Standing on a stepladder makes you age faster

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We think of relativity's effects on time as occurring at near light speeds or in the presence of crushing gravitational fields. But new atomic clock experiments show the pace of time changes at everyday speeds and heights – when you ride a bicycle or climb a stepladder.

Einstein's theory of relativity shattered the notion that time runs at the same rate for everyone, everywhere in the universe. Instead it predicts that time slows down in a gravitational field, making clocks run a little slower on Earth's surface than in deep space.

It also predicts time is skewed by velocity differences between observers, giving rise to the so-called twin paradox. A twin who returns from a journey in a fast-moving spacecraft will have aged much less then the twin who stayed home.

These effects have been demonstrated in numerous experiments, including one that sent atomic clocks flying on airplanes and showed they fell behind clocks that stayed put on the ground, due to the difference in velocity. Another showed that an atomic clock sped up when launched on a rocket 10,000 kilometres above Earth's surface, where the planet's gravitational field is weaker.

James Chin-Wen Chou of the National Institute of Standards and Technology in Boulder, Colorado, led a team that used atomic clocks to show the effects of relativity at more familiar scales.

Tick rate

The experiment kept time using a laser that emitted light only at a specific frequency. Tuning the laser to this frequency involved measuring when an aluminium ion held in place by an electric field absorbed the laser light, since the ion only absorbs light that oscillates 1.12×10^{15} times per second. The oscillations of the laser light could then be used like the ticks of a regular clock to measure the passage of time.

The experimenters measured the change in tick rate of one such clock when raised 33 centimetres in their lab, keeping a second identical clock fixed as a reference. The increased height made the clock run ever so slightly faster – by about 4 parts in 100 million billion (10^{17}). The effect is so small that it would add up to a difference of just 90 billionths of a second over a human lifetime of around 80 years.

In another experiment, an oscillating electric field was used to set the ion in one clock jiggling back and forth at a speed of about 10 metres per second, or 36 kilometres per hour. The ion in the other clock was kept fixed. Because of the difference in

motion between the two clocks, the one with the jiggling ion ran slightly more slowly, by 6 parts in 10^{16}.

Thought experiments

The time-slowing effects of gravity have been measured on even smaller distances than 33 centimetres. In February, a team that included US Energy Secretary and Nobel prizewinning physicist Steven Chu reported seeing these effects when the difference in height between two objects was just 0.1 millimetre. The experiment exploited the fact that, thanks to quantum mechanics, atoms can behave like waves. It showed that waves at different heights oscillate at different frequencies due to gravitational time stretching.

But the new results by Chou's team represent the first time that atomic clocks have been used to show the gravitational effect over such small distances and the velocity effect at such small speeds. "When we learn relativity in school, clocks in different reference frames are usually introduced to illustrate the results of relativity," Chou says. "In that sense, this paper resembles more closely the thought experiments that teachers use to teach relativity."

"It is truly wonderful that Chou and his partners have been able to measure time dilation associated with a height change of less than a metre," says Michael Bevis of Ohio State University in Columbus, who was not involved in the new experiments.