

LIGO Detects Most Massive Binary Black Hole to Date

July 15, 2025

The [Laser Interferometer Gravitational-Wave Observatory \(LIGO\)](#)'s [LIGO-Virgo-KAGRA \(LVK\) collaboration](#) has detected an extremely unusual binary black hole merger — a phenomenon that occurs when two black holes are pulled into each other's orbit and combine. Announced yesterday in a [California Institute of Technology press release](#), the binary black hole merger, GW231123, is the largest ever detected with gravitational waves.

Before merging, both black holes were spinning exceptionally fast, and their masses fell into a range that should be very rare — or impossible.

“Most models don't predict black holes this big can be made by supernovas, and our data indicates that they were spinning at a rate close to the limit of what's theoretically possible,” says [Margaret Millhouse](#), a research scientist in the [School of Physics](#) who played a key role in the research. “Where could they have come from? It raises interesting questions.”

A binary black hole merger absorbs characteristics from both of the contributors, she adds. “As a result, this is not only the most massive binary black hole ever seen but also the fastest-spinning binary black hole confidently detected with gravitational waves.”

“GW231123 is a record-breaking event,” says School of Physics Professor [Laura Cadonati](#), who has been a member of the [LIGO Scientific Collaboration](#) since 2002. “LIGO has been observing the cosmos for 10 years now. This discovery underscores that there is still so much that this instrument can help us learn.”

A Cosmic View

The findings challenge current theories on how smaller black holes form, says School of Physics Assistant Professor and LIGO collaborator [Surabhi Sachdev](#). Smaller black holes are the result of supernovae: dying and collapsing stars. During that collapse, explosions can tear apart or eject part of the star's mass — limiting the size of the black hole that forms.

“Black holes from supernovae can weigh up to about 60 times the mass of our Sun,” she says. “The black holes in this merger were likely the mass of *hundreds* of suns.”

Because of its size, GW231123 also allowed the team to study the merger in unprecedented detail. “LIGO has observed scores of black hole mergers,” says Cadonati. “Of these, GW231123 has provided us with the clearest view of the ‘grand

finale' of a merger thus far. This adds a new clue to solve the puzzle that are black holes, including their origins and properties."

"While we saw that our expectations matched the data, the extreme nature of this event pushed our models to their limits," Millhouse adds. "A massive, highly spinning system like this will be of interest to researchers who study how binary black holes form."

Decoding a Split-Second Signal

Millhouse and School of Physics Postdoctoral Fellow **Prathamesh Joshi** used Einstein's equations for general relativity to confirm LIGO's detections.

To find black holes, LIGO measures distortions in spacetime — ripples that are created when two black holes collide. These patterns in gravitational waves can be used to find the signature signal of black hole collisions.

"In this case, the signal lasted for just one-tenth of a second, but it was very clear," says Joshi. "Previously, we designed a special study to detect these interesting signals, which accounted for all the unusual properties of such massive systems — and it paid off!"

"To ensure it wasn't noise, the Georgia Tech team first reconstructed the signal in a model-agnostic way," Millhouse adds. "We then compared those reconstructions to a model that uses Einstein's equations of general relativity, and both reconstructions looked very similar, which helped confirm that this highly unusual phenomenon was a genuine detection."

Sachdev says that seeing the signal at both LIGO Observatories — placed in Hanford, Washington and Livingston, Louisiana — was also critical. "These short signals are very hard to detect, and this signal is so unlike any of the other binary black holes that we've seen before," she says. "Without both detectors, we would have missed it."

A Decade of Discovery

While the team has yet to determine how the original black holes formed, one theory is that they may have resulted from mergers themselves. "This could have been a chain of mergers," Sachdev explains. "This tells us that they could have existed in a very dense environment like a nuclear star cluster or an active galactic nucleus." Their spins provide another clue as spinning is a characteristic usually seen in black holes resulting from a merge.

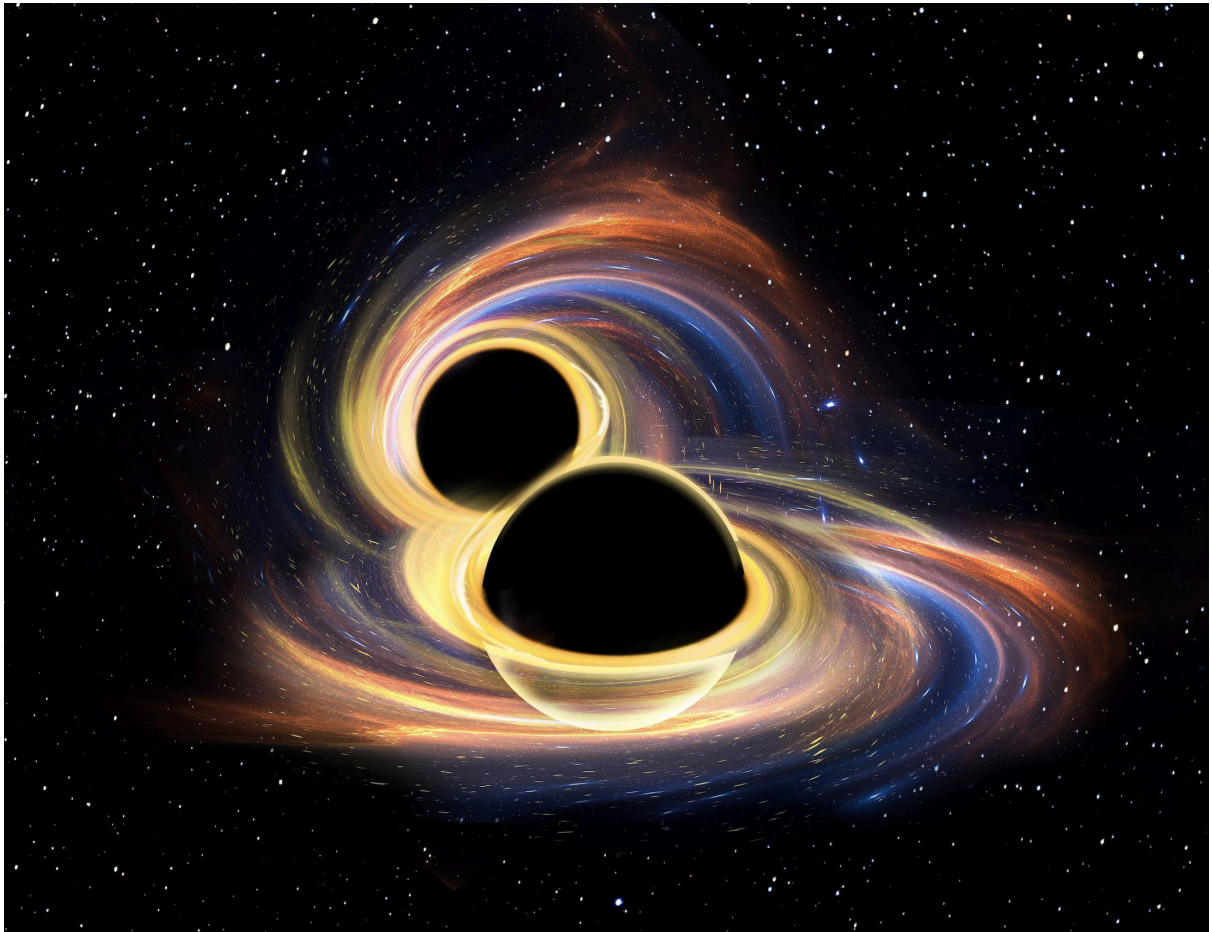
The team adds that GW231123 could provide clues on how larger black holes are formed — including the mysterious supermassive black holes at the center of galaxies.

"Gravitational wave science is almost a decade old, and we're still making fundamental discoveries," says Millhouse. "It's exciting that LIGO is continuing to detect new phenomena, and this is at the edge of what we've seen thus far. There's still so much we can learn."

The team expects to update their catalogue of black holes in August 2025, which will provide another window into how this exceptionally heavy black hole might fit into the universe, and what we can continue to learn from it.

Funding: *The LIGO Laboratory is supported by the U.S. National Science Foundation and operated jointly by Caltech and MIT.*

Related Media



An illustration of the binary black hole merger. (Image credit: Raul Perez and Davis Newell)

For More Information Contact

Written by Selena Langner

Contact: Jess Hunt-Ralston