# RIT study predicts how fast a black hole can be booted from a galaxy

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**Scientists say spin velocity determines the size and direction of the 'kick'**

Scientists have discovered for the first time just how fast a supermassive black hole can be thrown from a galaxy when it merges with another black hole. The crucial factor in producing large "kicks" turns out to be the spin that the black holes carry prior to the merger.

Manuela Campanelli and her team at Rochester Institute of Technology derived a formula based on detailed computer simulations that for the first time predicts the size and direction of the kick, or radiation recoil, that follows the merger of two black holes. Their findings will be published in an upcoming issue of Physical Review Letters. Their paper is also posted at http://arxiv.org/abs/gr-qc/0702133.

Black holes represent the strongest gravitational fields in nature. These strong fields of
gravity hold the black holes intact as they draw near and ultimately collapse upon each other. The collision creates waves of gravitational radiation that ripple outward through the galaxy at the speed of light, just slightly less than 300,000 kilometers per second, and kick the black holes out.

Campanelli's team carried out new computer simulations that follow the merger of two
spinning black holes. The black holes merge while spinning at the same speed but in different directions. Based on the simulations, the team of

scientists—which includes Carlos Lousto, Yosef Zlochower and David Merritt—determined that supermassive black holes could be ejected from a galaxy at the speed of 4,000 kilometers per second. In contrast, non-spinning black holes can only be kicked from galaxies with speeds of about 200 kilometers per second.

"The magnitude of the kick comes from the spin orientation of the black holes," says
Campanelli, director of the new Center for Computational Relativity and Gravitation in RIT's School of Mathematical Sciences. "This was shocking to the astrophysical community. People knew that the black-hole spins would affect kicks, but not to this extent."

A black hole ejected from a galaxy at 4,000 kilometers per second moves only at a fraction of the speed of light. At that rate, the speed significantly exceeds the galaxy escape velocity, which is how fast the black hole has to be kicked to completely leave the galaxy—or 1,000 to 2,000 kilometers per second for big galaxies.

Campanelli's group was also the first to study simulated mergers of black holes that were spinning in random directions. Their findings published in Astrophysical Journal Letters in December 2006 showed that the spin axis and tilt of the spin determined the biggest kicks.

The team observed changes in the gravitational field when spinning black holes collided. Their results depart from most previous studies, which focus on idealized black holes—non-spinning or symmetrical in size. Campanelli's findings showed spinning black holes wobbling like a top and confirmed the spin-flip phenomenon that occurs when the remaining black hole in a merger changes its orientation.

Campanelli and her team also verified the occurrence of recoil or "kick" that forms the basis of their current findings. "Predicting kick helped us

understand if black holes can get ejected from a large galaxy," Campanelli says. "A kicked black hole will carry with it any gas that is tightly enough bound to it before the merger," says Merritt, a professor of physics at RIT. "The black hole could continue to shine until it had swallowed this gas."

According to Merritt, small galaxies probably also lack black holes because the low escape velocities do not contain them. Even though a black hole is only about one-tenth of one percent of the size of a galaxy, its sudden expulsion will shift matter in the galaxy.

"It does change central properties of a galaxy in ways people are beginning to think about," Merritt says. "The center of the galaxy expands. Gravity from the black hole is not there, so stars move farther from the center, 'puffing up'."

Alessia Gualandris, a post-doctoral fellow in RIT's Center for Computational Relativity and Gravitation, is currently looking at what happens when black holes are removed from a galaxy.

Most likely, an ejected black hole will eventually return to its position at the center of a galaxy, although that would take a long time, Merritt says.

Source: Rochester Institute of Technology

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