Death by black hole: Astronomers spot flare from “spaghettification” of star

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Animation depicting a star experiencing spaghettification as it’s sucked in by a supermassive black hole during a “tidal disruption event.”
It’s a popular misconception that black holes behave like cosmic vacuum cleaners, ravenously sucking up any matter in their surroundings. In reality, only stuff that passes beyond the event horizon—including light—is swallowed up and can’t escape, although black holes are also messy eaters. That means that part of an object’s matter is actually ejected out in a powerful jet.

If that object is a star, the process of being shredded (or “spaghettified”) by the powerful gravitational forces of a black hole occurs outside the event horizon, and part of the star’s original mass is ejected violently outward. This in turn can form a rotating ring of matter (aka an accretion disk) around the black hole that emits powerful X-rays and visible light. Those jets are one way astronomers can indirectly infer the presence of a black hole. Now astronomers have recorded the final death throes of a star being shredded by a supermassive black hole in just such a “tidal disruption event” (TDE), described in a new paper published in the journal Monthly Notices of the Royal Astronomical Society.

“The idea of a black hole ‘sucking in’ a nearby star sounds like science fiction. But this is exactly what happens in a tidal disruption event,” said co-author Matt Nicholl of the University of Birmingham. “We were able to investigate in detail what happens when a star is eaten by such a monster.”

“A tidal disruption event results from the destruction of a star that strays too close to a supermassive black hole,” said Edo Berger of Harvard University’s Center for Astrophysics, another co-author. “In this case the star was torn apart with about half of its mass feeding—or accreting—into a black hole of one million times the mass of the Sun, and the other half was ejected outward.”

Death by tidal forces

The notion of being “spaghettified” after falling into a black hole was popularized in Stephen Hawking’s 1988 best-selling book, *A Brief History of Time*. Hawking envisioned an unfortunate astronaut who passed beyond the event horizon and would find themselves subject to the intense gravitational gradient of the black hole. (The gravitational gradient is the difference in strength of gravity’s pull depending on an object’s orientation.)

If the astronaut fell in feet first, for example, the pull would be stronger on the feet than the head. The astronaut would be stretched vertically and compressed horizontally by the black hole’s tidal forces until they resembled a strand of spaghetti. From a physics standpoint, it’s the same reason the Earth experiences tides: the gravitational pull from the moon pulls oceans one way and flattens them the other way. At least it would be quick; the whole process would occur in less than a second.

Enlarge / Artist’s impression of a star being tidally disrupted by the powerful gravity of a supermassive black hole.
ESO/M. Kornmesser

All of this is purely hypothetical, the subject of various thought experiments. But on the scale of stars and galaxies, a kind of spaghettification is a real phenomenon, albeit one that occurs outside the black hole’s event horizon rather than inside. These tidal disruption events are likely quite common in our universe, even though only a few have been detected to date.

For instance, in 2018, astronomers announced the first direct image of the aftermath of a star being shredded by a black hole 20 million times more massive than our Sun, in a pair of colliding galaxies called Arp 299 about 150 million light years from Earth. They used a combination of radio and infrared telescopes, including the Very Long Baseline Array (VLBA), to follow a particular formation and expansion of the jet of matter ejected in the wake of a star being shredded by a supermassive black hole at the center of one of the

colliding galaxies.

However, these powerful bursts of light are often shrouded behind a curtain of interstellar dust and debris, making it difficult for astronomers to study them in greater detail. This latest event (dubbed AT 2019qiz) was discovered shortly after the star had been shredded last year, making it easier to study in detail, before that curtain of dust and debris had fully formed. Astronomers conducted follow-up observations across the electromagnetic spectrum over the next six months, using multiple telescopes around the world, including the Very Large Telescope (VLT) array and the New Technology Telescope (NTT), both located in Chile.

“Because we caught it early, we could actually see the curtain of dust and debris being drawn up as the black hole launched a powerful outflow of material with velocities up to 10,000 km/s,” said co-author Kate Alexander of Northwestern University. “This is a unique ‘peek behind the curtain’ that provided the first opportunity to pinpoint the origin of the obscuring material and follow in real time how it engulfs the black hole.”

According to Berger, these observations provide the first direct evidence that outflowing gas during disruption and accretion produces the powerful optical and radio emissions previously observed. “Until now, the nature of these emissions has been heavily debated, but here we see that the two regimes are connected through a single process,” he said.

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