Proposed test of weak equivalence principle could be most accurate yet

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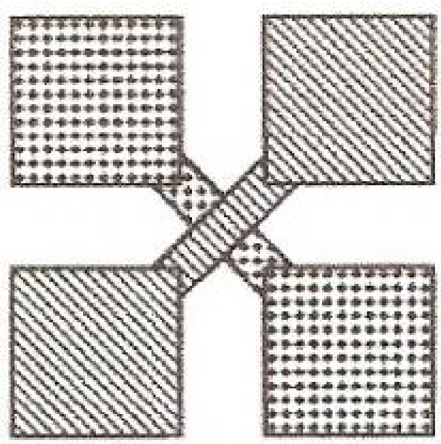

This illustration shows the two test mass assemblies, which consists of two pairs of aluminum cubes. Four tracking frequency laser gauges measure each cube's acceleration as it falls to Earth from altitudes of up to 1200 km. Image credit: Reasenberg and Phillips.

(PhysOrg.com) -- The weak equivalence principle (WEP) - which states that all bodies fall at the same rate in a gravitational field, regardless of structure or composition - is one of the key postulates of general relativity. Tests have shown that the WEP is accurate to within one part in 10 trillion, or an uncertainty of 10^{-13} of the acceleration of gravity. However, a violation of the WEP is suggested by most theories that attempt to unify gravity with the other forces, which is one of the biggest challenges in physics today. Looking for new ways to test the WEP to even greater accuracy and perhaps detect a violation, astrophysicists at the Harvard-Smithsonian Center for Astrophysics have designed a new WEP test to be conducted during free fall in a rocket flight.

As astrophysicists Robert Reasenberg and James Phillips explain in a series of papers, their proposed test is aimed at a very small measurement uncertainty of 10^{-16} after averaging the results of eight separate free fall drops. If the experiment is successful, it would be the most accurate WEP test to date, although it is not the most accurate WEP test that has been proposed: the satellite test of the equivalence principle (STEP) is aimed at a 100-fold smaller measurement uncertainty (10^{-18}). STEP is a proposed cryogenic experiment in an Earth-orbiting spacecraft.

One way that scientists can test the WEP is by measuring the accelerations of two bodies made of different materials falling in the same gravitational field. As far back as the 6th century AD, people have tested the WEP simply by dropping two objects of different masses, and observing no detectable difference. Astronauts even performed the test to low accuracy on the Moon with a feather and hammer, which reached the surface at the same time. The most precise tests to date use a rotating torsion pendulum, which can measure the acceleration of different samples toward the Earth, Sun, or center of the Milky Way. However, this technique is approaching technical limitations.

In their proposed experiment, Dr. Reasenberg and Dr. Phillips compare the accelerations of two test mass assemblies dropped inside an experiment chamber that is carried by a NASA Black Brant XII rocket. The experiment is designed to be conducted at altitudes that range from about 800 km to 1200 km, and includes eight drops of 40 seconds each.

Both test mass assemblies consist of a pair of aluminum cubes connected by a short rod or pair of rods. In one test mass assembly, holes are drilled into the aluminum, and lead tubes are inserted into the holes. Although lead is denser than aluminum, the objects are designed so that they both have the same mass, and only the material is different. The two objects are laid in a crisscrossed configuration in the same plane, so that the four aluminum cubes form a square. Above this configuration, four tracking frequency laser gauges are aimed down at the four cubes toward Earth's center of mass, measuring each cube's acceleration as it falls to Earth.

"The extreme speed and sensitivity of the tracking frequency laser gauge makes it possible to do this experiment quickly," Phillips told *PhysOrg.com*. "A slower or less sensitive measuring device would not allow the experiment to be carried out in the brief time available during a sounding rocket flight."

Reasenberg and Phillips have received support from the Astrophysics Division of NASA to develop both the sounding rocket test and the laser gauge. The sounding rocket will be launched from the NASA Flight Facility at Wallops Island, VA.

"A central theme of this experiment's design is to mitigate systemic errors," Reasenberg explained.

One way this is done is by reversing the orientation of the free-falling experiment between successive pairs of the eight drops. Other design tactics that reduce errors include precisely aligning the lasers to the test mass assemblies using a hexapod motion system (also known as a Stewart platform) and minimizing thermal perturbations to insignificant levels in many ways, such as flying at night to avoid directional solar heating.

Although taking all these pains to achieve extreme precision may seem tedious, the scientists do so enthusiastically because the discovery of a WEP violation would have profound implications for physics, astrophysics, and cosmology. For instance, knowledge of a WEP violation would guide the formulation of a theory of gravity to supersede general relativity, which might be a quantum theory of gravity. The quantum theories of gravity being developed now generally predict a violation of the WEP, but most are not yet able to predict the magnitude of the violation. The magnitude of a WEP violation could be within the range of the sounding-rocket experiment, or well below it.

More information: Robert D. Reasenberg and James D. Phillips. "A weak equivalence principle test on a suborbital rocket." *Class. Quantum Grav.* 27 (2010) 095005 (14pp). Doi:10.1088/0264-9381/27/9/095005

Harvard-Smithsonian Center for Astrophysics: Test of the Weak Equivalence Principle
www.cfa.harvard.edu/PAG/index_files/Page1098.htm

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