Does weak equivalence break down at the quantum level?

December 8 2009, By Miranda Marquit

(PhysOrg.com) -- One of the givens in physics is the weak equivalence principle. This principle has been considered solid since Einstein proposed that it is not possible to detect the difference between uniform acceleration and a uniform static gravitational field. The uniqueness of freefall allows uniform acceleration, even between masses that are different, according to Einstein's postulate in the theory of General Relativity. The weak equivalence principle is well established amongst the science community, but it has yet to be demonstrated completely. This is where Phillippe Bouyer at Laboratoire Charles Fabry de l'Institut d'Optique, Campus Polytechnique in Palaiseau, France, and his colleagues are attempting to go.

“We are looking to see to which extent this principle holds,” Bouyer tells *PhysOrg.com*. “Does the principle break down at a certain level? And if it does, what is that level? If it breaks down, that opens up a whole range of fundamental questions, such as the existence of new interactions as predicted by many current quantum theories of gravity. We have created a test that we hope will open the field to see whether the weak equivalence principle holds at the quantum level.”

In order to test the weak equivalence principle, Bouyer and his peers Varoquaux, Nyman, Geiger and Cheinet at the Laboratoire Charles Fabry, and Landragin at SYRTE, suggest a technique using a parabolic flight plane outfitted with an atom interferometer. The device would be used to determine whether the acceleration is the same for two different atoms in free fall. Their proposed method is described in *New Journal of*

Physics: “How to estimate the differential acceleration in a two-species atom interferometer to test the equivalence principle.”

“If you want to test the acceleration of atoms on the ground, you have very little time before the atoms hit the floor” Bouyer explains. “In parabolic flights, though, you have up to 20 seconds of free fall to see whether there is a difference in acceleration. When dealing with atoms, this is a rather long time indeed.” The atoms would be captured, laser cooled using well known techniques and then dropped in the “free falling” plane. It would then be possible to precisely measure the acceleration of the two different atoms using atom interferometry. “We plan to use rubidium and potassium,” he says, “since they are very different atoms with a difference in mass that is significant. This way, if they have no difference in acceleration, the equivalence principle is demonstrated. If there is a difference in acceleration, we know that it breaks down at the precision level of our measurement.”

One of the problems, though, is that the parabolic flight plane is very noisy. Bouyer and a team from various scientific institutes in France addressed this problem last year. They tested the operation of a specially designed atom interferometer in a free fall plane (results can be found in *The European Physical Journal D*), finding that the sensitivity of measurement was enhanced, allowing acceleration in rubidium to be measured. To cancel out the noise, Bouyer and his colleagues worked out a way to extract the acceleration using Bayesian statistical estimation. “Our dedicated statistical analogy allows us to extract the EP signal out of the noise of the environment,” he explains.

For now, the proposed experiment remains just that: proposed. But Bouyer is hopeful. “We are very close to getting two atoms at the same place, and using our interferometer in a state of free fall should enable us to take measurements that may help us demonstrate the viability of the equivalence principle at the quantum level.”

More information:

• Varoquaux, et al, "How to estimate the differential acceleration in a two-species atom interferometer to test the equivalence principle," New Journal of Physics (2009). Available online: http://www.iop.org/EJ/abstract/1367-2630/11/11/113010/.

• Stern, et al, "Light-pulse atom interferometry in microgravity," *European Physical Journal D* (2009). Available online.