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Press Release

Keio University

Two Bright Swirls Around the Milky Way's Central Black Hole
—A New View Revealed by Intermittent Periodic Variability—

A research team consisting of Kazuki Yanagisawa, MS '26, from the Keio University Graduate School of Science and Technology and Professor Tomoharu Oka of the Faculty of Science and Technology, together with researchers from the National Astronomical Observatory of Japan (NAOJ), analyzed radio intensity data from Sagittarius A* (Sgr A*), the compact radio source at the center of the Milky Way Galaxy, obtained with the Atacama Large Millimeter/submillimeter Array (ALMA).

Using observational data acquired on August 31, 2016, the team identified brightness variability structures with characteristic timescales of approximately 30 minutes and 50 minutes. These variations may be produced by two hot spots orbiting the supermassive black hole of four million solar masses while gradually losing energy.

This study suggests that the brightness variability observed in Sgr A* may be caused by the formation, evolution, and disappearance of multiple hot spots. Whereas periodic and random variations in Sgr A* have traditionally been thought to originate from different physical mechanisms, the team's latest findings provide new observational evidence that both types of variability may be explained by a unified hot-spot model, and offer an important clue toward understanding the physical environment in the immediate vicinity of a black hole. The team's findings were published in the May 18 issue of *The Astrophysical Journal Letters*, an American academic journal that specializes in astrophysics research.

1. Research Highlights

- Analysis of ALMA[*1] observations revealed short-timescale variability in the millimeter-wave[*2] brightness of Sagittarius A (Sgr A*), the black hole at the center of the Milky Way Galaxy, with characteristic timescales of approximately 30 minutes and 50 minutes.
- These variations may be explained by the presence of two hot spots orbiting the supermassive black hole at speeds of approximately 40% and 30% of the speed of light, respectively.
- The results suggest that the brightness variability of Sgr A* is produced by the formation, evolution, and disappearance of multiple hot spots, and that both periodic and aperiodic variations—previously thought to arise from different physical origins—may be explained within a unified hot-spot framework.
- These findings provide an important clue to understanding the physical environment in the immediate vicinity of a black hole.

2. Research Background

The present study aimed to elucidate the origin of periodic variability observed in Sgr A*. In the early 2000s, quasi-periodic oscillations (QPOs)[*3] associated with flaring activity were first reported in Sgr A*, and a variety of models, including the hot-spot model, were proposed to explain their origin. Subsequently, in 2018, infrared observations directly revealed a hot spot orbiting around Sgr A*, and in 2025, prominent periodic oscillations were reported at millimeter wavelengths.

Motivated by these developments, this study investigated the relationship between millimeter-wave variability and hot-spot motion in order to explore the physical origin of the observed periodic behavior.

3. Results

A research team from Keio University and the National Astronomical Observatory of Japan analyzed publicly available ALMA observations of Sgr A*, the compact radio source at the center of the Milky Way Galaxy, and detected brightness variability structures with characteristic timescales of approximately 30 and 50 minutes. These variations may be produced by two "hot spots" (localized clumps of heated gas) orbiting the supermassive black hole while gradually losing energy (Figure 1). At the same time, the team found that such characteristic variability was present only in a subset of the observations, indicating that these variations do not occur continuously.

These results suggest that the brightness variability of the supermassive black hole may be driven by the orbital motion of multiple hot spots, together with their formation, evolution, and disappearance. Traditionally, periodic and aperiodic brightness variations in black holes have been attributed to different emission mechanisms. The present study provides observational evidence that both types of variability may instead be interpreted within a unified framework based on the hot-spot model.

These findings represent an important step toward understanding the physical environment in the immediate vicinity of a black hole. Combined with future high-precision observations, they are expected to provide deeper insight into the structure and dynamics of matter surrounding black holes.

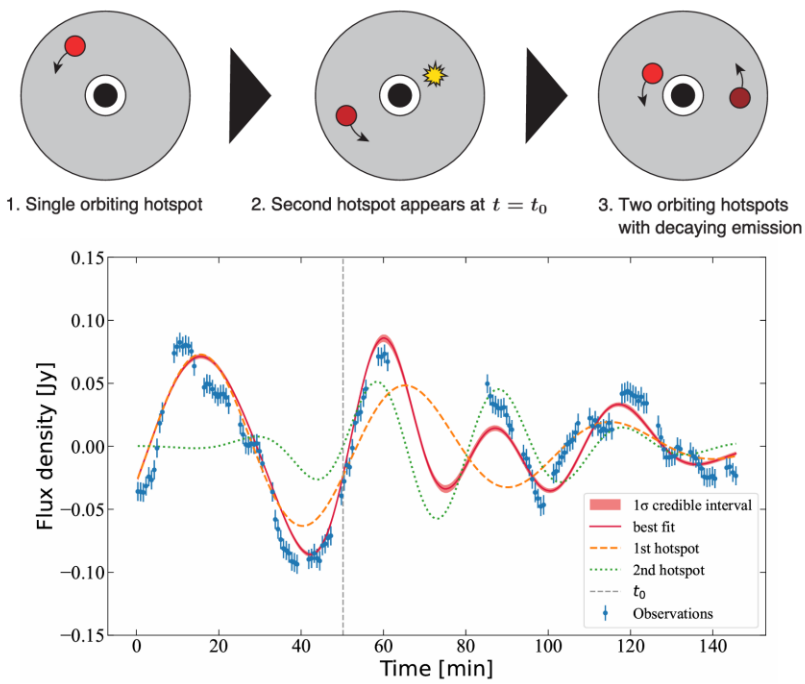

Figure 1. Top: Schematic illustration of two orbiting hot spots. Initially, a single hot spot orbits the black hole. At $t = t_0$, a second hot spot appears. Thereafter, both hot spots continue orbiting while gradually losing energy.
Bottom: Light curve reproduced by the hot-spot model. The blue points show the brightness derived from publicly available ALMA observations, while the red curve represents the total brightness variation reproduced by the model. The orange and green curves indicate the brightness variation components associated with each individual hot spot.

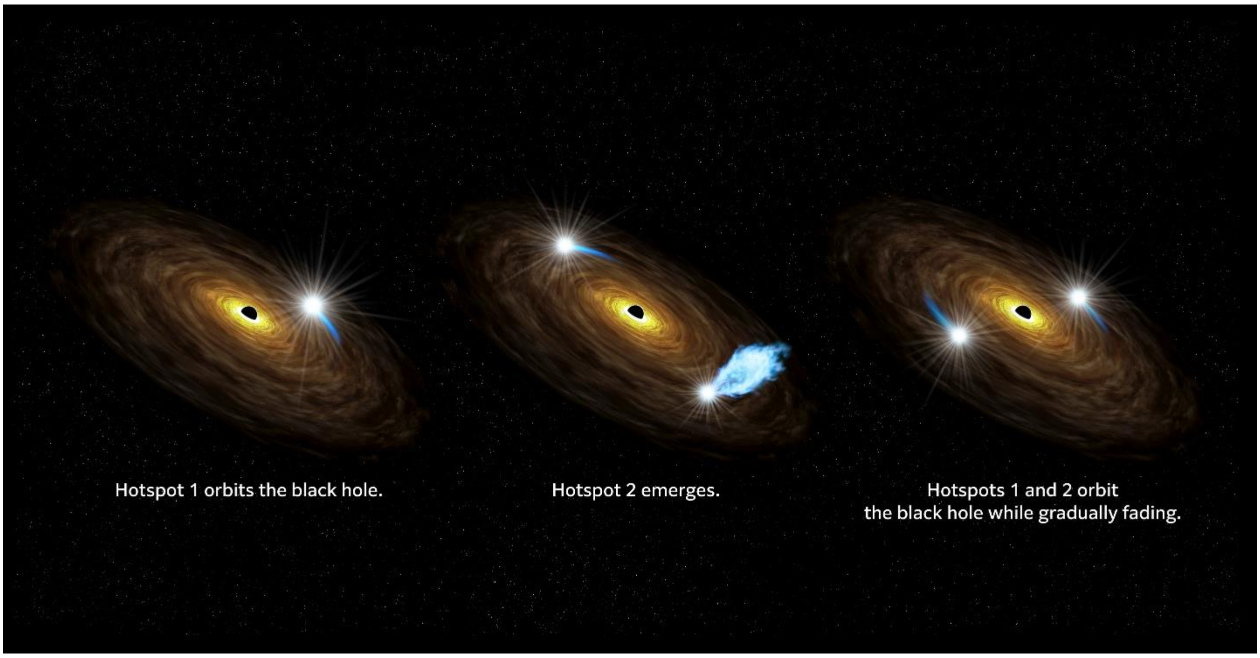

Figure 2. Schematic illustration of hot spots orbiting around the black hole at the center of the Milky Way Galaxy. Initially, a single hot spot orbits the black hole. A second hot spot then emerges, and both hot spots continue orbiting while gradually losing energy.

4. Future Prospects

In this study, we showed that the millimeter-wave brightness variability of Sgr A*, the supermassive black hole at the center of the Milky Way Galaxy, may be explained by the motion of multiple hot spots. However, many aspects of the physical processes responsible for the formation, evolution, and disappearance of hot spots remain poorly understood.

Future long-duration, high-cadence monitoring observations with ALMA, combined with simultaneous X-ray and near-infrared observations, are expected to provide a more detailed understanding of the physical origin of the short-timescale variability occurring in the immediate vicinity of the black hole. In addition, simultaneous analysis of polarization*4 variability may make it possible to distinguish between variability caused by the orbital motion of hot spots and variability arising from intrinsic changes within the hot spots themselves.

Advances in these observations are expected not only to provide a unified understanding of both periodic and irregular variability in Sgr A*, but also to shed light on the physical environment surrounding the supermassive black hole, including its magnetic-field structure and gas dynamics.

Details of Journal Article

Title: "Evidence for Multiple Orbiting Hotspots in the 340 GHz Variability of Sgr A*"

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Glossary

*1. ALMA (Atacama Large Millimeter/submillimeter Array): A large radio interferometer constructed in the Atacama Desert of Chile through international collaboration among East Asia, North America, and Europe.
*2. Millimeter-waves: Electromagnetic waves with frequencies of approximately 30–300 GHz.
*3. Quasi-periodic oscillations (QPOs): Periodic variations, commonly detected in X-ray binaries, whose periods gradually change over time.
*4. Polarization: A state in which an electromagnetic wave oscillates in a specific direction within the plane perpendicular to its direction of propagation.

*Please direct any requests or inquiries to the contacts listed below in advance of any press coverage.
*This news release has been sent to the MEXT Press Club, Science Press Club, and the science departments of other media outlets.

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