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WEEKLY 25 November 2023

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Physics

Einstein put to the test on the ISS

Ultracold atoms on the International Space Station will test general relativity and beyond

Karmela Padavic-Callaghan

PHYSICISTS are lining up the most accurate test yet of Albert Einstein's ideas about gravity. It involves manipulating extremely cold atoms aboard the International Space Station (ISS).

A key part of Einstein's general theory of relativity is the equivalence principle. This states that all objects fall with the same acceleration when gravity is the only force acting on them.

One of the most sensitive tests yet of this principle involved very cold rubidium atoms in freefall at a facility in California; another explored the effects of gravity on materials of precise mass launched into space on a satellite.

Naceur Gaaloul at Leibniz University Hannover in Germany and his colleagues have now built an experiment that combines elements of both tests by using ultracold atoms in the Cold Atoms Laboratory (CAL) on the ISS. The atoms are kept on a chip-sized device and made very cold by being pushed, pulled and hit by magnetic forces and lasers.

NASA

The International Space Station is home to cutting-edge physics experiments

At temperatures only billionths of a degree above absolute zero, quantum effects make these atoms behave like a collection of overlapping "matter waves" rather than distinct particles. For the experiment, the researchers cooled potassium and rubidium atoms on the same chip and then manipulated them to effectively turn the chip into two separate devices called interferometers (*Nature*, doi.org/k5fb).

Interferometers measure acceleration, so because the ISS is always accelerating due to gravity, if the two devices record different values, the equivalence principle would be broken.

While the researchers have made the two devices in the CAL, they need to optimise them further before they can use them to test the equivalence principle.

"The equivalence principle is the bedrock of our understanding of gravity, but these experiments could go beyond just testing general relativity," says Timothy Kovachy at Northwestern University in Illinois. "There could be new particles which are not included in the standard model that manifest as breaking this principle."

The CAL experiments are expected to be hundreds of times more accurate than satellite-based tests, and hundreds of thousands of times more accurate than Earth-based experiments, but Gaaloul says that ultimately it will be necessary to go beyond the ISS, too. "Because of the vibrations from astronauts biking and other things that are going on, the ISS is not perfect for precision experiments," he says. "But here we will make sure of techniques for equivalence principle tests which will ultimately happen on a dedicated satellite." ▮

Zoology

Anemones are the first animals known to track the sun

PHOTOSYNTHETIC sea anemones do something that was thought to be limited to plants until now: following the sun's daily movement across the sky. These are the first known "heliotropic" animals.

Vengamanaidu Modepalli at the Marine Biological Association in Plymouth, UK, noticed that the snakelocks anemones (*Anemonia viridis*) in an aquarium at the facility were all pointing their tentacles towards a window. These anemones host symbiotic algae (*Symbiodinium*) in their tissues, which use photosynthesis to supply food to their animal partner. When Modepalli closed the shutter, the tentacles fell into a disordered tangle, and perked up again within minutes of reopening the shutter.

To see if the anemones responded similarly in their natural habitat, Modepalli and his colleagues filmed them in intertidal rock pools over the course of a day and found that the animals tracked the sun's position with their tentacles. The animals also did the same thing with a slowly moving light source in a laboratory tank.

Experiments with different coloured light revealed that, just like sun-tracking plants, the anemones' movements are primarily influenced by blue light wavelengths, which are highly absorbed in photosynthesis. When the team bleached anemones, removing their algal partners, the number of tentacles pointing towards blue light fell from about 61 per cent to nearly none (bioRxiv, doi.org/k5d8).

"[The bleached anemone] didn't show any behaviour, it was completely lost," says Modepalli.

"If you expose organisms to a similar environmental pressure, they evolve similar behaviours"

Some other anemones, jellies and other animals were known to exhibit phototaxis, where they move their bodies closer to a source of light. But the snakelocks anemones are the first to be recorded showing stationary sun-tracking behaviour. Modepalli thinks it may be a useful adaptation in rock pools, where it is difficult to move to get more or less sun exposure. Lacking the ability to move, plants also evolved to do this.

"Both are doing photosynthesis and showing the same kind of behaviour," says Modepalli. "It looks like if you expose these organisms to a similar environmental pressure, they [evolve] similar behaviours."

These anemones probably aren't the only animals doing this, says Claudia Pogoreutz at the University of Perpignan Via Domitia, France. "I would expect that heliotropism is likely universal to the photosymbiotic lifestyle," she says. ▮

Jake Buehler