

Title: Physics & Universe: Missing matter and energy.

Venue: Spica Science Center, Thalassery, Kerala 670107, India.

Date: 2022 Jul 13

Speakers: Prachi Parashar and K. V. Shajesh

① Classifications

→ solid, liquid, gas
plasma, superfluid, Bose-Einstein condensate

→ Matter and Energy

Examples

Atoms (periodic table)
particles (standard model)

localized in space

Examples

Magnetic field
Gravitational field
Electrostatic field (chemical bonds)
(gasoline)

not localized in space.

Open Question: Is 'thought' come under matter or energy?

② What is missing?

Extrapolation of multiple experiments (Theory)

32%

Direct observations and understanding (Experiments)

2% (✓) + 3% (WMIM) + 27% dark matter.

Matter

68%

Energy

1% (✓) + dark energy (67%)

→ consistency between interpretations of multiple experiments requires the presence of dark

(missing) matter and energy.

→ It might be missing because we might be interpreting (for example adding and subtracting energies) incorrectly.

③ Relevant experiments:

- Gravitational lensing (dark matter)
- Acceleration of Hubble expansion (dark energy)
- Galaxy rotation curves (dark matter)
- Cosmic microwave background (dark matter and energy)

④ Gravitational lensing

→ Newton's law of gravitation

→ Can mass be zero? Can it be negative?
↓
light leads to logical inconsistency

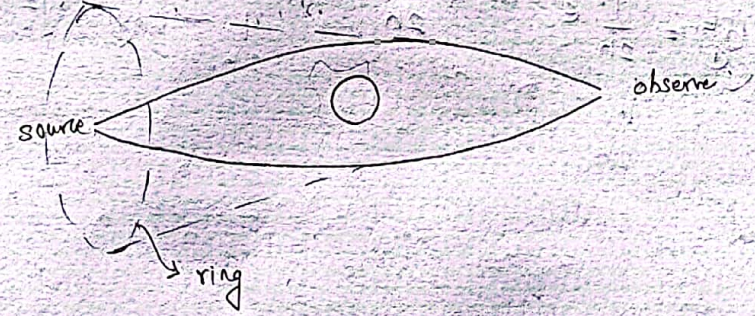
→ $E = mc^2$ (equivalence principle)

→ bending of light (during solar eclipse, 1918)
star

→ Quasars (very bright and very far)

Galaxy clusters (very heavy)

→ Gravitational lensing



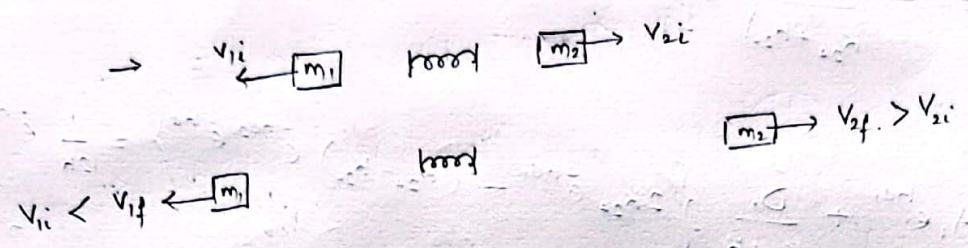
→ These rings are visible in the image released by Webb space telescope on July 11.

→ Radius of rings is related to mass. We are missing matter.

→ Photon (light) presumably does not interact with dark matter, but it interacts with the gravity of dark matter.

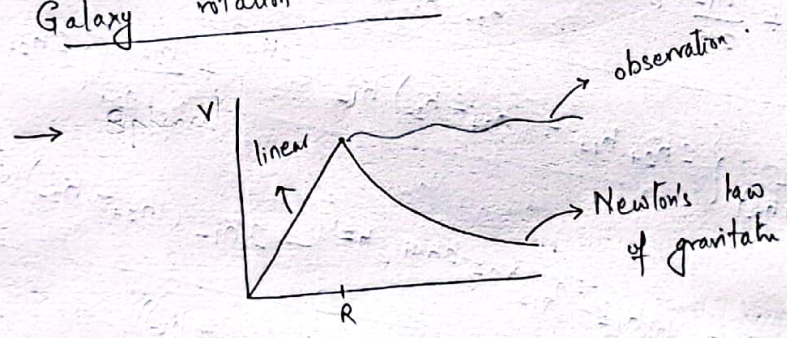
⑤ Acceleration of Hubble expansion of universe

- Hubble expansion.
- Dominant force at cosmological scale is gravity.



→ There is a missing 'field' causing the matter to repel. Recall mass cannot be negative.

⑥ Galaxy rotation curves



$$\frac{dv^2}{r} = \frac{GM}{r^2}$$

$$v = \sqrt{\frac{GM}{r}}$$

$\left. \begin{matrix} r \text{ inside} \\ \frac{1}{r} \text{ outside} \end{matrix} \right\}$

$$M \propto r^3 \text{ (sphere with uniform density).}$$

- inside velocities match, outside do not.
- Missing matter in the outer regions of the galaxy.

⑦ Cosmic microwave background radiation

- Big bang
- dominated by energy
- cools under expansion
- Hydrogen atom is formed (recombination)
- Energy spectrum
- before recombination, radiation of any frequency could collide (interact) with plasma constituents, after recombination, radiate with energy less than 13.6 eV could not interact. They are free. This is CMB.