

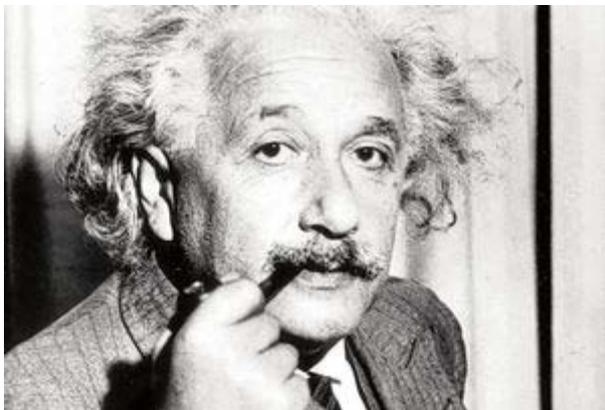
# Einstein's theory is proved – and it is bad news if you own a penthouse

Scientists use atomic clocks to show that time moves faster at altitude, even on Earth

By Steve Connor, Science Editor

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Albert Einstein proposed that time is a relative concept and the higher you live above sea level the faster you should age

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The world's most accurate clock has neatly shown how right Albert Einstein was 100 years ago, when he proposed that time is a relative concept and the higher you live above sea level the faster you should age.

Einstein's theory of relativity states that time and space are not as constant as everyday life would suggest. He suggested that the only true constant, the speed of light, meant that time can run faster or slower depending on how high you are, and how fast you are travelling.

Now scientists have demonstrated the true nature of Einstein's theory for the first time with an incredibly accurate atomic clock that is able to keep time to within one second in about 3.7 billion years – roughly the same length of time that life has existed on Earth.

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James Chin-Wen Chou and his colleagues from the US National Institute of Standards and Technology in Boulder, Colorado, found that **when they monitored two such clocks positioned just a foot apart in height above sea level**, they found that time really does run **more quickly the higher you are** – just as Einstein predicted.

"**These precise clocks reveal the effects of gravitational pull**, so if we position one clock closer to a planet, **you also increase the gravitational pull and time actually runs slower than for another, similar clock positioned higher up**," Dr Chou said. "No one has seen such effects before with clocks which is why we wanted to see if these effects are there. We would say our results agree with Einstein's theory – we weren't expecting any discrepancies and we didn't find any," he explained.

**The atomic clocks used in the study are based on the tiny vibrations of aluminium atoms trapped in an electric field.** These vibrations are in the same frequency range of ultraviolet light, **detected by lasers**, which effectively means that **the atomic timepieces are optical clocks, accurate enough to measure billionths of a second and to keep time accurately over millions of years.**

**It means that** the clocks were able to perceive **the dilation of time with height above ground** that was first predicted by Einstein. For every foot above ground, for instance, the clocks showed that someone would age about 90 billionths of a second faster over a 79-year lifetime, Dr Chou said.

**The time dilation experiment, published in the journal Science, is vivid proof of how time is not what we think it is.** The researchers also demonstrated that when the atomic clocks were altered **in a way that mimics the effect of travelling through space**, time began to **slow down, as the theory of relativity says it should.**

This is a practical demonstration of the "twin paradox", a thought experiment of Einstein's special theory of relativity which states that **an identical twin sibling who travels through space in a rocket will actually age more slowly than the other twin living on terra firma.**

Marcus Chown, author of the best-selling *We Need to Talk about Kelvin*, which is shortlisted for this year's Science Book Prize, said that the results of the atomic clock experiments were a remarkable demonstration of Einstein's theories.

"What's really remarkable is that these studies show these incredibly small effects of relativity over such short distances," he said. "They have demonstrated graphically that although we think of relativity as an esoteric theory of no relevance to everyday life, we can in fact show that it is **really true that you will grow old marginally faster if you stand just one step higher on a staircase.**

"It's a very small effect, but it brings these esoteric effects into the everyday world. It shows that if you want to live longer, buy a bungalow," he added.

**The theory: Einstein's Eureka moment at the Patent Office**

Albert Einstein was sitting in his chair at the Patent Office in Bern one day when the breakthrough happened. "Suddenly, the thought struck me: if a man falls freely, he does not feel his own weight. I was taken aback. This simple thought experiment made a deep impression on me," he wrote in 1907. This was two years after the publication of his Special Theory of Relativity and it led directly to his theory of gravity, and still later to his General Theory of Relativity. In effect, Einstein had stumbled upon one of his greatest insights: gravity is acceleration.

From this simple concept came the idea that the stronger the gravitational pull on a clock, whether it is from a planet or another massive object, the slower time itself would run. It would mean, he predicted, that time would run faster and people would age more quickly the higher they were from the ground.

Einstein said that realising gravity and acceleration were the same thing was "the happiest thought of my life". It is at the heart of the theory of relativity, which states that time and space are not as immutable and fixed as we think they are from the immediate experience of everyday life.

With the invention of atomic clocks, which can now measure time to billionths of a second and are accurate to within one second over 3.7 billion years, scientists are now able to show the truth of Einstein's predictions about how time can slow down or speed up depending on the position and speed of whoever is making the observation.