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Breakdown of the Equivalence Principle for a composite quantum body

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We investigate simplest composite quantum body – hydrogen atom – in a weak external gravitational field. Using the local Lorentz invariance of spacetime in general relativity, we calculate electron gravitational mass taking into account both kinetic and potential energies of electron in the atom. In addition to the expected change of electron mass due to total energy, we obtain the unexpected virial term, which is doubled kinetic energy plus potential one. The appearance of this term breaks the Einstein's Equivalence Principle both at microscopic and macroscopic levels. Indeed, if we perform the quantum measurement of gravitational mass of an individual hydrogen atom, it can be not equal to the expected value E/c2. As to macroscopic level, we conclude that for macroscopic ensembles of the stationary quantum states the Equivalence Principle survives. Nevertheless, for special quantum macroscopic ensembles – coherent macroscopic ensembles of the quantum superpositions of stationary states – the Equivalence Principle is strongly broken due to the virial term [1,2]. We discuss possible experiments in the Earth's laboratories, where the above mentioned phenomenon can be discovered.
[1] A.G. Lebed, Int. J. Mod. Phys. D, v. 28, 1930020 (2019); [2] A.G. Lebed, Mod. Phys. Lett. A, v. 35, 2030010 (2020).

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