Muon g-2 Experiment - Challenging Known Laws of Physics

Why in news?

Newly published results of an international experiment (Muon g–2) suggest the possibility of new physics governing the laws of nature.

What is the recent finding?

- The experiment studied a subatomic particle called the **muon**.
- The results of the experiment do not match the predictions of the Standard Model.
- The Standard Model is that on which all particle physics is based.
- The results instead reconfirm a discrepancy that had been detected in an experiment 20 years previously.

What is the Standard Model?

- The Standard Model is a theory that predicts the behaviour of the building blocks of the universe.
- It lays out the rules for six types of quarks, six leptons, the Higgs boson, three fundamental forces, and how the subatomic particles behave under the influence of electromagnetic forces.
- The muon is one of the leptons. It is similar to the electron, but 200 times larger.
- It is much more unstable, surviving for a fraction of a second.

What is the Muon g–2 experiment about?

- The experiment, called Muon g–2 (g minus two), was conducted at the US Department of Energy's Fermi National Accelerator Laboratory (Fermilab).
- It measured a quantity relating to the muon.
- This followed up a previous experiment at Brookhaven National Laboratory, under the US Department of Energy.
- Concluded in 2001, the Brookhaven experiment came up with results that did not identically match predictions by the Standard Model.
- The Muon g–2 experiment measured this quantity with greater accuracy.
- It sought to find out whether the discrepancy would persist, or whether the new results would be closer to predictions.
- As it turned out, there was a discrepancy again, although smaller.

What was the quantity measured?

- It is called the **g–factor**, a measure that derives from the magnetic properties of the muon.
- As the muon is unstable, scientists study the effect it leaves behind on its surroundings.
- Muons act as if they have a tiny internal magnet.
- In a strong magnetic field, the direction of this magnet "wobbles," just like the axis of a spinning top.
- The rate at which the muon wobbles is described by the g-factor.
- This value is known to be close to 2.
- So scientists measure the deviation from 2; hence the name g–2 (g minus two).

How was it measured?

- The g-factor can be calculated precisely using the Standard Model.
- In the g–2 experiment, scientists measured it with high-precision instruments.
- They generated muons and got them to circulate in a large magnet.
- The muons also interacted with a "quantum foam" of subatomic particles "popping in and out of existence."
- These interactions affect the value of the g-factor, causing the muons to wobble slightly faster or slightly slower.

What do the recent findings mean?

- The results, while diverging from the Standard Model prediction, strongly agree with the Brookhaven results.
- The results from Brookhaven, and now Fermilab, hint at the existence of unknown interactions between the muon and the magnetic field.
- These are interactions that could possibly involve new particles or forces.
- To claim a discovery, scientists require results that diverge from the Standard Model by 5 standard deviations.
- The combined results from Fermilab and Brookhaven diverge by 4.2 standard deviations.
- While this may not be enough, it is very unlikely to be a fluke.
- In all, this is strong evidence that the muon is sensitive to something that is not in our best theory.
- The result thus suggests that there are forms of matter and energy vital to the nature and evolution of the cosmos that are not yet known to science.
- In other words, the physics now known could alone not explain the results measured.

Source: The Indian Express