

1. Mark your confusion.
2. Show evidence of a close reading.
3. Write a 1+ page reflection.

## **A Clock So Precise It's Beyond Space and Time**

Source: Deborah Netburn, *Los Angeles Times*, May 1, 2015

Scientists have created an atomic clock so precise that it won't lose or gain a single second in 15 billion years—roughly the age of our universe.

But the clock isn't just steady, it's also amazingly accurate. So accurate in fact, that it can detect tiny changes in the speed of its ticks depending on whether it is 2 centimeters closer or farther from the center of Earth.

"Time can be intricately connected to gravity," said Jun Ye, a physicist at JILA, a joint institute of the National Institute of Standards and Technology and the University of Colorado, Boulder. "It sounds like science fiction, but these measurements are a reality."

The ability of a hyper-sensitive clock to determine small differences in altitude is based on Einstein's prediction that the farther one gets from the center of an attractor (like Earth), the faster time moves.

Researchers have long ago proved this theory by comparing the speed of clocks separated by vast differences, either on board satellites in orbits a few dozen miles apart, or by comparing the ticks of clocks telling time at sea level and those placed on a mountain top.

Five years ago researchers at NIST created a clock so sensitive that it could detect the difference in time between two elevations just a foot from each other.

But the new clock is even better.

"Now when we measure this very weird property of time fabric in the laboratory, even a 2-centimeter change will result in a detectable time change in the clock," Ye said.

The clock is described Tuesday in *Nature Communications*. It is a tweaked version of an optical lattice clock that measures the oscillations of strontium atoms that have been trapped in a network of lasers.

Ye, who is the principal investigator on the paper, explains that the clock measures the speed of an electron as it zips around the nucleus of a strontium atom at the rate of about a million billion orbits per second.

To calculate this movement, the researchers hit a few thousand strontium atoms at a time with what they call a "clock laser." The laser can be tuned so that the peaks and troughs in its electric field match the oscillation of the electrons of the strontium atoms.

The result is a clock that is several orders of magnitude more accurate than the cesium microwave clock that governs official time today.

"The clock we use now is like a watch with a hand that moves 9 billion times per second," Ye said. "The 'watch' we are working on moves at the speed of a million billion times per second; we are basically keeping track of ripples of light."

In this latest iteration of the optical lattice clock, researchers reduced time-telling errors by installing highly sensitive thermometers around the trapped atoms so the effects of heat from the surrounding environment could be better measured. They were also able to reduce the effects of the laser net on the individual atoms, and they used one of the most stable lasers in the world to take the measure of the electron movement.

These tweaks lead to a clock that is at least three times more precise than the previous world-record holder introduced last year, as well as increased stability of 50%. The authors are anticipating continued progress.

A clock with this extreme level of precision may seem like overkill, but it could be used to improve our understanding of the shape of Earth, help to conduct tests of the fundamental laws that govern space and time, and provide a new pathway for investigating dark matter.

And the possibilities grow as the clocks grow more precise.

"If we can make a clock 1,000 times more accurate, we could hear the symphony of the universe," Ye said. "For instance, you would sense how space time shifts when a distant galaxy explodes."

**Possible Response Questions:**

- Explain why this new clock is an important step forward in science.
- Google the article, "Ten Things Everyone Should Know About Time," and respond to it.
- Select any passage in this AoW and respond to it.