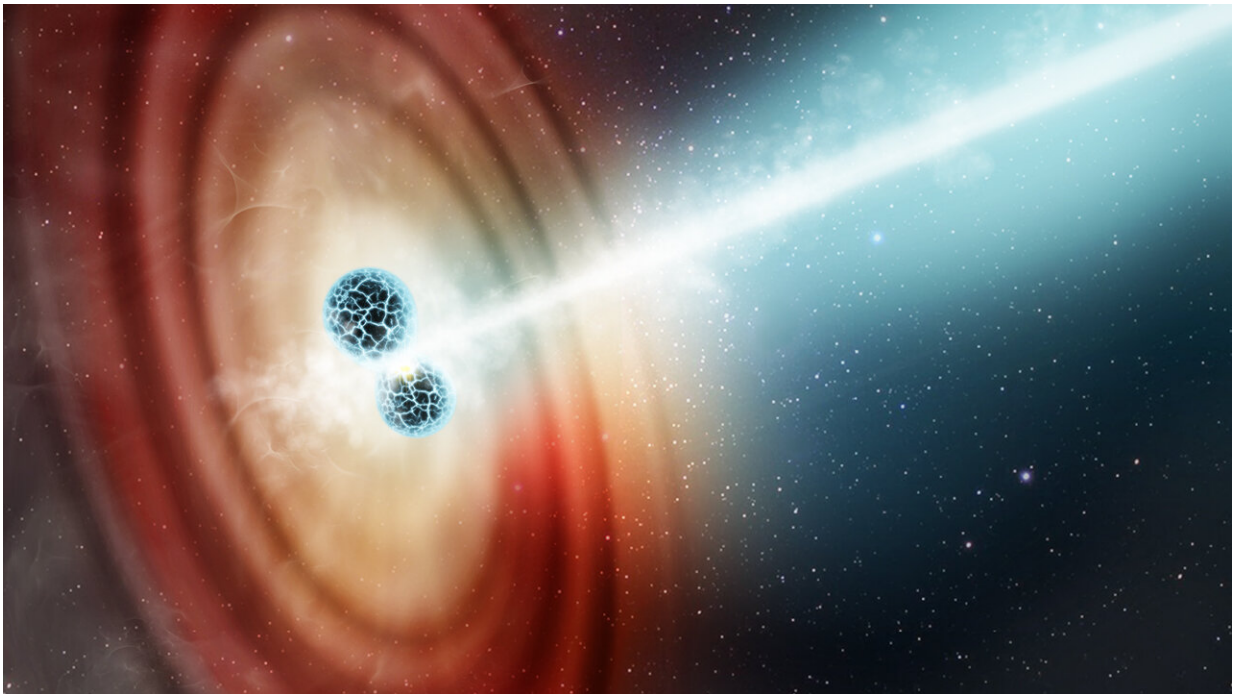


Hubble spots ultra-speedy jet blasting from star crash

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This is an artist's impression of two neutron stars colliding. The smashup between two dense stellar remnants unleashes the energy of 1,000 standard stellar nova explosions. In the aftermath of the collision a blowtorch jet of radiation is ejected at nearly the speed of light. The jet is directed along a narrow beam confined by powerful magnetic fields. The roaring jet plowed into and swept up material in the surrounding interstellar medium. Credit: Elizabeth Wheatley (STScI)

Astronomers using NASA's Hubble Space Telescope have made a unique measurement that indicates a jet, plowing through space at speeds greater than 99.97% the speed of light, was propelled by the titanic collision between two neutron stars.

The explosive event, named GW170817, was observed in August 2017. The blast released the energy comparable to that of a supernova explosion. It was the first combined detection of gravitational waves and [gamma radiation](#) from a binary neutron star merger.

This was a major watershed in the ongoing investigation of these extraordinary collisions. The aftermath of this merger was collectively seen by 70 observatories around the globe and in space, across a broad swath of the electromagnetic spectrum in addition to the gravitational wave detection. This heralded a significant breakthrough for the emerging field of Time Domain and Multi-Messenger Astrophysics, the use of multiple "messengers" like light and gravitational waves to study the universe as it changes over time.

Scientists quickly aimed Hubble at the site of the explosion just two days later. The [neutron stars](#) collapsed into a black hole whose powerful gravity began pulling material toward it. That material formed a rapidly-spinning disk that generated jets moving outward from its poles. The roaring jet smashed into and swept up material in the expanding shell of explosion debris. This included a blob of material through which a jet emerged.

While the event took place in 2017, it has taken several years for scientists to come up with a way to analyze the Hubble data and data from other telescopes to paint this full picture.

The Hubble observation was combined with observations from multiple National Science Foundation radio telescopes working together for very

long baseline interferometry (VLBI). The radio data were taken 75 days and 230 days after the explosion.

"I'm amazed that Hubble could give us such a precise measurement, which rivals the precision achieved by powerful radio VLBI telescopes spread across the globe," said Kunal P. Mooley of Caltech in Pasadena, California, lead author of a paper being published in *Nature*.

The authors used Hubble data together with data from ESA's (the European Space Agency) Gaia satellite, in addition to VLBI, to achieve extreme precision. "It took months of careful analysis of the data to make this measurement," said Jay Anderson of the Space Telescope Science Institute in Baltimore, Maryland.

By combining the different observations, they were able to pinpoint the explosion site. The Hubble measurement showed the jet was moving at an apparent velocity of seven times the [speed of light](#). The radio observations show the jet later had decelerated to an apparent speed of four times faster than the speed of light.

In reality, nothing can exceed the speed of light, so this "superluminal" motion is an illusion. Because the jet is approaching Earth at nearly the speed of light, the light it emits at a later time has a shorter distance to go. In essence the jet is chasing its own light. In actuality more time has passed between the jet's emission of the light than the observer thinks. This causes the object's velocity to be overestimated—in this case seemingly exceeding the speed of light.

"Our result indicates that the jet was moving at least at 99.97% the speed of light when it was launched," said Wenbin Lu of the University of California, Berkeley.

The Hubble measurements, combined with the VLBI measurements,

announced in 2018, greatly strengthen the long-presumed connection between neutron star mergers and short-duration gamma-ray bursts. That connection requires a fast-moving jet to emerge, which has now been measured in GW170817.

This work paves the way for more precision studies of neutron star mergers, detected by the LIGO, Virgo and KAGRA gravitational wave observatories. With a large enough sample over the coming years, relativistic jet observations might provide another line of inquiry into measuring the universe's expansion rate, associated with a number known as the Hubble constant.

At present there is a discrepancy between Hubble constant values as estimated for the early universe and nearby universe—one of the biggest mysteries in astrophysics today. The differing values are based on extremely precise measurements of Type Ia supernovae by Hubble and other observatories, and Cosmic Microwave Background measurements by ESA's Planck satellite. More views of relativistic jets could add information for astronomers trying to solve the puzzle.

More information: Kunal Mooley, Optical superluminal motion measurement in the neutron-star merger GW170817, *Nature* (2022).

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