominator represents the vorticity in SDE, as we see Planck constant (§3.1.1) divided by dark energy fundamental parameters, expressed as speed of sound through SDE. The resulting dimensionless ratio of 1/137 might then refer to how many rotations (the value in the denominator) a vortex-particle completes before it emits the following virtual photon, giving a measure of the strength of its electrostatic field and respecting the meaning of the fine-structure constant. In this case the elapsed time before the emission would correspond to the value $t_{emission}$ represented in Fig. 31.

6.2 Weak interaction, vortex geometry in neutral particles, neutrinos.

We already argued in §6.1 that in SQG an isolated neutral particle is condemned to decay, as it absorbs DEQ but does not emit virtual photons, undergoing in this way a disequilibrium. Only when neutral particles are bound to charged particles, as neutrons and protons in the nucleus, the decay is avoided. By comparing the figures 31 and 35, we see that in the latter the absence of virtual photons emission leads the particle to instability and to decay.

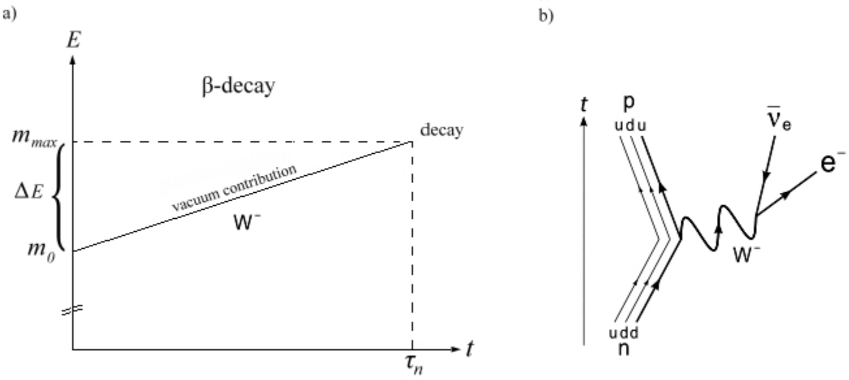

Figure 35: β-decay in unbound neutrons, (a) caused by vacuum energy (DEQ) absorption, being τ_n the neutron's mean lifetime. Here the W^-boson corresponds to the sum of the exceeding absorbed DEQ. In (b), a comparison with Feynman diagram for neutron's decay.

A prediction of this theory would be that of a greater mass of isolated neutrons before they decay, if compared with the mass of bound neutrons in the 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. The decay would also occur in unstable charged particles, where the equilibrium absorption-emission is imperfect. In summary, the same mechanism of SQG (absorption of DEQ) is the cause of β-decay and the link among gravity, electromagnetism and weak interaction.

As far as the vortex geometry of a neutral particle is concerned, taking into account the torus model described in §3.1, the absence of virtual photons emission would suggest a ring torus instead of a horn torus. Different is the case of the neutrino. Since it is a neutral particle, a ring-torus vortex geometry would be suggested but this is incompatible with the fact neutrinos are stable, albeit some studies suggest it can decay [72]. A simple explanation to this apparent violation is that a neutrino possesses a horn-torus geometry but its mass is too small to pack DEQ into virtual photons, so they are directionally re-emitted as smaller, trivial amounts or single quanta. Thus, we assume that a neutrino is the smallest possible horn-torus vortex and its mass, as for every other mass-endowed particle, arises from the DEQ circulating in its superfluid structure. Within this hydrodynamic model, flavour oscillations observed in neutrinos are not something difficult to justify, as a vortex is a dynamic structure which can undergo changements in its energy or in its behavior due to the interactions with the surrounding quanta, which can occur because of translational motion, vorticity, 0^+ viscosity, temperature.

6.3 Quantum chromodynamics and strong interaction.

By describing the elementary fermions as superfluid vortices of DEQ, it is clear that their spins can be conflicting or mutual when two particles approach. Two adjacent vortices with conflicting spins would annihilate each other. The relationship between spin orientations could explain several known issues of atomic physics (Fig. 36).

Only electrons with antiparallel spin (Fig. 36.b) can be in the same orbital, obeying Pauli exclusion principle. Otherwise, if they did not repulse each other and came into contact, two electrons with parallel spin (Fig. 36.a) would annihilate like a pair electron-positron (Fig. 36.c), because of their conflicting spins. Matter-antimatter annihilation would be therefore due to the conflicting spins of left- and right-handed vortices in conflicting spin orientation. A hydrodynamic phenomenon would be therefore at the basis of matter-energy conversion, confirming the hydrodynamic nature of the formula $E = mc^2$, as discussed in §3.2.1. When they possess parallel spin, the vortices can form unstable particles such as mesons (for instance a neutral pion π^0, Fig. 36.d) or ortho-positronium.

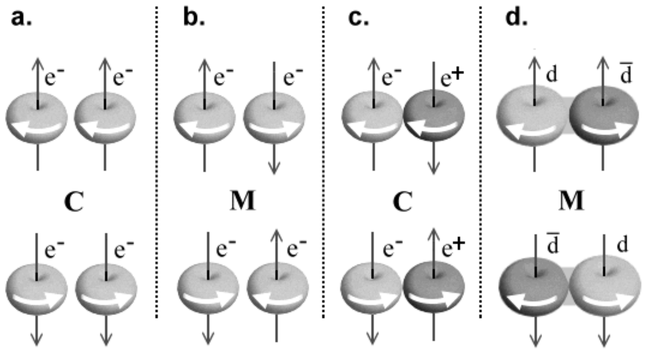

Figure 36: Conflicting (C) or mutual (M) spin would explain: Pauli exclusion principle (a, forbidden; b, allowed); particle-antiparticle annihilation (c); mesons, such as the π^0 (d) or exotic atoms as the ortho-positronium. Light grey vortices correspond to matter (left-handed) and dark grey ones to antimatter (right-handed). Without electrostatic repulsion to keep them separated, annihilation between two same charges with parallel spins would occur (a) even without involving antiparticles, due to conflicting rotations.

Conflicting spins may also explain the decay occurring in nucleon resonances. Now, what happens to vortex-particles posessing mutual spin which come into contact? The answer may be "quantum chromodynamics" (QCD). The strong fundamental interaction can be indeed described in the superfluid approach as an exchange of gluons seen as discrete amounts of DEQ passing from a vortex to another, as shown in Fig. 37.

This continuous exchange of DEQ is interpreted as the action of gluons and would account for the fact that most of the mass-energy of bound quarks is in the form of force-field energy and for the fact that "color" continuously migrates from a quark to another. Also the gluon flow would be nothing more than a hydrodynamic manifestation of SDE.

The so-called residual strong interaction can be likewise described as exchange of DEQ between vortices which are close together. A vortex tube arises which, once broken, results in two vortex rings and then in two vortex tori (§3.1, Fig. 38) that correspond to a quark-antiquark pair (π^0), belonging to the representations 3 and $\overline{3}$ of color SU(3), and in our case they result in a vortex-antivortex pair, within a self-sustainable process.

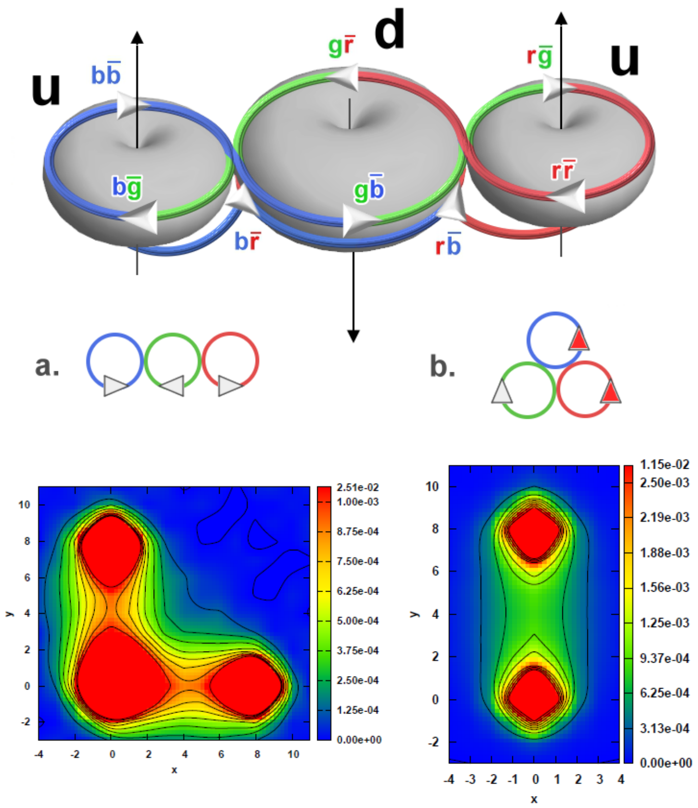

Figure 37: Quantum chromodynamics as a system of superfluid vortices of DEQ in mutual-spin configuration (here the hypothetical structure of a proton). The gluon octet is represented as the exchange (flow) of discrete amounts of DEQ among the vortices. The charge of the whole system is determined by the emission of virtual photons from the central vortex (down quark), while the DEQ expelled from the other quarks are reuptaked by the central quark ($b\bar{r}$, $r\bar{b}$ flows). This superfluid model would explain why most of the mass of the quarks in the proton is expressed as binding energy (gluon flow): DEQ, discretized as gluons, continuously flow among the quarks (which exchange mass the one with the other) and this determines their continuous change of *color*. The geometry in (b) is forbidden since it determines in any case conflicting spins, while that in (a) is allowed. Below, Lagrangian density in lattice QCD computations of the colour fields, from [65]. The L-shape geometry on the left is compatible with the mutual spin configuration in (a), while the geometry on the right may refer to a meson.

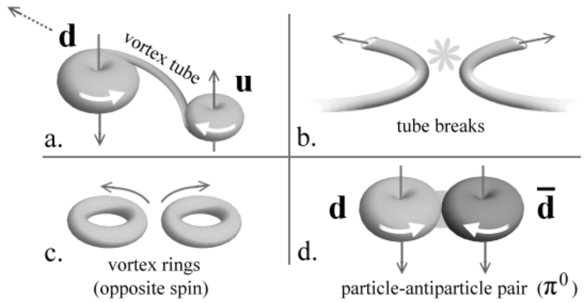

Figure 38: residual strong interaction (in proton-neutron bond). In a neutron, the quark down is separated from the quark up and a vortex tube appears. When the tube breaks it generates two vortex rings, which evolve as a couple of down/antidown quarks, forming a neutral pion that will complete the process of residual strong interaction. Here the vortex tube is a consequence of the already present exchange of DEQ between the two quarks d, u having mutual spins.

7 Technological perspectives and conclusion.

To date, technologies such as antigravitational flight, superluminal velocity or energy produced by resorting to antimatter have populated the imagination of science fiction. But a mobile phone could not even be imagined only a century ago and now also children use it everyday. For sure, we cannot develop a new technology before having understood the underlying theoretical basis but we fear that modern physics has got lost in some dead ends. The most significant are two:

- The interpretation of Hubble's redshift as recessional velocity of the galaxies.
- The interpretation of gravity as curved space-time.

We already discussed that the first has produced several paradoxes: the Big Bang with its singularity, a "dimensionless" point which contained all the mass-energy of the universe and mysteriously exploded; the consequent horizon problem, flatness problem, magnetic monopoles problem; the fantasious "inflation", aimed to solve the previous issues but being itself a bigger question, and, last but not least, the mysterious accelerated escape of the most distant galaxies. After decades we are still investing billions and great minds to solve what maybe is not solvable simply because the starting hypothesis was wrong.

In §2.2. we have reflected that everything might be immersed in a sea of superfluid, quantized dark energy and that light itself could be nothing more than the sound propagation in dark energy. If this is true, and we should run specific laser tests to verify it, Hubble's redshift can be due to a loss of energy of light which has nothing to do with the recessional, accelerated velocity of galaxies. The hypothesis of tired light based on scattering (e.g. due to stray electrons in the cosmos which deflect and absorb photons), as proposed by Zwicky in 1929, has been rejected by the scientific community on the basis of just and proven reasons, but in this work we show that the loss of energy (hence the redshift) in light can be due to different reasons too, such as the tiny, non-zero positive viscosity of dark energy and a variation in its density across the universe. The distances between stars and galaxies, the age of the universe and its possible evolution could have to be recalculated. In short, modern cosmology is somewhat fragile, since completely based on the recessional hypothesis of Hubble's redshift. And – to arrive at the second dead end, which prevents us from understanding (and manipulating?) gravity from a quantum point of view – on the idea of curved space-time.

Computationally treating a hypothetical space-time as a curved geometrical entity due to the presence of mass-energy, as defined by the energy-stress tensor ($T^{\mu\nu}$) of Einstein field equation, is a theoretically useful tool but the fact that the predictions of such an approach be correct does not mean that it reflects the real world. Indeed, by fluid dynamically approaching the same relativistic effects predicted by special and general relativity, we can ascertain that the results are the same. Not only. Within a hydrodynamic approach, relativity loses its misteries and appears to be simplified (§4.8). The Schwarzschild solution, the gravitational lensing, the Lense-Thirring precession, the insuperability of the speed of light (not explained but simply adopted as a matter of fact by Einstein), gravitational waves and light itself are phenomena which become clearly explained through a hydrodynamic approach which takes into account that $\sim 70\%$ of SDE filling the universe. Everything is a hydrodynamic manifestation of superfluid dark energy. If this is true, we should not call it dark anymore. We need nothing more than dark energy to obtain our world, what we see, what we touch, the energy we use and, lastly, life itself.

At the beginning of this chapter I have pointed out that before any technological advancement, we need to establish a suitable theoretical background and to understand when it is time to change direction, if necessary. Sabine Hossenfelder [88] states: "We use the approved methods of our field, see they don't work, but don't draw consequences. Like a fly hitting the window pane, we repeat ourselves over and over again, expecting different results. Some of my colleagues will disagree we have a crisis. They'll tell you that we have made great progress in the past few decades (despite nothing coming out of it), and that it's normal for progress to slow down as a field matures — this isn't the eighteenth century, and finding fundamentally new physics today isn't as simple as it used to be. Fair enough. But my issue isn't the snail's pace of progress perse, it's that the current practices in theory development signal a failure of the scientific method. [...] In the foundations of physics it has become extremely rare for any model to be ruled out. The accepted practice is instead to adjust the model so that it continues to agree with the lack of empirical support".

The hypothesis of the recessional velocity of galaxies to explain Hubble's redshift producing more questions than answers, is in my opinion a representative example of insisting in the wrong direction, on which all modern cosmology is at the moment based. We should remember to always apply Ockham razor on theoretical physics. On the other hand, the goal of science is the technological advancement of humanity. From medicine and from promoting economic progress through new technologies up to the conquest of space. Technology needs empirical evidence. The superfluid interpretation of modern physics which has been presented in this work, has been built on available evidences, from observations of vortices in superfluid helium, up to the insuperability of the speed of light and the phenomenon of (apparent) mass increase in synchrotrons to hypothesize, for instance, the passage from superfluid to dilatant (Fig. 7) regime of quantum vacuum, that we call "dark energy" since we know from QFT that zero-energy vacuum does not exist and that the physical space is filled by a dark substance which constitutes the $\sim 70\%$ of all the energy in the universe. In short, I think we already have all the evidences which are necessary to build a theory of everything without resorting to fantasy [33], i.e. to further dimensions, singularities, curved space-time or new mathematical worlds. The superfluidity of the (very) fundamental scalar field might be enough to explain all we see.

So, let us reflect on what a superfluid approach to space and gravity could mean as far as our technological progress is concerned. It is clear that in the Einsteinian framework only mass-energy can determine or condition gravity. To defeat the Earth's gravity we should use and manipulate objects of greater mass, which is impossible. On the contrary, in SQG a gravitational field is a flow of dark energy quanta. Thus, if we were able to deflect, interrupt or absorb the quantum gravitational flow, we would create a zero-weight area. If we could for instance apply a hydrodynamic action (vorticity on femto-scale) to the flow and transform it into particle-antiparticle pairs similarly to what observed in the Kármán vortex street (§3), we might not only interrupt the gravitational field in a certain area but, at the same time, separately capture particles and antiparticles which could be later recombined in a controlled manner to have (infinite and cheap) free energy. The observed phenomenon of vacuum birefringence [87], tells us that the manipulation of vacuum (of dark energy) on electrodynamic basis is possible. Of course, as it happened for the Manhattan project, matter-antimatter recombination from dark energy manipulation would also present morally dangerous aspects, far from the interests of science. The same mechanism hypothesized above could be used to obtain vehicles able to overcome the speed of light. If indeed the insuperability of light is due to the dilatant behavior of dark energy (§3.2.2) we could drill the compact wall of dark energy which arises with the progressive increase of shear stress by passively causing a different hydrodynamic behavior of the DEQ, inducing them to assume the geometry of particles and antiparticles which are then electromagnetically captured and kept thanks to magnetic confinement and used to produce (through controlled matter-antimatter recombination) the energy the vehicle needs to accelerate/decelerate and for any necessity on board. Revolutionary technologies which could be different sides of the same coin: the hydrodynamic manipulation of superfluid dark energy.

In any case, it would be first of all useful to start with laser tests, as suggested (§4.7), and with experiments with dilatant fluids, for instance concerning how to overcome the speed of sound in a dilatant fluid without cracking it. From Nikola Tesla up to the present days, many have speculated whether we can anyhow capture the infinite energy of "vacuum" but much more people felt this is likely to remain a fantasy. However, if the hydrodynamics of dark energy really builds up our universe, we have first of all to begin to rethink these fantasies in quantum hydrodynamic terms, to perhaps transform them in real technology.

Acknowledgments

I wish to thank Valeriy Sbitnev for the fruitful exchange of views on the superfluid approach and for our recent collaboration on a chapter of the book *Cosmology* edited by Intech. A special word of thanks also to Michele Ignelzi and to Lorenzo Brandi, astronomer, for advice and discussion. The author also thanks Dr. Lathrop for e-mail correspondence about the unpublished speculation on spiral galaxies and black holes formation. We finally remember and thank prof. Huang, who understood the importance of an overall superfluid approach to physics.

References

[1] L. de Broglie, *Une interpretation causale et non linéare de la mécanique ondulatoire: la théorie de la double solution.* Gauthier-Villars, Paris (1956)

[2] L. de Broglie, *The reinterpretation of quantum mechanics.* Found. Phys **1**, 5 (1970)

[3] I. Licata, D. Fiscaletti, *Quantum potential: physics, geometry and algebra.* Springer briefs in physics, Springer, Cham Heidelberg New York Dordrecht London (2014)

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

[5] V.I. Sbitnev, *Hydrodynamics of the physical vacuum: I. Scalar quantum sector.* Foundations of Physics. 2016; **46**: 606-619

[6] V.I. Sbitnev, *Hydrodynamics of the physical vacuum: dark matter is an illusion.* Mod. Phys. Lett. A. 2015; **30**: 1550184

[7] V.I. Sbitnev, *Dark matter is a manifestation of the vacuum Bose-Einstein condensate.* 2016, URL: http://arxiv.org/abs/1601.04536

[8] V.I. Sbitnev, *Hydrodynamics of the physical vacuum: II. Vorticity dynamics.* Found. of Physics. 2016; URL: http://rdcu.be/kdon.

[9] V.I. Sbitnev, *Physical Vacuum is a Special Superfluid Medium.* In: Pahlavani MR, editor. Selected Topics in Applications of Quantum Mechanics. InTech, Rijeka (2015)

[10] G.E.Volovik, *Topology of Quantum Vacuum*, arXiv:1111.4627v6 (2012)

[11] G.E. Volovik, *The Universe in a helium droplet*, Int. Ser. Monogr. Phys. **117** (2003)

[12] K. Huang, *A Superfluid Universe.* World Scientific, Singapore (2016)

[13] K. Huang, *Quantum vorticity in nature*, arXiv:1508.05619v1 (2015)

[14] K. Huang, *Dark energy and dark matter in a superfluid universe.* arXiv:1309.5707 (2013)

[15] M. Fedi, *Gravity as a fluid dynamic phenomenon in a superfluid quantum space.* URL: https://hal.archives-ouvertes.fr/hal-01248015v6 (2015)

[16] A.A. Michelson, E.W. Morley, *On the Relative Motion of the Earth and the Luminiferous Ether.* American Journal of Science 34: 333–345 (1887)

[17] H.A. Lorentz, *The theory of electrons and its applications to the phenomena of light and radiant heat.* B.G. Teubner, Leipzig & Berlin (1909)

[18] A. Einstein, *Ether and the theory of relativity* (1920). In: Sidelights on Relativity. Methuen, London (1922)

[19] Planck Collaboration; P.A.R. Ade, N. Aghanim, M. Arnaud, et al., *Planck 2015 results. XIII. Cosmological parameters.* arXiv:1502.01589 (2015)

[20] P. De Bernardis, P.A.R. Ade, J.J. Bock, et al., *A flat Universe from high-resolution maps of the cosmic microwave background radiation.* Nature. 404 (6781): 955–9 (2000)

[21] P.A.M. Dirac, *Is there an Aether?*, Nature 168 (1951)

[22] Annales de la Fondation Louis de Broglie, Volume 12, no.4 (1987)

[23] N.C. Petroni, J.P. Vigier, Found Phys (1983) **13**: 253.

[24] Y. Couder, S. Protière, E. Fort and A. Boudaoud. *Dynamical phenomena: Walking and orbiting droplets.* Nature, 437(7056), (2005)

[25] D. Bohm, *A new suggested interpretation of quantum theory in terms of hidden variables.* Part I, Phys. Rev. **85**, 166-179 (1952)

[26] D. Bohm, *Proof that probability density approaches* $|\Psi|^2$ *in causal interpretation of the quantum theory.* Phys. Rev. **85**, 180-193 (1952)

[27] H. Poincaré, *The Connection Between Ether and Matter*, Annual Report of the Board of Regents of the Smithsonian Institution (1912)

[28] R.B. Laughlin, *A Different Universe: Reinventing Physics from the Bottom Down.* NY, NY: Basic Books (2005)

[29] J.A. Wheeler, K. Ford, *Geons, Black Holes, and Quantum Foam*, W.W. Norton & Company (1995)

[30] P. Higgs, *Broken Symmetries and the Masses of Gauge Bosons.* Physical Review Letters. **13** (16): 508. (1964)

[31] D. Huterer, M.S. Turner, *Prospects for probing the dark energy via supernova distance measurements*, Phys. Rev. D **60**, 081301 (1999)

[32] A. Einstein, *Kosmologische Betrachtungen zur allgemeinen Relativitaetstheorie.* Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften Berlin. part 1: 142–152. (1917)

[33] R. Penrose, *Fashion Faith and Fantasy in the New Physics of the Universe*, Princeton University Press, Princeton and Oxford (2016)

[34] L. Amendola, S. Tsujikawa, *Dark Energy. Theory and observations.* Cambridge University Press, Cambridge (2010)

[35] E. Komatsu *et al.* [WMAP collaboration], *Five-year Wilkinson Microwave Anisotropy Probe (WMAP) observations. Cosmological interpretation*, Astrophys. J. Suppl. **180** (2009), 330.

[36] L.F. Gomez, K.R. Ferguson, J.P. Cryan *et al., Shapes and vorticities of superfluid helium nanodroplets*, Science, Vol. 345 n. 6199 pp. 906-909 (2014)

[37] F. Dalfovo, S. Giorgini, L.P. Pitaevskii, A. Stringari, Rev. Mod. Phys. **71**, 463 (1999)

[38] R. P. Feynman, in *Progress in Low Temperature Physics*, Vol.1, ed. C.J. Gorter, North-Holland, Amsterdam (1955)

[39] K. S. Schwarz, Phys. Rev. B **31**, 5782 (1985); Phys Rev. **38**, 2389 (1988)

[40] J. Koplik, H. Levine, Phys. Rev. Lett. **71**, 1375 (1993)

[41] D. Kivotides, C.F. Barenghi, D.C. Samuels, Phys. Rev. Lett., **87**, 155301 (2001)

[42] T. von Kármán, *Aerodynamics.* McGraw-Hill (1963)

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

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

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

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

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

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

[49] A.O. Santillán, K. Volke-Sepúlveda. *A demonstration of rotating sound waves in free space and the transfer of their angular momentum to matter*, Am. J. Phys. 77, 209 (2009)

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

[51] D.E. Reiter *et al., Generation of squeezed phonon states by optical excitation of a quantum dot*, J.Phys.: Conf. Ser. 193 012121, Institute of Physics (2009)

[52] V.I. Sbitnev, *Bohmian 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)

[53] V.I. Sbitnev, *Bohmian traectories and the path integral paradigm. Complexified Lagrangian mechanics.* Int. J. Bifurcat. Chaos **19**(7), 2335-2346 (2009)

[54] R.T. Cahill, *Gravity as quantum foam in-flow.* URL: https://arxiv.org/abs/physics/0307003 (2003)

[55] A. Einstein. *Über Gravitationswellen.* Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften Berlin (1918)

[56] B. P. Abbott (LIGO Scientific Collaboration and Virgo Collaboration) *et al.*, *Observation of Gravitational Waves from a Binary Black Hole Merger.* Physical Review Letters. 116 (6): 061102. arXiv:1602.03837 (2016)

[57] M. Grusenick. *Extended Michelson-Morley interferometer experiment.* (URL checked April 14, 2017):
https://www.youtube.com/watch?v=7T0d7o8X2-E (2009)

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

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

[60] A. Dupays, C. Rizzo, D. Bakalov, G.F. Bignami. *Quantum Vacuum Friction in Highly Magnetized Neutron Stars*, arXiv:0804.1841 (2008)

[61] F. Zwicky, *On the Red Shift of Spectral Lines through Interstellar Space.* PNAS; 15: 773-779 (1929)

[62] The LHCb collaboration. *Measurement of matter–antimatter differences in beauty baryon decays.* Nature Physics **13**, 391–396 (2017)

[63] E. Schrödinger, *Über die kräftefreie Bewegung in der relativistischen Quantenmechanik*, Berliner Ber. (1930)

[64] D. Hestenes, *The Zitterbewegung interpretation of quantum mechanics*, Foundations of Physics **20**(10) (1990)

[65] M. Cardoso *et al.*, *Lattice QCD computation of the colour fields for the static hybrid quark–gluon–antiquark system, and microscopic study of the Casimir scaling*, Phys. Rev. D 81, 034504 (2010)

[66] M. Vogelsberger, S. Genel, V. Springel, P. Torrey, D. Sijacki *et al.*, 2014a. ArXiv e-prints

[67] P. Moroshkin, V. Lebedev, B. Grobety, C. Neururer, E. B. Gordon, A. Weis. *Nanowire formation by gold nano-fragment coalescence on quantized vortices in He II.* Europhysics letters, Vol. 90, N.3 (2010)

[68] D.P. Lathrop, private communications.

[69] R. L. Kirkwood, *The Physical Basis of Gravitation*, Phys. Rev. **92**, 1557 (1953)

[70] G.P. Bewley, M.S. Paoletti, K.R. Sreenivasan, D.P. Lathrop. Characterization of reconnecting vortices in superfluid helium, arXiv:0801.2872 (2008)

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

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

[73] P. L. Arnold, G. M. Jones, S. O. Odoh, G. Schreckenbach, N. Magnani, J. B. Love. Strongly coupled binuclear uranium–oxo complexes from uranyl oxo rearrangement and reductive silylation. Nature Chemistry **4**, 221–227 (2012)

[74] V.I. Sbitnev, *Hydrodynamics of Superfluid Quantum Space: de Broglie interpretation of the quantum mechanics* (to be published) and private communications.

[75] W.G.Unruh, R.M.Wald, Phys. Rev. D **29**, 1047 (1984)

[76] D.E. Dìaz, J. Stephany, *Rindler Particles and Classical Radiation.* arXiv:gr-qc/0111041v2

[77] A.Higuchi, G.E.A.Matsas, and D.Sudarsky, Phys. Rev. D **45**, R3308 (1992)

[78] A.Higuchi, G.E.A.Matsas, and D.Sudarsky, Phys. Rev. D **46**, 3450 (1992).

[79] H.Ren and E.J.Weinberg, Phys. Rev. D **49**, 6526 (1994).

[80] G. Sewell, Ann. Phys. 141, 201 (1982); Phys. Lett. A **79**, 23 (1980)

[81] V.L. Ginzburg, V.P. Frolov, Sov. Phys. Usp **30**, 1073 (1987)

[82] B.F. Svaiter and N.F. Svaiter, Phys. Rev. D **46**, 5267 (1992).

[83] G. E. A. Matsas, D. A. T. Vanzella, *The Fulling-Davies-Unruh Effect is Mandatory: The Proton's Testimony*, arXiv:gr-qc/0205078

[84] V. Lebedev, P. Moroshkin, B. Grobey, A. Weis, J. Low Temp. Phys.**165**, 166 (2011).

[85] M. Visser, C. Barceló, S. Liberati, *Analogue models of and for gravity.* General Relativity and Gravitation. **34** (10): 1719–1734 (2002).

[86] C. Barceló, S. Liberati, M. Visser, *Analogue Gravity.* Living Reviews in Relativity. **14** (3), 2011

[87] R. P. Mignani, V. Testa, D. González Caniulef, R. Taverna, R. Turolla, S. Zane, K. Wu, *Evidence for vacuum birefringence from the first optical-polarimetry measurement of the isolated neutron star RX J1856.5−3754*, Mon Not R Astron Soc (2017) **465** (1): 492-500

[88] S. Hossenfelder, *Science needs reason to be trusted*, Nature Physics v. 13, pp. 316–317 (2017)