GW190425: the merger of a compact binary with total mass of about 3.4 Msun

Today January 6th 2020, the LIGO Scientific Collaboration and the Virgo Collaboration announce GW190425, the first detection of gravitational waves from the third observation period, O3.

On April the 25th, 2019, the network of gravitational-wave (GW) detectors formed by the European Advanced Virgo, in Italy, and the two Advanced LIGO, in the US, detected a signal, named GW190425. This is the second observation of a gravitational-wave signal consistent with the merger of a binary-neutron-star (BNS) system after GW170817. GW190425 was detected at 08:18:05 UTC; about 40 minutes later the LIGO Scientific Collaboration and the Virgo Collaboration sent an alert to trigger follow-up telescope observations.

“We have detected a second event consistent with a binary neutron star (BNS) system and this is an important confirmation of GW170817, the event that started multi-messenger astronomy two years ago. The total mass is larger than any known BNS, and this has interesting astrophysical implications for the formation of this system,” says Jo van den Brand, Virgo Spokesperson and professor at Maastricht University, Nikhef and VU University Amsterdam in the Netherlands. "What's surprising is that the combined mass of this binary is much higher than what was expected," adds Ben Farr, a LIGO team member based at the University of Oregon, USA.

The source of GW190425 is estimated to be at a distance of 500 million light years from the Earth. It is localized in the sky within an area about 200 times broader than was the case for the BNS observed by LIGO and Virgo in 2017, the famous GW170817, which gave birth to multi-messenger astrophysics. This is due to the fact that the GW190425 signal was only detected with a high signal-to-noise ratio by LIGO at Livingston. At the time, the LIGO Hanford detector was temporarily offline, while the signal reconstructed in Virgo was weak, because of a difference in sensitivity with respect to LIGO Livingston and because of the likely direction of origin of the signal: a region of the sky in which Virgo was less sensitive at the time the signal arrived on Earth. This less precise sky localisation makes it very difficult to search for counterparts (electromagnetic signals, neutrinos or charged particles). Indeed, unlike GW170817, no such counterpart has been found to date. Nevertheless, Virgo data have been subsequently used to improve the characterisation of the astrophysical system.

“Despite the differences of the signal-to-noise ratio coming from the different interferometers, due to the known differences in range and angular sensitivities, the joint detection stresses once more the importance of the international network”, says Stavros Katsanevas, Director of the European Gravitational Observatory (EGO) which hosts Advanced Virgo in Italy, near Pisa.

There are a few explanations for the origin of GW190425. The most likely is the merger of a BNS system. Alternatively, it might have been produced by the merger of a system with a black hole (BH) as one or both components, even if light BHs in the mass-range consistent with GW190425 have not been observed. Yet, on the basis solely of GW data, these exotic scenarios cannot be ruled out. The estimated total mass of the compact binary is 3.4 times the mass of the Sun. Under the hypothesis that GW190425 originated from the merger of a BNS system, the latter would have been considerably different to all known BNS in our galaxy, the total mass range of which is between 2.5 and 2.9 times the mass of the Sun. This indicates that the NS system that originated GW190425 may have formed differently than known galactic BNSs.

“After the surprise of the initial results”, says Alessandro Nagar of the Istituto Nazionale di Fisica Nucleare (INFN) of Turin, Italy, “we carefully analysed the data with robust analytical models of gravitational waves emitted by two neutron stars based on Einstein’s general relativity. After months of work, we have finally reached a reliable understanding of this event. Although predicted theoretically, heavy binary systems like those that might have originated GW190425 are invisible through electromagnetic observations.”

“While we did not observe the object formed by the coalescence, our computer simulations based on general relativity predict that the probability that a BH is formed promptly after the merger is high, about 96%”, says Sebastiano Bernuzzi of the University of Jena, Germany.

GW190425 was recognised as an interesting candidate event soon after the detection. It was issued as a public alert by LIGO-Virgo, as is done for all candidate gravitational-wave events during the underway third observation period, O3. Public alerts are freely accessible at the Gravitational-Wave Candidate Event Database.

“The LIGO and Virgo detectors are engaged in their third observation period since April 2019 and will continue until April 2020. The numbers of gravitational-wave compact binary sources candidates so far follow the predictions” says Marie-Anne Bizouard of the ARTEMIS Laboratory of the Observatoire de la Côte d’Azur, France.

The Virgo Collaboration is currently composed of approximately 520 scientists, engineers, and technicians from 100 institutes in 11 different countries, including: Belgium, France, Germany, Hungary, Italy, the Netherlands, Poland, and Spain. The European Gravitational Observatory (EGO) hosts the Virgo detector near Pisa in Italy, and is funded by the Centre National de la Recherche Scientifique (CNRS) in France, the Istituto Nazionale di Fisica Nucleare (INFN) in Italy, and Nikhef in the Netherlands. A list of the Virgo Collaboration groups can be found at **http://public.virgo-gw.eu/the-virgo-collaboration/**. More information is available on the Virgo website at **http://www.virgo-gw.eu**.

LIGO is funded by the National Science Foundation (NSF) and operated by Caltech and MIT, which conceived of LIGO and lead the project. Financial support for the Advanced LIGO project was led by the NSF with Germany (Max Planck Society), the U.K. (Science and Technology Facilities Council) and Australia (Australian Research Council-OzGrav) making significant commitments and contributions to the project. Approximately 1,300 scientists from around the world participate in the effort through the LIGO Scientific Collaboration, which includes the GEO Collaboration. A list of additional partners is available at **https://my.ligo.org/census.php**.