Dark Matter

Edern GILLOT & Jingjie YANG

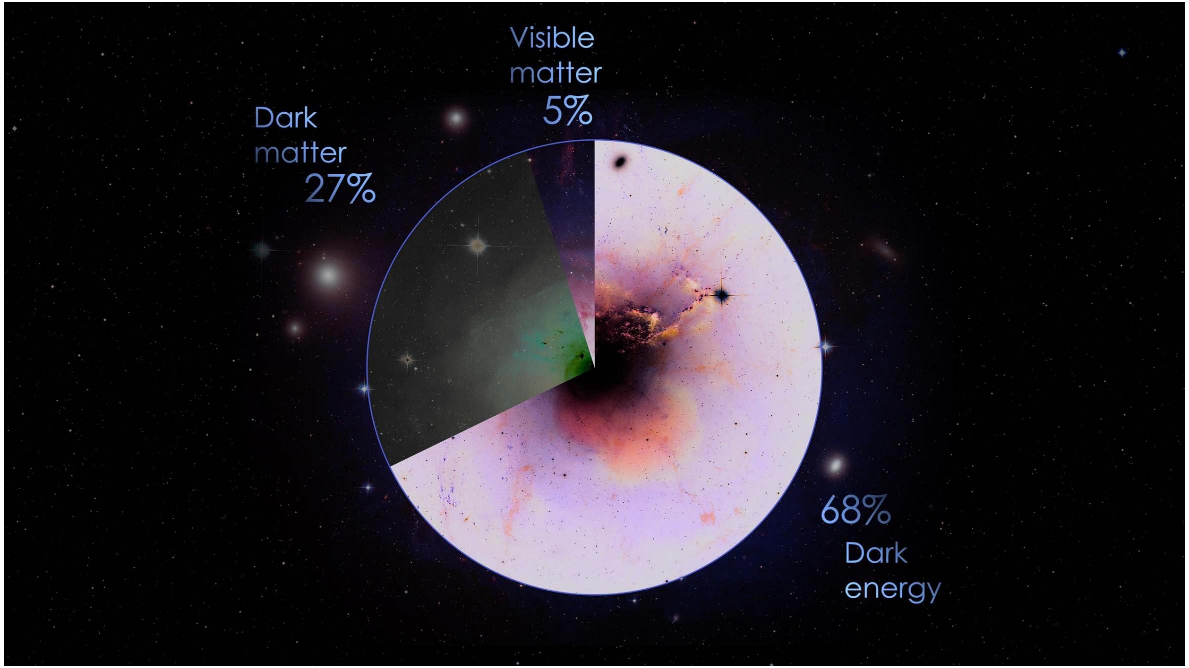
What is dark matter?

Dark matter is an unidentified type of matter made of WIMPs that is predicted to represent 26.8% of the total mass/energy of the universe (the remainder being dark energy, 68.3%, and ordinary matter, 4.9%).

*WIMPs: hypothetical particles that are thought to constitute dark matter.

not to be confused with **dark energy** or **antimatter**!

Content of Universe from NASA



What is it like?

- Dark matter does not interact with any electromagnetic waves, meaning it does not react with light, infrared waves … It is therefore rather transparent than dark.
- It also does not react with ordinary matter; it passes through like a fluid.
- To summarize, it is something heavy, invisible and unreactive whose existence has not been directly proven through observations.

Then…

How did we *“discover”* it?

- At the beginning of the 20th century, the first “sky maps” were made, and scientists discovered that some areas where dark.
- Since there was no apparent reasons for stars not to be evenly spread out, they thought there were *dark stars*.
- Lord Kelvin was the first scientist to “weight” the universe, using the speed of stars and Newtonian mechanics, and found out that there was a big difference between the mass of the universe and the average mass of stars and planets.
- He concluded that most of the stars were actually *dark stars*.

Then…

How did we *“discover”* it?

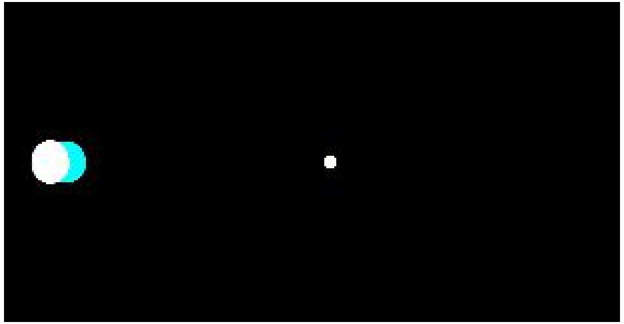
- Fritz Zwicky, a Swiss astronomer, decided to find out if dark matter really existed.
- While studying the attraction of some 800 galaxies on their stars, he found a strange result: in these galaxies, stars should be able to leave the gravitational attraction with a velocity of 80 km/s. However, most stars were moving at a speed of more than 1000 km/s, and did not leave the galaxies.
- He concluded that there was some invisible weight in this galaxies, and that it was at least 4 times heavier than the ordinary matter.

This *invisible weight* in the universe is better known as *dark matter* nowadays.

Observational evidence

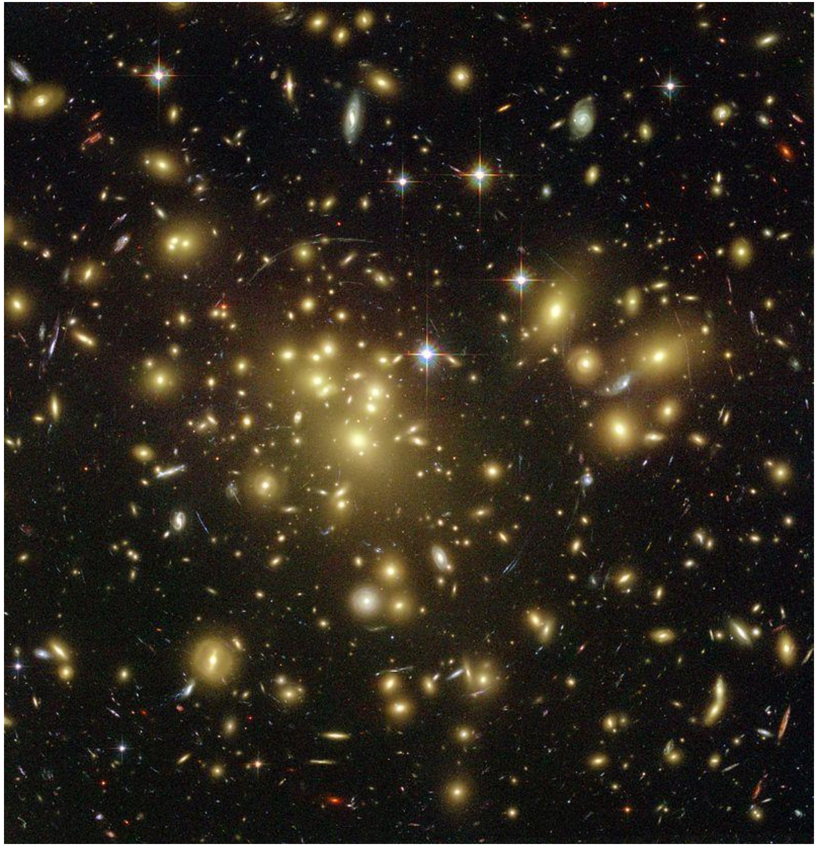
General relativity implies that a massive object should act as a lens, which blends the light from a more distant light source around itself.

- *Weak gravitational lensing*
- *Strong gravitational lensing*

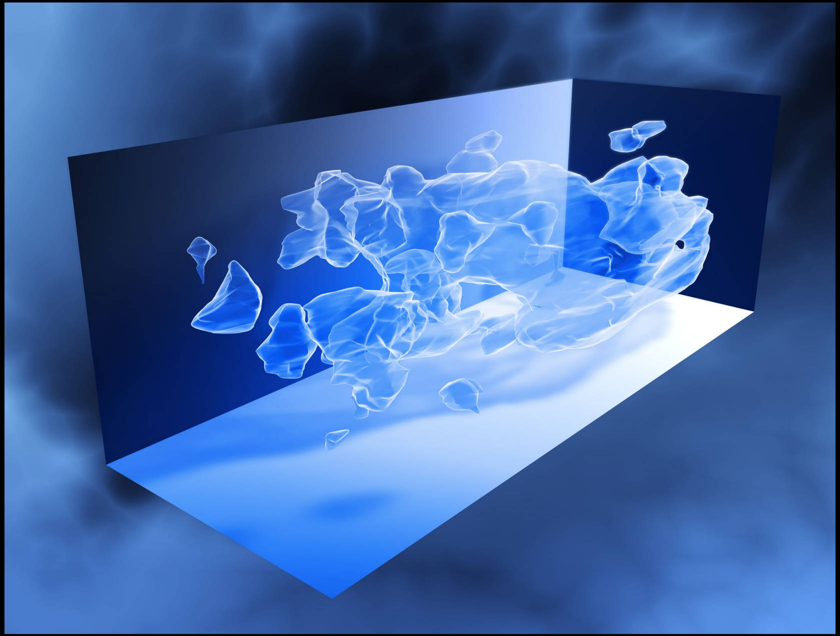


We can also observn it from the galaxy rotation curves.

- Strong gravitational lensing observed from Hubble Space Telescope
- The lensing arcs in the image indicate the presence of *dark matter*



3D map
illustrating the distribution of
dark matter in the universe



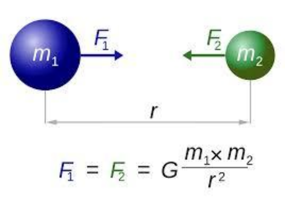
- Determined from measurements of *weak gravitational lensing* by the Hubble Space Telescope
- The axes correspond to sky position (*right ascension* and *declination*) and distance from earth (measured using *cosmological redshift*).
- Dark matter filaments growing clumpier over time, under the pull of gravity

Why is it still *unidentified* or *hypothetical*, then?

Some scientists are still sceptical about the WIMPs not fitting in the “standard model” of the basic particles. They think that instead of creating new things to explain strange events, we should change the old theories, in this case Newton’s classical mechanics.

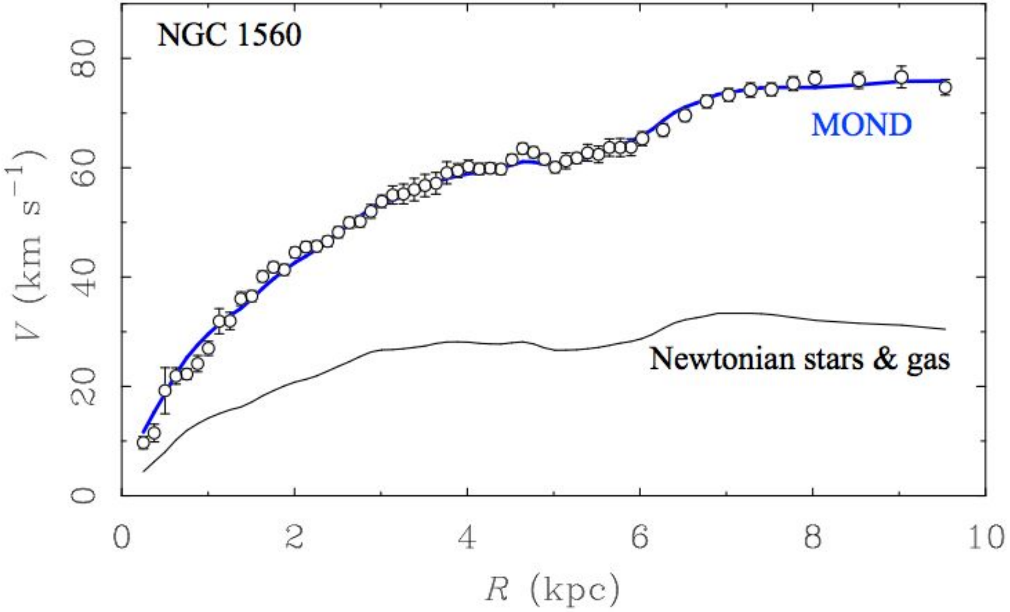
=> **Mo**dified **N**ewtonian **D**ynamics (**MOND**)

MOND

- Newtonian mechanics:
  - **F** = m **a**
  - 

- MOND:
  - gravitational force experienced by a star in outer regions of a galaxy is proportional to a^2
  - **alternatively**

$$F_1 = F_2 = G\,(m_1\, m_2)\,/\,r$$



The rotation curve of NGC 1560 (Begeman et al. 1991; Gentile et al. 2010). The black line shows the expected contribution of stars and gas ($f_g = 3/4$). The blue line is the MOND fit.

Stacy McGaugh (2011)

Bibliography

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The End.

Thank you for listening!