New source of gravitational waves discovered

July 3, 2021

In news

Recently, the scientists have for the first time detected gravitational waves ripples in the fabric of space-time produced by the collision of a neutron star and a black hole

Key points

- The discovery of gravitational waves from a pair of neutron star-black hole (NS-BH) mergers was published in the Astrophysical Journal.
- Until now, the LIGO-Virgo collaboration (LVC) of gravitational waves detectors has only been able to observe collisions between pairs of black holes or neutron stars.
- For the first time, in January 2020, the network of detectors made the discovery of gravitational waves from a pair of NS-BH mergers.

Its significance to science world

- There is a lot of interesting science that can be learnt from this. For instance, 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.
- 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.

- 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.
- Both of these events occurred 1 billion light years away.
- As the gravitational waves also travel with the speed of light, this means that they observed mergers that happened ~1 billion years ago well before life appeared on earth!

What are Gravitational waves?

- Gravitational waves are ‘ripples’ in the fabric of space-time caused by some of the most violent and energetic processes in the Universe.
- Albert Einstein predicted the existence of gravitational waves in 1916 in his general theory of relativity.
- In 2015, LIGO physically sensed the distortions in space-time caused by passing gravitational waves generated by two colliding black holes nearly 1.3 billion light years away.

The strongest gravitational waves are produced by catastrophic events such as

- Colliding black holes
- The collapse of stellar cores (supernovae)
- Coalescing neutron stars or white dwarf stars
- The slightly wobbly rotation of neutron stars that are not perfect spheres

- Possibly the remnants of gravitational radiation created by the birth of the Universe

The technique behind the detection

- The technique used here to detect the signal is called matched filtering.
- This was also used for the first discovery of gravitational waves.
- Basically, Scientists have been detecting binary black hole mergers and binary neutron star mergers and this is a hybrid collision.
- 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 matched filtering, 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, which is the case for both events.

How to confirm NS-BH mergers?

Using **Parameter Estimation tools**, scientists find the probable masses, spins, distances, locations of these mergers from the data.

Laser Interferometer Gravitational-wave Observatory (LIGO)

- LIGO is the world's largest gravitational wave observatory and a marvel of engineering.
- Comprising two enormous laser interferometers located thousands of kms apart, LIGO exploits the physical properties of light and of space itself to detect and understand the origins of gravitational waves.

VIRGO

Virgo is a giant laser interferometer designed to detect gravitational waves.

Virgo has been designed and built by a collaboration of

- The French Centre National de la Recherche Scientifique (CNRS)
- The Italian Istituto Nazionale di Fisica Nucleare (INFN)

Note: LIGO and VIRGO announce the detection of a black hole binary merger from June 8, 2017.

Laser Interferometer Gravitational-wave Observatory, India (LIGO-India).

LIGO-India is a collaboration between the LIGO Laboratory (operated by Caltech and MIT) and three Institutes in India: the Raja Ramanna Center for Advanced Technology (RRCAT, in Indore), the Institute for Plasma Research (IPR in Ahmedabad), and the Inter-University Centre for Astronomy and Astrophysics (IUCAA, in Pune).

LIGO- India is a planned advanced gravitational-wave observatory to be located in India as part of the worldwide network, whose concept proposal is now under active consideration in India and the USA.