How to Spot the Speediest Black Holes

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Astronomers are hunting an elusive target: rogue black holes that have been ejected from the centers of their home galaxies. Some doubted that the quarry could be spotted, since a black hole must be gobbling matter from an accretion disk in order for that matter to shine. And if a black hole is ripped from the core of its home galaxy and sent hurling into the outskirts, the thinking goes, then its accretion disk might be left behind.

New calculations by theorist Avi Loeb (Harvard-Smithsonian Center for Astrophysics) give black hole hunters a reason to hope. Loeb showed that, generically, a black hole ejected from the center of a galaxy could bring its accretion disk along for the ride and remain visible for millions of years.

"Matter in the disk is swirling around the black hole much faster than the typical black-hole ejection speed. That matter is so tightly bound that it follows the black hole like a herd of sheep around a shepherd," said Loeb.

In the scenario examined by Loeb, two galaxies collide and merge. The spinning, supermassive black holes at the core of each galaxy coalesce, emitting powerful gravitational radiation in a preferred direction. Computer simulations recently demonstrated that the net momentum carried by the radiation gives the remnant black hole a large kick in the opposite direction. The black hole recoils at speeds of up to ten million miles per hour -- fast enough to traverse an entire galaxy in a cosmically short time of only ten million years.

Although the prediction of recoiling black holes in galaxy mergers has been shown to be robust, it was unclear until Loeb's paper whether the phenomenon could have optically observable consequences. Loeb examined the question of whether the black hole could hold onto its accretion disk while being ejected. He found that as long as the gas within the disk was orbiting at a speed far greater than the black hole ejection speed, the accretion disk would follow the black hole on its journey.

Moreover, the gaseous disk should not be consumed during the earlier binary coalescence phase that precedes the ejection because the black hole binary tends to open a cavity in the disk, like a spinning blade in a food processor.

After the two black holes join to become one, the accretion disk could feed the remnant black hole for millions of years, allowing the black hole to shine brilliantly. Such black holes at cosmological distances are called quasars.

Before the black hole's fuel is exhausted, it could travel more than 30,000 light-years from the center of its galaxy. At typical cosmological distances, that would equate to a separation on the sky of about one arcsecond (the size of a dime viewed from one mile away). Such separations are challenging to detect, since the quasar's brightness may overwhelm the fainter galaxy.

The powerful release of energy by a quasar shapes the evolution of its host galaxy. Previous theoretical calculations assumed that a quasar is pinned to the center of its galaxy where most of the gas concentrates. "However, the feedback from a recoiled quasar would be distributed along its trajectory, and would resemble the visible track of a subatomic particle in a bubble chamber," commented Loeb.

His paper argues that although most of the kicked black holes would remain bound to their host galaxies, their feedback and growth would be different than previously envisioned.

"Most importantly, this work is a good motivation for observers to search for displaced quasars," added Loeb.

This work has been accepted for publication in Physical Review Lettersand is available online at http://xxx.lanl.gov/abs/astro-ph/0703722

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