Life Around Black Holes

By Abraham Loeb on February 18, 2019

Planets are known to exist around neutron stars, which are born out of the violent explosions of stars. It is therefore reasonable to assume that planets might also exist around black holes, born inside imploding stars which have a much weaker impact on their environment. And life may form on some of these planets, given its ability to adapt to extreme conditions on Earth. Planets may also exist around bigger black holes. About a tenth of a percent of mass in the central spheroid of each galaxy is drained to the center, forming a supermassive black hole surrounded by stars with their planets. Our own galaxy, the Milky Way, harbors a black hole weighting four million Suns, Sgr A*, whose innermost stable circular orbit (ISCO) has roughly the size of the orbit of Mercury around the Sun. What is life like around all these black holes?

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

1. Using the black hole as a source of clean energy by damping trash through an accretion disk. Up to 42% of the rest mass of this trash can be converted to radiation at the ISCO of a maximally spinning black hole.
2. Coupling some engineered device to the spin of the black hole, as a giant flywheel from which spin energy can be harnessed.
3. Surfing with light sails on relativistic jets up to the speed of light.
4. Having beauty salons to prolong youth near the horizon of the black hole, where time is ticking more slowly as a result of gravitational redshift.
5. Viewing the spectacle of the entire universe reflected in gravitationally lensed images around the black hole.
6. Establishing an amusement park at the so-called "photon sphere" around the black hole, where you can enjoy relativistic effects for fun, such as seeing you own back by looking straight ahead as light circles around the black hole.
7. Taking advantage of new opportunities for space travel. For example, when the Milky Way and its sister galaxy, Andromeda, will merge, 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 up to the speed of light, as described in two papers that we wrote with James Guillochon. Travel agencies may offer tickets to exceptional rides on ejected planets which traverse the entire universe.
8. 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' life. The lesser is 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.
9. Using gravitational waves from small objects orbiting the black hole for communication. Such signals cannot be blocked by any known form of matter.
10. Testing fundamental aspects quantum gravity through organized trips for string physics experimentalists.

The main danger for astronauts attempting to execute the above activities around a black hole stems from gravitational tides. As Albert Einstein noted in his famous thought experiment, boarding 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 space-time, could potentially reap your body apart. Tides 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 space-time curvature. Low mass black holes are formed through the collapse of the core of a massive star beyond the density 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 a hundred 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 supermassive black holes pose 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 their proximity to an active galactic nucleus over their past.

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 or exchange notes on quantum gravity with any backpackers from other civilizations who might have already camped out there.

ABOUT THE AUTHOR

Abraham Loeb

Abraham Loeb is chair of the astronomy department at Harvard University, founding director of Harvard's Black Hole Initiative and director of the Institute for Theory and Computation at the Harvard-Smithsonian Center for Astrophysics. He also chairs Board on Physics and Astronomy of the National Academies and the advisory board for the Breakthrough Starshot project. (Credit: Nick Higgins)