Closest Look Ever at the Edge of a Black Hole

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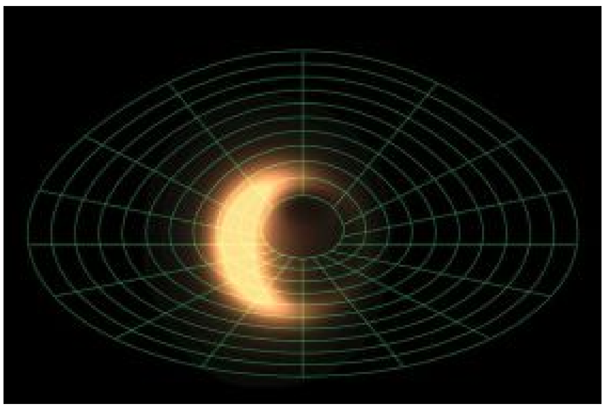

This computer simulation shows what a "hot spot" of gas orbiting a black hole would look like in an extremely high-resolution image. The black hole&acutes strong gravity distorts the appearance of nearby glowing gas, casting a silhouette. The green lines are a coordinate grid, also distorted by the black hole&acutes gravity. Here, the black hole is viewed from an angle of 30 degrees above the disk plane. Credit: Avery Broderick (CITA) & Avi Loeb (CfA)

(PhysOrg.com) -- Astronomers have taken the closest look ever at the giant black hole in the center of the Milky Way. By combining telescopes in Hawaii, Arizona, and California, they detected structure at a tiny angular scale of 37 micro-arcseconds - the equivalent of a baseball seen on the surface of the moon, 240,000 miles distant. These observations are among the highest resolution ever done in astronomy.

"This technique gives us an unmatched view of the region near the Milky

Way's central black hole," said Sheperd Doeleman of MIT, first author of the study that will be published in the Sept. 4 issue of the journal *Nature*.

"No one has seen such a fine-grained view of the galactic center before," agreed co-author Jonathan Weintroub of the Harvard-Smithsonian Center for Astrophysics (CfA). "We've observed nearly to the scale of the black hole event horizon - the region inside of which nothing, including light, can ever escape."

Using a technique called Very Long Baseline Interferometry (VLBI), a team of astronomers led by Doeleman employed an array of telescopes to study radio waves coming from the object known as Sagittarius A* (A-star). In VLBI, signals from multiple telescopes are combined to create the equivalent of a single giant telescope, as large as the separation between the facilities. As a result, VLBI yields exquisitely sharp resolution.

The Sgr A* radio emission, at a wavelength of 1.3 mm, escapes the galactic center more easily than emissions at longer wavelengths, which tend to suffer from interstellar scattering. Such scattering acts like fog around a streetlamp, both dimming the light and blurring details. VLBI is ordinarily limited to wavelengths of 3.5 mm and longer; however, using innovative instrumentation and analysis techniques, the team was able to tease out this remarkable result from 1.3-mm VLBI data.

The team clearly discerned structure with a 37 micro-arcsecond angular scale, which corresponds to a size of about 30 million miles (or about one-third the earth-sun distance) at the galactic center. With three telescopes, the astronomers could only vaguely determine the shape of the emitting region. Future investigations will help answer the question of what, precisely, they are seeing: a glowing corona around the black hole, an orbiting "hot spot," or a jet of material. Nevertheless, their result represents the first time that observations have gotten down to the scale of the black hole itself, which has a "Schwarzschild radius" of 10 million miles.

"This pioneering paper demonstrates that such observations are feasible," commented theorist Avi Loeb of Harvard University, who is not a member of the discovery team. "It also opens up a new window for probing the structure of space and time near a black hole and testing Einstein's theory of gravity."

In 2006, Loeb and his colleague, Avery Broderick, examined how ultra-high-resolution imaging of the galactic center could be used to look for the shadow or silhouette of the supermassive black hole lurking there, as well as any "hot spots" within material flowing into the black hole. Astronomers now are poised to test those theoretical predictions.

"This result, which is remarkable in and of itself, also confirms that the 1.3-mm VLBI technique has enormous potential, both for probing the galactic center and for studying other phenomena at similar small scales," said Weintroub.

The team plans to expand their work by developing novel instrumentation to make more sensitive 1.3-mm observations possible. They also hope to develop additional observing stations, which would provide additional baselines (pairings of two telescope facilities at different locations) to enhance the detail in the picture. Future plans also include observations at shorter, 0.85-mm wavelengths; however, such work will be even more challenging for many reasons, including stretching the capabilities of the instrumentation, and the requirement for a coincidence of excellent weather conditions at all sites.

"The technical capabilities that have been developed for the Smithsonian's Submillimeter Array on Mauna Kea are a crucial contribution to this program," said Jim Moran, one of the CfA participants in this work.

Other CfA or former CfA researchers who participated on the project include Ken Young and Dan Marrone.

Provided by Harvard-Smithsonian Center for Astrophysics

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