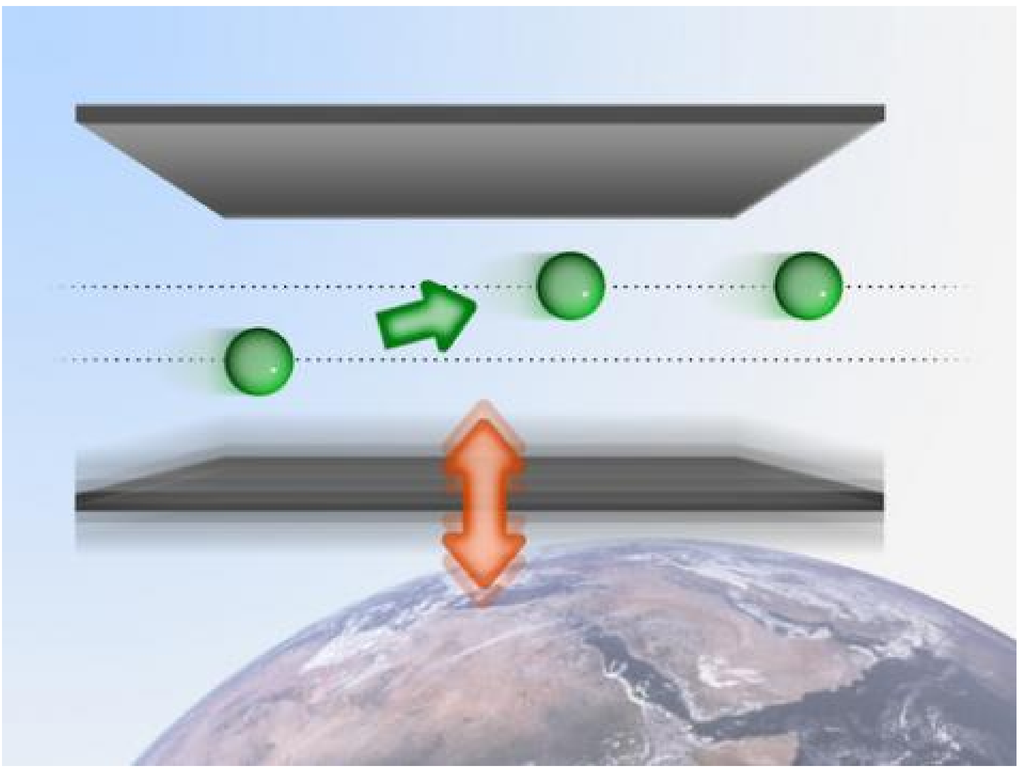
Probing the laws of gravity: A gravity resonance method

April 18 2011



Neutrons between two plates in the earth's gravitational field can occupy different quantum states. A vibrating plate (below) can excite them from one state into the other - which allows extremely accurate energy mearurements.

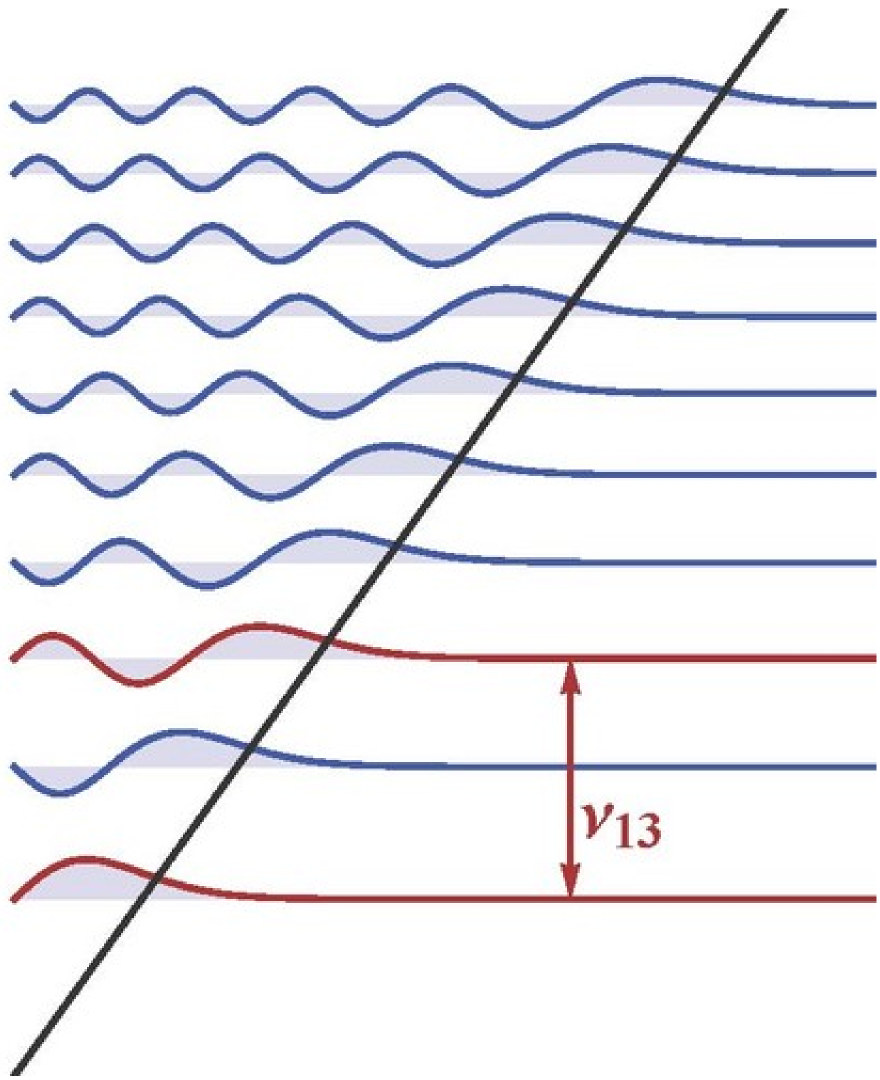
Quantum mechanical methods can now be used to study gravity: At the Vienna University of Technology (TU Vienna), a measurement method was developed, which allows to test the fundamental theories of physics.

The world's most precise measurement methods are based on quantum physics. Atomic clocks or high-resolution magnetic resonance, which is used in medicine, rely on accurate measurements of quantum leaps: A particle excited at exactly the right frequency changes its quantum state – this is called "resonance spectroscopy". Up until now, this method has only been used employing electromagnetic radiation. Researchers at TU Vienna have now developed a resonance method, which for the first time does not use electromagnetism, but the force of gravity. Gravity creates several possible quantum states for neutrons. The Gravity Resonance Method now allows to induce and accurately measure transitions between these states. The results of these experiments have now been published in the scientific journal *Nature Physics*.

At first glance, gravity and quantum physics do not appear to have much in common. We can feel gravity, when huge, heavy objects, such as stars or planets are involved. Quantum particles on the other hand are so light that gravity usually does not play a major role in describing them. The new method now links those two areas – now, the theory of gravity can be probed at minute distances. This way, scientists hope to gain insight into string theory or the nature of dark matter. So far, gravity research was limited to macroscopic or even astronomical distances.

Extremely Slow Neutrons

It is hard to measure the quantum physical effects of gravity at tiny length scales. "Atoms should better not be used for such experiments, because their behaviour is strongly influenced by short-range electromagnetic forces – such as the Van-der-Waals-force or the Casimir force", professor Hartmut Abele form the TU Vienna explains. "But with our ultra-cold neturons, which are uncharged and hardly polarizable, we can do high-precision measurements at short distances." Professor Abele carried out the experiments together with his assistants, Tobias Jenke and Dr. Hartmut Lemmel, and with Dr. Peter Geltenbort from the Institute Laue-Langevin in Grenoble.



Energy differences between quantum states have been measured for a long time, but the differences between quantum states which appear due to gravitation are a million millions smaller than the large energy gaps in atoms.

Quantum Leaps Between Gravity-States

We can lift up a stone to an arbitrary height – the higher we lift it, the more energy we have to spend. For quantum particles like neutrons, travelling between two horizontal plates, this is differerent: they can only take up discrete portions of gravitational energy. Using the neutron source of the Institute Laue-Langevin in Grenoble, the Vienna scientists managed to precisely define the quantum physical energy state of the neutrons between two plates. One of the plates was then vibrated at a precisely controlled frequency. If this frequency corresponds to the energy difference between two quantum states, the neutron is excited into the higher energy state. Measuring at which frequency this excitation takes places therefore reveals the exact energy difference between the quantum states.

Inertial mass and gravitational mass

Massive objects have two fundamental properties: They are inert (large forces are needed to accelerate them), and they are heavy (a strong gravitational force acts on them). Already in the 16. century, it was known that inertia and weight go together, and that this causes all objects to fall to the ground at the same speed. Whether this is only a good approximation, or whether this is also true at the minute length scales of quantum physics can now be investigated with the newly developed experiments.

For decades, physicists have been struggling to unify gravitation and quantum physics, creating a unified theory of everything. Different string theories have been developed, predicting the existence of hidden spatial dimensions, which have not yet been discovered. “Using our neutron method, we will try to test such theories in the laboratory”, professor Hartmut Abele announces. Even for cosmology, these experiments may play an important role. Theories about the mysterious “dark matter”, which is considered to govern the motion of galaxies, could now be investigated on tiny scales with high-precision measurements. “Our method, which is specially designed for minute length scales, could – if we are lucky – help us understand the evolution of the universe itself. In any case, thrilling new insights in gravity research are awaiting us", says professor Abele.

Provided by Vienna University of Technology