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Physics

Most accurate molecular clock yet uses extremely

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theory of relativity or to search for forces that have yet to be described

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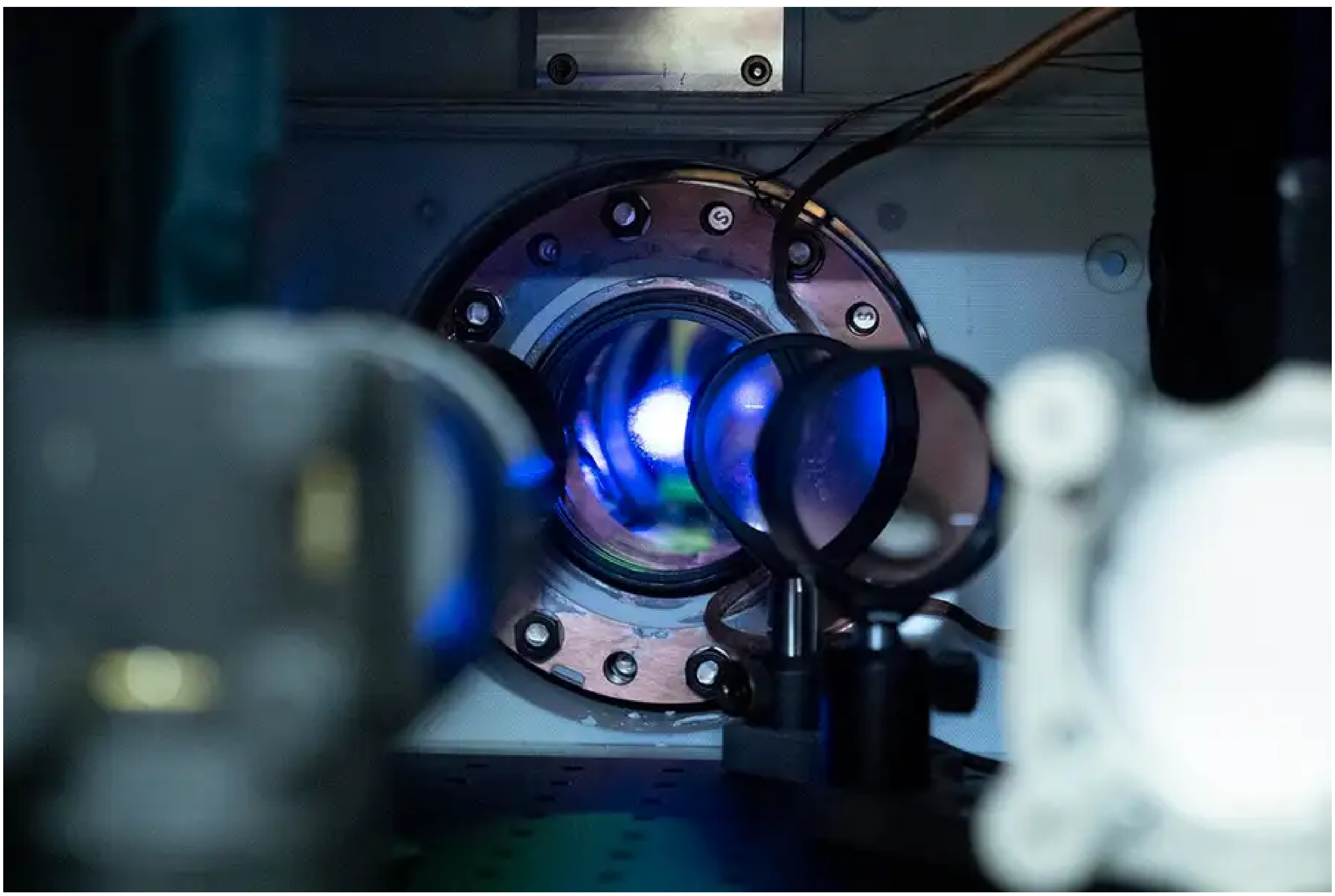

Like atomic clocks, molecular clocks may be used to test how gravity influences the flow of time

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Pairs of extremely cold strontium atoms have been used to make the most accurate molecular clock yet. It could be used to detect new forces and test some of Albert Einstein's ideas about gravity.

Today, the world's most accurate clocks are atomic clocks, which "tick" based on the behaviour of electrons in atoms that are nearly as cold as absolute zero. Though ultracold molecules – made of multiple atoms – have been proposed as ingredients for even more reliable and stable clocks, they have historically proven very difficult to control. Now, Kon Leung at Columbia University in New York and his colleagues have managed to build an unprecedentedly accurate clock out of ultracold molecules of strontium.

To make the molecular clock, the researchers cooled strontium atoms to two-millionths of a degree above absolute zero in a small, airless metal and glass container. They then used lasers to pair the atoms into molecules that were arranged into a line. Under these circumstances, the strontium molecules only have enough energy to repeatedly move their two atoms towards and away from each other at a predictable rate. A "tick" of the clock is one full movement back and forth.

This ultracold ticking was so steady that, when used for timekeeping, it would take about a million years for the clock's impeccable rhythm to drift by a whole second, an error one-tenth that of other molecular clocks.

"Just two decades ago, controlling molecules with light very well was considered a grand challenge. We had to combine the best of both worlds in terms of molecular physics and laser techniques," says Leung. Key to the improvement on previous molecular clocks was adjusting the lasers so that the fewest possible number of molecules get too warm to control. Starting with very cold atoms also helped, he says.

Though the best atomic clocks are 10,000 times more accurate than the new molecular clock, the clock's accuracy is a technical achievement, says Leung.

Jeroen Koelemeij at Vrije Universiteit Amsterdam in the Netherlands says that as molecular clocks improve they could become valuable for testing Einstein's theory of relativity by comparing them with atomic clocks. According to Einstein, the flow of time can be influenced by gravitational forces, but the timekeeping method a clock uses shouldn't have any influence on how this "time dilation" is experienced.

For instance, if put into microgravity onboard a satellite, an atomic clock and a molecular clock should similarly register the relatively faster flow of time in orbit. If the two types of clocks don't react similarly to the change in gravity and drift apart over time, that result would be in conflict with Einstein's theory, says Koelemeij.

The molecular clock could also be used to look for forces that have yet to be described, says Brandon Iritani, also at Columbia University. He says that some proposed possible forces only act between objects that are very close together, like the two atoms in each strontium molecule. If these forces existed, some might reveal themselves by causing irregularities in the clock's ticking, he says.

Reference: arxiv.org/abs/2209.10864

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