extremely small torques with significant freedom from effects that may limit the traditional, non-cryogenic applications of the torsion pendulum.

A new version [22] of the classical mass dropping Galileo–type experiment has been initiated by Italian scientists from the University of Pisa after the publication of [18]. Rather than dropping separate masses of different composition, the authors drop a (vertical) disk whose two halves are made of Al and Cu respectively (350 *g* each, with a drop height of about 4 *m*): any deviation from the Universality of Free Fall would cause an angular acceleration of the free falling disk around its axis and such a motion can be accurately measured by means of a modified Michelson interferometer in which the two arms terminate at two corner–cube reflectors mounted on the rim of the disk. The original goal of the experiment was to test for any composition dependent effect in the range between 10 *km* and the radius of the Earth. The experiment reached the sensitivity $\Delta g/g=7.2\cdot 10^{-10}$ finding no deviation from the Universality of Free Fall. It is interesting to note that the same experiment has been performed also with a homogeneous disk, which should obviously result in a zero signal.

A short distance test of the Equivalence Principle based on the torsion balance has been performed more recently [23] by the *Eöt–Wash* group using a large rotating source mass (3 *ton* of ^{238}U) and checking for its effect on a torsion balance with test cylinders in Cu/Pb. The balance was sensitive to a relative differential acceleration $\Delta a/a \cong 10^{-9}$ from the rotating source mass and the result helped to set better limits on new composition-dependent interactions in the distance range from 10 to 10000 *km*.

6 Advantages of an Equivalence Principle experiment in low Earth orbit

The advantage of performing an Equivalence Principle test in low Earth orbit is a *driving signal* about *3* orders of magnitude bigger than in ground laboratories. If test bodies of different composition orbit around the Earth at an altitude *h,* a violation of Equivalence η would make them fall differently toward the Earth, with a differential acceleration (one with respect to the other):

$$a_{EP} = \eta \cdot \frac{GM_\oplus}{(R_\oplus + h)^2} \qquad (a_{EP} \cong \eta \cdot 840 \ cm \cdot s^{-2} \quad for \quad h \cong 500\, km) \tag{19}$$

By comparison with Equivalence Principle experiments in which the test bodies are suspended against local gravity on the surface of the Earth this effect is –for the same value of the Eötvös parameter η – 500 or 1400 times bigger, depending on whether ground experiments consider the Earth or the Sun as the source mass (see (5) and (10)).

Another advantage of a space experiment is the absence of weight in orbit. The largest acceleration inside the orbiting laboratory (the spacecraft) is about 100 *million* times smaller than the local acceleration of gravity on the surface of the Earth. The goal of the experiment being the detection of an extremely small acceleration (η << 1 in (19)), this is obviously an advantage. In addition, in a space experiment the only nearby mass that can disturb the experiment is the mass of the spacecraft itself, which can be better controlled.

As a consequence, space missions can potentially test the Equivalence Principle to a considerable higher accuracy than ground tests, deeply probing a so far totally unknown field of physics where a violation is likely to occur. On these grounds space missions on the Equivalence Principle have been proposed since the early 1970s, and they have attracted more and more attention from space agencies around the world in the last 10 years.

Just as an additional example on the relevance of an Equivalence Principle test to a very high accuracy, let us consider the case of antiparticles. A peculiarity of gravity, strictly related to the Equivalence Principle, is that there is so far no evidence for antigravity, namely for the possibility that matter is gravitationally repelled by antimatter. A negative ratio of inertial to gravitational mass would obviously violate the Equivalence Principle and forbid any metric theory of gravity. Yet, there are theoretical formulations which would naturally lead to antigravity. Unfortunately, while experiments concerning the inertial mass of antiparticles have been highly successful, and these are very accurately known, gravitational experiments (i.e. involving the gravitational mass of antiparticles) are extremely difficult because of the far larger electric effects, such as those due to stray electric fields in the drift tube. In absence of such direct tests, an improvement by several orders of magnitude of current tests of the Equivalence Principle with ordinary matter would also be an important constraint as far as the relation between gravity and antimatter is concerned.

Yet, one should not undermine the difficulties of a space experiment. It must be operated from remote, with no direct access to the apparatus after launch. Experiment parts must be tested at 1–g, while they have been designed and optimized for weightlessness. Space is not as empty and quiet as one might think at first glance. Although there is no seismic noise of the kind we are used to on Earth, the spacecraft is subject to air resistance along its orbit, as well as to pressure from solar photons, both of them giving rise to disturbances on the test bodies. There are electric charges inside the spacecraft, whose interactions could completely mask gravitational effects. The spacecraft is exposed to heat sources (from the Sun and the Earth itself), which might produce relevant disturbances on the test bodies. All these are matters of concerns for any space experiment aiming to test the Equivalence Principle.

Data from a space experiment can be analyzed for checking any deviation from the Universality of Free Fall not only toward the Earth but also toward the Sun, or the center of our galaxy. However, except in the case of the Earth, the corresponding driving signal would be no bigger than it is in ground based experiments. Short range tests, which require an artificial source mass nearby (possibly a big one), are also not suitable candidates for a space experiment, and are much better carried out on the ground [23]

7 Proposed space experiments to test the Equivalence Principle

Ground tests of the Equivalence Principle based on the torsion balance have so far achieved the best accuracy. However, is the torsion balance the best instrument to fly? Test bodies on a torsion balance are sensitive to differential forces in the plane perpendicular to the suspension wire of the balance, which on the surface of the Earth aligns itself along the direction of the local vertical. Indeed, any deviation of the suspension wire from the verticality (e.g. due to terrain tilts related to microseismicity and Earth tides) is a disturbance and a serious matter of concern in these experiments. In an almost 0-g environment inside a spacecraft orbiting around the Earth there is no