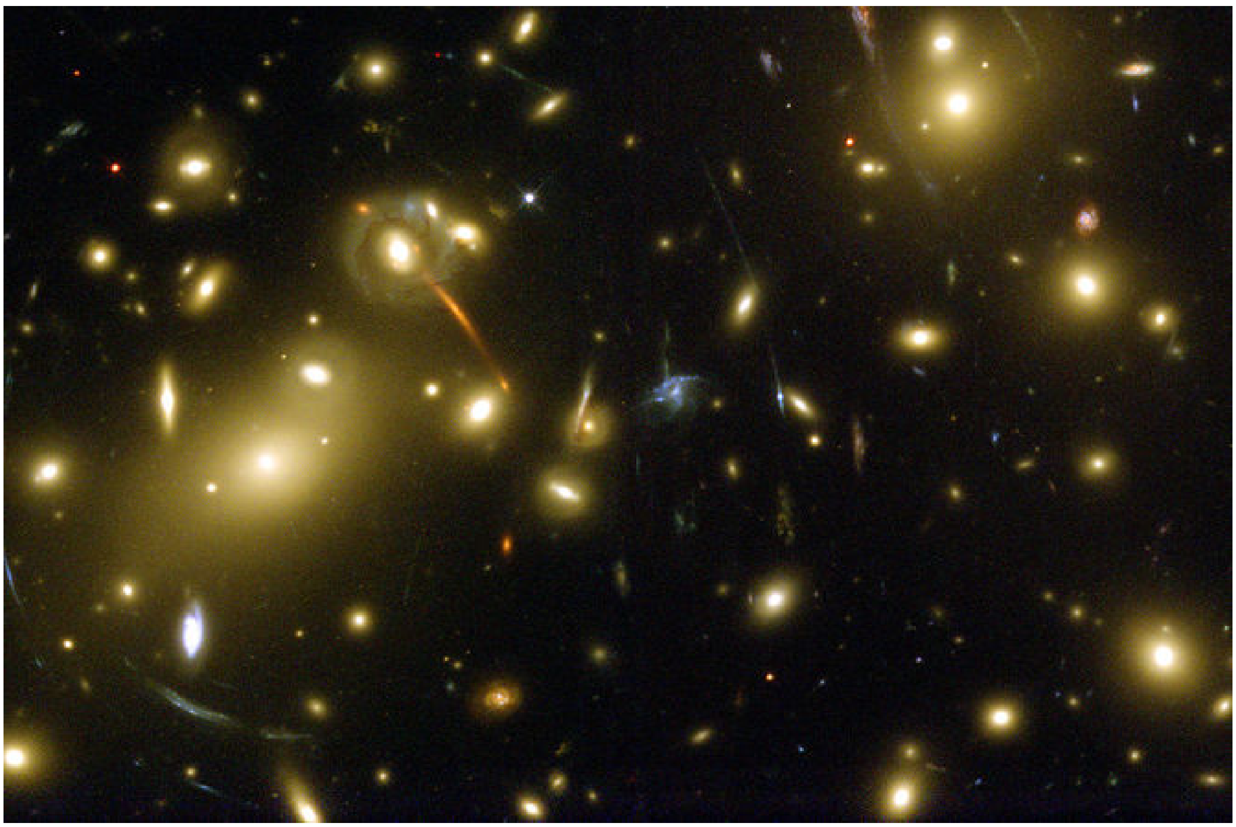
The search for 'dark matter' and 'dark energy' just got interesting

August 21 2015, by Ryan Wilkinson



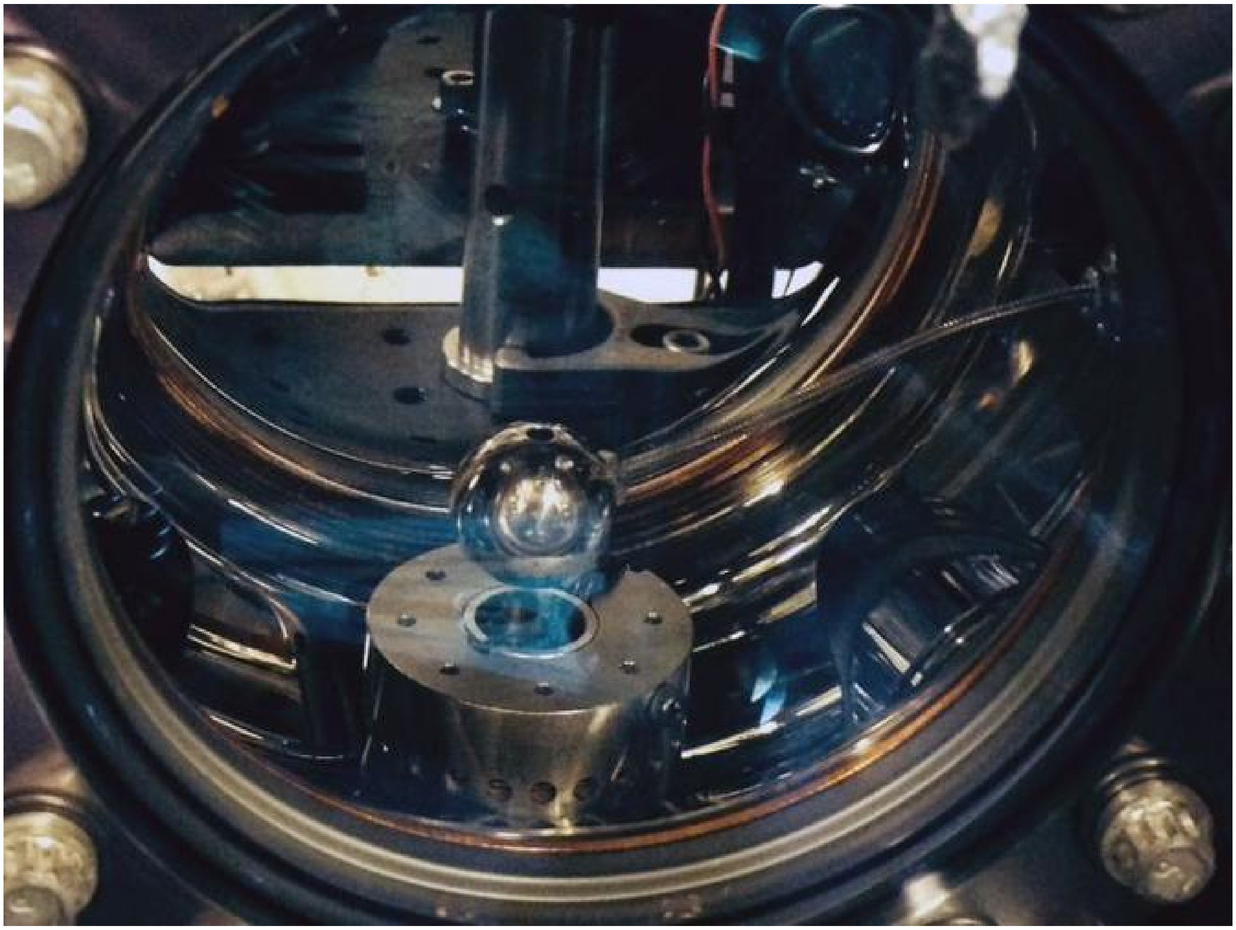
We are a big step closer to tracking down what's hiding in galaxy clusters like Abell 2218. Credit: NASA/ESA via wikipedia

Only about 5% of the universe consists of ordinary matter such as protons and electrons, with the rest being filled with mysterious substances known as dark matter and dark energy. So far, scientists have failed to detect these elusive materials, despite spending decades searching for them. But now, two new studies may be able to turn things around as they have narrowed down the search significantly.

Dark matter was first proposed more than 70 years ago to explain why the force of gravity in galaxy clusters is so much stronger than expected. If the clusters contained only the stars and gas we observe, their gravity should be much weaker, leading scientists to assume there is some sort of matter hidden there that we can't see. Such dark matter would provide additional mass to these large structures, increasing their gravitational pull. The main contender for the substance is a type of hypothetical particle known as a "weakly interacting massive particle" (WIMP).

To probe the nature of dark matter, physicists look for evidence of its interactions beyond gravity. If the WIMP hypothesis is correct, dark matter particles could be detected through their scattering off atomic nuclei or electrons on Earth. In such "direct" detection experiments, a WIMP collision would cause these charged particles to recoil, producing light that we can observe.

One of the main direct detection experiments in operation today is XENON100, which has just reported its latest results. The detector is located deep underground to reduce interference from cosmic rays, at the Gran Sasso laboratory in Italy. It consists of a 165kg container of liquid xenon, which is highly purified to minimise contamination. The detector material is surrounded by arrays of photomultiplier tubes (PMTs) to capture the light from potential WIMP interactions.



The vacuum chamber of the atom interferometer. Credit: Holger Muller photo., CC BY

The new XENON100 report has found no evidence of WIMPs scattering off electrons. Although this is a negative result, it rules out many so-called "leptophilic" models that predict frequent interactions between dark matter and electrons.

But the most important consequence of the XENON100 analysis is with regards to the controversial claim of dark matter detection by researchers at the DAMA/LIBRA experiment in Italy, which is in conflict with the results from many other detectors such as the

Cryogenic Dark Matter Search. Leptophilic dark matter was proposed as a viable explanation for this discrepancy since exclusions from other experiments would not directly apply. However, the new results from XENON100 firmly rule out this possibility.

Chasing chameleons

Meanwhile, dark energy explains our observation that the universe is expanding at an accelerating rate. Unlike normal matter, dark energy has a negative pressure, which allows gravity to be repulsive, driving the galaxies apart. One of the most promising dark energy candidates is a so-called "chameleon field".

In many dark energy models, we would expect to see significant effects on both laboratory and cosmological scales. However, the attractive feature of a chameleon field is that its impact depends on the environment. At small scales, such as on Earth, the density of matter is high and the field is effectively "screened out", allowing chameleons to evade our detectors. However, in the vacuum of space, the matter density is tiny and the field can drive the cosmic acceleration.

Until now, experiments have only used relatively large detectors, failing to observe chameleons as the density of matter is too high. However, it was recently proposed that an "atom interferometer", operating on microscopic scales, could be used to search for chameleons. This consists of an ultra-high vacuum chamber containing individual atoms and simulates the low-density conditions of empty space so that screening is reduced.

In the second report, researchers implement this idea for the first time. Their experiment works by dropping caesium atoms above an aluminium sphere. Using sensitive lasers, the researchers could then measure the forces on the atoms as they were in free fall. The results were perfectly consistent with only gravity and no chameleon-induced force. This implies that if chameleons exist, they must interact more weakly than we previous thought – narrowing the search for these particles by a thousand times compared to previous studies. The team are hoping that their innovative technique will help them to hunt down chameleons or other dark energy particles in a future experiment.

Both of these studies demonstrate how laboratory experiments can answer fundamental questions about the nature of the cosmos. But most importantly, they raise hope that we will one day track down these tantalising substances that make up a whopping 95% of our universe.

Source: The Conversation

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