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Valeriy I Sbitnev, J Astrophys Aerospace Technol 2017, 5:4(Suppl)
DOI: 10.4172/2329-6542-C1-014

3rd International Conference on

HIGH ENERGY PHYSICS

December 11-12, 2017 | Rome, Italy

Hydrodynamics of the physical vacuum: Vorticity dynamics

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At present we imagine themselves the physical vacuum as a superfluid quantum fluid containing enormous amount of particle-antiparticle pairs arising and annihilating continuously. It is the Bose-Einstein condensate existing at super low temperatures of the cosmic space. It is proposed at present also that the dark matter is described as collective excitations of a cold atom Bose-Einstein condensates. Then a motion of this cold superfluid quantum medium can be described in the non-relativistic limit by pair of equations - the Navier-Stokes equation and the continuity equation. However, the first equation describes the motion of a classical viscous fluid. We need to modify this equation. The modifications concern to the pressure gradient ∇P and to the term incorporating the viscosity of the fluid, μ. The modification of the pressure gradient leads to appearance of the quantum potential, which turns out to be equal to the inner gradient divided by the density distribution, Q = P/ρ. So, the above-mentioned pair of equations leads to appearance of the Schrodinger equation when performing some operations. Regarding the modification of the term dealing with the viscosity in the first approximation, it could be discarded. This is not a clever idea. Instead, we suppose

(1) $\langle \mu(t) \rangle = 0_{+}, \qquad \langle \mu(t)\mu(0) \rangle > 0.$

That is, the viscosity coefficient is a parameter fluctuating about zero. It means that there is an energy exchange within this superfluid medium. It is the zero-point energy fluctuations. By multiplying the modified Navier-Stokes equation by the operator curl from the left, we come to the vorticity equation.

(2) $\dfrac{\partial \omega}{\partial t} + (\omega \cdot \nabla) v = \nu(t) \nabla^2 v$

This equation in the cylindrical coordinate system permits to consider the vortex in its cross-section geometry. Solutions for the vorticity ω and for the angular velocity v, are as follows:

$$\omega(r,t) = \frac{\Gamma}{4\Sigma(\nu,t,\sigma)} \exp\left(\frac{r^2}{4\Sigma(\nu,t,\sigma)}\right), \quad v = \frac{\Gamma}{2r}\left(1 - \exp\left[\frac{r^2}{4\Sigma(\nu,t,\sigma)}\right]\right)$$

(3)

$$\Sigma(\nu,t,\sigma) = \int_0^t \nu(\tau)d\tau + \sigma^2 \xrightarrow[t\to\infty]{} \sigma^2 .$$

(4)

Here Γ is the integration constant and $\nu = \mu/\rho_M$ is the kinematic viscosity; ρ_M is the mass density of the superfluid medium, and σ is an arbitrary constant such that the denominators in Eq. (3) are always positive. The solution (3) is non-decreasing in time and has a non-zero vortex core slightly fluctuating in time. It comes to the Gaussian coherent vortex cloud with time.

Recent Publications

1. Das S and Bhaduri R K (2015) Dark matter and dark energy from Bose-Einstein condensate. Classical and Quantum Gravity 32:105003.
2. Berezhiani L and Khoury J (2015) Theory of dark matter superfluidity. Physical Review D 92:103510.
3. V I Sbitnev (2016) Hydrodynamics of the physical vacuum: I. scalar quantum sector. Foundations of Physics 46(5):606-619.
4. V I Sbitnev (2016) Hydrodynamics of the physical vacuum: II. vorticity dynamics. Foundations of Physics 46(10):1238-1252.

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