Scientists use Tokyo Skytree to test Einstein's theory of general relativity

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Video Abstract

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Abstract

Scientists have done it again. They've verified Einstein's theory of general relativity using real-life experiments. The latest group to do it is led by researchers at the RIKEN Center for Advanced Photonics and Cluster for Pioneering Research. And this time they've done it using a pair of ultraprecise clocks spaced 450 meters apart: one on the ground, and the other on the observatory floor of Tokyo Skytree, one of the tallest towers in the world. Einstein theorized that massive objects warp space-time, the fabric of existence throughout the universe. One consequence of that is that time runs differently between different gravitational fields: slowly in deep fields and faster in shallow ones. Theoretically, a pair of clocks could capture this time differential. And in real life, that might be easy when the difference in gravitational strength is gigantic. But measuring that difference between two spots on earth would be practically impossible—that is, if it weren't for optical lattice clocks. An optical lattice clock works by using laser cooling to corral atoms into a well-defined spatial pattern, or lattice. Because the parameters describing this system are so well-defined, scientists can reduce the tiniest disturbances to atomic pendulums. The oscillation of these undisturbed atomic pendulums gives the "tick" of the optical lattice clock. Clocks of this type are big enough to fill a small room, making it difficult to take measurements at two separate locations. The team led by RIKEN overcame that problem by miniaturizing their clocks to fit inside cabinet-sized boxes. Capable of measuring time with 18-digit precision, the clocks produced verifiable differences in the passage of time when separated by 450 meters. And thus, the RIKEN-led team could verify Einstein's theory. But the true innovation is the clocks' portability. Small and easy to transport, the clocks could be used to detect otherwise invisible differences in height. That includes foreboding differences in ground swelling in risky areas such as active volcanoes or regions of crustal deformation. In the future, the group plans to deploy hundreds of clocks spaced tens of kilometers apart to monitor the long-term uplift and depression of the ground. The ground networks of optical lattice clocks plays a complementary role to the conventional GNSS observation system.