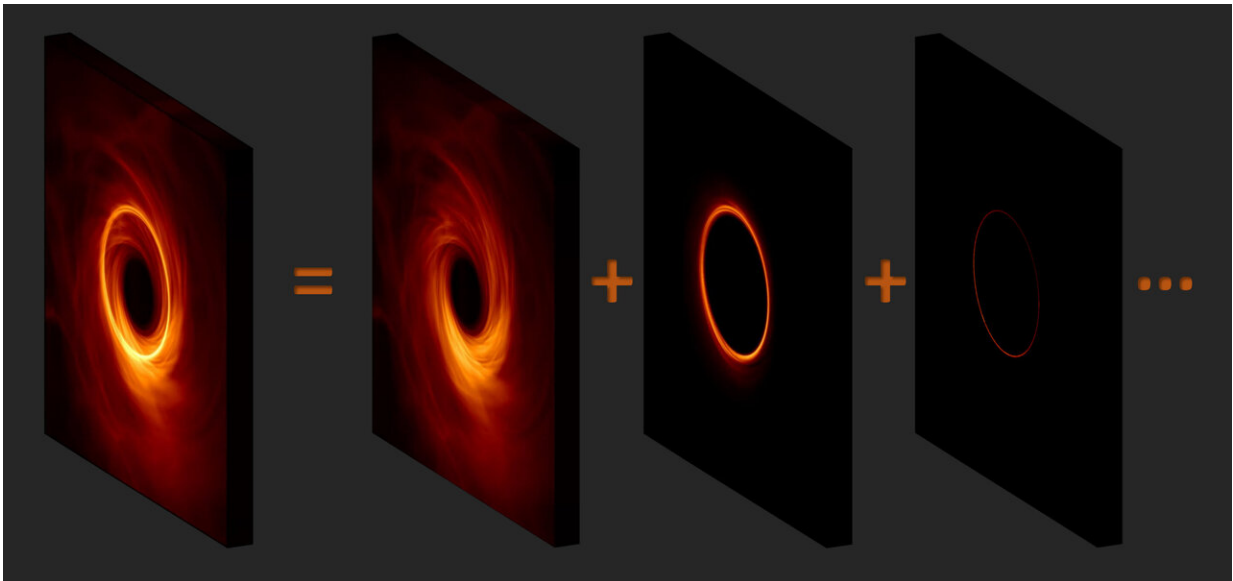


Research team discovers path to razor-sharp black hole images

March 18 2020, by Lee Sandberg



The image of a black hole has a bright ring of emission surrounding a "shadow" cast by the black hole. This ring is composed of a stack of increasingly sharp subrings that correspond to the number of orbits that photons took around the black hole before reaching the observer. Credit: George Wong (UIUC) and Michael Johnson (CfA)

Last April, the Event Horizon Telescope (EHT) sparked international excitement when it unveiled the first image of a black hole. Today, a team of researchers have published new calculations that predict a striking and intricate substructure within black hole images from

extreme gravitational light bending.

"The image of a black hole actually contains a nested series of rings," explains Michael Johnson of the Center for Astrophysics, Harvard and Smithsonian (CfA). "Each successive ring has about the same diameter but becomes increasingly sharper because its light orbited the black hole more times before reaching the observer. With the current EHT image, we've caught just a glimpse of the full complexity that should emerge in the image of any black hole."

Because black holes trap any photons that cross their event horizon, they cast a shadow on their bright surrounding emission from hot infalling gas. A "photon ring" encircles this shadow, produced from light that is concentrated by the strong gravity near the black hole. This photon ring carries the fingerprint of the black hole—its size and shape encode the mass and rotation or "spin" of the black hole. With the EHT images, black hole researchers have a new tool to study these extraordinary objects.

"This is an extremely exciting time to be thinking about the physics of black holes," says Daniel Kapec from the Institute for Advanced Study. "Einstein's [theory of general relativity](#) makes a number of striking predictions for the types of observations that are finally coming within reach, and I think we can look forward to lots of advances in the coming years. As a theorist, I find the rapid convergence between theory and experiment especially rewarding, and I hope we can continue to isolate and observe more universal predictions of general relativity as these experiments become more sensitive."

The research team included observational astronomers, [theoretical physicists](#), and astrophysicists.

"Bringing together experts from different fields enabled us to really

connect a theoretical understanding of the photon ring to what is possible with observation," notes George Wong, a physics graduate student at the University of Illinois at Urbana-Champaign. Wong developed software to produce simulated black hole images at higher resolutions than had previously been computed and to decompose these into the predicted series of sub-images. "What started as classic pencil-and-paper calculations prompted us to push our simulations to new limits."

The Image of a Black Hole

Black holes
 Black holes are so compact that light passing nearby is bent. Light that crosses the event horizon of a black hole is trapped forever. Light passing at a precise distance will orbit the black hole many times before escaping or falling in.

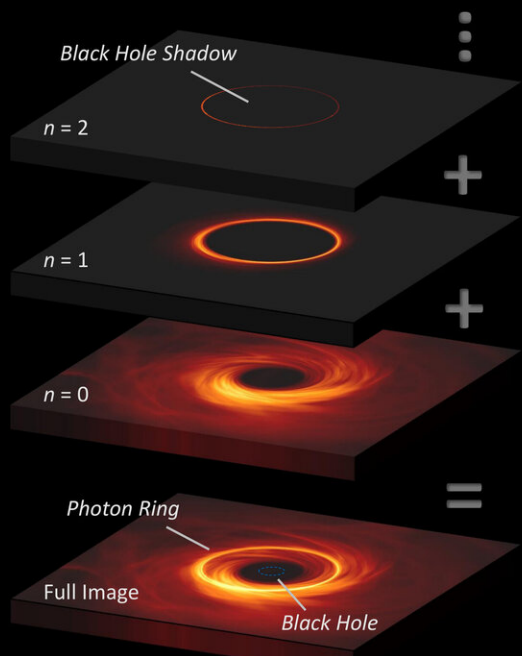
Supermassive black holes live at the centers of galaxies. The Event Horizon Telescope (EHT) recently captured a picture of the supermassive black hole in M87. This black hole has 2,000,000,000,000,000 times more mass than the Earth!

The Shadow and Photon Ring of a Black Hole
 Supermassive black holes are bathed in glowing gas that is heated to billions of degrees. Because their extreme gravity traps light, black holes cast a shadow on this bright emission. The shadow is surrounded by a bright photon ring.

The photon ring is composed of a series of increasingly sharp subrings. Each subring n is produced by photons that traveled around the black hole $n/2$ times before reaching the observer. These subrings stack to give the full image.

Ultra-Sharp Black Hole Images
 Photon subrings contain rich information about the black hole but are difficult to see. Nevertheless, they could be studied with an interferometer, which joins multiple telescopes. For M87, the $n = 1$ subring could be seen by extending the EHT to low Earth orbit, and $n = 2$ could be seen with a telescope on the Moon.

Reference: *Universal Interferometric Signatures of a Black Hole's Photon Ring*
 Credit: Michael D. Johnson (CfA), Simulation: George Wong (UIUC)



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The researchers also found that the black hole's image substructure creates new possibilities to observe [black holes](#). "What really surprised us was that while the nested subrings are almost imperceptible to the naked eye on images—even perfect images—they are strong and clear

signals for arrays of telescopes called interferometers," says Johnson. "While capturing black hole images normally requires many distributed telescopes, the subrings are perfect to study using only two telescopes that are very far apart. Adding one space telescope to the EHT would be enough."

"Black hole physics has always been a beautiful subject with deep theoretical implications, but now it has also become an experimental science," says Alex Lupsasca from the Harvard Society of Fellows. "As a theorist, I am delighted to finally glean real data about these objects that we've been abstractly thinking about for so long."

The results were published in *Science Advances*.

More information: M.D. Johnson et al., "Universal interferometric signatures of a black hole's photon ring," *Science Advances* (2020). [DOI: 10.1126/sciadv.aaz1310](https://doi.org/10.1126/sciadv.aaz1310) , advances.sciencemag.org/content/6/12/eaaz1310

Provided by Institute for Advanced Study

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