

# **Test of the Equivalence Principle with Quantum Degenerate Atomic Gases**

**[PLA03, PLA03, PLA03, Rev. Sci. Inst.06, Rev. Sci. Inst.06]**

**Proposal submitted to ASI (coordinator) within a global proposal on space experiments for fundamental physics**

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## Current and Future...

- Precise gravitation measurements are one of the keys for testing the foundations of cosmological theories and of the general relativity
- Crucial concept is the **Universality of Free Fall: all bodies fall with the same acceleration regardless of their mass and composition**
  - First experimented by Galileo with a  $10^{-3}$  accuracy and then formulated by Newton in terms of equivalence between inertial and gravitational mass, UFF leads to the Weak EP at the base of **General Relativity: gravitational field and accelerated ref frame are *locally* equivalent**
- Landmark experiments measuring differential accelerations are by Eotvos ( $\eta \cong 10^{-9}$ ) with a torsion balance, improved by Dicke and Braginski ( $\eta \cong 10^{-10}$ ) and Adelberger ( $\eta \cong 10^{-12} - 10^{-13}$ )

## Current and Future...

- Space experiments in low-Earth orbiting satellites would improve the accuracy by up to 4 orders of magnitude (larger driving signal) bringing the accuracy to the level where EP-violations are predicted
- Use of quantum objects instead of macroscopic bodies would be a major achievement, as the definition itself of EP requires some care [Viola&Onofrio]
- Ultracold atomic gases can be manipulated to accommodate different quantum states, and their dynamics can be controlled with high accuracy and are thus ideal candidates to test EP in the quantum world, with the perspective of linking gravitation and quantum mechanics

## Current and Future...

- Atomic fountains have been already realized, achieving ( $\eta \cong 10^{-10}$ ) **[Chu]** on the ground
- Experiments have been performed to measure the Casimir-Polder forces with BECs close to surfaces **[Cornell, JILA]**
- Submitted to ASI a project within a larger proposal, also in collaboration with Lorenza Viola and Roberto Onofrio to devise a space experiment (longer time-of-flight and higher sensitivity in the preparation of initial different quantum states) to test the EP and study the deviation from Newtonian gravity on a micro-scale