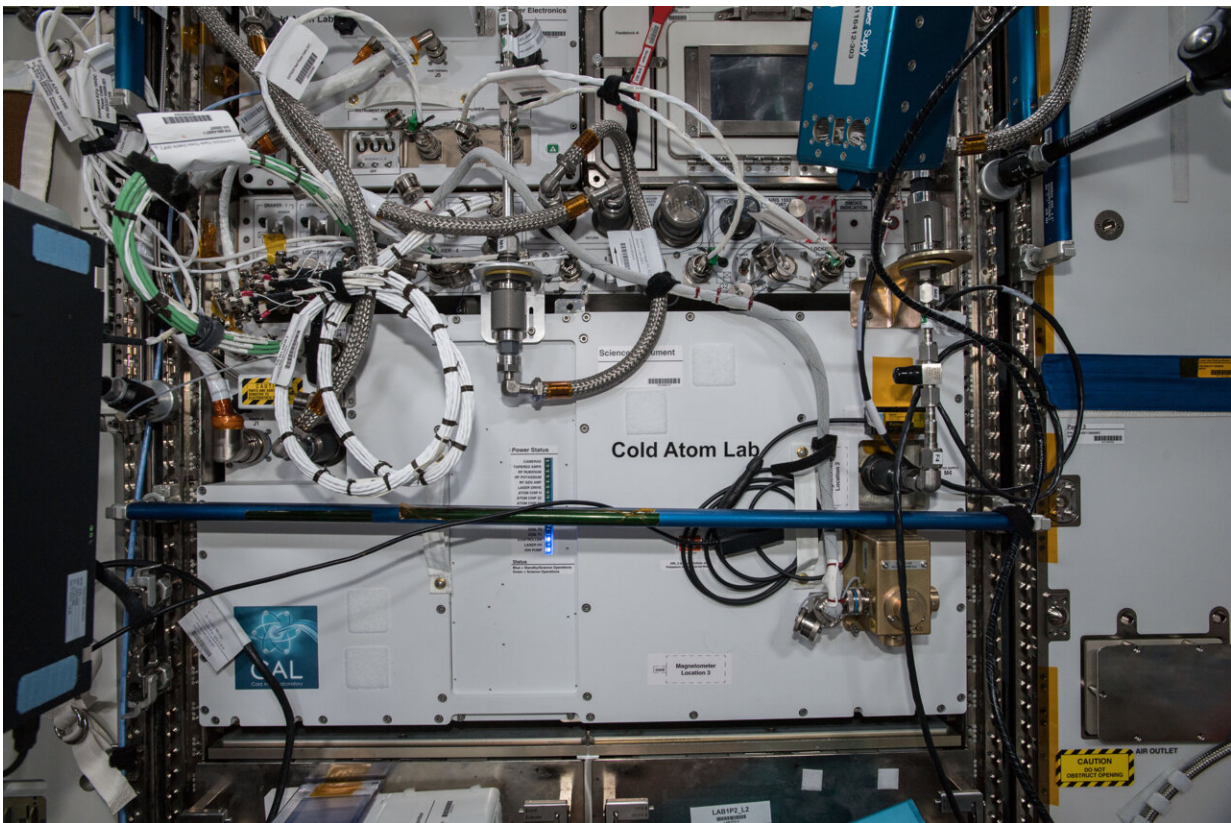


NASA demonstrates 'ultra-cool' quantum sensor for first time in space

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NASA's Cold Atom Lab, shown where it's installed aboard the International Space Station, recently demonstrated the use of a tool called an atom interferometer that can precisely measure gravity and other forces — and has many potential applications in space. Credit: NASA/JPL-Caltech

NASA's Cold Atom Lab, a first-of-its-kind facility aboard the

International Space Station, has taken another step toward revolutionizing how quantum science can be used in space. Members of the science team measured subtle vibrations of the space station with one of the lab's onboard tools—the first time ultra-cold atoms have been employed to detect changes in the surrounding environment in space.

The study, which [appeared](#) in *Nature Communications* on Aug. 13, also reports the longest demonstration of the wave-like nature of atoms in freefall in space.

The Cold Atom Lab science team made their measurements with a quantum tool called an [atom interferometer](#), which can precisely measure gravity, magnetic fields, and other forces. Scientists and engineers on Earth use this tool to study the fundamental nature of gravity and advance technologies that aid aircraft and ship navigation. (Cell phones, transistors, and GPS are just a few other major technologies based on quantum science but do not involve atom interferometry.)

Physicists have been eager to apply atom interferometry in space because the microgravity there allows longer measurement times and greater instrument sensitivity, but the exquisitely sensitive equipment has been considered too fragile to function for extended periods without hands-on assistance. The Cold Atom Lab, which is operated remotely from Earth, has now shown it's possible.

"Reaching this milestone was incredibly challenging, and our success was not always a given," said Jason Williams, the Cold Atom Lab project scientist at NASA's Jet Propulsion Laboratory in Southern California. "It took dedication and a sense of adventure by the team to make this happen."

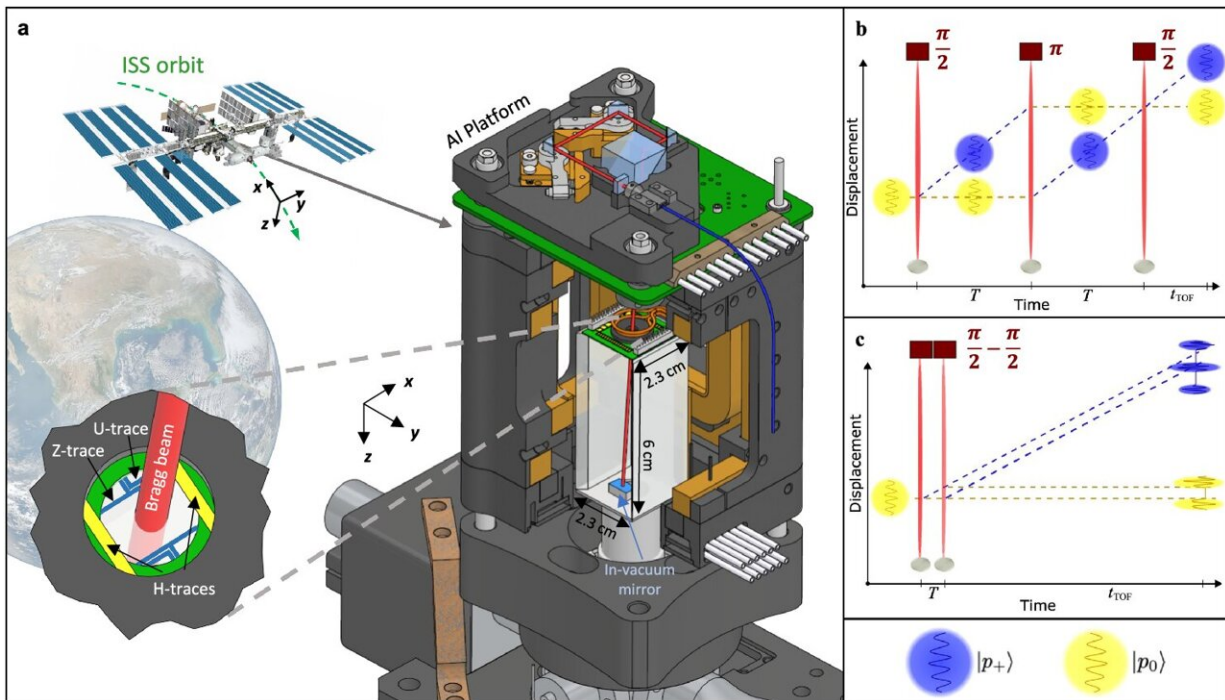
Power of precision

Space-based sensors that can measure gravity with high precision have a wide range of potential applications. For instance, they could reveal the composition of planets and moons in our solar system, because different materials have different densities that create subtle variations in gravity.

This type of measurement is already being performed by the U.S.-German collaboration GRACE-FO (Gravity Recovery and Climate Experiment Follow-on), which detects slight changes in gravity to track the movement of water and ice on Earth. An atom interferometer could provide additional precision and stability, revealing more detail about surface mass changes.

Precise measurements of gravity could also offer insights into the nature of [dark matter](#) and [dark energy](#), two major cosmological mysteries. Dark matter is an invisible substance five times more common in the universe than the "regular" matter that composes planets, stars, and everything else we can see. Dark energy is the name given to the unknown driver of the universe's accelerating expansion.

"Atom interferometry could also be used to test Einstein's theory of general relativity in new ways," said University of Virginia professor Cass Sackett, a Cold Atom Lab principal investigator and co-author of the new study. "This is the basic theory explaining the large-scale structure of our universe, and we know that there are aspects of the theory that we don't understand correctly. This technology may help us fill in those gaps and give us a more complete picture of the reality we inhabit."



Atom interferometer set up onboard the ISS. Credit: *Nature Communications* (2024). DOI: 10.1038/s41467-024-50585-6

A portable lab

About the size of a minifridge, the Cold Atom Lab launched to the space station in 2018 with the goal of advancing quantum science by putting a long-term facility in the microgravity environment of low Earth orbit. The lab cools atoms to almost absolute zero, or minus 459 degrees Fahrenheit (minus 273 degrees Celsius).

At this temperature, some atoms can form a Bose-Einstein condensate, a state of matter in which all atoms essentially share the same quantum identity. As a result, some of the atoms' typically microscopic quantum properties become macroscopic, making them easier to study.

Quantum properties include sometimes acting like solid particles and sometimes like waves. Scientists don't know how these building blocks of all matter can transition between such different physical behaviors, but they're using quantum technology like what's available on the Cold Atom Lab to seek answers.

In microgravity, Bose-Einstein condensates can reach colder temperatures and exist for longer, giving scientists more opportunities to study them. The atom interferometer is among several tools in the facility enabling precision measurements by harnessing the quantum nature of atoms.

Due to its wave-like behavior, a single atom can simultaneously travel two physically separate paths. If gravity or other forces are acting on those waves, scientists can measure that influence by observing how the waves recombine and interact.

"I expect that space-based atom interferometry will lead to exciting new discoveries and fantastic quantum technologies impacting everyday life, and will transport us into a quantum future," said Nick Bigelow, a professor at University of Rochester in New York and Cold Atom Lab principal investigator for a consortium of U.S. and German scientists who co-authored the study.

More information: Jason R. Williams et al, Pathfinder experiments with atom interferometry in the Cold Atom Lab onboard the International Space Station, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-50585-6](https://doi.org/10.1038/s41467-024-50585-6)

Provided by NASA

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