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A Flicker From the Dark

Looks can be deceiving. The light from an incandescent bulb seems steady, but it actually flickers 120 times per second. Because the brain perceives only an average of the information it receives, this flickering is blurred. The perception of constant illumination is a mere illusion.

While light cannot escape a black hole, the bright glow of rapidly orbiting gas (recall the 2019 images of M87's black hole) has its own unique flicker. In a recent paper submitted to Astrophysical Journal Letters, UC Santa Barbara's Sean Ressler, Lena Murchikova at the Institute for Advanced Study and Chris White at Princeton University were able to use this subtle flickering to construct the most accurate model to date of our own galaxy's central black hole — Sagittarius A* (Sgr A*) — providing insight into properties such as its structure and motion.

There has recently, and for good reason, been a lot of excitement about the new picture of the black hole in the center of our galaxy. "But a single picture only tells part of the story," said Ressler, a postdoctoral scholar at UCSB's Kavli Institute for Theoretical Physics (KITP). Ressler is supported by a grant to KITP from the Gordon and Betty Moore Foundation.

A video would be ideal, he noted, but as of now we can construct only blurry, flickering images. Fortunately, the flickering pattern encodes a lot of information. "Here we have shown that our model of gas falling inwards from nearby stars reproduces that same pattern far better than previous models," Ressler added.

This is the first time that researchers have shown, in a single model, the full story of how gas travels in the center of the Milky Way — from being blown off by stars to falling into the black hole. By reading between the proverbial lines (or flickering light), the team concluded that the most likely picture of black hole feeding in the galactic center involves directly in-falling gas from large distances, rather than a slow siphoning off of orbiting material over a long period of time.

“Black holes are the gatekeepers of their own secrets,” stated Murchikova. “In order to better understand these mysterious objects, we are dependent on direct observation and high-resolution modeling.”

The existence of black holes was predicted by Karl Schwarzschild about 100 years ago based on Albert Einstein’s new theory of gravity. However, researchers are only now starting to probe them through observations.

Ressler has spent years attempting to construct the most realistic simulations to date of the gas around Sgr A*. He has done this by incorporating observations of nearby stars directly into the simulations and meticulously tracking the material that they shed as they orbit the black hole. His recent work culminated in an Astrophysical Journal Letter paper in 2020.

In October 2021 Murchikova published a paper in Astrophysical Journal Letters, introducing a method to study black hole flickering on the timescale of a few seconds, instead of few minutes. This advance enabled a more accurate quantification of Sgr A*’s properties based on its flickering.

White, a former KITP postdoc, has been working on the details of what happens to the gas near black holes — where the strong effects of general relativity are important — and how this affects the light coming to us. An Astrophysical Journal publication earlier this year summarizes some of his findings.

Murchikova, White and Ressler then teamed up to compare the observed flickering pattern of Sgr A* with those predicted by their respective numerical models.

“The result turned out to be very interesting,” explained Murchikova. “For a long time, we thought that we could largely disregard where the gas around the black hole came from. Typical models imagine an artificial ring of gas, roughly donut shaped, at some large distance from the black hole. We found that such models produce patterns of flickering inconsistent with observations.”

Ressler’s stellar wind model takes a more realistic approach, in which the gas consumed by black holes is originally shed by stars near the galactic center. In this simulation, the in-falling gas reproduces the correct pattern of flickering. “The model was not built with the intent to explain this particular phenomenon. Success was by no means a guarantee,” Ressler said. “So, it was very encouraging to see the model succeed so dramatically after years of work.”

“When we study flickering, we can see changes in the amount of light emitted by the black hole second by second, making thousands of measurements over the course of a single night,” explained White. “However, this does not tell us how the gas is arranged in space as a large-scale image would. By combining these two types of observations, it is possible to mitigate the limitations of each, thereby obtaining the most authentic picture.”

(*This release was co-authored by Lee Sandberg at the Institute for Advanced Study*)

About UC Santa Barbara

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