Black holes do not exist where space and time do not exist, says new theory

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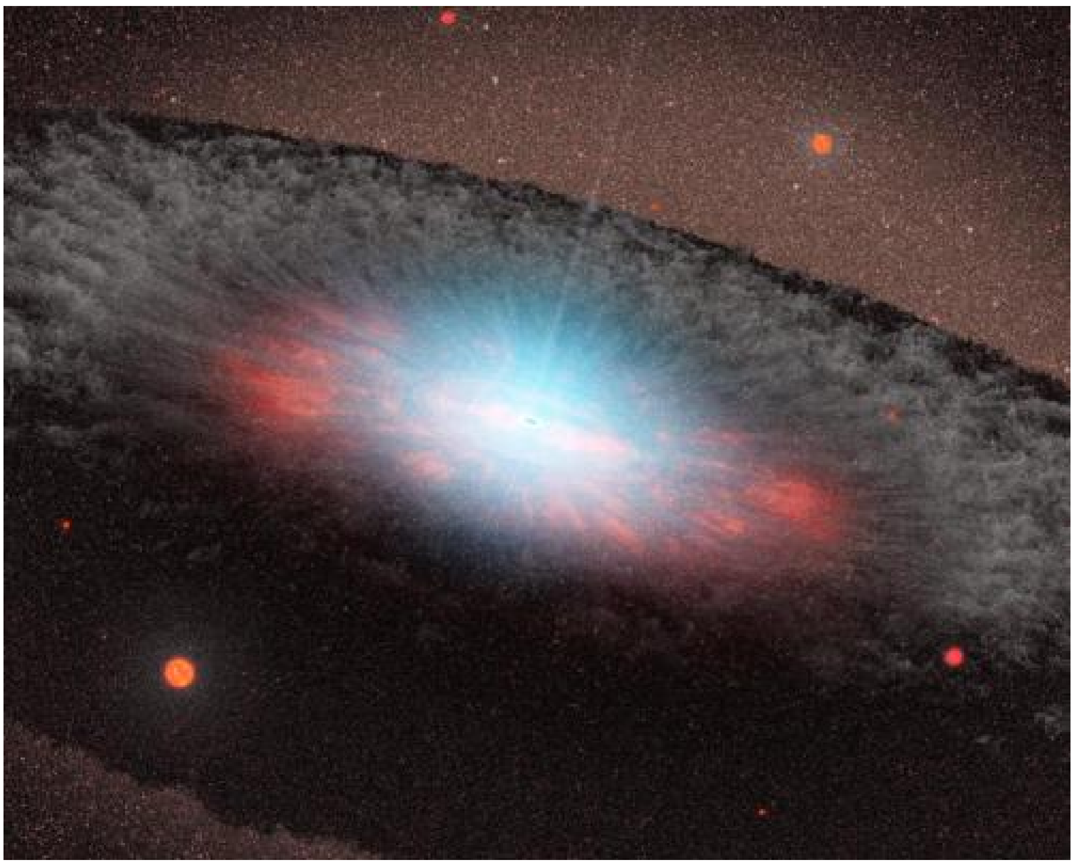

This artist's concept depicts a supermassive black hole at the center of a galaxy. The blue color here represents radiation pouring out from material very close to the black hole. The grayish structure surrounding the black hole, called a torus, is made up of gas and dust. Credit: NASA/JPL-Caltech

(Phys.org) —The quintessential feature of a black hole is its "point of no return," or what is more technically called its event horizon. When anything—a star, a particle, or wayward human—crosses this horizon, the black hole's massive gravity pulls it in with such force that it is impossible to escape. At least, this is what happens in traditional black hole models based on general relativity. In general, the existence of the event horizon is responsible for most of the strange phenomena associated with black holes.

In a new paper, physicists Ahmed Farag Ali, Mir Faizal, and Barun Majunder have shown that, according to a new generalization of Einstein's theory of gravity called "gravity's rainbow," it is not possible to define the position of the event horizon with arbitrary precision. If the event horizon can't be defined, then the black hole itself effectively does not exist.

"In gravity's rainbow, space does not exist below a certain minimum length, and time does not exist below a certain minimum time interval," Ali, a physicist at the Zewail City of Science and Technology and Benha University, both in Egypt, told *Phys.org*. "So, all objects existing in space and occurring at a time do not exist below that length and time interval [which are associated with the Planck scale]. As the event horizon is a place in space which exists at a point in time, it also does not exist below that scale."

When Ali talks about "all objects," he literally means everything around us, including ourselves.

"We also do not exist physically below that length and time interval," he said. "However, for us, our house, our car, etc., it does not matter if we do not exist at any one point of space and time, as long as we exist beyond a certain interval. However, for the event horizon it does matter, and this causes the main difference in our calculations."

Gravity's rainbow

Gravity's rainbow arises from attempts to develop a theory that combines both the theory of general relativity and quantum mechanics. To fully solve the problems related to black holes, or even the beginning of our universe, physicists require a theory of quantum gravity.

"Even though no one has been able to discover such a theory, there are various candidates," Ali said. "These include ideas like taking space and time as fundamentally discrete, or using some mathematical loops as a fundamental quantity to construct space and time, or even replacing particles by tiny strings, and many other exotic ideas.

"What many of these models have in common is that it can be inferred from them that the energy of a particle cannot get as large as possible, but that there is a maximum energy that any particle can reach. This restriction can be easily combined with Einstein's special theory of relativity, and the resultant theory is called the doubly special theory of relativity, or DSR."

As the physicists explain, it is possible to generalize DSR to include gravity, and this theory is called gravity's rainbow.

"General relativity predicts that the geometry of space and time curves in the presence of matter, and this causes gravity to exist," Ali said. "Gravity's rainbow predicts that this curvature also depends on the energy of the observer measuring it. So, in gravity's rainbow, gravity acts differently on particles with different energies. This difference is very small for objects like the Earth. However, it becomes significant for objects like black holes."

Information paradox

The point of the work is not simply to abolish one of the defining features of a black hole, but rather the results could resolve the 40-year-old black hole information paradox that began with work by Stephen Hawking back in the 1970s. At that time, Hawking proposed that black holes emit radiation as they rotate, causing them to lose mass faster than they gain mass, so that they steadily evaporate and eventually disappear altogether.

The paradox in this scenario is that Hawking radiation originates from the mass of objects that fell into the black hole, but (in theory) the radiation does not carry complete information about these objects as it radiates away from the black hole. Eventually this radiation is expected to cause the black hole to evaporate completely. So the question then arises: where does the information about the objects go?

In everyday life, shredding or burning paper documents may be common practice to destroy information, but according to quantum theory, information can never be completely destroyed. In principle, the initial state of a system can always be determined by using information about its final state. But Hawking radiation can't determine the initial state of anything.

Many proposals have been put forth to solve this paradox, including the possibility that some information slowly leaks out over time, that information is stored deep inside the black hole, and that Hawking radiation actually does contain complete information.

One of the most developed explanations of the paradox is called black hole complementarity, which is based on the idea that an observer falling into a black hole and an observer watching from a distance see two completely different things. The in-going observer sees information (in the form of himself) pass through the black hole's event horizon, but to a distant observer it appears that the in-going observer never actually reaches the event horizon due to the strange effect in general relativity of time dilation. Instead, the distant observer sees the information being reflected away from the event horizon in the form of radiation. Since the two observers cannot communicate, there is no paradox (though to many people, such a solution may sound even stranger than the paradox itself).

Planck-scale limits

In their new paper, Ali, Faizal, and Majunder show that something very different happens in black hole complementarity when there is no event horizon below a certain length and time interval, as suggested by gravity's rainbow. Instead of it appearing to the distant observer that it takes an infinite amount of time for the in-going observer to reach the event horizon, in the new theory, that time is finite. In other words, the distant observer eventually sees the in-going observer fall into the black hole.

Using this new insight gained from gravity's rainbow, Ali, Faizal, and Majumder claim that the mysteries surrounding a black hole arise from the fact that space and time are being described at a scale at which they do not exist.

"If we restrict our description to scales at which space and time exist, then the apparent paradoxes associated with black holes seem to naturally resolve," Ali said. "For example, as the information paradox depends on the existence of the event horizon, and an event horizon like all objects does not exist below a certain length and time interval, then there is no absolute information paradox in gravity's rainbow. The absence of an effective horizon means that there is nothing absolutely stopping information from going out of the black hole."

Beyond black holes

In addition to offering a solution to the black hole information paradox, the physicists explain that the existence of minimum length and time intervals reminds us that it is important to know what questions one is allowed to ask in physics to get the correct answer. The scientists explain this idea using the analogy of a metal rod:

"We can ask, how much will a rod bend at a given force without breaking the rod? When we apply a force so great that it breaks the rod, it is meaningless to talk of bending that rod. In the same way, in gravity's rainbow, it becomes meaningless to talk of space below a certain length scale, and time below a certain interval.

"The most important lesson from this paper is that space and time exist only beyond a certain scale," Ali concluded. "There is no space and time below that scale. Hence, it is meaningless to define particles, matter, or any object, including black holes, that exist in space and time below that scale. Thus, as long as we keep ourselves confined to the scales at which both space and time exist, we get sensible physical answers. However, when we try to ask questions at length and time intervals that are below the scales at which space and time exist, we end up getting paradoxes and problems."

More information: Ahmed Farag Ali, Mir Faizal, and Barun Majumder. "Absence of an effective Horizon for black holes in Gravity's Rainbow." *EPL*. DOI: 1209/0295-5075/109/20001

Also at: **arXiv:1406.1980 [gr-qc]**

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