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Extended Abstract

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Mergers of compact objects concordant with gravitational-wave events

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Recently several gravitational wave detections have shown evidence for compact object mergers. Three of gravitational waves are sourced by a black hole (BH)-BH mergers more massive than 30 solar mass and one is by neutron star (NS)-NS mergers. It is challenging to explain a high rate of such massive BH mergers, whose progenitors would be very metal-poor stars. Further, existing astrophysical models for neutron star mergers typically predict a lower merger rate than the observed rate. Hence the astrophysical origin of merging binaries is not well understood. One of the most plausible environments for massive BH mergers is galactic nuclei. Since galactic nucleus has a very dense stellar component, frequent two and three body interaction and resonant relaxation of the stellar component work for formation and evolution of binaries. Further, inactive phase, dense gas also plays a role in the formation and evolution. We found binary hardening in active galactic nuclei is faster than binary disruption when gas effects are considered. Then the merger rate in the galactic nucleus is increased significantly. We also have proposed a new channel for mergers of compact objects. We focus on the environments that stellar envelope expands due to a weak failed supernova explosion, neutrino mass loss, core disturbance or envelope instability. In such situations binaries are hardened by ambient gas as shown by density map in Image. Because of a low kick velocity and mergers from large separations, this pathway can be a major pathway for NS-NS mergers. In this talk, I introduce major pathways for compact object mergers and discuss observational differences between each model

More than 50 gravitational-wave events have been detected, emitted by the inspiral and merger of compact objects (i.e., neutron stars and black holes) in binary systems. The gravitational-wave event GW170817 was emitted by a binary neutron star merger 40 million parsecs from Earth. The collision also generated a highly energetic flash of gamma rays, which yielded the first multimessenger observation of a gravitational-wave source. These measurements showed that binary neutron star mergers are the progenitors of at least some gamma-ray bursts, confirming a hypothesis made decades earlier. The discovery of electromagnetic emission at lower energies—from x-ray to radio frequencies—has enabled an extensive study of the source and has shown that binary neutron stars can produce many of the elements heavier than iron.

Dozens of gravitational-wave events have been detected from binary black hole mergers. These have shown that the mass distributions of black holes cannot be a single power law, like the mass distribution of the parent stars. Instead, the preferred model has both a power law component and a Gaussian component, centered at 33.5+4.5−5.5 solar masses. This could indicate that gravitational-wave events arise from more than one astrophysical population. This two-component distribution might be a result of the physical processes involved in the explosions of stars of more than ~100 solar masses, which predict a maximum mass for black holes formed in supernovae

Existing gravitational-wave detectors are undergoing upgrades to their sensitivities, and additional detectors are under construction. These are expected to detect multiple neutron star binary mergers and ~100 binary black hole mergers every year. The growing dataset should provide a better understanding of the astrophysical formation pathways of compact objects over the mass range between ~1 and a few hundred solar masses. Independent measurements using pulsar timing arrays could detect the lower-frequency gravitational waves produced by supermassive black hole binaries, which are expected to form when galaxies merge.

Gravitational waves are ripples in spacetime generated by the acceleration of astrophysical objects; a direct consequence of general relativity, they were first directly observed in 2015. Here, I review the first 5 years of gravitational-wave detections. More than 50 gravitational-wave events have been found, emitted by pairs of merging compact objects such as neutron stars and black holes. These signals yield insights into the formation of compact objects and their progenitor stars, enable stringent tests of general relativity, and constrain the behavior of matter at densities higher than that of an atomic nucleus. Mergers that emit both gravitational and electromagnetic waves probe the formation of short gamma-ray bursts and the nucleosynthesis of heavy elements, and they measure the local expansion rate of the Universe.

A binary neutron star merger was detected in both gravitational waves and electromagnetic radiation, a form of multi-messenger astrophysics. Tests of general relativity and cosmological measurements have also been performed.

Bottom Note: *This work is partly presented at 4th International Conference on Astrophysics and Particle Physics*