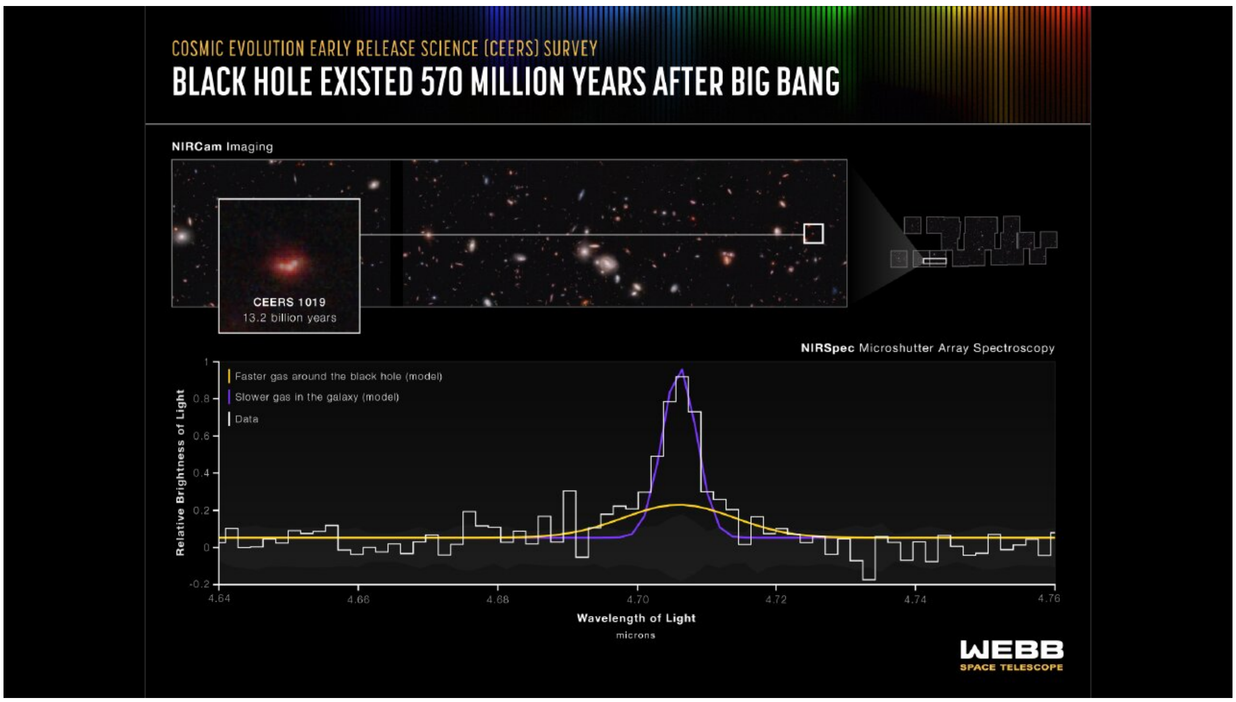
Webb detects most distant active supermassive black hole to date

July 7 2023



The graphic shows the redshift of one active supermassive black hole. At top right is the complete NIRCam image of the field, which has an uneven white outline and is very small. To its left is a large pull out, labeled NIRCam imaging, which shows galaxies of different colors, shapes, and sizes across most of the top row. A tiny open white box at far right, and a line drawn to a larger image at left. In the inset image is a larger blurry red dot with two green dots at its left and right. The pull out is labeled CEERS 1019, 13.2 billion years. The bottom row shows one line graph labeled NIRSpec Microshutter Array Spectroscopy. It shows data in white, a model in yellow labeled faster gas around the black hole, and a second model represented by a purple line that is labeled slower gas in the galaxy. For more details, view the Extended Description. Credit: NASA

It's a bonanza: The universe is absolutely teeming with black holes. Researchers have long known this, but less massive black holes that existed in the early universe were too dim to detect—that is until the James Webb Space Telescope began taking observations. Researchers behind the Cosmic Evolution Early Release Science (CEERS) Survey are among the first to begin plucking these bright, extremely distant objects from Webb's highly detailed images and data.

First up: The most distant active supermassive black hole ever found—just over 570 million years after the big bang. It is on the smaller side, more similar to the mass of the supermassive black hole at the center of our Milky Way galaxy than to the extremely large "monsters" we've glimpsed before with other telescopes.

CEERS researchers also identified two more small black holes in the early universe, along with almost a dozen extremely distant galaxies. These initial findings suggest that less massive black holes and galaxies might have been more common in the early universe than previously proven.

Researchers have discovered the most distant active supermassive black hole to date with the James Webb Space Telescope. The galaxy, CEERS 1019, existed just over 570 million years after the big bang, and its black hole is less massive than any other yet identified in the early universe. Not only that, they've easily "shaken out" two more black holes that are also on the smaller side, and existed 1 and 1.1 billion years after the big bang.

Stare deeply at this vast landscape. It was stitched together from multiple images captured by the James Webb Space Telescope in near-infrared light – and it is practically pulsing with activity. To the right of center is a clump of bright white spiral galaxies that seem to be twisting into one another. Threaded throughout the scene are light pink spirals that look like pinwheels twirling in the wind. The bright foreground stars, set off in blue, announce themselves with Webb's prominent eight-pointed diffraction spikes. Don't miss an unconventional sight: In the bottom row, find the square second from far right. At its right edge, a misshapen blue galaxy is outfitted in blue-and-pink sparkling star clusters. Credit: Credits: NASA, ESA, CSA, Steve Finkelstein (UT Austin), Micaela Bagley (UT Austin), Rebecca Larson (UT Austin)Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

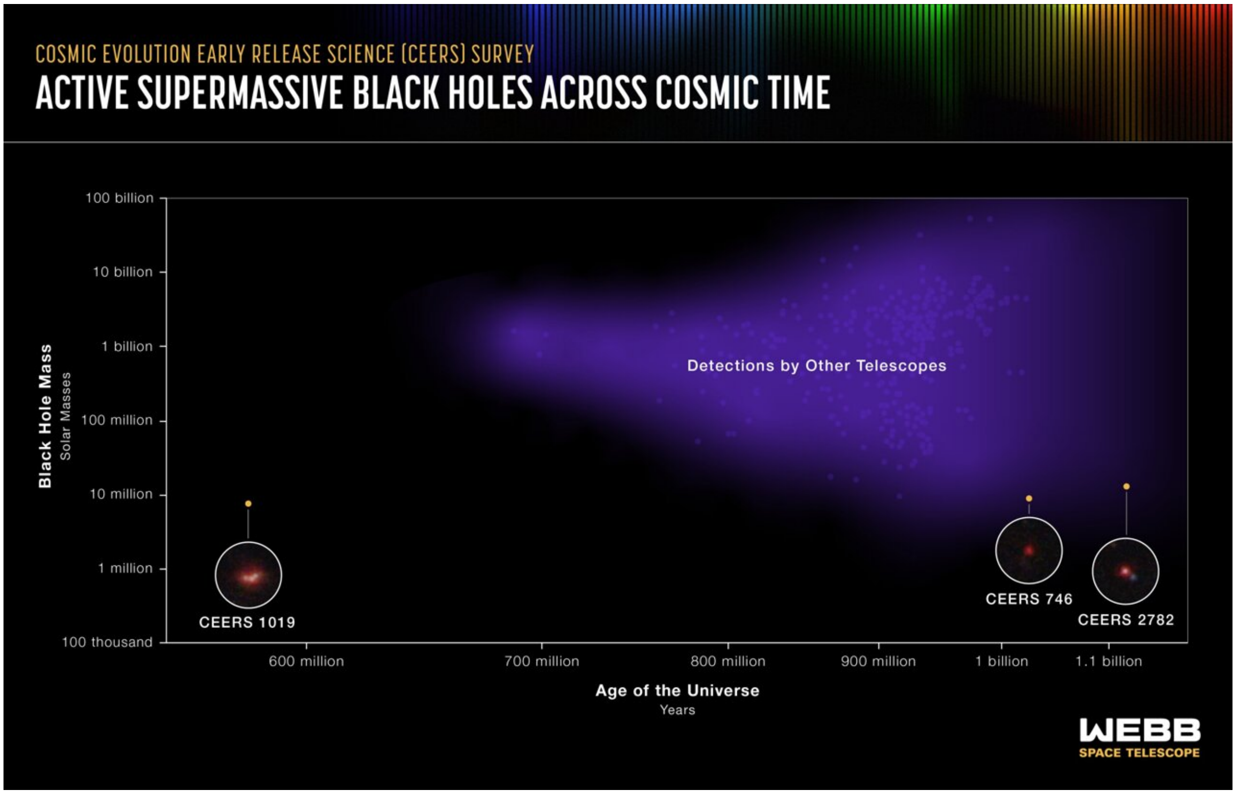
Webb also identified eleven galaxies that existed when the universe was 470 to 675 million years old. The evidence was provided by Webb's Cosmic Evolution Early Release Science (CEERS) Survey, led by Steven Finkelstein of the University of Texas at Austin. The program combines Webb's highly detailed near- and mid-infrared images and data known as spectra, all of which were used to make these discoveries.

CEERS 1019 is not only notable for how long ago it existed, but also how relatively little its black hole weighs. This black hole clocks in at about 9 million solar masses, far less than other black holes that also existed in the early universe and were detected by other telescopes. Those behemoths typically contain more than 1 billion times the mass of the sun—and they are easier to detect because they are much brighter. (They are actively "eating" matter, which lights up as it swirls toward the black hole.)

The black hole within CEERS 1019 is more similar to the black hole at the center of our Milky Way galaxy, which is 4.6 million times the mass of the sun. This black hole is also not as bright as the more massive behemoths previously detected. Though smaller, this black hole existed so much earlier that it is still difficult to explain how it formed so soon after the universe began.

Researchers have long known that smaller black holes must have existed earlier in the universe, but it wasn't until Webb began observing that they were able to make definitive detections. (CEERS 1019 may only hold this record for a few weeks—claims about other, more distant black holes identified by Webb are currently being carefully reviewed by the astronomical community.)

Webb's data are practically overflowing with precise information that makes these confirmations so easy to pull out of the data. "Looking at this distant object with this telescope is a lot like looking at data from black holes that exist in galaxies near our own," said Rebecca Larson of the University of Texas at Austin, who led this discovery. "There are so many spectral lines to analyze!"



This graphic shows detections of the most distant active supermassive black holes currently known in the universe. They were identified by a range of telescopes, both in space and on the ground. Three were recently identified by in the James Webb Space Telescope's Cosmic Evolution Early Release Science (CEERS) Survey. Credit: NASA, ESA, CSA, Leah Hustak (STScI)Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

Not only could the team untangle which emissions in the spectrum are from the black hole and which are from its host galaxy, they could also pinpoint how much gas the black hole is ingesting and determine its galaxy's star-formation rate.

The team found this galaxy is ingesting as much gas as it can while also churning out new stars. They turned to the images to explore why that might be. Visually, CEERS 1019 appears as three bright clumps, not a single circular disk. "We're not used to seeing so much structure in images at these distances," said CEERS team member Jeyhan Kartaltepe of the Rochester Institute of Technology in New York.

"A galaxy merger could be partly responsible for fueling the activity in this galaxy's black hole, and that could also lead to increased star formation."

More extremely distant black holes, galaxies hit the scene

The CEERS Survey is expansive, and there is a lot more to explore. Team member Dale Kocevski of Colby College in Waterville, Maine, and the team quickly spotted another pair of small black holes in the data. The first, within galaxy CEERS 2782, was easiest to pick out. There isn't any dust obscuring Webb's view of it, so researchers could immediately determine when its black hole existed in the history of the universe—only 1.1 billion years after the big bang.

The second black hole, in galaxy CEERS 746, existed slightly earlier, 1 billion years after the big bang. Its bright accretion disk, a ring made up of gas and dust that encircles its supermassive black hole, is still partially clouded by dust. "The central black hole is visible, but the presence of dust suggests it might lie within a galaxy that is also furiously pumping out stars," Kocevski explained.

Like the one in CEERS 1019, these two black holes are also "light weights"—at least when compared to previously known supermassive black holes at these distances. They are only about 10 million times the mass of the sun. "Researchers have long known that there must be lower mass black holes in the early universe. Webb is the first observatory that can capture them so clearly," Kocevski added. "Now we think that lower mass black holes might be all over the place, waiting to be discovered."

Before Webb, all three black holes were too faint to be detected. "With other telescopes, these targets look like ordinary star-forming galaxies, not active supermassive black holes," Finkelstein added.

Webb's sensitive spectra also allowed these researchers to measure precise distances to, and therefore the ages of, galaxies in the early universe. Team members Pablo Arrabal Haro of NSF's NOIRLab and Seiji Fujimoto of the University of Texas at Austin identified 11 galaxies that existed 470 to 675 million years after the big bang. Not only are they extremely distant, the fact that so many bright galaxies were detected is notable.

Researchers theorized that Webb would detect fewer galaxies than are being found at these distances. "I am overwhelmed by the amount of highly detailed spectra of remote galaxies Webb returned," Arrabal Haro said. "These data are absolutely incredible."

These galaxies are rapidly forming stars, but are not yet as chemically enriched as galaxies that are much closer to home. "Webb was the first to detect some of these galaxies," explained Fujimoto. "This set, along with other distant galaxies we may identify in the future, might change our understanding of star formation and galaxy evolution throughout cosmic history," he added.

These are only the first groundbreaking findings from the CEERS survey. "Until now, research about objects in the early universe was largely theoretical," Finkelstein said. "With Webb, not only can we see black holes and galaxies at extreme distances, we can now start to accurately measure them. That's the tremendous power of this telescope."

In the future, it's possible Webb's data may also be used to explain how early black holes formed, revising researchers' models of how black holes grew and evolved in the first several hundred million years of the universe's history.

Several papers about CEERS Survey data have been accepted by the *Astrophysical Journal Letters*. They're currently available on the *arXiv* preprint server.

More information: Rebecca L. Larson et al, A CEERS Discovery of an Accreting Supermassive Black Hole 570 Myr after the Big Bang: Identifying a Progenitor of Massive z > 6 Quasars, *arXiv* (2023). DOI: 10.48550/arxiv.2303.08918

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Provided by NASA

https://phys.org/news/2023-07-webb-distant-supermassive-black-hole.html