Data suggest black holes swallow stellar debris in bursts

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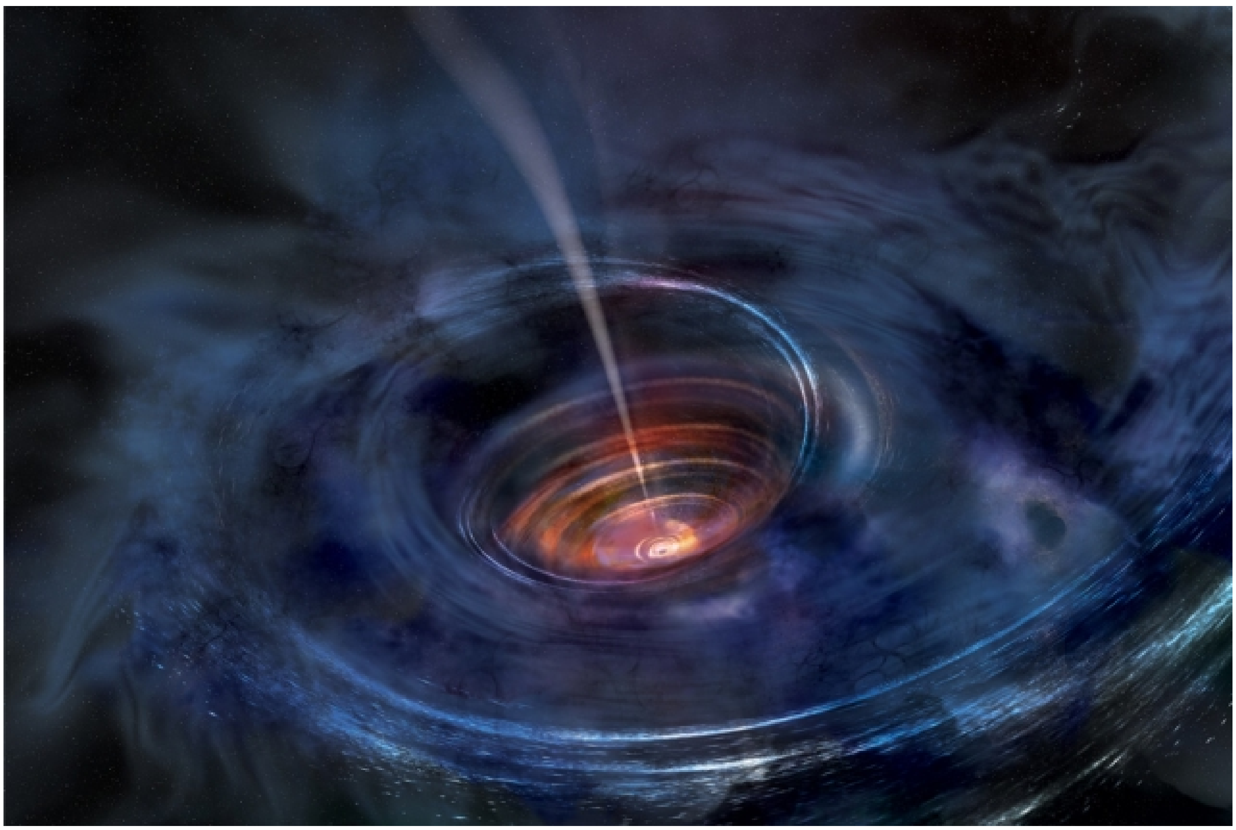

In this artist's rendering, a thick accretion disk has formed around a supermassive black hole following the tidal disruption of a star that wandered too close. Stellar debris has fallen toward the black hole and collected into a thick chaotic disk of hot gas. Flashes of X-ray light near the center of the disk result in light echoes that allow astronomers to map the structure of the funnel-like flow, revealing for the first time strong gravity effects around a normally quiescent black hole. Credit: NASA/Swift/Aurore Simonnet, Sonoma State University

In the center of a distant galaxy, almost 300 million light years from Earth, scientists have discovered a supermassive black hole that is "choking" on a sudden influx of stellar debris.

In a paper published today in *Astrophysical Journal Letters*, researchers from MIT, NASA's Goddard Space Flight Center, and elsewhere report on a "tidal disruption flare"—a dramatic burst of electromagnetic activity that occurs when a black hole obliterates a nearby star. The flare was first discovered on Nov. 11, 2014, and scientists have since trained a variety of telescopes on the event to learn more about how black holes grow and evolve.

The MIT-led team looked through data collected by two different telescopes and identified a curious pattern in the energy emitted by the flare: As the obliterated star's dust fell into the black hole, the researchers observed small fluctuations in the optical and ultraviolet (UV) bands of the electromagnetic spectrum. This very same pattern repeated itself 32 days later, this time in the X-ray band.

The researchers used simulations of the event performed by others to infer that such energy "echoes" were produced from the following scenario: As a star migrated close to the black hole, it was quickly ripped apart by the black hole's gravitational energy. The resulting stellar debris, swirling ever closer to the black hole, collided with itself, giving off bursts of optical and UV light at the collision sites. As it was pulled further in, the colliding debris heated up, producing X-ray flares, in the same pattern as the optical bursts, just before the debris fell into the black hole.

"In essence, this black hole has not had much to feed on for a while, and suddenly along comes an unlucky star full of matter," says Dheeraj Pasham, the paper's first author and a postdoc in MIT's Kavli Institute for Astrophysics and Space Research. "What we're seeing is, this stellar material is not just continuously being fed onto the black hole, but it's interacting with itself—stopping and going, stopping and going. This is telling us that the black hole is 'choking' on this sudden supply of stellar debris."

Pasham's co-authors include MIT Kavli postdoc Aleksander Sadowski and researchers from NASA's Goddard Space Flight Center, the University of Maryland, the Harvard-Smithsonian Center for Astrophysics, Columbia University, and Johns Hopkins University.

A "lucky" sighting

Pasham says tidal disruption flares are a potential window into the universe's many "hidden" black holes, which are not actively accreting, or feeding on material.

"Almost every massive galaxy contains a supermassive black hole," Pasham says. "But we won't know about them if they're sitting around doing nothing, unless there's an event like a tidal disruption flare."

Such flares occur when a star, migrating close to a black hole, gets pulled apart from the black hole's immense gravitational energy. This stellar obliteration can give off incredible bursts of energy all along the electromagnetic spectrum, from the radio band, through the optical and UV wavelengths, and on through the X-ray and high-energy gamma ray bands. As extreme as they are, tidal disruption flares are difficult to observe, as they happen infrequently.

"You'd have to stare at one galaxy for roughly 10,000 to 100,000 years to see a star getting disrupted by the black hole at the center," Pasham says.

Nevertheless, on Nov. 11, 2014, a global network of robotic telescopes named ASASSN (All Sky Automated Survey for SuperNovae) picked up signals of a possible tidal disruption flare from a galaxy 300 million light years away. Scientists quickly focused other telescopes on the event, including the X-ray telescope aboard NASA's Swift satellite, an orbiting spacecraft that scans the sky for bursts of extremely high energy.

"Only recently have telescopes started 'talking' to each other, and for this particular event we were lucky because a lot of people were ready for it," Pasham says. "It just resulted in a lot of data."

A light-on collision

With access to these data, Pasham and his colleagues wanted to solve a longstanding mystery: Where did a flare's bursts of light first arise? Using models of black hole dynamics, scientists have been able to estimate that as a black hole rips a star apart, the resulting tidal disruption flare can produce X-ray emissions very close to the black hole. But it's been difficult to pinpoint the origin of optical and UV emissions. Doing so would be an added step toward understanding what happens when a star gets disrupted.

"Supermassive black holes and their host galaxies grow in-situ," Pasham says. "Knowing exactly what happens in tidal disruption flares could help us understand this black hole and galaxy coevolution process."

The researchers studied the first 270 days following the detection of the tidal disruption flare, named ASASSN-14li. In particular, they analyzed X-ray and optical/UV data taken by the Swift satellite and the Las Cumbres Observatory Global

Telescope. They identified fluctuations, or bursts, in the X-ray band—two broad peaks (one around day 50, and the other around day 110) followed by a short dip around day 80. They identified this very same pattern in the optical/UV data some 32 days earlier.

To explain these emission "echoes," the team ran simulations of a tidal disruption flare produced from a black hole obliterating a star. The researchers modeled the resulting accretion disc—an elliptical disc of stellar debris swirling around the black hole—along with its probable speed, radius, and rate of infall, or speed at which material falls onto the black hole.

From simulations run by others, the researchers conclude that the optical and UV bursts likely originated from the collision of stellar debris on the outer perimeter of the black hole. As this colliding material circles closer into the black hole, it heats up, eventually giving off X-ray emissions, which can lag behind the optical emissions, similar to what the scientists observed in the data.

"For supermassive black holes steadily accreting, you wouldn't expect this choking to happen," Pasham says. "The material around the black hole would be slowly rotating and losing some energy with each circular orbit. But that's not what's happening here. Because you have a lot of material falling onto the black hole, it's interacting with itself, falling in again, and interacting again. If there are more events in the future, maybe we can see if this is what happens for other tidal disruption flares."

More information: Dheeraj R. Pasham et al. Optical/UV-to-X-Ray Echoes from the Tidal Disruption Flare ASASSN-14li, *The Astrophysical Journal* (2017). DOI: 10.3847/2041-8213/aa6003 , iopscience.iop.org/article/10. … 847/2041-8213/aa6003

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