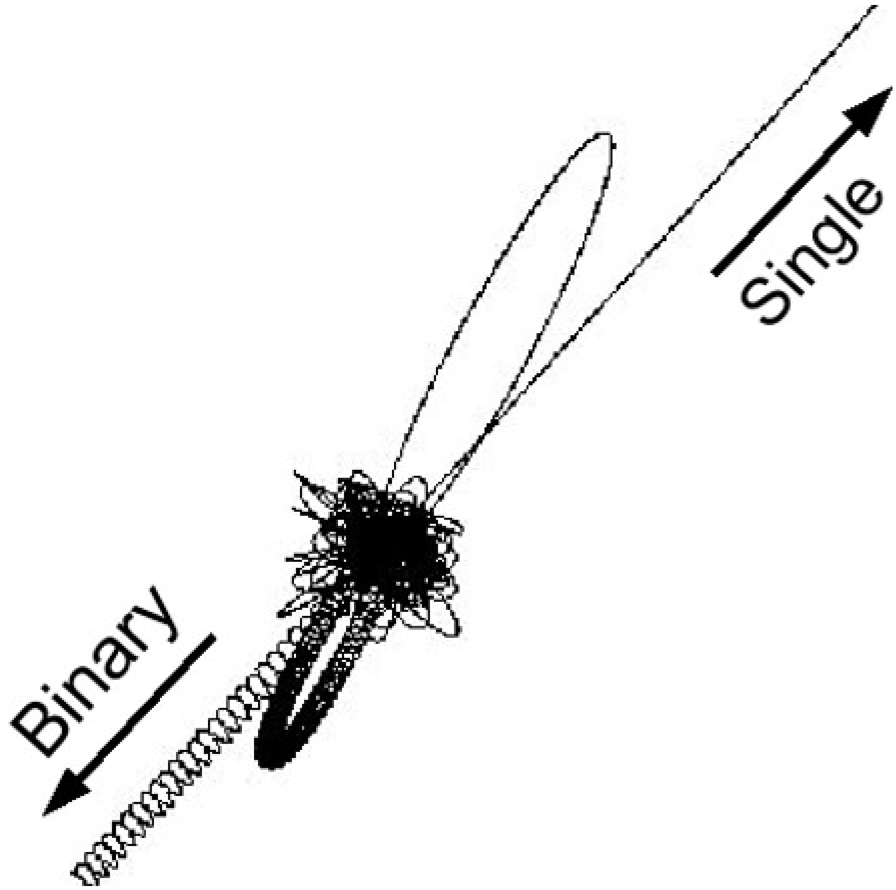
Cosmic menages a trois

Triple black hole systems undergo chaoitc interactions.

Provided by Northwestern University



Here are trajectories of three black holes interacting gravitationally. The chaotic dynamics result in the final ejection of a single black-hole (moving towards the upper-right corner) and a black hole binary (moving down to the left). *Stefan Umbreit, Northwestern Univ.*

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New cosmological computer simulations produced by a team of astronomers from Northwestern University, Harvard University and the University of Michigan show for the first time that supermassive black holes (SMBHs), which exist at the centers of nearly all galaxies, often come together during triple galaxy interactions.

Frederic Rasio, a theoretical astrophysicist and professor of physics and astronomy in the Weinberg College of Arts and Sciences at Northwestern University in Evanston, Ill., presented the findings at the meeting of the American Astronomical Society in Seattle.

The theoretical results are of special interest because of the recent discovery by astronomers at the California Institute of Technology of a possible triple quasar, findings that were also reported at the Seattle meeting.

"SMBHs become visible as quasars when they accrete large quantities of gas from their host galaxies, releasing prodigious amounts of energy in radiation," said Rasio. "The observation of three quasars in very close proximity shows that the kinds of interactions predicted by our computer simulations are indeed taking place, even in the nearby, present-day universe."

The existence of binary SMBHs, formed when two galaxies come together, that merge and bring together their central SMBHs, has been discussed by astronomers for many years. The new work reported by Rasio shows that interactions between three SMBHs are also quite frequent, occurring perhaps up to a few times per year within the observable universe. While the merger of a binary SMBH following the collision between two galaxies simply leads to the formation of a bigger SMBH at the center of a bigger galaxy, triple black hole interactions can be much more violent and interesting.

"Three is so much better than two because the dynamics of three gravitationally interacting bodies is chaotic, as opposed to the much more regular motion of two bodies simply orbiting each other," said Rasio.

These violent triple interactions were especially frequent at early cosmological times, when our universe was only about one-tenth of its present age, and galaxies were smaller and collided much more frequently than today. At that earlier epoch, galaxies were living in a very crowded environment, as the universe had yet to expand to its present size. Smaller galaxies merged together to form some of the much bigger galaxies we see today. Although slower today, this process is ongoing. Even our own galaxy, the Milky Way, will experience a "major merger" event when it collides with its nearest neighbor, the Andromeda galaxy, in about three billion years.

Triple encounters of SMBHs often end in the complete coalescence of an SMBH pair, guaranteeing a high cosmic merger rate of black holes. They can also lead to SMBH binaries being kicked out of their parent galaxies and wandering "naked" through the universe.

"Triple black hole systems undergo complex, chaotic interactions often ending in the high-velocity ejection of one component, often straight out of the host galaxy," said Loren Hoffman, a doctoral student at Harvard and a member of the research team.

"The detection of wandering black hole binaries flying in empty space would give us a unique signature of triple interactions in the early universe," said team member Marta Volonteri, assistant professor of astronomy at the University of Michigan. "Gravitational waves emission seems to be the only way of spotting these wandering binaries."

Merging SMBH binaries are key sources of gravitational radiation that astronomers hope to detect with future observatories such as the Laser Interferometer Space Antenna (LISA), a billion-dollar joint venture of NASA and the European Space Agency, which is currently in a design phase and is expected to begin observations in or around 2017.

In addition to Rasio, Hoffman and Volonteri, the research team includes Stefan Umbreit, a postdoctoral fellow at Northwestern.