Using an atomic clock to demonstrate general relativity

October 20 2021, by Bob Yirka

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A team of researchers at the JILA, National Institute of Standards and Technology at the University of Colorado has found a way to use an atomic clock to demonstrate a principle of general relativity. The team has published a paper describing their work on the arXiv preprint server.

Einstein's theory of relativity states that clocks running closer to a large body (such as the Earth) will run slower than those farther away, such as out in space. This phenomenon, known as gravitational redshift, has been previously validated by researchers. In this new effort, the researchers have once again shown the theory to be true by measuring the "ticks" of a very tiny atomic clock with its parts spaced just a single millimeter apart, one above the other. They note that general relativity should hold true no matter the size or distance of the clocks.

The atomic clock used by the researchers was made up of 100,000 strontium atoms that were super-chilled and arranged in a vertical lattice. The researchers then measured the rate of "wiggling" of light waves for the atoms at the top of the lattice (the ticks of the clock) and compared them with the rate of the light waves for the atoms on the bottom; the difference accounted for a redshift. As they took their measurements, the researchers also made corrections to remove other factors that might impact the ticking of their clock. They found a shift in frequency of approximately one-100th of a quadrillion percent over a distance of a single millimeter—almost exactly what theory had predicted. The researchers then repeated the experiment multiple times for approximately 90 hours, comparing the differences in the ticks and then averaging them together. In so doing, they found they were able to obtain a measurement precision that was 0.76 millionths of a trillionth of a percent—a new record.

In somewhat related work, a team at the University of Wisconsin created a multiplexed optical lattice clock and used it to conduct high-precision differential clock comparisons. They have also posted their work on the arXiv preprint server.

More information: Tobias Bothwell et al, Resolving the gravitational redshift within a millimeter atomic sample. arXiv:2109.12238v1 [physics.atom-ph], arxiv.org/abs/2109.12238

Xin Zheng et al, High precision differential clock comparisons with a multiplexed optical lattice clock. arXiv:2109.12237v1 [physics.atom-ph], arxiv.org/abs/2109.12237