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Dark matter and dark energy as superfluid vacuum phenomenon

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Quantum liquids described by wave equations with logarithmic nonlinearity, usually referred as "logarithmic fluids", are very instrumental in describing generic condensate-like matter [1], including strongly-interacting quantum liquids, one example being a superfluid component of He-4 [2,3]. Applications of the logarithmic fluids can also be found in a theory of physical vacuum, which is a popular framework for explaining a phenomenon of gravity. Using the logarithmic superfluid model, one can formulate quantum post-relativistic theory of superfluid vacuum, which merges with special and general relativity in the "phononic" (low-momenta) limit, but differs at higher momenta [4-9].

Here we derive an effective gravitational potential induced by the quantum wavefunction of physical vacuum in a stationary state, while the vacuum itself is viewed as the superfluid described by the logarithmic quantum wave equation. We determine that gravity has a multiple-scale pattern, to the extent that one can distinguish sub-Newtonian, Newtonian, galactic, metagalactic and cosmological terms. The last of these dominates at the largest length scale of the model, where superfluid vacuum induces an asymptotically Friedmann–Lemaitre–Robertson–Walker-type spacetime, which provides an explanation for the accelerating expansion of the Universe. Under certain conditions, the model predicts an occurrence of two expansion mechanisms, which could explain the discrepancy between measurements of the Hubble constant using different methods. On a galactic scale, our model explains the non-Keplerian behaviour of galactic rotation curves, as well as why their profiles can vary depending on the galaxy. It also makes a number of predictions about the behaviour of gravity at larger galactic and extragalactic scales, which are expected to be seen in the outer regions of large spiral galaxies [10].

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