Precise gravitation measurements on Earth and in space: Tests of the Equivalence Principle

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Summary

Experiments to test the *Universality of Free Fall* (UFF) –whereby, in a gravitational field, all bodies fall with the same acceleration regardless of their mass and composition– have played a major rôle in the history of experimental gravitation, alongside with experiments to measure the universal constant of gravity *G.* Indeed, experiments to test the UFF have started even earlier than big *G* experiments, with Galileo in Pisa already at the end of the 16th century. Newton's formulation of the law of gravitational attraction has brought the fundamental constant *G* and its measurement to the limelight of experimental physics. Ever since, the two lines of experiments have proceeded almost in parallel for about 300 years, sharing the difficulties of detecting extremely small forces and very often using similar experimental apparata. The birth of General Relativity, at the beginning of the 20th century, has put experiments on the UFF in a new perspective. The *Universality of Free Fall* is not only a relevant experimental fact, worth testing on its own right, but the direct consequence of the *Equivalence Principle* on which the theory of General Relativity is based. Hence, putting to test the *Universality of Free Fall* amounts to putting to test the foundations of General Relativity itself.

These lectures are devoted to the *Equivalence Principle*, its relevance and its testing, from the early work of Galileo through the major contributions of Eötvös, Dicke and Braginsky, till the recent successes of the "Eöt-Wash" group at the University of Washington. Yet, the emphasis of the lectures is on the leap forward in sensitivity which might come, were an Equivalence Principle experiment carried out in low orbit around the Earth. Three such missions are currently under investigation by space agencies around the world. The experimental apparata and mission designs are presented and compared.

The structure of the lectures is as follows: Scientific relevance of the Equivalence Principle (Section 1); Experiment principle and the expected signal (Section 2); Brief history of past ground experiments (Section 3); Equivalence principle tests by Lunar Laser Ranging (Section 4); Recent and ongoing laboratory experiments (Section 5); Advantages of an Equivalence Principle test in low Earth orbit (Section 6); Proposed space experiments to test the Equivalence Principle (Section 7), divided in two subsections, The STEP and μSCOPE space experiments (Section 7.1) and, The GG space experiment (Section 7.2); The GGG ("GG on the Ground") experiment: laboratory test of a proposed space apparatus (Section 8).