Bose-Einstein condensates in Space

Where is the coldest place in the Universe? Surprisingly, as far as we know, it is in the International Space Station. The Cold Atom Laboratory (CAL), a facility that has been onboard the ISS since 2018, can reach temperatures that are 'fraction of a degree above absolute zero -- even colder than the average temperature of deep space', according to NASA's Jet Propulsion Laboratory (JPL).

Recently, this facility has allowed the creation of Bose-Einstein condensates for the first time in a research laboratory in Low Earth Orbit.

What is a Bose-Einstein condensate?

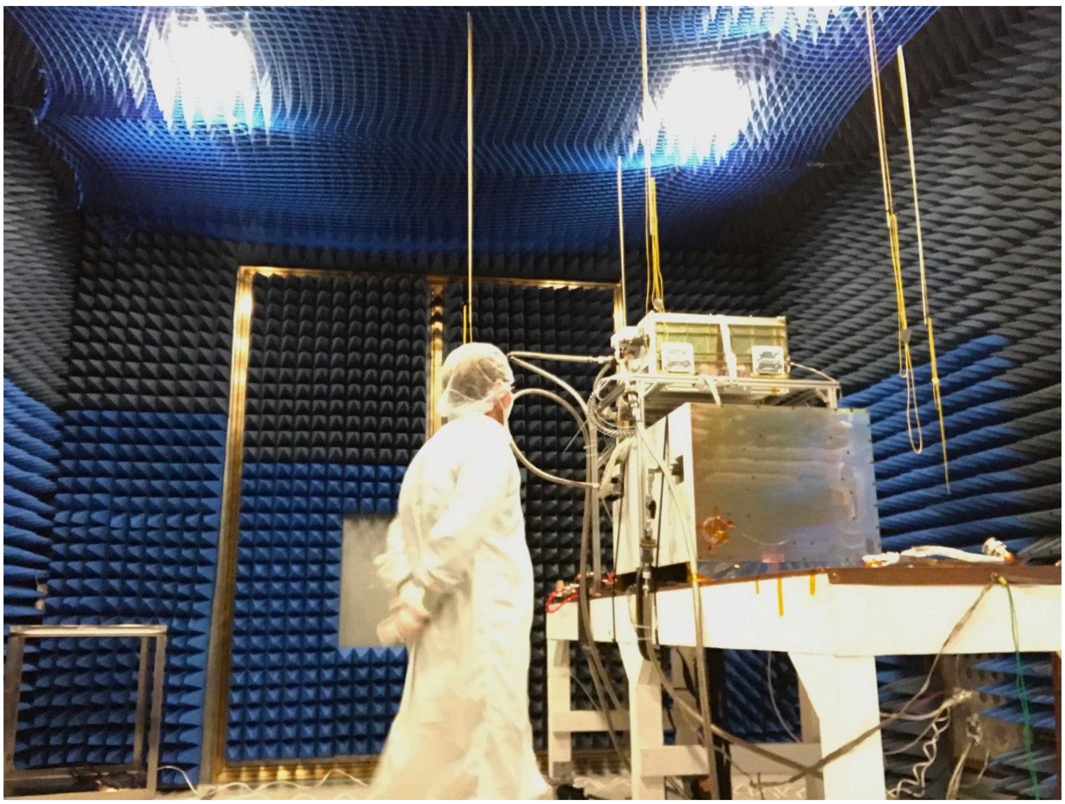
When a low-density gas of atoms is cooled down to temperatures close to absolute zero (which corresponds to −273.15 °C), the atoms start occupying the lowest energy state possible. At this point, they become indistinguishable, and the whole ultracold gas starts to behave collectively, forming a BEC (Bose-Einstein Condensate), a sort of blob. Due to this collective behaviour, quantum effects are magnified. In this state, quantum behaviours happening at subatomic scales become apparent macroscopically.

However, this "fifth state of matter", as many people like to refer to BECs, is an ephemeral object. On Earth, gravity causes the rapid disappearance of the BECs after creation. They are hardly observed for more than a fraction of a second. BECs are also fragile, as their formation requires extremely low temperatures, which are hard to maintain with current equipment, and even one small disturbance in the system can cause the BEC to vanish. This is where the Cold Atom Laboratory's idea comes in.

The Cold Atom Laboratory's achievement

The Cold Atom Laboratory was made with the idea that creating BECs in microgravity increases their lifetime, as the effects of gravity on the production are reduced. This increase of lifetime would greatly improve the experiments that can be conducted on BECs, and push the frontiers of this field. The advantages of microgravity were already demonstrated by the production of BECs in a free-fall tower in Bremen, Germany.

The Cold Atom Laboratory team did a trial BEC creation in space by launching a rocket into space in which a BEC was produced, and allowing it to free-fall while performing experiments on it. After this successful first creation of the BEC, the CAL was sent to the International Space Station (ISS), hoping to give an opportunity for further research on Bose-Einstein condensates in space.



CAL testing at NASA's Jet Propulsion Laboratory before the launch (Credits: NASA JPL).

In a paper published in the journal *Nature* on the 11th of June, the CAL reported the observation of a Bose-Einstein condensate for little more than a second on the ISS. Indeed, microgravity makes a big difference for this fifth state of matter. This achievement opens up a door in this field, allowing for new research.

The study of Bose-Einstein condensates are important because of its potential for atomic physics. Atomic lasers and measurement instruments with increased precision could be achieved. For example, BECs may be used for precise gravitational wave detection. BECs also have the ability to slow down light, and it has been shown that light pulses can even be trapped in them. This could lead to ample applications in the field of light-based technology, and influence the world of quantum computing, among others. All in all, the ability to research longer-lasting BECs in the CAL at ISS is definitely going to lead to exciting opportunities.

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