Small black holes affect the life of large galaxies?

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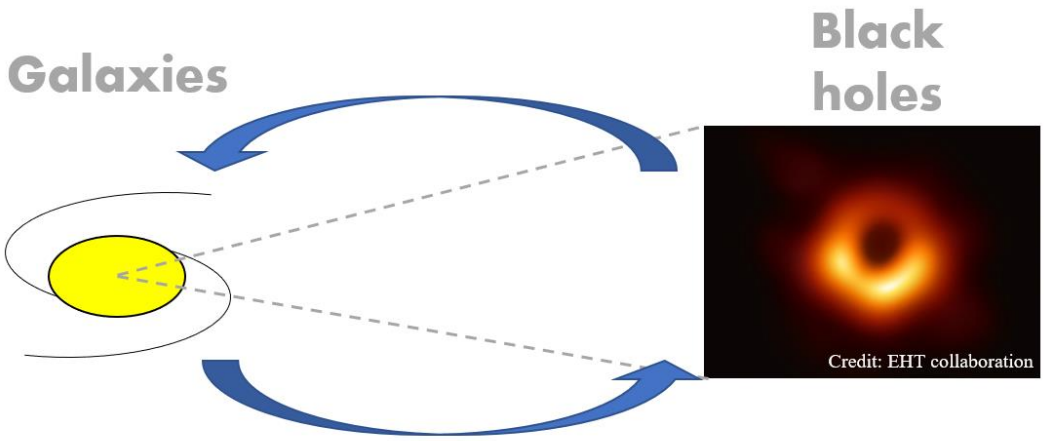
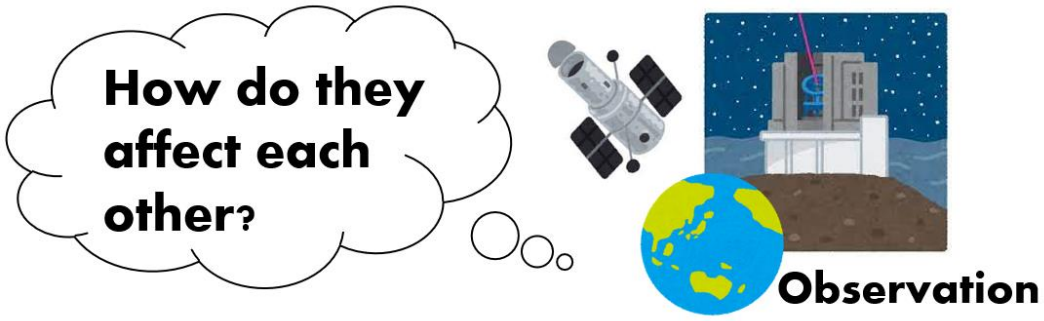
The Solar System is part of the Milky Way Galaxy, and observational studies have revealed that there are so many galaxies other than the Milky Way Galaxy in the Universe. Some studies suggest that there are as many as two trillion galaxies in the observable Universe. In astronomy, observations are often made using electromagnetic waves. Electromagnetic waves have a finite speed, meaning that electromagnetic waves from distant galaxies at astronomical distances take time to reach us. For example, light from a galaxy with the distance of one hundred million light years (light year means the distance where light travels in a vacuum in one year) takes about one hundred million years to reach us! Therefore, looking at distant galaxies, we can see older galaxies, i.e., those still growing. Then, it is possible to discuss how galaxies have formed and evolved with observations. In this way, previous studies found that galaxies have grown and increased in mass by forming stars and merging over the long history of the Universe.

You may have heard of a “black hole.” Some of you may remember that the Event Horizon Telescope, a project using large radio telescopes from around the world to observe black holes, recently released images of the black hole at the center of a galaxy called M87 and the Milky Way Galaxy. Observations have strongly suggested that all galaxies have a massive black hole at their center, with a mass more than a hundred million times the mass of the Sun!

So, what is a black hole actually? A black hole is a celestial body that is so dense that it is impossible to go out even with the speed of light, just like a ball would fall if we threw it straight up on the Earth. A black hole was first predicted by Schwarzschild in 1916 using Einstein's theory of general relativity, and after that, a black hole was discovered by observations. It has a unique history as a theoretically based predicted object because many celestial objects are discovered in observation-driven studies and still has much unsolved mysteries. The major open question about the galactic-center black holes is the relationship between such massive black holes and galaxies. Magorrian et al. (1998) is one of the famous studies addressing this question.





They observed 36 galaxies near the Milky Way Galaxy using the Hubble Space

Telescope and ground-based large telescopes. From these data, they estimated the mass of black holes and galaxies using a simple dynamical model. Then, they investigated the relationship between the mass of the galaxy and the mass of its central black hole for the first time. They found that the mass of the black holes is strongly correlated with the mass of the galaxies, i.e., heavier galaxies host heavier black holes.

What do you think about this result? You might think it is natural that heavier galaxies have heavier black holes. However, for astronomers, this result was very surprising. The result suggests that galaxies and black holes have been growing in interaction. However, the mass of black holes is about a thousand times smaller than the mass of galaxies, and the size of black holes is about ten billion times smaller than the size of galaxies! Thus, This result means a black hole that is much smaller than the galaxy can affect the entire galaxy, just like an insect in the Earth can affect the entire Earth.

So, the natural question is what the processes by which black holes and galaxies interact with each other are. Many researchers have been debating on this question since Magorrian et al. (1998) found this relationship, including the effects of radiation from the hot accretion gas surrounding the black hole and the effects of star formation within the galaxy. Recent observations suggest that gas falling into the center of the galaxy contributes to both the black hole and galaxy growth, i.e., it allows the galaxy to form stars in its central region and the black hole to increase its mass through falling gas. Theoretical studies using simulation have also progressed, but it is challenging to simulate the extreme environment of a black hole and structures that are far apart from each other in scale within the same framework. Therefore, a unified understanding is

not yet available for this question.

Discussing the mechanisms of coevolution will deepen our understanding of not only the evolution of galaxies but also the evolution of black holes. Black holes are generally thought to form at the death of very massive stars. The mass of the "seed" black hole that is formed when the massive stars die is at most ten times the mass of the Sun. It is widely thought that black holes increase their mass by falling gas into them or through mergers between black holes to be supermassive black holes with a mass of over a hundred million times greater than the mass of the Sun. Recent studies have succeeded in observing black holes in more distant galaxies, i.e., older galaxies. These observations allow us to measure the mass of old black holes, and the results have shown that there are heavier black holes than predicted by previous studies. This difference suggests that the known physics of black hole growth processes or the formation of seed black holes may need to be modified. If the growth of galaxies affects the growth or formation of black holes, discussing the relationship between galaxies and black holes would lead to new constraints on the physics of black holes, a physics in the extreme environment.

Reference

- Magorrian, J., Tremaine, S., Richstone, D., et al., 1998, The Astronomical Journal, 115, 2285

※ I used Grammaly to check my English grammar.