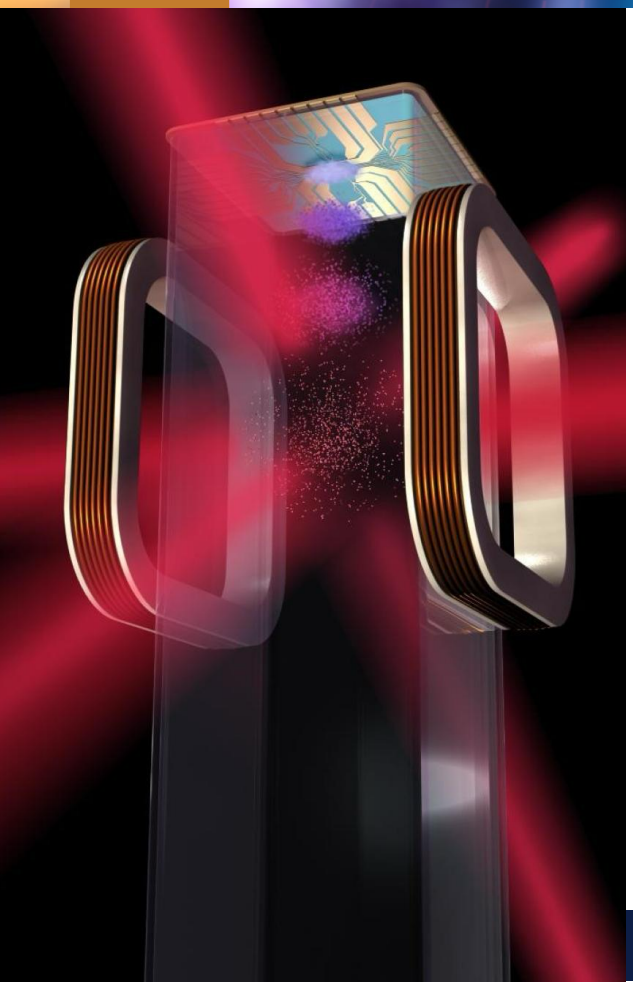
BIOLOGICAL & PHYSICAL SCIENCES

Quantum Leaps

Unraveling mysteries of the universe

Quantum researchers seek to understand the mysterious behaviors of matter and energy that make up the world around us. Over 100 years have passed since quantum theory was first posited by scientists, yet much of quantum phenomena remains unknown. NASA science is leading the way in revealing new insights that could transform our understanding of the quantum realm.



NASA uses space to pioneer breakthroughs in quantum science in ways not possible on Earth. This research contributes to breakthroughs in scientific knowledge that could advance technologies used in navigation, computing, and national defense.

ENABLING SPACE EXPLORATION:

- Precision atomic clocks that improve GPS navigation
- Advancements in quantum sensors and technologies
- Enhancements in communication systems

BENEFITTING HUMANITY:

- Breakthroughs in scientific knowledge
- New and next-generation technologies
- Career paths for future generations
- Economic growth opportunities

MISSIONS AND INVESTIGATIONS INCLUDE:

- Cold Atom Laboratory with JPL (Jet Propulsion Laboratory)
- ACES (Atomic Clock Ensemble in Space) with European Space Agency
- SEAQUE (Space Entanglement & Annealing Quantum Experiment) with JPL

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QUANTUM LEAPS

UNRAVELING MYSTERIES OF THE UNIVERSE

5 QUICK QUANTUM FACTS:

1. Approximately 95% of our known universe remains a mystery.
2. Even with the most advanced instruments on Earth, gravity and other terrestrial limitations obscure our ability to observe quantum behaviors.
3. Researchers use the Cold Atom Lab aboard the space station to cool atoms to near absolute zero.
4. Cooling atoms enables scientists to slow them down and better observe mysterious quantum phenomena.
5. Fundamental quantum research has contributed to technologies used in everyday life, such as cell phones, computers, GPS, medical imaging, and more.

INVESTIGATION HIGHLIGHTS:

The Cold Atom Lab: A facility the size of a mini-refrigerator is investigating phenomena at the smallest scale using an orbiting laboratory in space. The Cold Atom Lab, which has operated aboard the International Space Station since 2018, enables researchers to study the nature of atoms and quantum science in ways not possible on Earth. Scientists have pioneered numerous “firsts in space” using the lab, including the first quantum bubbles in space, first dual-species Bose Einstein Condensates (AKA the “fifth state of matter”), and quantum gasses.

SEAQUE (Space Entanglement and Annealing Quantum Experiment): This experiment tests technology to make communications easier and stronger between quantum systems across significant distances. It will validate a new technology in space that aims to improve how quantum computers communicate using space entanglement. The SEAQUE platform was launched to low Earth orbit in 2024 and attached to the outside of the space station, where the instrument is exposed directly to the space radiation environment. A collaboration with the Jet Propulsion Lab (JPL).

ACES (Atomic Clock Ensemble in Space): ACES is an ultra-stable clock experiment that could be used to improve GPS navigation in space and on Earth. According to Einstein’s theory of general relativity, gravity affects the passing of time. Experiments on Earth have shown that time flies faster at higher altitudes, such as the tops of mountains, than at sea level. ACES will take this experiment to the next level, making precise measurements on the space station as it flies 400 km above Earth. The data gathered by ACES will offer scientists new insights into the relationship between gravity and time, advancing our understanding of fundamental laws of physics. A collaboration with the European Space Agency (ESA), scheduled to launch to the space station in spring 2025.

Probing biological and physical phenomenon under extreme conditions advances the fundamental scientific knowledge required to go farther and stay longer in space, while also benefitting life on Earth.