Black Holes Aren't So Black

October 3 2005

Common wisdom holds that we can never see a black hole because nothing can escape it - not even light. Fortunately, black holes aren't completely black. As gas is pulled into a black hole by its strong gravitational force, the gas heats up and radiates. That radiation can be used to illuminate the black hole and paint its profile.

Within a few years, astronomers believe they will be able to peer close to the horizon of the black hole at the center of the Milky Way. Already, they have spotted light from "hot spots" just outside the black hole. While current technology is not quite ready for the final plunge, Harvard theorists Avery Broderick and Avi Loeb (Harvard-Smithsonian Center for Astrophysics) already have modeled what observers will see when they look into the maw of this monster.

"It will be really remarkable when observers can see all the way to the edge of the Milky Way's central black hole - a hole 10 million miles in diameter that's more than 25,000 light-years away," said Broderick.

All it will take is a cross-continental array of submillimeter telescopes to effectively create a single telescope as large as the Earth. This process, known as interferometry, has already been used to study longer wavelength radio emissions from outer space. By studying shorter wavelength submillimeter emissions, astronomers could get a high-resolution view of the region just outside the black hole.

"The Holy Grail of black hole astronomy is within our grasp," said Broderick. "We could see the shadow that the black hole casts on

surrounding material, and determine the size and spin of the black hole itself."

Infrared observations using existing and near-future interferometric instruments also offer the possibility of imaging the core of our Galaxy in incredible detail, with resolutions better than one milli-arcsecond.

"Submillimeter and infrared observations are complementary," said Smithsonian astronomer Lincoln Greenhill of the Center. "We need to use both to tackle the problem of getting high-resolution observations. It's the only way to get a complete picture of the Galactic center."

The black hole at the center of the Milky Way is the best target for interferometric observations because it spans the largest area in the sky of any known black hole. Nevertheless, its angular size of tens of micro-arcseconds poses a major challenge to observers, requiring resolution 10,000 times better than the Hubble Space Telescope provides in visible light.

"When astronomers achieve it, that first image of the black hole's shadow and inner accretion disk will enter textbooks, and will test our current notions on gravity in the regime where spacetime is strongly curved," said Loeb.

"Ultimately, we want to test Einstein's general theory of relativity in the strong field limit - within a strong gravitational field like that of a black hole," said Broderick.

In preparation for that observational leap, Broderick and Loeb created a computer program to simulate the view. Emissions from the Galaxy's central black hole are known to fluctuate, probably due to clumps of material being swallowed. The researchers modeled those clumps of hot gas and predicted the up-close appearance. They also summed the total

light from the "hot spots" to simulate low-resolution observations possible with current technology.

New observational results are starting to come out and already are proving consistent with Broderick and Loeb's prediction.

"Observations to date only span a limited time interval," said Loeb. "With routine monitoring, astronomers will be able to collect many examples of flares and start deriving the characteristics of the black hole itself."

A paper on the hot-spot modeling has been accepted for publication by the Monthly Notices of the Royal Astronomical Society and is available online at arxiv.org/abs/astro-ph/0506433

A second paper modeling the accretion disk has been submitted to The Astrophysical Journal Letters and is available online at arxiv.org/abs/astro-ph/0508386

A third paper combining the accretion disk with hot spots has been submitted to Monthly Notices of the Royal Astronomical Society and is available online at arxiv.org/abs/astro-ph/0509237

Source: Harvard-Smithsonian Center for Astrophysics