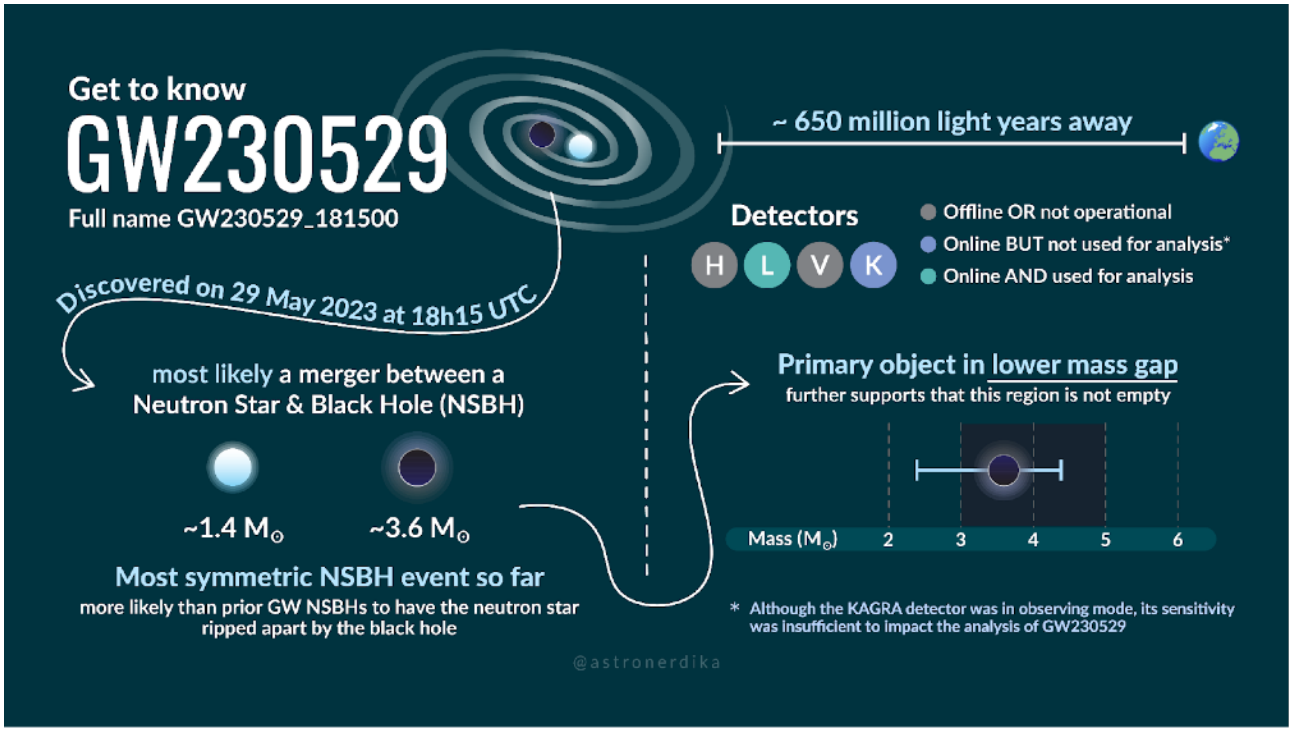
Mystery Compact Object colliding with a Neutron Star discovered in Gravitational Waves

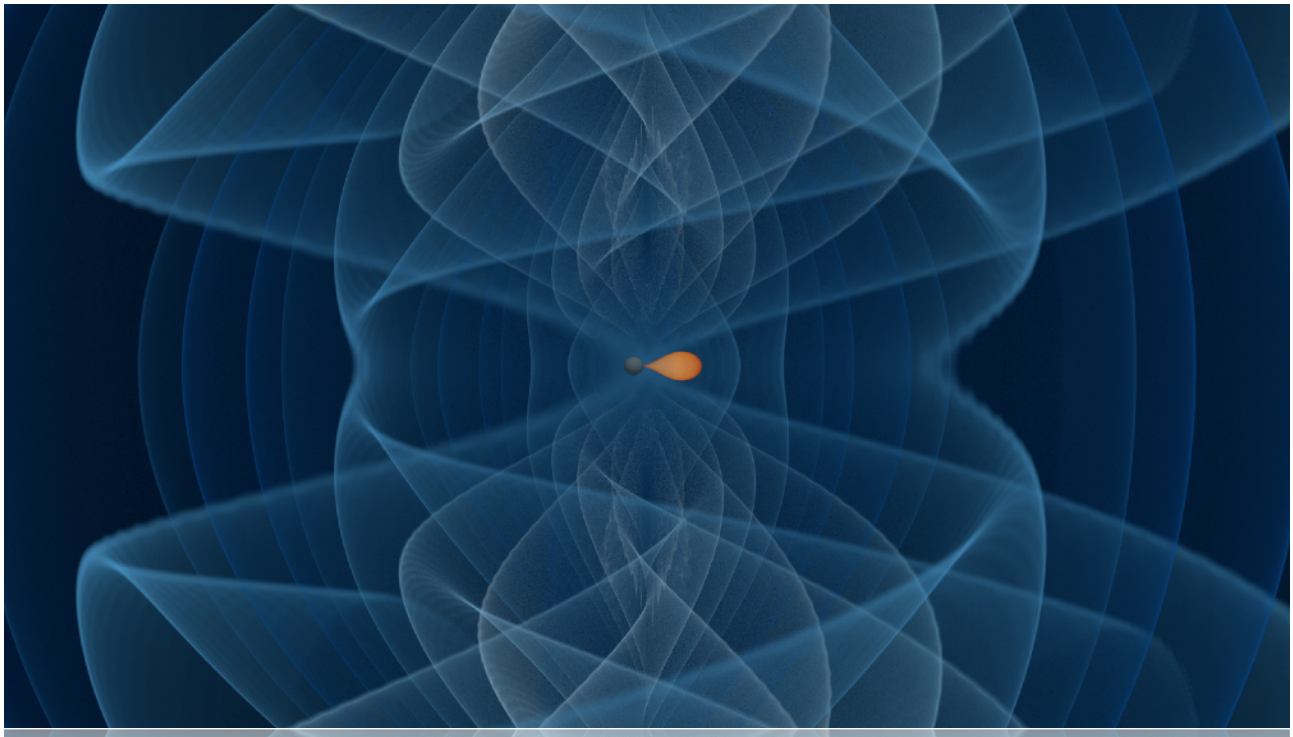
The international network of Gravitational Wave (GW) observatories announced the discovery of an exceptional event this week. The event is named GW230529, as it was detected during the first week of the current observing run on May 29 2023 by the LIGO Livingston Observatory in the U.S. The signal resulted from the collision of a neutron star and another compact object. The mass of this mystery object falls within a possible mass-gap between the heaviest known neutron stars and the lightest black holes. The gravitational-wave signal alone cannot reveal the nature of this object. Future detections of similar events, especially those accompanied by bursts of electromagnetic radiation, could hold the key to solving this cosmic mystery.



Key facts about the event GW230529 (credit: Shanika Galaudage)

Neutron stars and black holes are ultradense compact objects (weighing several solar-masses and measuring a few km across) left behind when massive stars die. Previous observations of neutron stars and black holes in our galaxy with ordinary telescopes suggested the existence of a “mass-gap” that separates the two populations of compact objects. But the direct detection of gravitational waves have now made it possible to probe more such compact stars. GW230529 is an example of a collision of a neutron star and an object in the “mass-gap”. Unlike past GW events, we have high confidence that the heavier of the two compact objects in GW230529 is below the upper edge of the "mass gap" (below 5 times the mass of our sun).

"This unique system with the primary object in the lower mass-gap challenges the stellar evolution models and the compact binary formation channels," says Archana Pai, professor at IIT Bombay and PI of LIGO India Scientific Collaboration (LISC).



Still from an animation depicting the collision and merger of a black hole (in gray) with a neutron star (in orange), accompanied by gravitational waves in blue. (credit: I. Markin (Potsdam University), T. Dietrich (Potsdam University and Max Planck Institute for Gravitational Physics), H. Pfeiffer, A. Buonanno (Max Planck Institute for Gravitational Physics)

Celebrated physicist Albert Einstein predicted more than a hundred years ago that massive cosmic objects strongly distort space-time that they are embedded in, and any disturbance, such as a collision of such objects, could trigger an emission of tiny ripples in the fabric of space-time, called gravitational waves. These elusive waves carry information about the properties of the compact star. GW230529 is not the first compact object to be found in the “mass-gap”. In the previous observing run, LVK collaboration also found the event GW190814, reported as a collision between a massive black-hole with another unknown compact object in the mass-gap.

Of all the neutron star-black hole mergers observed to date, GW230529 has the least difference between the masses of the colliding objects. This observation suggests that future observations of similar systems may be more common than researchers had previously thought. Systems like GW230529 have a greater chance of producing an electromagnetic counterpart as the black hole is not massive enough to swallow the neutron star before it is ripped apart, so although this particular event was observed only in gravitational waves, it increases the expectation that more such events will also be observed with electromagnetic waves in the future. It is for the precise localization of such events that LIGO-India is going to play an important role once it is operational.

"Understanding the precise astrophysical mechanisms by which these mystery compact objects form will be an exciting line of research. As we detect more of these binaries in the future, some of them hopefully with electromagnetic counterparts, we may be able to crack the mystery," says K. G. Arun, professor at the Chennai Mathematical Institute and a member of the LISC.