Cosmology

Dark Matter

CONTENT

01

Ordinary Matter
& Dark Matter

Ordinary Matter

- **Ordinary matter** is the stuff that we are made of, protons, neutrons, and electrons.
  Ex :- Stars, Trees, Animals etc.

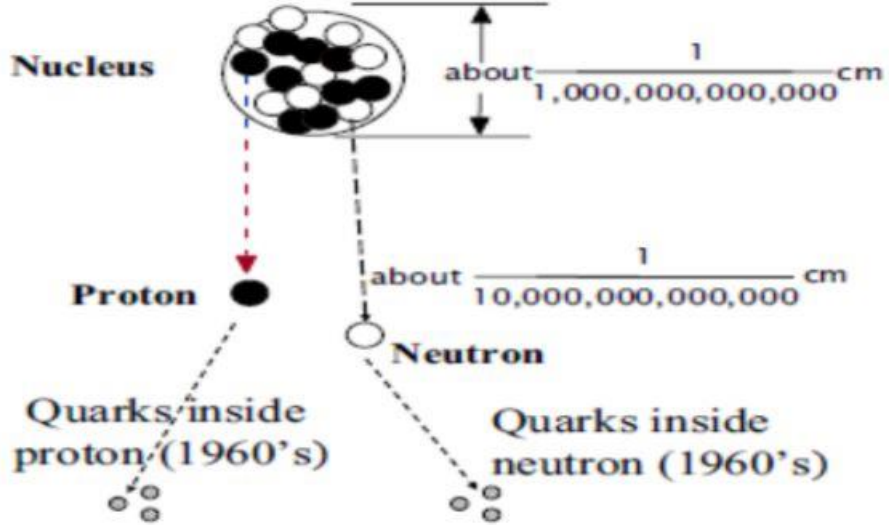
- Everything we can see or detect with telescopes is **ordinary matter**, which scientists call **baryonic matter**.

- All ordinary matter are made up of Elementary Particles.
- The Electron is an elementary particle We can not break it up into smaller parts.

$$M_e = 10^{-27} g$$

- Size less than 10^{-16} cm.

The Proton and Neutron, Unlike the Electron, Are Not Elementary Particles



Quarks are much smaller than the proton or neutron, they may have no size at all.

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- Basically, Dark Matter is matter that we cannot see.
- They neither emit nor reflect any light.

- If we can’t see them, how do we know it exists?

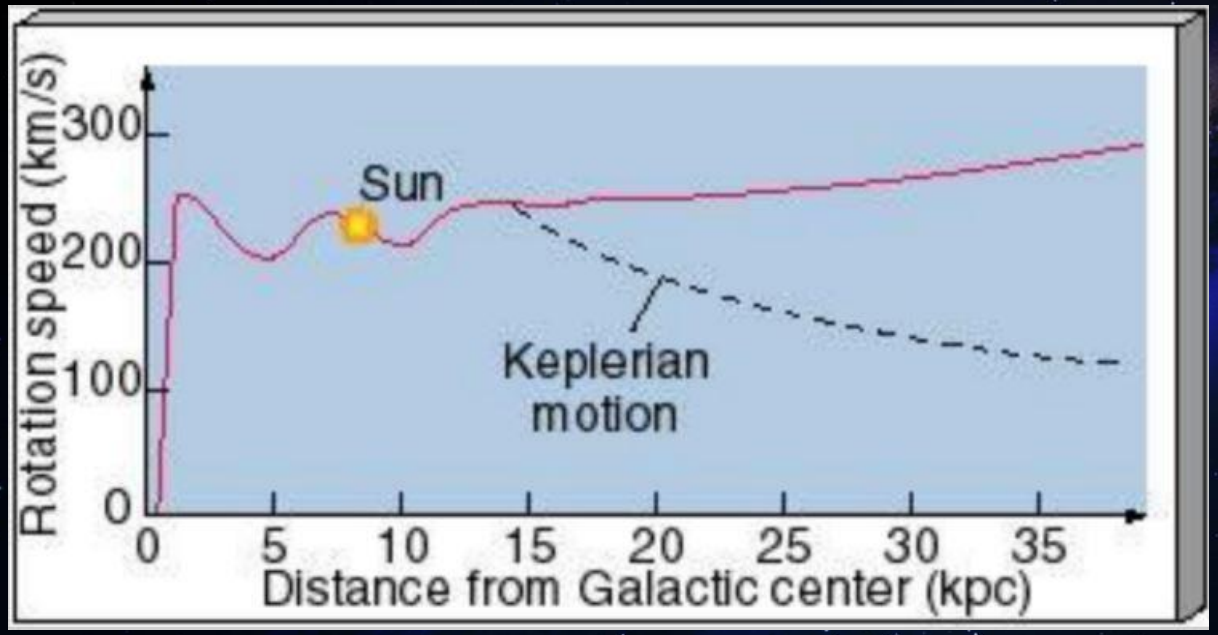
- Scientists can measure dark matter indirectly by observing its gravitational effects in a variety of ways.


02
Is there Dark Matter?

Galaxies Rotate

- Galaxies are collections of billions of stars.
- Most of the light from a galaxy comes from its center.
- This indicated that most of the galaxies stars and most of its mass is concentrated at its center.
- Under this scenario, we should expect the stars in the outer part of the galaxy to rotate about the center, and this is just what we observe.
- But they are not!!!

- If gravity causes galaxies to rotate, as we assume it does, Inner planets should rotate faster and outer planets should rotate slower.
- This is called **Keplerian motion**.
- In galaxies, however, both inner and outer stars rotate at about the same speed.



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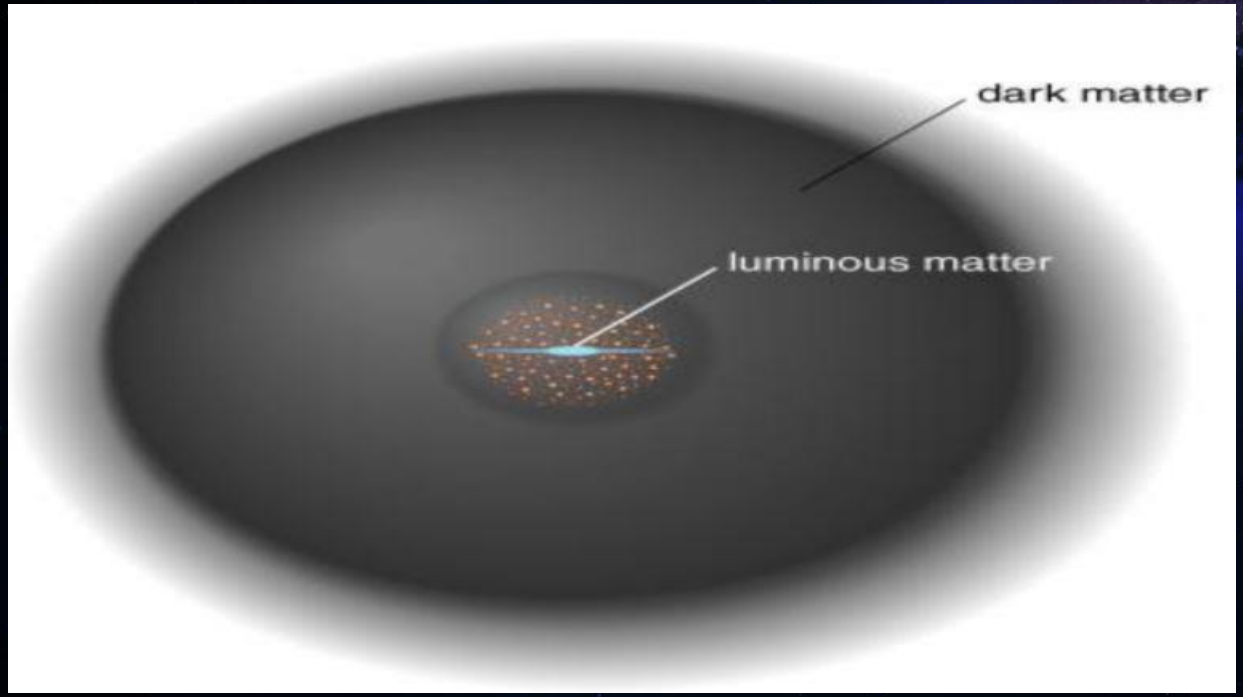
Conclusion

- In order for gravity to cause this type of rotation, each galaxy must be surrounded by a super-massive halo of matter.
- No such halos, however, can be seen. So we conclude that they are made of dark matter.

Assumed distribution of Dark Matter in Solar System



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03

Lensing by Dark Matter

Gravitational Lensing

- As the light emitted by distant galaxies passes by massive objects in the universe, the **gravitational** pull from these objects can distort or bend the light. This is called **gravitational lensing**.

Lensing by Dark Matter

- Sometimes galaxies are lensed by other galaxies. Other times they were lensed by invisible objects – dark matter.
- By measuring the distortion of the galaxies, scientists were able to “weigh” the dark matter.
- They found that it accounts for 90% of the mass of the universe.


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Galaxy Clusters

- Galaxies have been called the atoms of the universe.
- Nearly all the visible matter in the universe is found in galaxies which are distributed throughout space.
- Galaxies are often found in groups called clusters.

- Radio astronomers have found hot gas in the space between galaxies in a cluster. This gas produces a pressure that pushes the galaxies apart.

- The galaxies' mutual gravitational attraction causes them to cling together. The heavier the galaxies, the stronger the gravitational attraction.

- So, are galaxies massive enough to hang together?

How to mass a galaxy?

$$Mass\ of\ a\ galaxy = Number\ of\ stars \times average\ mass\ of\ a\ star$$

$$Number\ of\ stars = \frac{light\ emmited\ by\ a\ galaxy}{light\ emitted\ by\ average\ star}$$

- It turns out that galaxies do not have enough visible mass to stay grouped in clusters.
- The extra mass they need must come from dark matter.

- In the 1930’3 Zwicky showed that the velocity of galaxies would cause a cluster to fall apart unless the galaxies has hidden mass called Dark Matter.

Temperature of Dark Matter

- If the particles that make up dark matter are **small, then dark matter is said to be hot**. If the particles are large, **then it is called cold**.

- Theories with cold dark matter have more success explaining how galaxies formed. Theories with hot dark matter do a better job explaining the origins of clusters and superclusters.

- Recent experiments suggest that dark matter is cold, but some researchers believe that the universe contains a mix of both hot and cold dark matter.

Any Questions?

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Thank You
For Participation

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