A Theoretical Study of Link between Gravity and Dynamics of Quantum Liquids and Evaluation of some of Its Parameters

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ABSTRACT

Using the theoretical formalism of G E Volvik[8] and Macro Fedi[9], we have studied the links between gravity and dynamics of quantum liquids. We have also outlined the gravity as a fluid dynamic phenomenon in super fluid quantum space. The detailed studies are the following:

From above theoretical investigation, we have discussed effective gravity of super fluids. Quantized vortices with circulating super fluid velocity around them simulate the spinning cosmic strings.

We have very elaborately discussed gravity as fluid dynamic phenomenon in a super fluid quantum space (SQS). We have outlined various examples in which quantum phenomenon resembles quantum super fluid.

Keywords: Quantum gravity, quantum liquids, Quantum field theory, Lorentz invariance, CPT violation, Super fluid helium, Super fluid quantum space.

INTRODUCTION

In a modern viewpoint the relativistic quantum field theory is an effective theory[1]. It is an emergent phenomenon arising in the low energy corner of the physical vacuum-the medium, whose nature becomes unknown. Also it is argued that in the low energy corner the symmetry must be enhanced[2]. If one neglects the very low energy region of electroweak scale,

where some symmetry are spontaneously violated, then above this scale one can expect that the lower the energy, the better is the Lorentz invariance and other symmetries of the physical laws. The same phenomena occur in the condensed matter systems. If the spontaneous symmetry breaking at very low energy is neglected or avoided then in the limit of low energy the symmetry of the condensed matter is really enhanced. Moreover, there is special universality class of Fermi systems, where in the low energy corner there appears almost all the symmetries, which one knows today in high energy physics. Lorentz invariance, gauge invariance, elements of general covariance etc. super fluid ^{3}He-A is a representative of this class[3]. The chiral fermions and gauge bosons and gravity field arise as fermionic and bosonic collective modes of such a system. The inhomogeneous state of the condensed matter ground state-vacuum- induces nontrivial effective metrics of the space. Here, the fee quasi-particles move along geodesics. The conceptual similarity between condensed matter and quantum vacuum allows one's to simulate many phenomena in high energy physics and Cosmology, including axial anomaly, baryon-production and magneto-genesis, event horizon and Hawking radiation, rotating vacuum, expansion of the universe etc. These phenomena can be probed in ultra-low temperature super fluid helium, atomic Bose condensate and superconductors. Some of the experiments have been already conducted.

The quantum field theory which one has now is incomplete due to ultraviolet divergences at small scales, where the 'microscopic' physics of vacuum becomes important. Here, the analogy between quantum vacuum and condensed matter could give an insight into the trans-Planckian physics. As in condensed matter system, one can expect that some or all of the known symmetries in Nature wiil be lost when the Planck energy scale is approached. The condensed matter analogue gives examples of physically imposed deviations from Lorentz invariance. This is important in many different areas of high energy physics and Cosmology including possible CPT violation and black holes, where the infinite red shift at the horizon opens the route to the trans-Plackian physics.[4-6]

The low-energy properties of different condensed matter substances (magnets, super fluids, crystals, superconductors etc. are robust, i.e. they do not depend much on the details of microscopic (atomic) structure of these substances. The main role is played b symmetry and topology of condensed matter: they determine the soft (low-energy) hydrodynamic variables, the effective Lagrangian describing the low-energy dynamics and topological defects. The microscopic details provide us only with the 'fundamental constants', which enter the effective phenomenological Lagrangian, such as speed of light, super fluid density, modulus of elasicity, magnetic susceptibility etc. Apart from these fundamental constants, which can be rescaled, the system behaves similarly in the infrared limit, if they belong to the same universality classes, irrespective of their microscopic origin. The detailed information on the system is lost in acoustic and hydrodynamic limit[4]. From the properties of the low energy collective modes of the system-acoustic waves in case of crystals-one cannot reconstruct the atomic structure of the crystal since all the crystals have similar acoustic waves described by the same equations of the same effective theory, in a given case the classical theory of elasticity. The classical fields of collective modes can be quantized to obtain the quanta of acoustic waves the phonons,

but the quantum field remains the effective fields. This does not provide us the detailed information on the real quantum structure of the underlying crystal.[7]

In this paper, using the theoretical formalism of G. E Volvik[8] and M Fedi[9], we have studied links between gravity and dynamics of quantum liquids. We have also discussed gravity as fluid dynamic phenomenon in a super fluid quantum space in this paper.

MATHEMATICAL FORMULA USED IN THE STUDY

In order to study the link between gravity and dynamics of quantum liquids, one takes (i) gravity as fluid dynamic phenomenon in a super fluid quantum space (ii) Quantum vortices in a glass of Bose-Einstein condensate.

Gravity as a fluid dynamic phenomenon in a superfluid quantum space

The engine of quantum gravity: spin, pressure and non-zero viscosity of super fluid quantum space (SQS)

Viscosity of SQS along with Bernoulli pressure would cause the attraction of the space's quanta surrounding the vortices. The result is a force gradient around the vortex which obeys the inverse square law. Thus, one proclaims that quantum gravity can be described without resorting to gravitons, where space quanta (dark energy quanta) are the passive carriers of gravity. This occurs around massive particles as apparent force mediated by a negative pressure gradient due to quanta absorption. CFD simulations using Navier-Stokes equations have been performed with a positive result. One observed in the simulation that a spherical geometry of the attracting object would exactly correspond to Gauss's law for gravity which is directly connected with Newton's law of gravitation. Navier-Stokes equations representing mass, momentum and energy have been used

$$\frac{\partial(u_j)}{\partial x_j} = 0 \tag{1}$$

$$\frac{\partial(u_i u_j)}{\partial x_j} = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} + \frac{\mu}{\rho}\frac{\partial}{\partial x_j}[\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}] \tag{2}$$

$$\frac{\partial(\rho E + p)u_j)}{\partial x_j} = -k\frac{\partial}{\partial x_j}(\frac{\partial T}{\partial x_j}) \tag{3}$$

The condition of two stationary spheres immersed in an incompressible fluid was set and the pressure integral of the force acting on them was calculated.

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

$$F_a = \int_A [p + \rho(\vec{u} \bullet \vec{n})(\vec{u} \bullet \vec{d})dA \bullet \vec{d} \tag{4}$$

Where A corresponds to the surface of inner sphere, $\vec{n}$ is the normal unit vector to the sphere's surface and $\vec{d}$ is the unit vector for the distance between the spheres.

Super fluid quantum gravity in general relativity

Now, one notices that a sphere absorbing the field in which it is immersed generates a radial attractive field equal to Schwarzchild solution[10]

$$ds^2 = (1 - \frac{2Gm}{c^2\tau})^{-1} dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2) - c^2(1 - \frac{2Gm}{c^2\tau})dt^2 \tag{5}$$

This suggests that the metric tensor of GR may be expressed through fluid dynamic forces. Super fluid quantum space whose hydrodynamics produces time and influences clocks through gravity is described as a fluid phenomenon itself, instead of deformable geometric space-teme. One describes the strong hydrodynamic analogy with Coriolis effect, where the gravitational field is related to Lense Thrilling effect expressed as

$$B = -\frac{4}{5}\frac{m\omega R^2}{r^3}\cos\theta \tag{6}$$

The Coriolis force can be written as

$$F_C = -2m_\omega \omega R u_R \tag{7}$$

Where the difference between a 3D (Gravito-magnetic field) and a 2D (Coriolis) model has to be considered. SQS"s hydrodynamics describes the orbital motion, the angular velocity for any inverse square law for gravity yields

$$u(\theta) = \frac{\mu}{h^2} - A\cos(\theta - \theta_0) \tag{8}$$

Here A and θ_0 are arbitrary constants and h is the angular momentum and μ is the standard gravitational parameter.

All this suggests that the found solutions to Einstein's field equations could be fully replaced by hydrodynamic solutions based on modified quantum Navier Stokes equations. Einstein's space-time as a single inter-woven continuum is here described by the inter-dependence space-time, since time would arise from the hydrodynamics of the SQS and it is influenced by gravity, which is the framework as a super fluid phenomenon.

Gravitational waves as periodic pressure variations propagating through a SQS (Super fluid quantum space)

Gravitational waves may be defined as a periodic (negative) pressure waves in the SQS caused by the variable positions of a quadrupole in time and therefore corresponding to a variable pace in the absorption of SQ. In this case the gravitational waves arise as negative pulse propagating through SQS and not as space-time deformations. In this way, photons can be described as pulses (photons) through the SQS. Gravitational waves travel at the speed of

light. Photons as positive pulses (phonons) that carry energy like sound wave can provide kinetic energy to the target (radiation pressure).The changing pace to the absorption of space quanta occurring twice the orbital frequency causes periodic decompressions in SQS currently interpreted as a deformation of space-time. He quantum potential arises from pressure variations. Quantum like gravity waves has been investigated which supports the SQS[11-13].

Time dilation and length contraction in super fluid relativity

Absolute time cannot exist. Time exists in physics if a clock in a reference system can measure it and different measurements produce different time scales. Now the super fluid approach to nature, gravity exists and acts onto clocks. Time dilation also means to clocks retardation. So, one will replace Einstein's curved space-time. With the hydrodynamics of SQS, this approach only considers a flat universe in which pressure forces mime the effects of a curved space-time and can account for all relativistic effects of general relativity.

According to the mainstream, Lorentz Fitzgerald contraction (relativistic length contraction) depends on time dilation and consequently on gravity. This effect therefore exists in this super fluid approach too. It affects measurements taken in two different frames of reference which are in motion.

$$l = v\Delta t \tag{9}$$

Here R is an inertial frame of reference and R' is a frame moving with velocity v. The length is measured in both frames by the formula (9) . Here $\Delta t = t' - t$ and the motion always occur with Lorentz factor given by

$$l = v\frac{\Delta t}{\sqrt{1 - \dfrac{v^2}{c^2}}}, \tag{10}$$

Clocks tick slower in R' then Δt is shorter in that frame.

Photon as phonon through a super fluid quantum space

If space is filled with super fluid then light has to propagate through it. One considers here that photons are pulses through The SQS i.e. a photon is actually a special spin-1 phonon propagating through the SQS i.e. through dark energy. Waves existing in nature would reduce to only one type (medium dependent) and photon electromagnetic field could be interpreted as a periodic excitation of dark energy's quanta producing a transversal wave due to spin[14,15]

Let us consider the formulae indicating the speed of mechanical wave through fluid $a = \sqrt{\dfrac{K}{\rho}}$

in which K is the bulk modulus in the dark energy. By putting $\beta_s = 1/K$ as an isentropic compressibility, one gets

$$a = \frac{1}{\sqrt{\beta_s \rho}} \tag{11}$$

If one considers $\beta_s = \beta_d$ as dark energy, ρ_d as its density, c is the speed of sound in the dark energy then one equate $\beta_d \rho_d = \varepsilon_0 \mu_0$, one gets

$$c = \frac{1}{\sqrt{\beta_d \rho_d}} \tag{12}$$

Expressing the speed of photon as that of phonon through super fluid dark energy, mathematically analogous to $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$, as resulting from Maxwell's equations. Maxwell himself derived the expressions for the dielectric constant (ε_0) and the magnetic susceptibility (μ_0) of vacuum in terms of transverse elasticity and density of dark energy.

One has to observe light propagation as a phenomenon of second sound through dark energy as in super fluids energy is dissipated as heat at small scales by phonon radiation[16] and as one knows that bodies radiate heat through the emission of photons (infrared light) As one knows that both photons and phonons
Are bosons
Have wave-particle duality
Obey the Doppler effect
Are symmetric under exchange $|\alpha, \beta\rangle = \langle\beta, \alpha|$
Can be created by applying the creation operator b$^+$

Share the same momentum where that of the photon $p_{ph} = \hbar k = \frac{h}{\lambda}, k = \frac{2\pi}{\lambda}$. Hence the parallelism: radiation pressure==sound pressure
Can produce photoelectric effect and Compton scattering thanks to their momentum
can possess spin
can produce squeezed coherent states
can interact via parametric down conservation
Both for photons and phonons $(1/2)\hbar\omega$ is vacuun's (dark energy's) contribution where the harmonic oscillator eigen values for the mode ω_K (k is wave number) are

$$E_n = (n + 1/2)\hbar\omega_k \text{, n=1, 2, 3---} \tag{13}$$

CONCLUSION

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