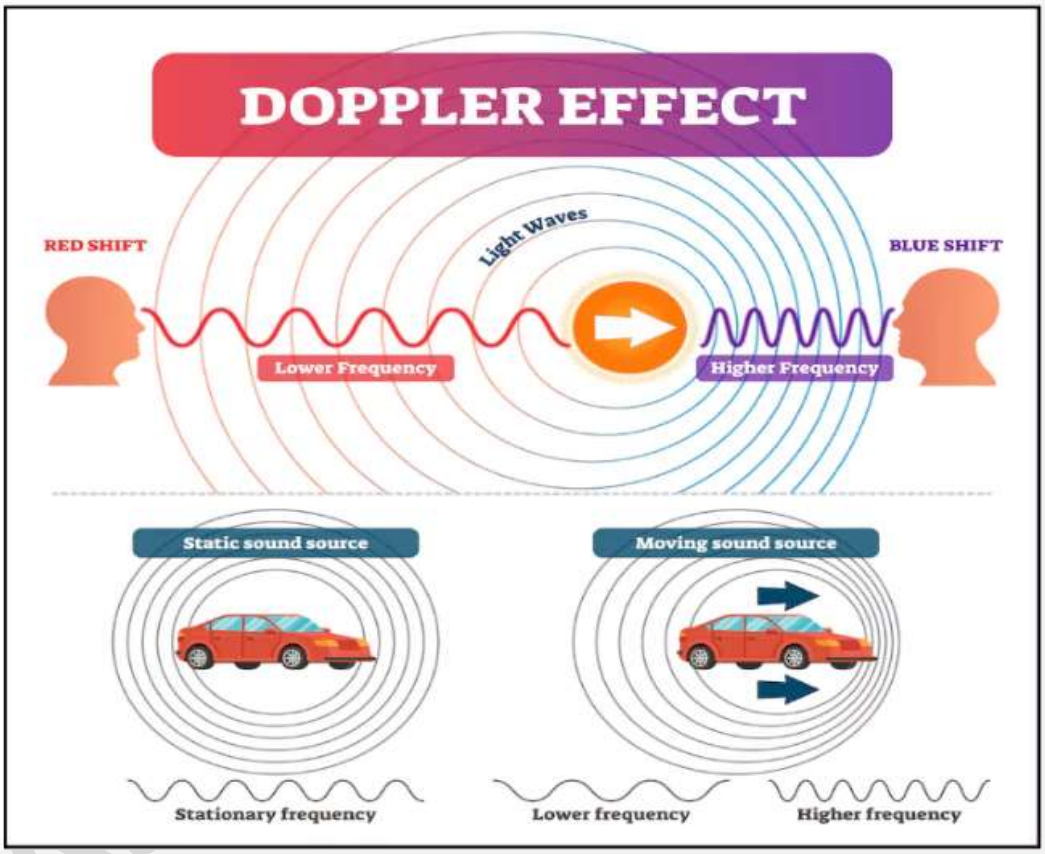
Gravitational Waves, Doppler Shift & Cosmic Microwave Background

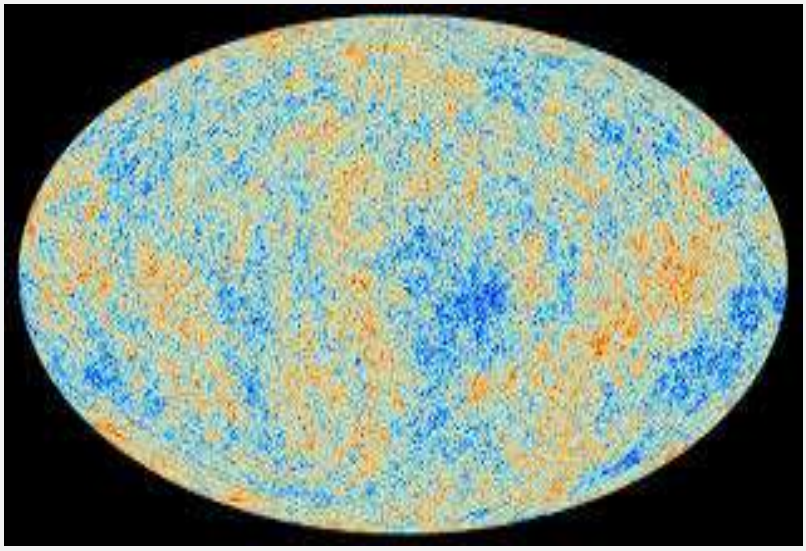
1. Doppler Shift (Redshift & Blueshift)

- Redshift/Blueshift = change in light wavelength as celestial objects move away or towards us.
- **Edwin Hubble** first described galactic redshift → proved that **the universe is expanding**.
- **Hubble's Law:** The farther a galaxy → faster it moves away → shows **accelerating expansion of the Universe**.



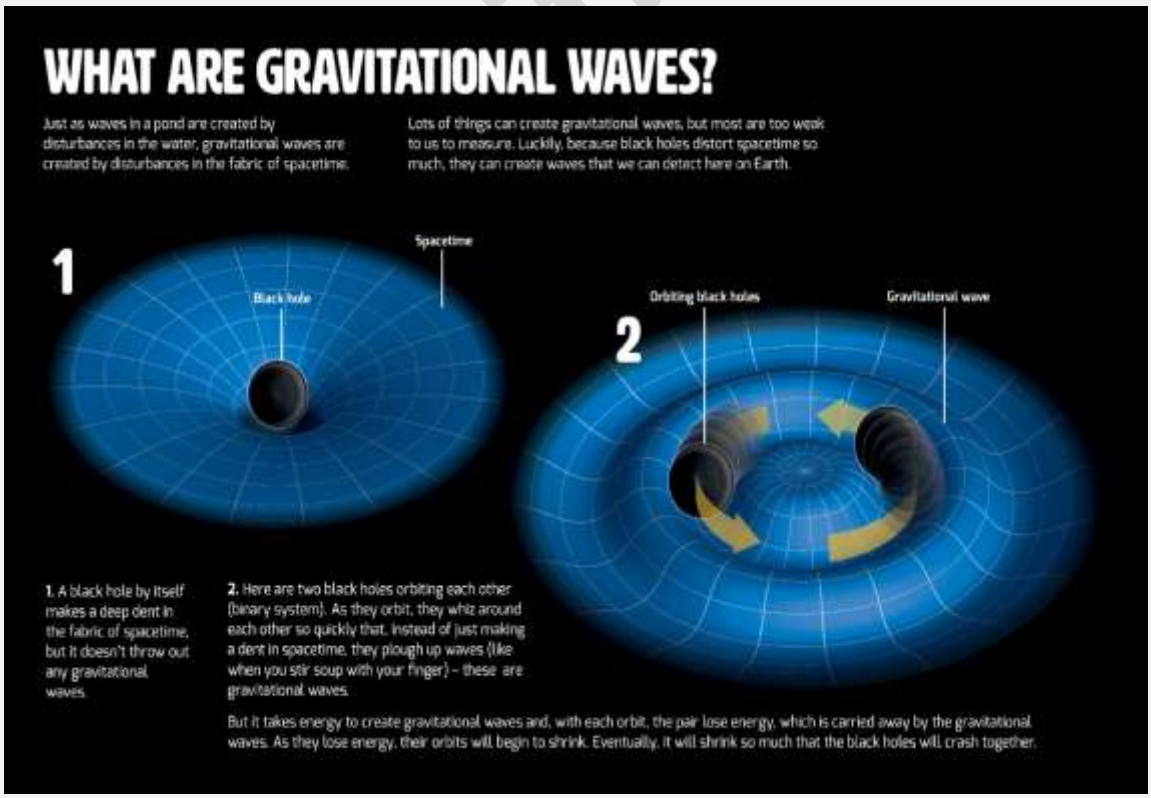
2. Cosmic Microwave Background (CMB)

- With optical telescopes → space between galaxies is dark.
- Radio telescopes detect a faint glow → strongest in the **microwave** region → called **Cosmic Microwave Background (CMB)**.
- CMB = **relic radiation** from the Big Bang; the oldest observable light in the Universe.
- Present in all directions; key proof for **Big Bang Theory** & **accelerating expansion**.



3. Gravitational Waves

- Predicted by **Einstein (1916)** in **General Relativity**.
- "Ripples" in **spacetime** are produced by massive accelerating bodies (e.g., merging black holes, neutron stars).
- Travel at the **speed of light**, carrying information about the origin.
- **LIGO (USA), 2015**: first physical detection of two merging black holes, 1.3 billion light-years away.
- Waves reaching Earth are extremely faint (billions of times smaller).

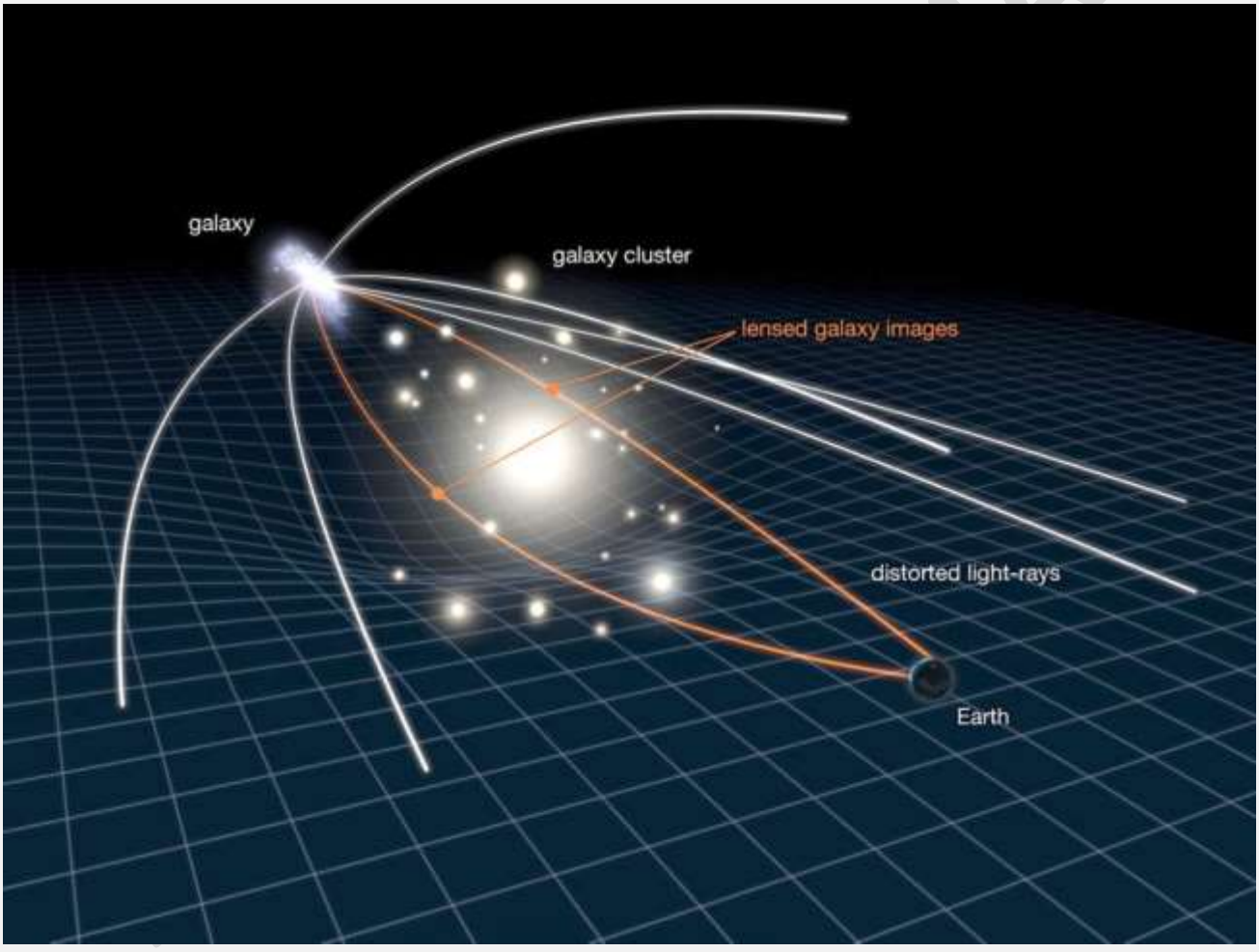


4. Einstein's Relativity & Spacetime

- **Special Relativity (1905):**
  - Laws of physics are identical for all non-accelerating observers.
  - Speed of light constant → space and time merge into **spacetime**.
- **General Relativity (1915):**
  - Massive objects **distort spacetime** → felt as **gravity**.
  - Evidence: **Gravitational lensing**, **gravitational waves**.

5. Gravitational Lensing

- Light bends around massive objects (e.g., black holes).
- Acts like a "lens" magnifying objects behind it.



6. Importance of Gravitational Waves

- "Standard sirens" for measuring the **Hubble Constant** (rate of universal expansion).
- Velocity estimated from light flash (from merging bodies).
- Distance estimated from gravitational waves.
- Together → more precise, independent measurement of the Universe's expansion rate.

MCQs:

1. With reference to Cosmic Microwave Background (CMB) radiation, consider the following statements:

1. It is strongest in the infrared region of the electromagnetic spectrum.
2. It is considered the oldest observable light in the Universe.
3. Its discovery provided evidence supporting the Big Bang Theory.

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

Answer: B

2. Which of the following best explains cosmological redshift?

A. Light appears red because of the presence of dust clouds between galaxies.
B. Light from galaxies shifts to longer wavelengths because they are moving away from us.
C. Stars emit more red light in the final stages of their life cycle.
D. The gravitational pull of black holes converts blue light into red light.

Answer: B