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SCIENCE

Black Hole at Heart of Our Galaxy Is on Crash Course, Space-Time Ripples Reveal

Gravitational waves coming from supermassive black holes like the one at the center of the Milky Way are offering clues to their fates

By Aylin Woodward Follow
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An artist's rendering of pulsars affected by gravitational waves produced by a pair of merging black holes. ILLUSTRATION: AURORE SIMONNET/NANOGRAV

Supermassive black holes all over the universe are merging, a fate that will eventually come for the black hole at the center of our galaxy.

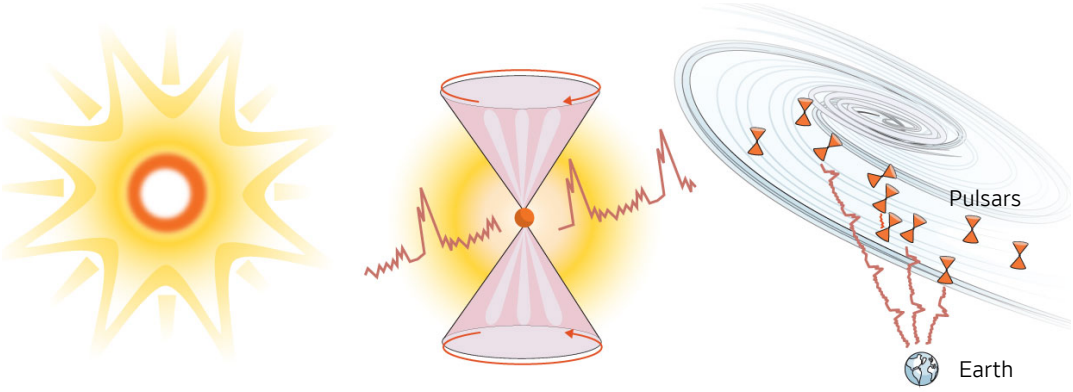
These mysterious cosmic structures at the heart of nearly every galaxy consume light and matter and are impossible to glimpse with traditional telescopes.

But now, for the first time, astrophysicists have gathered knowledge directly from these titans, in the form of gravitational waves that ripple through space and time. What they learned suggests that the population of massive black hole pairs that are merging numbers in the hundreds of thousands—perhaps even millions. The gravitational waves from these mergers are all contributing to an underlying background hum of the universe that researchers can detect from Earth.

The findings, from a collaboration of more than 100 scientists, help confirm what will one day happen to the supermassive black hole at our galaxy's center, known as Sagittarius A*, as it crashes into the black hole at the heart of the Andromeda galaxy.

Colliding Supermassive Black Holes

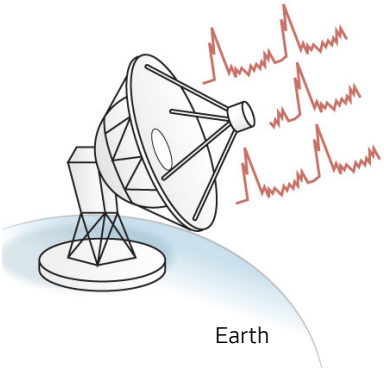
Scientists at the North American Nanohertz Observatory for Gravitational Waves, or Nanograv, led an international effort to detect gravitational waves from two supermassive black holes combining for the first time. Here is how they made their discoveries:

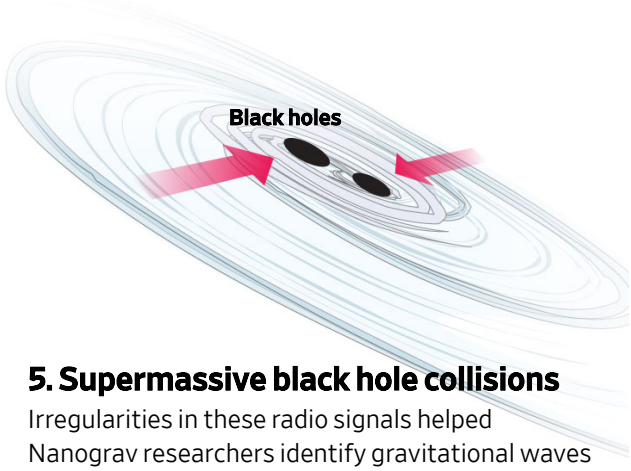


1. Dead stars
After a star explodes as a supernova, the dense material left over is what is known as a pulsar.

2. Pulsars
Pulsars, the lighthouses of space, can rotate hundreds of times a second, regularly emitting pulses of radio waves from their opposite poles.

3. Milky Way
For more than 15 years, researchers observed and analyzed the timing of radio waves from dozens of pulsars in the galaxy.





4. Earth-based detection
Scientists detected the timing of these signals using radio telescopes on Earth. If the timing of these regularly beamed radio waves is a little bit early or late, that indicates the effect of gravitational waves.

5. Supermassive black hole collisions
Irregularities in these radio signals helped Nanograv researchers identify gravitational waves coming from likely hundreds of thousands of pairs of merging supermassive black holes across the universe.

Source: North American Nanohertz Observatory for Gravitational Waves (Nanograv)
Kevin Hand/THE WALL STREET JOURNAL

"The Milky Way galaxy is on a collision course with the Andromeda galaxy, and in about 4.5 billion years, the two galaxies are set to merge," said Joseph Simon, a University of Colorado, Boulder, astrophysicist and a member of the North American Nanohertz Observatory for Gravitational Waves, or Nanograv, which helped lead the new work with support from the National Science Foundation.

That merger, he said, will eventually result in the black hole at the center of Andromeda and Sagittarius A* sinking into the center of the newly combined galaxy and forming what is known as a binary system. The results were

announced in a series of papers published Wednesday in the Astrophysical Journal Letters.

“Before now, we didn’t even know if supermassive black holes merged, and now we have evidence that hundreds of thousands of them are merging,” said Chiara Mingarelli, a Yale University astrophysicist and a member of Nanograv.

The new work could answer questions such as how these black holes grow, and how often their host galaxies merge, the researchers said.

“These are some of the craziest objects in our universe,” said Masha Baryakhtar, a physicist at the University of Washington in Seattle, who wasn’t involved in the research. “There’s no kind of consensus yet for how they get so big.”

If scientists understand more about the history of merging supermassive black holes, it could help reveal how they form in the first place, Baryakhtar said.

Essential to these findings is the detection of elusive gravitational waves, and understanding how they are produced.

The Arecibo telescope in Puerto Rico was used to observe the timing of radio waves from pulsars until it collapsed in 2020. PHOTO: ARECIBO OBSERVATORY/NSF

Any object with mass that is moving causes these waves—invisible distortion in time and space that were first theorized by Albert Einstein in 1916 but not detected until roughly 100 years later. (Imagine the universe as a trampoline rippling as a bowling ball rolls around on the surface.) In 2015, scientists used the ground-based Laser Interferometer Gravitational-Wave Observatory, or LIGO, to detect how short, high-frequency gravitational waves from one merger between less massive black holes jiggled the Earth by less than the width of a single subatomic particle. The effort won them a Nobel Prize.

LIGO can measure waves from colliding objects such as neutron stars that change on short time scales, according to Sarah Vigeland, a University of Wisconsin-Milwaukee physicist who oversees the gravitational-waves searches for Nanograv.

"You get this burst of gravitational waves, and then it's over," she said.

The observatory can't detect low-frequency gravitational waves that change on longer time scales—on the order of months to decades coming from more massive objects. So the Nanograv group, as part of an international consortium including groups doing similar work in Europe, Asia and Australia, decided to use a different method to measure these space-time ripples: tracking how they mess with the emissions of star remnants known as pulsars.

Pulsars are effectively like cosmic clocks, according to Columbia University astrophysicist Slavko Bogdanov, who wasn't involved in the work. These remnants of dead stars rapidly rotate hundreds of times per second, emitting radio waves at regular intervals that can be detected from radio telescopes on Earth.

Because the regularity of these radio wave pulses can be calculated with great precision, any deviation in their arrival to Earth, whether they are just a little bit late or a little bit early, can be chalked up to the effect of gravitational waves—the strength and source of which can then be calculated.

For 15 years, Vigeland said, the Nanograv group observed the timing of radio waves from pulsars in our galaxy using the Arecibo Observatory in Puerto Rico, the Green Bank Telescope in West Virginia and the Very Large Array in New Mexico.

"We monitor our pulsars on a regular basis, about once a month," she said, adding that the findings included data from 68 pulsars.

While 15 years might seem like a long time to collect data, such a time span is necessary for measuring the type of slowly undulating gravitational waves coming from supermassive black holes, according to Simon, who said the arrival time of the pulses from these clocklike spinning stars changes by just hundreds of billionths of a second over the span of a decade.

Bogdanov said that finding and adding more pulsars into the data set would be essential to improving how sensitive these gravitational wave detections are. There are still other things in the universe producing gravitational waves that haven't been detected yet, according to Julie Comerford, an astrophysicist at the University of Colorado, Boulder, and a Nanograv member. One of those other sources, she said, could be ripples in space-time from the big bang itself.

Nearly 14 billion years ago, the early universe had a lot of curvature, a bit like a crumpled-up blanket, Comerford said, before expanding at the speed of light or faster, spreading and smoothing out.

"So you could see remnant gravitational waves from that process," she said.

Write to Aylin Woodward at aylin.woodward@wsj.com

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