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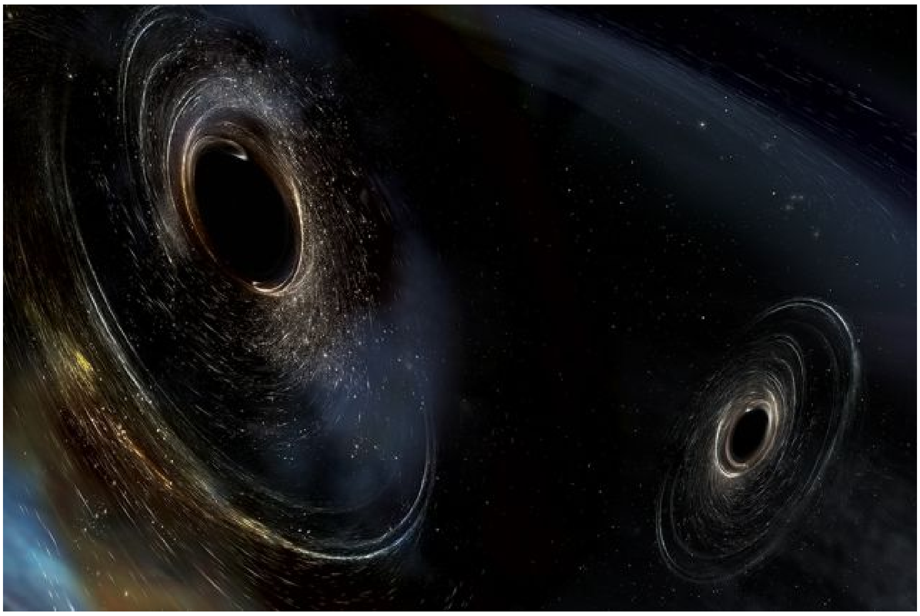

FULL SCREEN

This artist's conception shows two merging black holes similar to those detected by LIGO. The black holes are spinning in a nonaligned fashion, which means they have different orientations relative to the overall orbital motion of the pair. LIGO found hints that at least one black hole in the system called GW170104 was nonaligned with its orbital motion before it merged with its partner.

Image: LIGO/Caltech/MIT/Sonoma State (Aurore Simonnet)

LIGO detects merging black holes for third time

Nearly 3 billion light years from Earth, the black holes are the farthest ever detected.

Jennifer Chu | MIT News Office
June 1, 2017

Press Inquiries

PRESS MENTIONS

The collision of a pair of colossal, stellar-mass black holes has made itself heard, nearly 3 billion light years away, through a cosmic microphone on Earth.

On Jan. 4, the Laser Interferometry Gravitational-wave Observatory (LIGO) picked up a barely perceptible signal that scientists quickly determined to be a gravitational wave — a ripple of energy passing through the curvature of spacetime. The event, published today in *Physical Review Letters*, marks the third direct detection of a gravitational wave.

Catalogued as GW170104, the signal, when translated into the audio band, resembles an upward-sweeping chirp, characteristic of a “binary coalescence,” or a merging of two massive astrophysical objects in the distant universe. The team has concluded that the gravitational wave was produced by the collision of two heavy, stellar–mass black holes, one estimated to be about 31 times, and the other 19 times, as massive as the sun.

The signal captured by LIGO lasts less than two-tenths of a second, and in that fraction of a moment, scientists calculate that the black holes whirled around each other about six times before merging into one giant, 49-solar-mass black hole. This cosmic collision gave off an enormous amount of energy in the form of gravitational waves, equivalent to two times the mass of the sun.

The merger took place about 3 billion light years from Earth, measuring about twice as far as the black hole collision that produced GW150914, LIGO’s first-ever gravitational wave detection.

“This is indeed the farthest out stellar-mass black hole system anyone has seen,” says Erik Katsavounidis, senior research scientist in MIT’s Kavli Institute for Astrophysics and Space Research and a member of the LIGO team.

LIGO’s third detection of black holes merging solidifies gravitational wave astronomy as an observational science, writes Amina Khan for *The Los Angeles Times*. Khan explains that scientists are, “moving LIGO’s work from the examination of singular curiosities to demographic studies of the sky’s invisible denizens."

LIGO scientists have detected a third black hole merger, reports Sophie Bushwick for *Popular Science*. Bushwick explains that the finding shows that LIGO is, “coming into its own as a black hole telescope: The latest finding proves the existence of a new category of black hole and adds a puzzle piece to the question of how these systems form.”

LIGO scientists have successfully detected two black holes merging for the third time, reports Eric Moskowitz for *The Boston Globe*. MIT’s David Shoemaker, LIGO’s spokesperson, explains that researchers can use the information gathered by LIGO to get a, “more complete picture of Einstein’s general relativity and the population of these purely relativistic objects we call black holes.”

A mathematical simulation of the warped space-time near two merging black holes, consistent with LIGO's observation of the event dubbed GW170104. The colored bands are gravitational-wave peaks and troughs, with the colors getting brighter as the wave amplitude increases. (Image: SXS Collaboration)

Out of alignment

The new gravitational wave signal is similar to LIGO's first two detections, both in its source — a binary black hole merger — and the overall mass of that source.

However, the scientists discovered an interesting feature in the newest signal: The spin of at least one of the black holes may have been "antialigned" with the orbital angular momentum — the direction in which the black holes were orbiting each other. This phenomenon would be similar to teacups spinning counterclockwise on a clockwise-rotating carnival platform.

Katsavounidis stresses that the signs for antialignment are small, though potentially significant. If scientists detect more antialigned systems, such evidence may support a formation scenario known as dynamical capture, in which black holes evolve separately in a cosmic environment cluttered with stellar objects. In such an environment, black holes with various spins can eventually pair up in binary systems, simply through gravitational, "dynamic" attraction.

Dynamical capture runs counter to a model called "common envelope evolution," in which binary black holes evolve together, with spins that are aligned with their orbital angular momentum. In fact, the LIGO team inferred that the December 2015 detection had a strong probability of aligned spins, contrary to this newest signal.

"Here for the first time, we're seeing antialignment is favored," Katsavounidis says. "If we can detect more systems, we can nail down under what circumstances black holes formed and evolved to form binary systems that ultimately merged."

Real-time serendipity

After undergoing tune-ups to improve its sensitivity, LIGO began its second observing run on Nov. 30, 2016. Katsavounidis says GW170104's detection had "a certain aspect of serendipity."

On Jan. 4, 2017, at 10:11:58.6 UTC, a gravitational ripple was recorded passing through one of LIGO's detectors, in Hanford, Washington. Three milliseconds later it passed through the twin detector more than 3,000 kilometers away in Livingston, Louisiana. The ripple caused each detector to alternately expand and shrink ever so slightly, generating a small wiggle in the data gathered by both detectors.

Within tens of seconds, LIGO's search algorithms automatically analyzed the signal, comparing it to waveforms characteristic of gravitational waves.

"A very careful researcher in Germany was looking at the data as they were coming in, and noticed one of the two detectors picked up something significant," Katsavounidis says. "That event was identified in near-real time, thanks to that colleague."

The researcher immediately notified LIGO's detector operations, characterization, and data analysis working groups, which set to work further dissecting the signal. The scientists used computational tools to narrow in on a likely set of parameters, such as a system's mass, spin, and orientation, that would produce a gravitational signal matching the one seen in the data.

The best fit turned out to be a pair of merging black holes, which the scientists calculated to be the second most massive stellar-mass binary black hole system, behind GW150914, LIGO's first gravitational wave detection.

in a substantial way away from novelty towards where we can seriously say we are developing black-hole astronomy," says David Shoemaker, director of the MIT LIGO Lab and spokesperson for the LIGO Scientific Collaboration.

CBS News reporter William Harwood writes that LIGO scientists have detected the merger of two black holes three billion light years away. David Shoemaker, director of the MIT LIGO Lab and the spokesperson for LIGO, explains that researchers detected, "the merging of black holes roughly 20 and 30 times the mass of our sun."

MIT's David Shoemaker, spokesperson for the LIGO Scientific Collaboration, speaks with Doyle Rice of *USA Today* about LIGO's third successful detection of gravitational waves. "It is remarkable that humans can put together a story, and test it, for such strange and extreme events that took place billions of years ago and billions of light-years distant from us," explains Shoemaker.

For the third time, researchers from the LIGO Scientific Collaboration have detected gravitational waves produced by the merger of two black holes, reports Irene Klotz for Reuters. "We're really moving from novelty to a new observational science," says MIT's David Shoemaker, spokesperson for the LIGO Scientific Collaboration.

Wall Street Journal reporter Robert Lee Hotz writes that scientists from the Laser Interferometer Gravitational-Wave Observatory (LIGO) have successfully detected two black holes merging for the third time. MIT's David Shoemaker, spokesperson for the LIGO Scientific Collaboration, explains that the discovery shows, "we are really moving to a new astronomy of gravitational waves."

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Erik Katsavounidis

LIGO-MIT

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Fighting gravitational fuzziness

With this new detection, the team again confirmed Albert Einstein's theory of general relativity, observing that the behavior of the merging black holes agreed with Einstein's predictions of gravitational effects, even at such extreme scales.

"That's an amazing thing," Katsavounidis says. "Whether you talk about gravity on Earth, or something where the gravitational potential is a billion times greater, general relativity still describes how those gravitational waves are generated and how those objects behave gravitationally."

As part of the initial analysis of the signal, LIGO researchers produced "sky maps" with approximate areas in the sky for where the binary black hole system might be located. As part of its standard procedure, LIGO sent these sky maps out to about 80 partner astronomy groups, each of which has access to imaging tools that span the entire electromagnetic spectrum, as well as neutrinos. While LIGO continues to listen for signs of other extreme events in the universe, astronomers have been pointing their telescopes in the direction of GW170104's source, hoping to see glimmers of the colliding black holes.

"LIGO acts as our ears, so to speak, and we want to listen for something and quickly move our eyes to follow the signal," Katsavounidis says. "Our mission is to fight the fuzziness of gravitational wave detectors by adding more of them in the global network, and by pairing [the detections] with light as soon as possible."

The search for gravitational waves will soon gain an additional set of ears, in the form of Virgo, a similar detector located near Pisa, Italy, that is scheduled to come online this summer and will pair with LIGO.

"Coming from a field of looking for something rare, I've always been hesitant, with one detection only, to declare victory," Katsavounidis says. "I can tell you I've started sleeping much better after the second detection. Now this third one solidifies LIGO and LIGO's observations as the ultimate tool to see the mass spectrum of black holes in our universe."

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Topics: Astronomy Astrophysics Black holes Kavli Institute LIGO Research School of Science Space, astronomy and planetary science National Science Foundation (NSF) Physics

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IN THE MEDIA

The Economist highlights Prof. Michael Triantafyllou's work studying how seals employ their whiskers to detect their surroundings. Triantafyllou is using the seal whisker as a model for developing an underwater sensor that would, "detect the wakes of natural objects, such as fish and marine mammals, and artificial ones, such as other robots, surface ships and submarines."

MIT researchers have developed a new prosthetic device that allows amputees to feel where their limbs are located, reports Simon Makin for *Scientific American*. "What's new here is the ability to provide feedback the brain knows how to interpret as sensations of position, speed and force," explains postdoctoral associate Tyler Clites.

Edd Gent highlights MIT's ingestible origami robot in this *NBC Mach* article on the ways origami is impacting science and engineering. "[T]he intricate folding patterns can be used to make complex mechanical systems," like the MIT robot, which is "designed to unfurl and steer its way through the gut with help from external magnets," writes Gent.

Boston Globe reporter Mark Feeney reviews "Imagined Communities," a new exhibit of the photography of Mila Teshaieva at the MIT Museum. Feeney notes that, "Teshaieva is the latest in an impressive roster of contemporary European photographers brought to the

In an article for *Popular Mechanics*, Tiana Cline spotlights SoFi, an autonomous, soft, robotic fish that can swim alongside real fish. “SoFi has the potential to be a new type of tool for ocean exploration and to open up new avenues for uncovering the mysteries of marine life,” Cline notes.

MIT researchers have developed a sensor that can determine if cancer cells are responding to a certain chemotherapy drug. “Another potential use is to screen patients before they receive such drugs, to see if the drugs will be successful against each patient's tumor,” writes Li Xia for Xinhua.

Steven Melendez of *Fast Company* reports on a new system from MIT researchers called Accountability of Unreleased Data for Improved Transparency, or AUDIT, which could help the public track police surveillance. “While certain information may need to stay secret for an investigation to be done properly, some details have to be revealed for accountability to even be possible,” says graduate student Jonathan Frankle.

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