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WEEKLY June 13–19, 2020

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Physics

Quantum clouds in orbit

A chilly experiment on the International Space Station is probing the nature of matter

Jonathan O'Callaghan

AN EXOTIC fifth type of matter has been created in one of the coldest places in the universe – a device on board the International Space Station (ISS).

The Cold Atom Laboratory (CAL) was launched to the ISS in 2018 to investigate a strange kind of matter, known as a Bose-Einstein condensate (BEC). This suitcase-sized device chills atoms of rubidium and potassium in a vacuum chamber, using laser light to slow their movement. Magnetic fields then contain the resulting cloud of atoms, which is cooled to nearly absolute zero at -273°C, producing a BEC.

This chilly substance was initially theorised by Albert Einstein and Satyendra Nath Bose in the early 1920s as the fifth state of matter, following solids, liquids, gases and plasma. It is a supercooled gas that no longer behaves as individual atoms and particles, but rather an entity in a single quantum state.

"This is pretty remarkable because this gives you a macroscopic-sized quantum mechanical object," says Maike Lachmann at Leibniz University Hannover in Germany.

NASA/JSC

Astronaut Christina Koch installing the Cold Atom Laboratory on the ISS

BECs have been produced in a variety of experiments on Earth since 1995, but these are hindered by gravity, which collapses the clouds in a split second. The microgravity environment of the ISS keeps them stable for multiple seconds, allowing them to be studied in more detail.

Robert Thompson at NASA's Jet Propulsion Laboratory and his colleagues have been operating the CAL remotely and have published their first results. While mostly just a demonstration that the machine works, there are some tantalising glimpses of what might be possible one day.

"It's more of a technological achievement," says Thompson. "But in the future, it will enable a wide spectrum of science."

The initial results show that BECs behave differently in orbit. The team found that about half of the atoms form into a halo-like cloud around the main body of the BEC. On the ground, these atoms would simply fall due to gravity, but in microgravity on the ISS, the cloud remains suspended (*Nature*, DOI: 10.1038/s41586-020-2346-1).

In the near future, the researchers hope to use the experiment to watch atoms collide on a quantum level. They also want to probe ripples in space-time called gravitational waves by monitoring disturbances in the movement of the atoms.

Looking further ahead, the experiment could also tackle ideas like Einstein's equivalence principle, which says that all masses in a given gravitational field accelerate in the same way. Tests in microgravity could reveal whether there are any violations of the principle. "It's usually unwise to bet against Einstein," says Thompson. "But it's always important to test these things." ▮

Robotics

Four-legged robot gets job as a sewer inspector

A ROBOT that inspects concrete by scratching it can walk through underground sewerage tunnels and detect when they need repairing.

Because many modern sewerage systems were built decades ago, they need monitoring to prevent major leaks. Currently, human inspectors do the job manually.

"It's damp, it's slippery, it's dangerous, you have all sorts of rats," says Hendrik Kolvenbach at ETH Zurich in Switzerland.

Kolvenbach and his colleagues have developed a four-legged robot called ANYmal that can do the job instead. Each of its limbs has three joints for manoeuvrability, allowing it to wade through water and climb over obstacles.

The robot is equipped with lidar, which uses lasers to map 3D spaces, and a stereo camera to help it position itself. It also has sensors built into its feet.

When the robot scratches a foot against the concrete, it measures the vibrations generated, giving an indication of the roughness of the surface: the smoother the concrete, the better condition it is in.

The team tested ANYmal in sewerage tunnels in Zurich, and first tasked it with inspecting an area where the concrete conditions had already been checked by humans.

The robot took 625 samples of concrete conditions in areas where it had been classified by humans as either good, satisfactory or fair. The team then used this information to train a machine learning algorithm for ANYmal, which was able to distinguish between the three conditions with over 92 per cent accuracy (*Journal of Field Robotics*, doi.org/dxqb).

"The robot was able to assess the condition of the concrete with over 92 per cent accuracy"

The robot has since been used to inspect a 300-metre-long section that hasn't been checked by humans, mapping the concrete floor every 2 to 3 metres.

In the future, the team plans to test ANYmal on other tasks in different environments, such as underground mines. ▮

Donna Lu