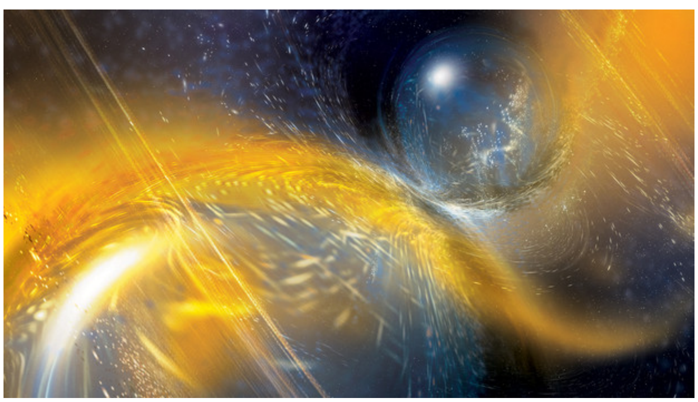
LIGO-Virgo network catches another neutron star collision



Artist's rendition of two colliding neutron stars. ***IMAGE: NATIONAL SCIENCE FOUNDATION/LIGO/SONOMA STATE UNIVERSITY/A. SIMONNET***

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UNIVERSITY PARK, Pa. — Gravitational waves detected on April 25, 2019, by the LIGO Livingston Observatory were likely produced by a collision of two neutron stars, according to a new study by an international team including Penn State researchers. This is only the second time this type of event has been observed through gravitational waves. In this case, the source that produced the April 2019 event — referred to as GW190425 — has a larger total mass than that of any other known neutron star binaries. The unexpectedly high mass of the system could point towards a new class of binary neutron star systems.

Neutron stars are the dense remnants of dying stars that undergo catastrophic explosions as they collapse at the end of their lives. When two neutron stars spiral together, they undergo a violent merger that sends gravitational shudders through the fabric of space and time.

The first observation of a neutron star-neutron star merger, which took place in August 2017, marked the first time that both gravitational waves and light were detected from the same cosmic event, heralding a new era of multi-messenger astronomy in which different types of signals are witnessed simultaneously. The April 2019 merger, by contrast, did not result in any light being detected. However, through an analysis of the gravitational-wave data, researchers have learned that the collision produced an object with an unusually high mass.

“The second observation of a binary neutron star merger firms up our knowledge of how often we should expect to see such systems,” said Surabhi Sachdev, an Eberly Postdoctoral Research Fellow at Penn State and a LIGO team member.

GW190425 was detected in near real time by an analysis developed and operated by researchers in the gravitational-wave research group at Penn State.

“The latest LIGO-Virgo observing run is the first time in which fully automated public alerts are being sent out for gravitational-wave events," said Patrick Godwin, a graduate student at Penn State and a LIGO team member. “Developing cyberinfrastructure to detect and send out alerts for gravitational-wave events in near real time is critical to allow astronomers to rapidly follow up events such as GW190425.”

The results were presented at a press briefing Jan. 6 at the 235th meeting of the American Astronomical Society in Honolulu, Hawaii, by the LIGO Scientific Collaboration, a team which includes researchers at Penn State, and the Virgo Collaboration, which is associated with the Virgo gravitational-wave detector in Italy.

Single-detector event

The August 2017 neutron star merger was witnessed by both LIGO detectors — one in Livingston, Louisiana, and one in Hanford, Washington — together with a host of light-based telescopes around the world. (Neutron star collisions produce light, while black hole collisions are generally thought not to do so). Although this merger was not clearly visible in the Virgo data, this lack of visibility provided key information that ultimately pinpointed the event's location in the sky.

Conversely, the April 2019 event was first identified from data from the LIGO Livingston detector alone. The LIGO Hanford detector was temporarily offline at the time, and, at a distance of more than 500 million light-years, the event was too faint to be visible in Virgo's data. However, using the Livingston data, combined with information derived from Virgo's subthreshold data, the team narrowed the location of the event to a patch of sky more than 8,200 square degrees in size, or about 20 percent of the sky. For comparison, the August 2017 event was narrowed to a region of just 16 square degrees, or 0.04 percent of the sky.

“We can't localize the binary system's position on the sky as accurately without the third detector, which makes searching for electromagnetic counterparts more difficult,” said Ryan Magee, a graduate student at Penn State and a LIGO team member.

Surprisingly massive neutron star binary

The LIGO data from the April 2019 event reveal that the combined mass of the merged bodies is about 3.4 times the mass of our sun, whereas known binary neutron star systems in our galaxy have combined masses up to only 2.9 times that of the sun. One possible explanation for the unusually high mass is that the collision took place not between two neutron stars, but between a neutron star and a black hole, since black holes are heavier than neutron stars. But if this were the case, the black hole would have to be exceptionally small for its class. Instead, the scientists believe it is much more likely that LIGO witnessed a collision of two neutron stars.

"What we know from the data are the masses, and the individual masses most likely correspond to neutron stars. However, as a binary neutron star system, the total mass is much higher than any of the other known galactic neutron star binaries," said Sachdev. "And this could have interesting implications for how the pair originally formed."

Neutron star pairs are thought to form in one of two ways, either from binary systems of massive stars that each end their lives as neutron stars, or when two separately formed neutron stars come together within a dense stellar environment. The LIGO data for the April 2019 event do not indicate which of these scenarios is more likely, but they do suggest that more data and new models are needed to explain the merger's unexpectedly high mass.

“The more massive companion in this binary could be either the heaviest neutron star or the lightest black hole ever discovered,” said B.S. Sathyaprakash, Elsbach Professor of Physics and professor of astronomy and astrophysics at Penn State, and a LIGO team member. “We don't know which of these is the case. Gravitational-wave detectors are continuing to make intriguing discoveries, keeping up the promise of opening a new window for observing the universe.”

LIGO Research at Penn State is supported by the National Science Foundation and is conducted within the Institute for Gravitation and the Cosmos and the Institute for Computational and Data Sciences. Faculty, students and postdocs in the Penn State LIGO group are members of the Physics and Astronomy and Astrophysics departments within the Eberly College of Science.

Additional information about the gravitational-wave observatories:

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.

The Virgo Collaboration is currently composed of approximately 520 members from 99 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 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.

MEDIA CONTACTS

Surabhi Sachdev, szs1416@psu.edu

Chad Hanna, crh184@psu.edu
Work Phone: 814-865-2924

B.S. Sathyaprakash, bss25@psu.edu
Work Phone: 814-865-3062

Gail McCormick, gailmccormick@psu.edu
Work Phone: 814-863-0901

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