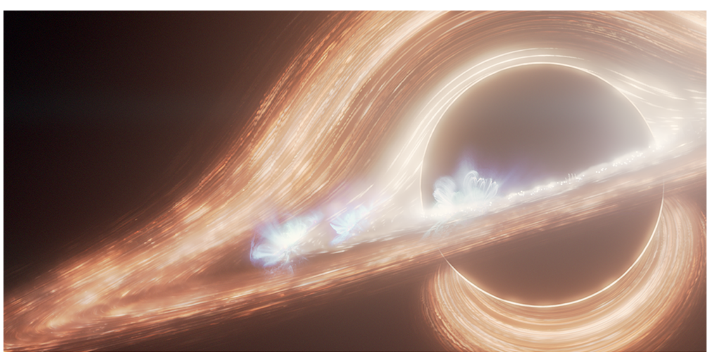
Synchrotron Radiation Could Explain Black Hole's Flaring

JWST observations reveal two distinct types of flares from the Milky Way's black hole, suggesting that they originate from two different electron-acceleration mechanisms within the supermassive black hole's accretion disk.

By **Samuel Jarman**

Variability in the brightness of Sagittarius A* (Sgr A*), the black hole at the center of the Milky Way, could emerge through synchrotron radiation emitted by electrons accelerated by the supermassive black hole's accretion disk [**1**]. That is the finding of a team of astronomers led by Farhad Yusef-Zadeh at Northwestern University, Illinois. The researchers hope that their results could lead to deeper insights into the distinctive flaring patterns in the material that surrounds many black holes.

Weighing in at just over 4 million solar masses, Sgr A* is a supermassive black hole, which is fueled by the material it draws in from interstellar space. Since it is both relatively close by and vastly more massive than any other body in the Galaxy, Sgr A* provides astronomers with an ideal opportunity to study how fueling material is irradiated, captured, accreted, and ejected by a black hole. In particular, astronomers have identified short outbursts, or flares, in the near-infrared (NIR) emission from infalling material. In many cases, radiation at this frequency is a key tracer of flow dynamics within a black hole's inner accretion disk and can hint at the mechanisms driving those flows.



An artist's concept of the supermassive black hole at the center of the Milky Way galaxy, known as Sagittarius A*. Researchers have observed two distinctive types of flare in the disk of gas that surrounds the black hole.
Credit: NASA; ESA; CSA; R. Crawford/STScI

Yusef-Zadeh's team observed these flares several times between 2023 and 2024 using the NIR instrument aboard the JWST observatory. This instrument allowed the team to observe Sgr A* at two different NIR frequencies, which enabled the researchers to study both the time variability of the flares and their energy distribution.

The team's observations revealed two distinctive types of flare, each with strikingly different NIR emission timescales and energy distributions. The first type consists of flares that were dim and short-lived (lasting less than a minute), with emission concentrated at short NIR wavelengths. These flares occurred relatively frequently. In contrast, the second, less frequent but brighter type of flare glowed for about an hour, emitting light that was more evenly distributed across the range of NIR wavelengths that the JWST can measure.

For Yusef-Zadeh and colleagues, a possible explanation for this difference lies in their observation that the timing in the peak brightness of the flares appeared to shift depending on the

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emitted wavelengths. This type of behavior is a characteristic fingerprint of synchrotron radiation that is produced when relativistic charged particles enter strong magnetic fields, forcing them to move in curved paths.

To investigate this idea further, the researchers created models of the sources of synchrotron radiation that could produce both types of flare. Their calculations indicated that the emissions could have originated from so-called age-stratified electrons within Sgr A*'s accretion disk, where the age indicates how much time has passed since the electrons were initially accelerated.

Connecting the flaring behavior to the age of the electrons makes sense to Sean Ressler, a theoretical astrophysicist at the University of Toronto, who also studies Sgr A*'s accretion disk. Ressler says that electrons may be "born," or initially energized, through a continuous process, in which case, "you will always have a range of electron energies, spanning the range from the 'youngest,' which have just been energized, to the 'oldest,' which have cooled significantly."

Within their model, Yusef-Zadeh and colleagues found that they could replicate several key features of the observed NIR variability, provided that the mechanisms that initially accelerated the responsible electrons were only active for a short time. This finding led to the question of what these mechanisms could be.

The researchers considered two mechanisms that should be at work in an accretion disk. The first is a turbulence mechanism, where a highly chaotic flow causes electrons to bounce back and forth and to heat up to higher energies. These kinds of chaotic motions are widely seen in large-scale flows in astrophysics and are especially common in black hole accretion disks. The second is magnetic reconnection, where magnetic fields of opposite signs get pushed together and spontaneously reorient to a new configuration—a process known to produce flaring in the Sun.

Crucially, these possible explanations suggest that Sgr A*'s flaring may be driven by two distinct populations of electrons in the black hole's accretion disk. "A compelling explanation for [the flaring behavior] would be that the fainter emission is caused by the ever-present turbulence in the accretion flow, while the brighter emission is caused by isolated magnetic reconnection events," Ressler says.

Since both of these events occur naturally within the latest models of Sgr A*'s accretion disk, Yusef-Zadeh's team is confident that a combination of turbulence and magnetic reconnection could be a plausible explanation for the origins of its distinctive flaring patterns. All the same, the astronomers acknowledge that this variability will need to be monitored in more detail with the JWST before their theories can be confirmed.

Samuel Jarman is a science writer based in the UK.

REFERENCES

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