

“Rotation, Equivalence Principle, and Gravity Probe B (GP-B) Experiment” has appeared in Physical Review Letters [107, 051103 (2011)]

Equivalence principles are cornerstones in the foundation of gravitation theories. Galilei Equivalence Principle states that test bodies with the same initial position and initial velocity fall in the same way in a gravitational field. This principle is also called Universality of Free Fall (UFF) or Weak Equivalence Principle (WEP).

Since a macroscopic test body has 3 translational and 3 rotational degrees of freedom, true equivalence must address to all six degrees of freedom. We propose a second Weak Equivalence Principle (WEP II) to be tested by experiments. WEP II states that the motion of all six degrees of freedom of a macroscopic test body must be the same for all test bodies [Ni, PRL 38, 301(1977)]. There are two different scenarios that WEP II would be violated: (i) the translational motion is affected by the rotational state; (ii) the rotational state changes with angular momentum (rotational direction/speed) or species. In the latter part of 1980’s and early 1990’s, a focus in gravitation is on whether the rotation state would affect the trajectory.

The ultra-precise Gravity Probe B experiment measured the frame-dragging effect and geodetic precession on four quartz gyros [Everitt et al., PRL 106, 221101 (2011)]. Professor Ni of our department used this result to test WEP II (Weak Equivalence Principle II) which includes rotation in the universal free-fall motion. The free-fall Eötvös parameter η for rotating body is 10^{-11} with four-order improvement over previous results. The anomalous torque per unit angular momentum parameter λ is constrained to $(-0.05 \pm 3.67) \times 10^{-15} \text{ s}^{-1}$, $(0.24 \pm 0.98) \times 10^{-15} \text{ s}^{-1}$, and $(0 \pm 3.6) \times 10^{-13} \text{ s}^{-1}$ respectively in the directions of geodetic effect, frame-dragging effect and angular momentum axis; the dimensionless frequency-dependence parameter κ is constrained to $(1.75 \pm 4.96)10^{-17}$, $(1.80 \pm 1.34) \times 10^{-17}$, and $(0 \pm 3) \times 10^{-14}$ respectively.