Researchers conduct first direct measurement of gravity's curvature

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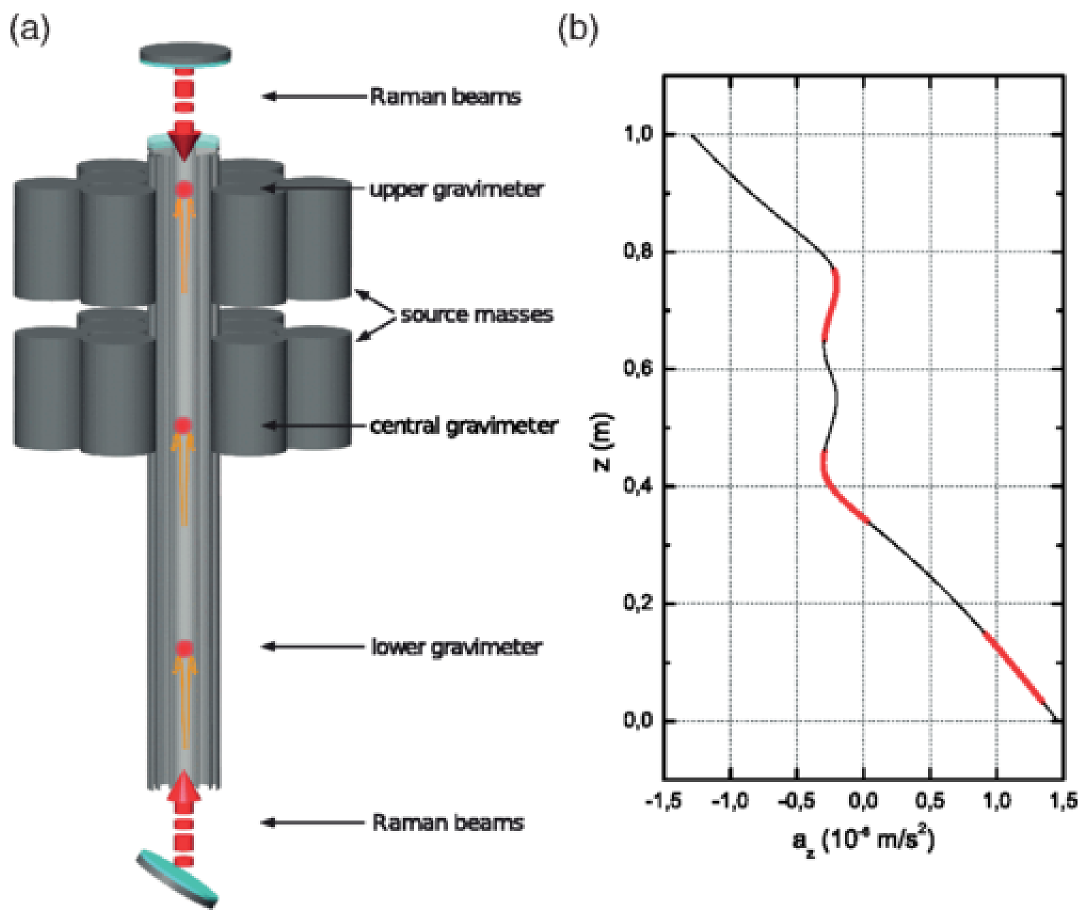

(a) Scheme of the experiment. (b) Gravitational acceleration along the symmetry axis (az) produced by the source masses and the Earth's gravity gradient. Credit: *Phys. Rev. Lett*. 114, 013001

(Phys.org)—A team of researchers working in Italy has successfully conducted an experiment to directly measure gravity's curvature for the first time. In their paper published in the journal *Physical Review Letters*, the team describes their work and note that what they have accomplished could lead to an improvement in *G*, the Newtonian constant of gravity.

Over many years, scientists have developed more sophisticated ways to measure gravity, one of the latest is to use atom interferometry—it enables distance measurement with very high precision and works by exploiting the quantum-mechanical wavelike nature of atoms. Up till now researchers have been able to measure the changes in gravity as altitude increases, for heights as little as a few feet, creating a gradient. In this new research the team has found a way to measure the change in gravity that is produced by a large mass. This change in the gradient is known as gravity's curvature.

To directly measure the change in a gradient, the team used measurements made at three different heights. Measuring gravity at two locations close to one another can give the gradient as the measured difference of the two divided by the distance between them. Measuring gravity at three locations allows for calculating the rate of change, or curvature—an idea for an experiment to carry out this measurement was first proposed back in 2002. The experiment conducted by the team in Italy is based on that proposal.

To allow for measuring gravity at three locations all at the same time, the team created three plumes of ultracold atoms at three different heights inside of a one meter pipe. The top half of the piper was surrounded by tungsten alloy weights to cause an increase in variation of the gravitational field. The atoms were irradiated with pulses from a laser to cause them to separate the plumes into two parts, one that absorbed photons and a second that was left in a ground state. The additional momentum caused the atoms in the first group to fall a different distance over a measured time period, which led to a difference in quantum wave cycles that elapsed between the two. The team then added two more wave pulses to cause the two groups to recombine, which allowed them to interfere. Measuring the interference allowed for calculating the variations in gravitational acceleration and curvature, which turned out to be $1.4\times10^{-5}\ s^{-2}\ m^{-1}$, as predicted.

The team believes their method should prove useful for geologic and mapping work as well as improving the measurement of *G*.

More information: Measurement of the Gravity-Field Curvature by Atom Interferometry, *Phys. Rev. Lett.* 114, 013001 – Published 5 January 2015. dx.doi.org/10.1103/PhysRevLett.114.013001 . On *Arxiv*: arxiv.org/abs/1501.01500

ABSTRACT
We present the first direct measurement of the gravity-field curvature based on three conjugated atom interferometers. Three atomic clouds launched in the vertical direction are simultaneously interrogated by the same atom interferometry sequence and used to probe the gravity field at three equally spaced positions. The vertical component of the gravity-field curvature generated by nearby source masses is measured from the difference between adjacent gravity gradient values. Curvature measurements are of interest in geodesy studies and for the validation of gravitational models of the surrounding environment. The possibility of using such a scheme for a new determination of the Newtonian constant of gravity is also discussed.