Gravitational states of antihydrogen atoms bouncing on the solid surface

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Modern theories trying to unify the general relativity theory with quantum mechanics tend to doubt the universal validity of the Weak Equivalence Principle and allow the presence of finite range, non-Newtonian components in the gravitational interaction. Violations of WEP could occur as the result of difference in gravitational coupling to the rest mass and to the binding energy. WEP is now being tested for various isotops of atoms [1]. The special interest in gravitational experiments with *antiatoms* is stimulted by the fact that the non-Newtonian deviations are anticipated to be stronger for matter-antimatter than for matter-matter interaction.

We consider the interaction of antiatoms with a solid surface in the presence of gravity and argue on the possibility of exploiting such scenario for probing the gravitational interaction between matter and antimatter.

We show that sufficiently cold antihydrogen atoms falling on the solid surface are reflected (rather than annihilated). The antiatoms interact with the surface *via* purely attractive van der Waals - Casimir potential, which is sufficiently fast-changing to induce quantum reflection. We present calculations of the reflection probability as function of the incident energy [2]. We show that ultracod antiatoms, confined from below by quantum reflection *via* Casimir forces and from above by the gravitational force form meta-stable states. We forsee that the antihydrogen will bounce on the surface for a finite lifetime (on the order of 0.1 s) and show how the latter depends on the gravitational force (mg) acting on the antiatom. That opens the possibility of probing the gravitational properties of antimatter.

We are currently studying the motion of antihydrogen atoms in the presence of gravitational field and partially absorbing mirror using the method of wave packet dynamics. We wish to compare quantum and classical features of antihydrogen motion, such as classical periods and quantum revivals, and study their dependence on the energy spectrum of the quasi-bound gravitational states.

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[1] S. Fray and C. Diez and T.W. Hänsch and M. Weitz, Phys. Rev. Letters **93** (2004) 240404.

[2] A. Voronin and P. Froelich, J. Phys. B **38** (2005) L 301.