Black hole spin may create jets that control galaxy

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An artist's drawing shows a large black hole pulling gas away from a nearby star. Image Credit: NASA E/PO, Sonoma State University, Aurore Simonnet

(PhysOrg.com) -- Scattered throughout every galaxy are black holes, regions that gobble up matter and energy. Although we can't see black holes, scientists can infer their size, location and other properties by using sensitive telescopes to detect the heat they generate. This heat, which we see as X-rays, is produced as material spirals around a black hole faster and faster until it reaches a point of no return -- the "event horizon" -- from which nothing, not even light, can escape.

In addition to a galaxy's collection of black holes, which includes black holes up to 10 times the sun's mass, there is a supermassive black hole embedded in the heart of each galaxy that is roughly one million to one billion times the mass of the sun. About 10 percent of these giant black holes feature jets of plasma, or highly ionized gas, that extend in opposite directions of the black hole. By spewing huge amounts of mostly kinetic energy, or energy created by motion, from the black holes into the universe, the jets affect how stars and other bodies form, and play a crucial role in the evolution of clusters of galaxies, the largest structures in the universe.

"This black hole in the center of the cluster is affecting everything else in that cluster," said Dan Evans, a postdoctoral researcher at MIT Kavli Institute for Astrophysics and Space Research (MKI), who studies supermassive black holes and their jets. Because a jet gently heats the gas it carries throughout a galaxy cluster, it can slow and even prevent stars, which are created by the condensation and collapse of cool molecular gas, from forming, thereby affecting the growth of galaxies, Evans explained. "Without these jets, clusters of galaxies would look very different."

How these jets form remains one of the most important unsolved mysteries in extragalactic astrophysics. Now Evans may be one step closer to unlocking that mystery.

The importance of spin

For two years, Evans has been comparing several dozen galaxies whose black holes host powerful jets (these galaxies are known as radio-loud active galactic nuclei, or AGN) to those galaxies with supermassive black holes that do not eject jets. All black holes — those with and without jets — feature accretion disks, the clumps of dust and gas rotating just outside the event horizon. By examining the light reflected in the accretion disk of an AGN black hole, he concluded that jets may form right outside black holes that have a retrograde spin — or which spin in the opposite direction from their accretion disk. Although Evans and a colleague recently hypothesized that the gravitational effects of black hole spin may have something to do with why some have jets, Evans now has observational results to support the theory in a paper published in the Feb. 10 issue of the Astrophysical Journal.

While researchers know that the mass of a black hole is intimately linked to the galaxy in which it is located, they have, until now, known little about the role of its second fundamental property — spin. With this paper, Evans asserts that spin is crucial to understanding the dynamics of a black hole's host galaxy because it may actually create the jet that regulates the growth of that galaxy and the universe.

"It's the first convincing galaxy of this type seen at this angle where the result is pretty robust," said Patrick Ogle, an assistant research scientist at the California Institute of Technology, who studies AGN. Ogle believes Evans's theory regarding retrograde spin is among the best explanations he has heard for why some AGN contain a super-massive black hole with a jet and others don't.

Although Evans has suspected for nearly five years that retrograde black holes with jets are missing the innermost portion of their accretion disk, it wasn't until last year that computational advances meant that he could analyze data collected between late 2007 and early 2008 by the Suzaku observatory, a Japanese satellite launched in 2005 with collaboration from NASA, to provide an example to support the theory. With these data, Evans and colleagues from the Harvard-Smithsonian Center for Astrophysics, Yale University, Keele University and the University of Hertfordshire in the United Kingdom analyzed the spectra of a supermassive black hole with a jet located about 800 million light years away in an AGN named 3C 33.

Astrophysicists can see the signatures of X-ray emission from the inner regions of the accretion disk, which is located close to the edge of a black hole, as a result of a super hot atmospheric ring called a corona that lies above the disk and emits light that an observatory like Suzaku can detect. In addition to this direct light, a fraction of light passes down from the corona onto the black hole's accretion disk and is reflected from the disk's surface, resulting in a spectral signature pattern called the Compton reflection hump, also detected by Suzaku.

But Evans' team never found a Compton reflection hump in the X-ray emission given off by 3C 33, a finding the researchers believe provides crucial evidence that the accretion disk for a black hole with a jet is truncated, meaning it doesn't extend as close to the center of the black hole with a jet as it does for a black hole that does not have a jet. The absence of this innermost portion of the disk means that nothing can reflect the light from the corona, which explains why observers only see a direct spectrum of X-ray light.

The researchers believe the absence may result from retrograde spin, which pushes out the orbit of the innermost portion of accretion material as a result of general relativity, or the gravitational pull between masses. This absence creates a gap between the disk and the center of the black hole that leads to the piling of magnetic fields that provide the force to fuel a jet.

While Ogle believes that the retrograde spin theory is a good explanation for Evans's observations, he said it is far from being confirmed, and that it will take more examples with consistent results to convince the astrophysical community.

The field of research will expand considerably in August 2011 with the planned launch of NASA's Nuclear Spectroscopic Telescope Array (NuSTAR) satellite, which is 10 to 50 times more sensitive to spectra and the Compton reflection hump than current technology. NuSTAR will help researchers conduct a "giant census" of supermassive black holes that "will absolutely revolutionize the way we look at X-ray spectra of AGN," Evans explained. He plans to spend another two years comparing black holes with and without jets, hoping to learn more about the properties of AGN. His goal over the next decade is to determine how the spin of a supermassive black hole evolves over time.

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