Dark Matter

For Prelims: Dark Matter, Dark Energy, Universe, Galaxy, Bullet Cluster

For Mains: Dark Matter and Dark Energy

Why in News?

Recently, a highly sensitive experiment named **LUX-ZEPLIN (LZ) has been used to detect dark matter in the universe in the U.S.**

- Earlier, while investigating how the shape of dark matter affects the motion of stars in the centre of some galaxies (stellar bars), **scientists have found that out-of-plane bending can be explained** through dark matter halos in barred galaxies.

What is Dark Matter?

- Dark matter is made up of particles that do not have a charge.
  - So, these particles are “dark”, namely because they do not emit light, which is an electromagnetic phenomenon, and “matter” because they possess mass like normal matter and interact through gravity.
- The **visible universe** we see is the result of various **interactions among the four Fundamental forces** acting upon the particles, namely-
  - **Strong nuclear force**
  - **Weak nuclear force**
  - **Electromagnetic force**
  - **Gravitation**
- Only 5% of the entire visible universe is made up of all matter and the rest of 95% is dark matter and dark energy.
  - So far gravitational force is less understood as its extremely weak force, and that's why it's not easy to detect any particle which interacts with gravitational force.

What is Dark Energy?

- Dark Energy is a theorized type of energy that **exerts a negative, repulsive force, acting in the opposite direction of gravity.**
  - It has been proposed to explain the observed features of distant types of supernovae, which **reveal the universe expanding at an accelerated rate.**
  - Dark Energy, like Dark Matter, is inferred from measurements of gravitational interactions between celestial objects rather than explicitly observed.

What is the difference between Dark Matter and Dark Energy?

- **Dark matter acts as an attractive force**, a kind of cosmic mortar that holds our world together.
  - This is because dark matter interacts with gravity yet does not reflect, absorb, or emit light.

Meanwhile, dark energy is a **repulsive force,** a kind of anti-gravity that **slows down the expansion of the universe.**

- **Dark energy** is by far the most powerful of the two, accounting for **around 68% of the universe's total mass and energy.**
    - Dark matter accounts for 27% of the total. The rest a meagre 5%, is all the ordinary matter we see and interact with on a daily basis.
    - This also helps in **speeding up the universe's expansion.**

What is the Proof of Dark Matter?

- There is **strong indirect evidence**, as reflected in various levels like **distance scales,** for example:
    - For example, as you move from the centre of the galaxy to its periphery, there is a significant disparity between the observed plot of star speeds and their estimated figure.
    - This implies that the galaxy has a significant amount of dark matter.
- Other distance scale evidence:
    - There are **many levels to observe the universe** like the level of **electrons and nuclei of atoms, galaxies, galaxy clusters,** or even larger distances where the entire universe can be mapped and studied.
    - There are **Bullet clusters of galaxies** that are formed through the **merging of two galaxies**, as per scientists their merger could only be explained through the presence of some dark matter.

What are the particles used to observe dark matter?

- **Neutrino** would have been very helpful in detecting dark matter but they are too light and hence would not be useful.
- There are **several other proposed entities** which include the **Z boson's supersymmetric companion**, a particle that **mediates the electro-weak interaction.**
- But still, no proper particle had been found which can interact with gravity and is also detectable using present technology on earth.

UPSC Civil Services Examination Previous Year Question (PYQ)

Q. In the context of modern scientific research, consider the following statements about 'IceCube', a particle detector located at South Pole, which was recently in the news: (2015)

1. It is the world's largest neutrino detector, encompassing a cubic kilometre of ice.
2. It is a powerful telescope to search for dark matter.
3. It is buried deep in the ice

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Ans: (d)

Exp:

- **IceCube Neutrino Observatory is buried deep inside Antarctic ice and is spread over a cubic kilometre. Hence, statements 1 and 3 are correct.**
- **Weakly Interacting Massive Particle (WIMP) dark matter could be gravitationally captured by massive objects like the Sun and accumulate in the core of the Sun.**
- **With such high density of these particles, they annihilate each other at a significant**

rate. The products of this annihilation decay into neutrinos, which could be observed by IceCube as an excess of neutrinos from the direction of the Sun.

- IceCube was built specifically to identify and track high-energy neutrinos. Hence, statement 2 is correct.
- The National Science Foundation (a US agency that supports fundamental research) provided the primary funding for the IceCube Neutrino Observatory, with assistance from partner funding agencies around the world. Therefore, option (d) is the correct answer.

Source: TH