# Astronomers discover close-knit pairs of massive black holes

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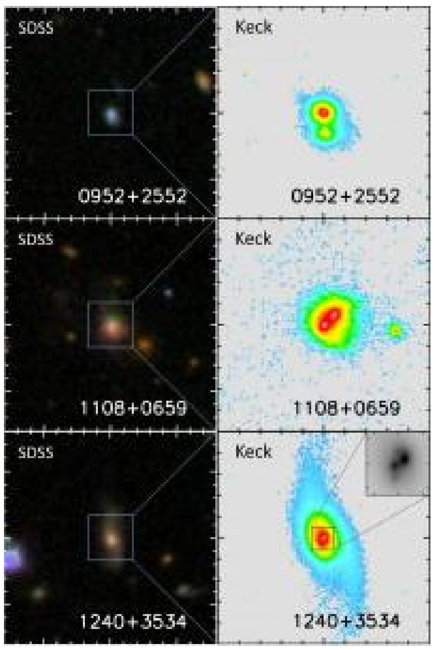


Three of the newly discovered black-hole pairs. On the left are images from the Sloan Digital Sky Survey. The images on the right show the same galaxies taken with the Keck telescope and the aid of adaptive optics, revealing pairs of active galactic nuclei, which are powered by massive black holes. Credit: S. George Djorgovski

Astronomers at the California Institute of Technology (Caltech), University of Illinois at Urbana-Champaign (UIUC), and University of Hawaii (UH) have discovered 16 close-knit pairs of supermassive black holes in merging galaxies.

The discovery, based on observations done at the W. M. Keck Observatory on Hawaii's Mauna Kea, is being presented in Seattle on January 12 at the meeting of the American Astronomical Society, and has been submitted for publication in the Astrophysical Journal.

These black-hole pairs, also called binaries, are about a hundred to a thousand times closer together than most that have been observed before, providing astronomers a glimpse into how these behemoths and their host galaxies merge—a crucial part of understanding the evolution of the universe. Although few similarly close pairs have been seen previously, this is the largest population of such objects observed as the result of a systematic search.

"This is a very nice confirmation of theoretical predictions," says S. George Djorgovski, professor of astronomy, who will present the results at the conference. "These close pairs are a missing link between the wide binary systems seen previously and the merging black-hole pairs at even smaller separations that we believe must be there."

As the universe has evolved, galaxies have collided and merged to form larger ones. Nearly every one—or perhaps all—of these large galaxies contains a giant black hole at its center, with a mass millions—or even billions—of times higher than the sun's. Material such as interstellar gas falls into the black hole, producing enough energy to outshine galaxies composed of a hundred billion stars. The hot gas and black hole form an active galactic nucleus, the brightest and most distant of which are called quasars. The prodigious energy output of active galactic nuclei can affect the evolution of galaxies themselves.

While galaxies merge, so should their central black holes, producing an even more massive black hole in the nucleus of the resulting galaxy. Such collisions are expected to generate bursts of gravitational waves, which have yet to be detected. Some merging galaxies should contain pairs of active nuclei, indicating the presence of supermassive black holes on their way to coalescing. Until now, astronomers have generally observed only widely separated pairs—binary quasars—which are typically hundreds of thousands of light-years apart.

"If our understanding of structure formation in the universe is correct, closer pairs of active nuclei must exist," adds Adam Myers, a research scientist at UIUC and one of the coauthors. "However, they would be hard to discern in typical images blurred by Earth's atmosphere."

The solution was to use Laser Guide Star Adaptive Optics, a technique that enables astronomers to remove the atmospheric blur and capture images as sharp as those taken from space. One such system is deployed on the W. M. Keck Observatory's 10-meter telescopes on Mauna Kea.

The astronomers selected their targets using spectra of known galaxies from the Sloan Digital Sky Survey (SDSS). In the SDSS images, the galaxies are unresolved, appearing as single objects instead of binaries. To find potential pairs, the astronomers identified targets with double sets of emission lines—a key feature that suggests the existence of two active nuclei.

By using adaptive optics on Keck, the astronomers were able to resolve close pairs of galactic nuclei, discovering 16 such binaries out of 50 targets. "The pairs we see are separated only by a few thousands of light-years—and there are probably many more to be found," says Hai Fu, a Caltech postdoctoral scholar and the lead author of the paper.

"Our results add to the growing understanding of how galaxies and their central black holes evolve," adds Lin Yan, a staff scientist at Caltech and one of the coauthors of the study.

"These results illustrate the discovery power of adaptive optics on large telescopes," Djorgovski says. "With the upcoming Thirty Meter Telescope, we'll be able to push our observational capabilities to see pairs with separations that are three times closer."

**More information:** Images of some of the merging systems are available at www.astro.caltech.edu/~george/bbh

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