

## GRAVITATIONAL STATES OF ANTIHYDROGEN ATOMS BOUNCING ON THE SOLID SURFACE

**Piotr Froelich** and Alexei Voronin

<sup>a</sup>*Department of Quantum Chemistry, Uppsala University, Box 518, 751 20 Uppsala, Sweden*

<sup>b</sup>*P.N. Lebedev Physical Institute, 53 Leninsky prospect, 117924 Moscow, Russia*

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 isotopes of atoms [1]. The special interest in gravitational experiments with *antiatoms* is stimulated 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 ultracold antiatoms, confined from below by quantum reflection *via* Casimir forces and from above by the gravitational force form meta-stable states. We foresee 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.

The motion of antihydrogen atoms in the presence of gravitational field and partially absorbing mirror is visualized using the method of wave packet dynamics. We

## QUANTUM REFLECTION WORKSHOP ABSTRACT

analyse the 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.

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

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