

# SCIENTIFIC AMERICAN Space & Physics

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INTERSTELLAR  
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A SINGLE  
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REALITY

# At Last

A 10-YEAR EFFORT PAYS OFF AND FINALLY REVEALS  
THE SHADOWY FACE OF A SUPERMASSIVE BLACK HOLE

WITH COVERAGE FROM

**nature**

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● *Opinion*

SPACE

# Living Near a Supermassive Black Hole

**It would pose some dangers, of course—but it could also be fun!**

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**W**e have known since the 1990s that planets exist around pulsars, which are extraordinarily dense objects born out of the violent explosions of stars. It is therefore reasonable to assume that planets might also exist around black holes, which, perhaps surprisingly to many people, have a much weaker impact on their environment than pulsars. It's even possible that life may form on some of these planets, given that organisms on Earth have adapted to extreme conditions, including boiling heat, freezing cold, and acidic, highly salty and even radioactive environments.

Inhabited planets could exist near the supermassive black holes that lie at the cores of most galaxies. Our own galaxy, the Milky Way, harbors a black hole whose mass is as great as four million stars put together. Known as Sgr A\* (Sgr stands for Sagittarius), its innermost stable circular orbit



(ISCO) has roughly the size of the orbit of Mercury around our sun.

So, what would life be like on such a planet?

Before addressing the many health hazards for life near a black hole, we should consider the benefits. If civilizations form in, or migrate to, the vicinity of black holes, what could they do for fun and profit? The following top 10 activities come to mind:

- Using the black hole as a source of clean energy by dumping trash through the accretion disk of matter that swirls around it. Up to 42 percent of the rest mass of this trash can be converted to radiation at the ISCO of a maximally spinning black hole.
- Coupling some engineered device to the spin of the black hole, as a giant flywheel from which spin energy can be harnessed.

- Surfing with light sails on relativistic jets at speeds approaching that of light.
- Prolonging youth by visiting beauty salons near the horizon of the black hole, where time is ticking more slowly as a result of gravitational redshift.
- Viewing the spectacle of the entire universe reflected and distorted as gravitationally lensed images around the black hole.
- Establishing an amusement park at the so-called photon sphere, where one could enjoy relativistic effects for fun, such as seeing oneself from behind by looking straight ahead as light circles around the black hole.
- Taking advantage of new opportunities for space travel. For example, when the Milky Way and its sister galaxy Andromeda merge billions of years from now, the two black holes at their centers will pair into a tight binary, which should act as a gravitational slingshot and eject stars or planets at up to the speed of light, as described in [two papers](#) that the author wrote with James Guillochon. Travel agencies may offer tickets to exceptional rides on ejected planets that traverse the entire universe.
- Sending criminals into the black hole as the ultimate prison with a death sentence at the singularity. The mass of the black hole will determine how much time is left for the prisoners to live. The lesser their crime, the more massive the black hole would be, extending their remaining life span after crossing the “prison walls” associated with the black hole horizon.

- Using gravitational waves from small objects orbiting the black hole for communication. Such signals cannot be blocked by any known form of matter.
- Testing fundamental aspects of quantum gravity through organized trips for string physics experimentalists.

The main danger for astronauts attempting to execute these activities stems from gravitational tides. As Albert Einstein noted in his famous thought experiment, being inside a free-falling elevator or spacecraft feels like having no gravity at all. But any difference in gravitational acceleration between your head and toes, which measures the curvature of spacetime, could potentially rip your body apart. Such tides would impose a death sentence near a stellar-mass black hole but are of no threat to the human body in the much more expansive environment around a supermassive black hole, like Sgr A\*.

Correspondingly, the density of matter required to make a black hole scales linearly with its spacetime curvature. Low-mass black holes are formed through the collapse of the core of a massive star to densities far greater than that of an atomic nucleus. But to make a supermassive black hole, which is much more rarefied, it is sufficient to fill the orbit of Jupiter with liquid water. As simple as this engineering project might sound, it is by no means practical since it requires about 100 million solar masses of water. And the heat generated while pouring the water in would burn any associated facilities.

Indeed, the heat released by accreting super-

massive black holes poses an existential threat to civilizations residing near the centers of galaxies. In a [paper](#) with John Forbes, we showed that a significant fraction of all planets in the universe are vulnerable to their atmospheres being stripped or their oceans being boiled off as a result of having been close to an active galactic nucleus sometime during their lives.

For the first time in human history, we now have the technology to image the silhouettes of the supermassive black holes at the centers of the Milky Way and the giant elliptical galaxy M87 on the background of the glowing gas behind them. The first such images are scheduled to be released later this year.

In the summary lecture of the 2018 conference of Harvard’s [Black Hole Initiative](#), an interdisciplinary center that focuses on the study of black holes, I suggested that [future advances in space propulsion](#) might allow us to organize a field trip to a nearby black hole. This will provide a great opportunity to pursue some of the aforementioned activities—and perhaps even exchange notes on quantum gravity with any backpackers from other civilizations who might have already camped out there.