New research reveals how galaxies avoid early death

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An artist's impression showing bi-polar jets of gas originating from a supermassive black hole at the center of a galaxy. Credit: ESA/Hubble, L. Calçada (ESO)

Galaxies avoid an early death because they have a "heart and lungs" which effectively regulate their "breathing" and prevent them from growing out of control, a new study suggests.

If they didn't, the universe would have aged much faster than it has and all we would see today is huge "zombie" galaxies teeming with dead and dying stars.

That's according to a new study published in the *Monthly Notices of the Royal Astronomical Society*, which investigates one of the great mysteries of the universe—why galaxies are not as large as astronomers would expect.

Something appears to be stifling their enormous potential by limiting the amount of gas they absorb to convert into stars, meaning that instead of endlessly growing, something inside resists what was thought to be the inevitable pull of gravity.

Now, astrophysicists at the University of Kent think they may have uncovered the secret. They suggest that galaxies could in fact control the rate at which they grow through how they "breathe."

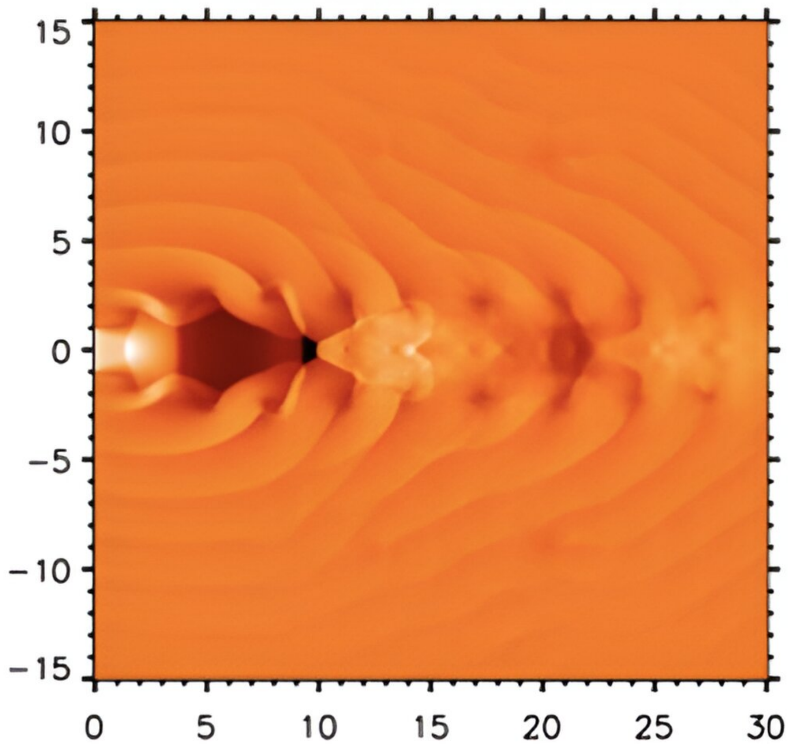
In their analogy, the researchers compared the supermassive black hole at the center of a galaxy to its heart, and the two bi-polar supersonic jets of gas and radiation they emit to airways feeding a pair of lungs.

Pulses from the black hole—or "heart"—can lead to jet shock fronts oscillating back and forth along both jet axes, much like the thoracic diaphragm in the human body moves up and down inside a chest cavity to inflate and deflate both lungs.

This can result in jet energy being transmitted widely into the surrounding medium, just as we breathe out warm air, resulting in slowing galaxy gas-accretion and growth.

Ph.D. student Carl Richards came up with the theory after creating new, never-before-tried simulations to investigate the role supersonic jets might play in inhibiting galaxy growth.

These involved allowing the black hole "heart" to pulse and the jets to be at high pressure—much like a form of hypertension, if extending the comparison to the human body. This caused the jets to "act like bellows," he said, by sending out sound waves "like ripples on a pond surface."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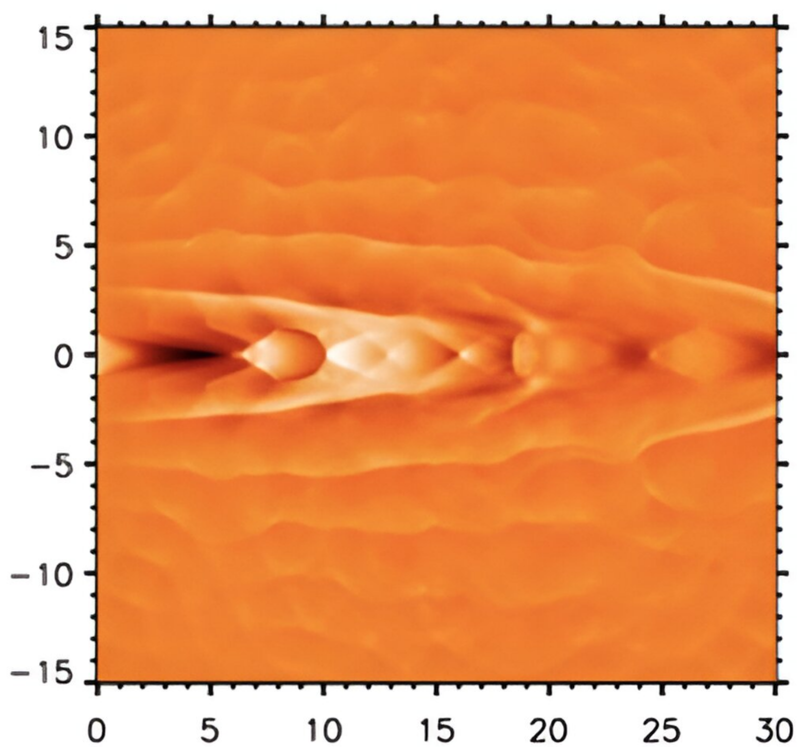
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Two different examples of the simulation of one side of symmetric bi-polar jets, where pressure ripples spread out across the extra-galactic medium. Shown here are pressure variations using a red-temperature color scale (dark=low pressure, light=high pressure). Each jet enters from the left with a pressure that rapidly falls as it pushes against the ambient medium. The axes are non-dimensional distance scales. Credit: C Richards/MD Smith/University of Kent

The phenomenon is similar to the terrestrial equivalent of sound and shock waves being produced when opening a bottle of champagne, the screech of a car, rocket exhausts and the puncture of pressurized enclosures.

"We realized that there would have to be some means for the jets to support the body—the galaxy's surrounding ambient gas—and that is what we discovered in our computer simulations," Richards said.

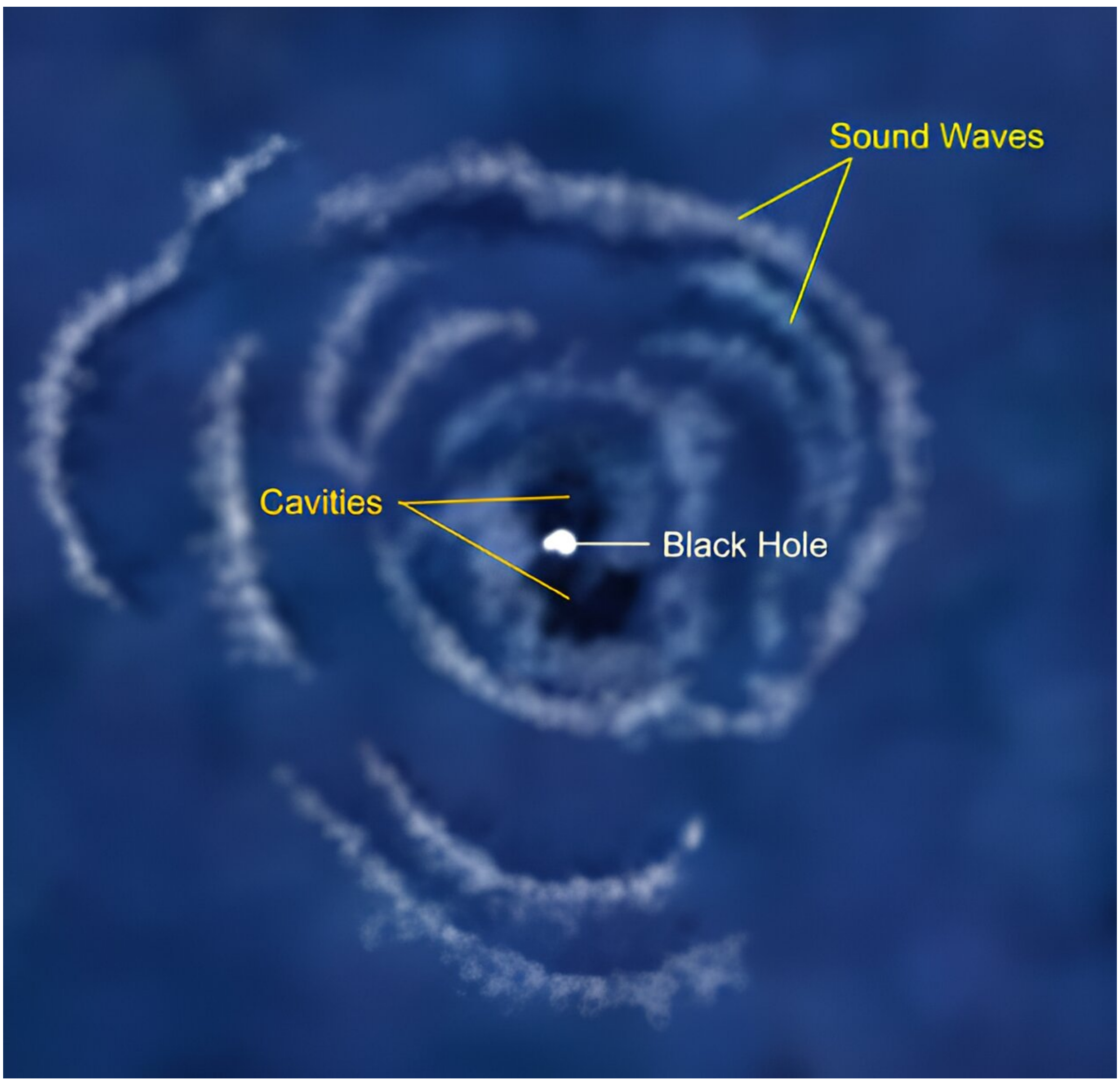
"The unexpected behavior was revealed when we analyzed the computer simulations of high pressure and allowed the heart to pulse. This sent a stream of pulses into the high-pressure jets, causing them to change shape as a result of the bellows-like action of the oscillating jet shock fronts."

These overpressured jets effectively expanded "like air-filled lungs," the researchers said.

In doing so, they transmitted sound waves into the surrounding galaxy in the form of a series of pressure ripples, which were then shown to suppress the galaxy's growth.

There is some evidence of ripples in extra-galactic media, such as those observed in the nearby Perseus galaxy cluster associated with enormous hot gas bubbles, which are believed to be examples of sound waves.

These ripples were already thought to be responsible for sustaining the ambient environment surrounding a galaxy, although a mechanism to generate them was missing.



The sound waves (ripples) in the hot gas that fills the Perseus cluster are shown in this artist's impression. They are thought to have been generated by cavities blown out by jets from a supermassive black hole (bright white spot) at the center of the galaxy. Credit: NASA/NASA/CXC/M.Weiss

Conventional cosmological simulations are therefore unable to account for the flow of gas into galaxies, leading to one of the great mysteries of the universe, so it relies on the highly-active black hole at a galaxy's heart to provide some resistance.

"To do this is not easy, however, and we have constraints on the type of pulsation, the size of the black hole and the quality of the lungs," said co-author Professor Michael Smith. "Breathing too fast or too slow will not provide the life-giving tremors needed to maintain the galaxy medium and, at the same time, keep the heart supplied with fuel."

The researchers concluded that a galaxy's lifespan can be extended with the help of its "heart and lungs," where the supermassive black hole engine at its core helps inhibit growth by limiting the amount of gas collapsing into stars from an early stage.

This, they say, has helped create the galaxies we see today.

Without such a mechanism, galaxies would have exhausted their fuel by now and fizzled out, as some do in the form of "red and dead" or "zombie" galaxies.

More information: Carl Richards et al, Simulations of Pulsed Over-Pressure Jets: Formation of Bellows and Ripples in Galactic Environments, *Monthly Notices of the Royal Astronomical Society* (2024).

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