String theory solves mystery about how particles behave outside a black hole photon sphere

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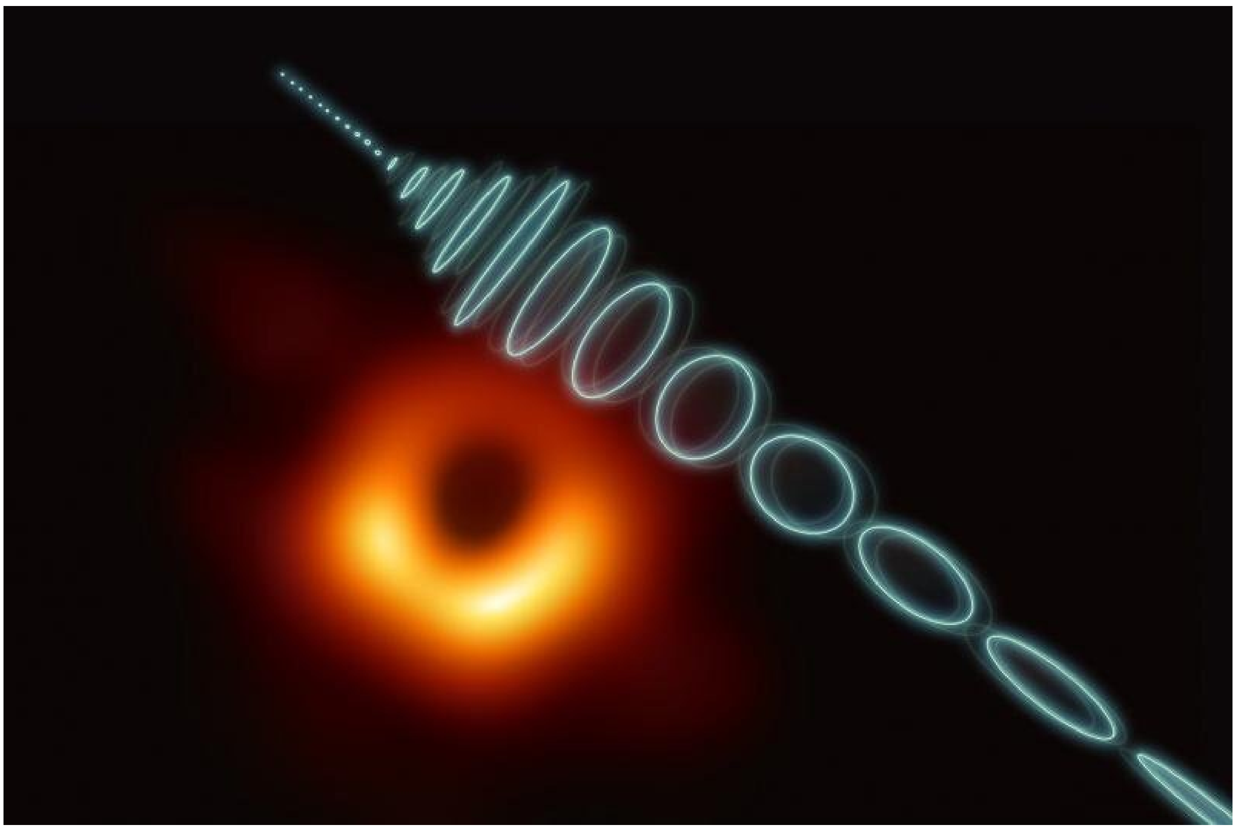

Figure 1. An artist's impression of a "string" passing near a black hole. As the string approaches the black hole, it is gradually stretched. Then, as it moves past the black hole, it begins to vibrate. The image to the left, which was captured by the Event Horizon Telescope, represents the shadow of the supermassive black hole at the center of the galaxy M87, including the ring of light around it. Credit: EHT Collaboration; Kavli IPMU

A paper by the Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) Director Ooguri Hirosi and Project Researcher Matthew Dodelson on the string theoretical effects outside the black hole photon sphere has been selected for the "Editors' Suggestion" of the journal *Physical Review D*. Their paper was published on March 24, 2021.

In a quantum theory of point particles, a fundamental quantity is the correlation function, which measures the probability for a particle to propagate from one point to another. The correlation function develops singularities when the two points are connected by light-like trajectories. In a flat spacetime, there is such a unique trajectory, but when spacetime is curved, there can be many light-like trajectories connecting two points. This is a result of gravitational lensing, which describes the effect of curved geometry on the propagation of light.

In the case of a black hole spacetime, there are light-like trajectories winding around the black hole several times, resulting in a black hole photon sphere, as seen in the recent images by the Event Horizon Telescope (EHT) of the supermassive black hole at the center of the galaxy M87.

Released on April 10, 2019, the EHT Collaboration's images captured the shadow of a black hole and its photon sphere, the ring of light surrounding it. A photon sphere can occur in a region of a black hole where light entering in a horizontal direction can be forced by gravity to travel in various orbits. These orbits lead to singularities in the aforementioned correlation function.

However, there are cases when the singularities generated by trajectories winding around a black hole multiple times contradict with physical expectations. Dodelson and Ooguri have shown that such singularities are resolved in string theory.

In string theory, every particle is considered as a particular excited state of a string. When the particle travels along a nearly light-like trajectory around a black hole, the spacetime curvature leads to tidal effects, which stretch the string.

Dodelson and Ooguri showed that, if one takes these effects into account, the singularities disappear consistently with physical expectations. Their result provides evidence that a consistent quantum gravity must contain extended objects such as strings as its degrees of freedom.

Ooguri says, "Our results show how string theoretical effects are enhanced near a black hole. Though the effects we found are not strong enough to have an observable consequence on ETH's black hole image, further research may show us a way to test string theory using black holes."

More information: Matthew Dodelson et al. Singularities of thermal correlators at strong coupling, *Physical Review D* (2021). DOI: 10.1103/PhysRevD.103.066018

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