New Source of Gravitational Waves Discovered

Why in News

Recently, **LIGO Scientific Collaboration (LSC)** has made the **discovery of gravitational waves from a pair of neutron star-black hole (NS-BH) mergers.**

- The reverberations from these two objects were picked up using a **global network of gravitational wave detectors**, the most sensitive scientific instruments ever built.
- Until now, the **LIGO-Virgo Collaboration (LVC)** was only able to observe collisions between pairs of black holes or neutron stars. The **NS-BH merger is a hybrid collision.**

Black Hole

- A black hole is a **place in space where gravity pulls so much that even light can not get out.** The gravity is so strong because matter has been squeezed into a tiny space.
- **Gravitational waves are created** when two black holes orbit each other and merge.

Neutron Stars

- Neutron stars c**omprise one of the possible evolutionary end-points of** high mass stars**.**
- Once the core of the star has completely burned to iron, energy production stops and the core rapidly collapses, squeezing electrons and protons together to form neutrons and neutrinos.
- A **star supported by neutron degeneracy pressure is known as a 'neutron star',** which may be seen as a pulsar if its magnetic field is favourably aligned with its spin axis.

Key Points:

- **About the Gravitational Waves:**
    - These are **invisible ripples in space** that form when:
        - A star explodes in a **supernova**.
        - Two big stars orbit each other.
        - Two **black holes** merge.
        - Neutron star-Black hole (NS-BH) merges.
    - They **travel at the speed of light** (1,86,000 miles per second) and squeeze and stretch anything in their path.
        - As a gravitational wave travels through space-time, it causes it to stretch in one direction and compress in the other.
        - Any object that occupies that region of space-time also stretches and compresses as the wave passes over them, though very slightly, which can only be detected by specialized devices like LIGO.
    - **Theory and Discovery:**

        - These were proposed by **Albert Einstein in his General Theory of Relativity**, over a century ago.
        - However, the first **gravitational wave** was actually detected by LIGO only in 2015.
- **Detection Technique:**
    - As the **two compact and massive bodies orbit around each other**, they come closer, and **finally merge, due to the energy lost in the form of gravitational waves.**
    - The Gravitational Waves signals are buried deep inside a lot of background noise. To search for the signals, scientists use a **method called matched filtering.**
    - In this method, **various expected gravitational waveforms predicted by Einstein's theory of relativity, are compared with the different chunks of data** to produce a quantity that signifies how well the signal in the data (if any) matches with any one of the waveforms.
    - Whenever this match (in technical terms **"signal-to-noise ratio" or SNR) is significant (larger than 8), an event is said to be detected.**
    - **Observing an event in multiple detectors** separated by thousands of kilometers almost simultaneously gives scientists increased confidence that the signal is of astrophysical origin.
- **Importance of Discovery:**
    - **A neutron star has a surface** and black hole does not. **A neutron star is about 1.4-2 times the mass of the sun** while the other black hole is much more massive. **Widely unequal mergers** have very interesting effects that can be detected.
        - Inferring from data as to how often they merge **will also give us clues about their origin and how they were formed.**
    - These observations **help us understand the formation and relative abundance of such binaries.**
        - **Neutron stars are the densest objects in the Universe**, so these findings can also **help us understand the behaviour of matter at extreme densities.**
        - **Neutron stars are also the most precise 'clocks' in the Universe**, if they emit extremely periodic pulses.
        - The discovery of pulsars going around Black Holes **could help scientists probe effects under extreme gravity.**
- **LIGO Scientific Collaboration (LSC):**
    - LSC was **founded in 1997** and currently made up of more than 1000 scientists from over 100 institutions and 18 countries worldwide.
    - It is a **group of scientists** focused on the **direct detection of gravitational waves**, using them to explore the fundamental physics of gravity, and developing the emerging field of gravitational wave science as a tool of astronomical discovery.
    - LIGO Observatories**:** The LSC carries out the science of the **LIGO Observatories**, located in **Hanford, Washington** and **Livingston, Louisiana** as well as that of the GEO600 detector in Hannover, Germany.
    - **Other Observatories:**
        - **VIRGO:** Virgo is located **near Pisa in Italy.** The Virgo Collaboration is currently composed of approximately 650 members from 119 institutions in 14 different countries including Belgium, France, Germany, Hungary, Italy, the Netherlands, Poland, and Spain.
        - **The Kamioka Gravitational Wave Detector (KAGRA):** The KAGRA detector is **located in Kamioka, Gifu, Japan.** The host institute is the Institute of Cosmic Ray Researches (ICRR) at the University of Tokyo.
            - This interferometer is underground and uses cryogenic mirrors. It has 3 km arms.

LIGO-India Project

- The **LIGO-India observatory** is scheduled for completion in 2024, and will be built in the **Hingoli District of Maharashtra.**
- LIGO India is a planned **advanced gravitational-wave observatory** to be located in India as part of the worldwide network.
    - The LIGO project operates three gravitational-wave (GW) detectors.
    - Two are at Hanford in the State of Washington, north-western USA, and one is at Livingston in Louisiana, south-eastern USA.
- The LIGO-India project is an **international collaboration between** the LIGO Laboratory and three lead institutions in the LIGO-India consortium: **Institute of Plasma Research, Gandhinagar; IUCAA, Pune;** and **Raja Ramanna Centre for Advanced Technology, Indore.**
    - It will significantly improve the sky localisation of these events.
    - This increases the chance of observation of these distant sources using electromagnetic telescopes, which will, in turn, give us a more precise measurement of how fast the universe is expanding.

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