プレスリリース

慶應義塾大学

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Press Release

Keio University

ALMA Detects a 52-minute Millimeter-Wave Signal from the Milky Way's Central Black Hole — Revealing We Have Been Observing Sgr A* from Almost Directly Below

A research team has analyzed seven years of ALMA (Atacama Large Millimeter/submillimeter Array) observations and discovered a remarkably clear 52-minute periodic signal from Sagittarius A* (Sgr A*), the supermassive black hole at the center of the Milky Way. The team consisted of Kazuki Yanagisawa from the Graduate School of Science and Technology, Professor Tomoharu Oka from the Faculty of Science and Technology, as well as other researchers from Keio University, the National Astronomical Observatory of Japan and National Institute of Technology at Tokyo College. The signal, observed on July 22, 2021, is attributed to relativistic Doppler beaming produced by a compact hotspot orbiting extremely close to the black hole at about one-third the speed of light.

The analysis constrains the inclination of the system to **~172°**, meaning that Earth is observing the accretion disk from **almost directly "below."** This discovery provides new observational constraints on the relativistic dynamics and geometry of matter in the immediate environment of a supermassive black hole.

These findings were published in *The Astrophysical Journal* on December 1, 2025.

1. Main Points of Research

- A clear 52-minute sinusoidal variation was detected in the millimeter-wave[*1] brightness of Sgr A*, the supermassive black hole at the center of the Milky Way, based on an analysis of 7 years of ALMA[*2] observations.
- The variation is caused by relativistic Doppler beaming[*3] produced by a hotspot orbiting extremely close to the black hole at about one-third the speed of light.
- Analysis of the periodic variation constrains the inclination[*4] of the accretion disk to be approximately 172°, indicating that we are viewing the black hole from almost directly below the disk.
- These results provide new observational evidence that directly reveals both the geometry and relativistic motion of matter in the immediate vicinity of a black hole, representing a significant advancement in our understanding of black hole physics.

2. Background of Research

This research was conducted to investigate the physical origin of periodic variability observed in Sgr A*, the supermassive black hole at the Galactic Center.

Quasi-periodic oscillations[*5] associated with flaring activity were first reported in the early 2000s, and numerous theoretical models, including the hot-spot model, were proposed to explain their origin. Subsequently, direct evidence for orbiting hot spots was obtained in near-infrared observations in 2018, and periodic variability at millimeter wavelengths was reported in 2020.

In light of these findings, this study aimed to examine the connection between millimeter-wave periodic variability and hot-spot dynamics in order to clarify the mechanism responsible for the observed periodic variation.

3. Results

The research team analyzed publicly available observational data of Sagittarius A* (Sgr A*), the supermassive black hole at the center of the Milky Way, obtained with ALMA. As a result, the team detected a highly clear sinusoidal variation with a period of ~52 minutes in the millimeter-wave emission from Sgr A* (Figure 1).

The observed periodic modulation is interpreted as arising from relativistic Doppler beaming caused by a localized region of a “hotspot” (localized region of heated gas) orbiting extremely close to the black hole, at a distance of ~0.3 AU, with a velocity of about one-third the speed of light.

Further analysis shows that the inclination of the accretion disk is ~172° (Figure 2). This means that our line of sight from earth is nearly aligned with the black hole’s rotation axis; in other words, scientists are effectively viewing the system from “below” (“below” refers only to the disk’s geometric orientation and does not indicate a physical observation point beneath the disk).

These results provide valuable observational evidence that directly constrains both the geometric structure and relativistic dynamics in the immediate environment of a supermassive black hole and represent a significant contribution to the advancement of black hole astrophysics.

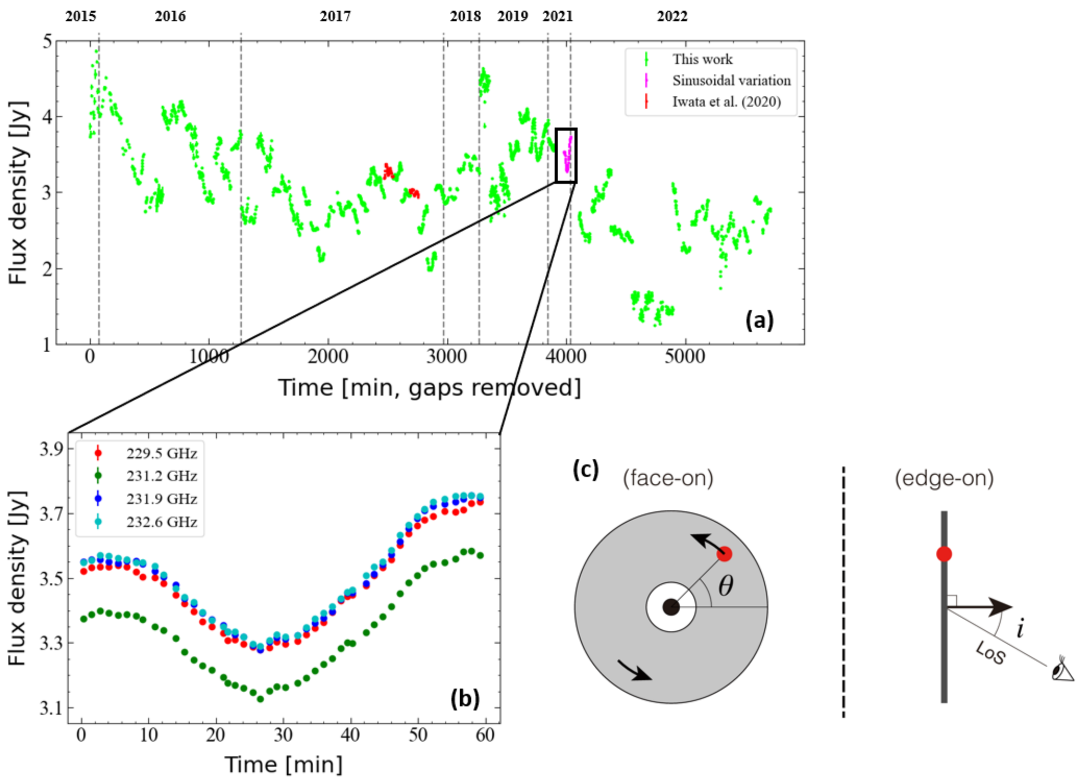

Figure 1. (a) Millimeter-wave light curves of Sgr A* obtained with ALMA from 2015 to 2022. Time gaps between observations have been removed, and the interval exhibiting periodic variation is shown in color.
(b) A remarkably clear sinusoidal variation detected on July 22, 2021. Colors denote observing frequencies: red (229.5 GHz), green (231.2 GHz), blue (231.9 GHz), and cyan (232.6 GHz).
(c) Schematic illustration of the orbiting hotspot model. Left: face-on view of the accretion disk. Right: edge-on view. The red dot marks the hotspot, and the line of sight (LoS) toward the observer is indicated.

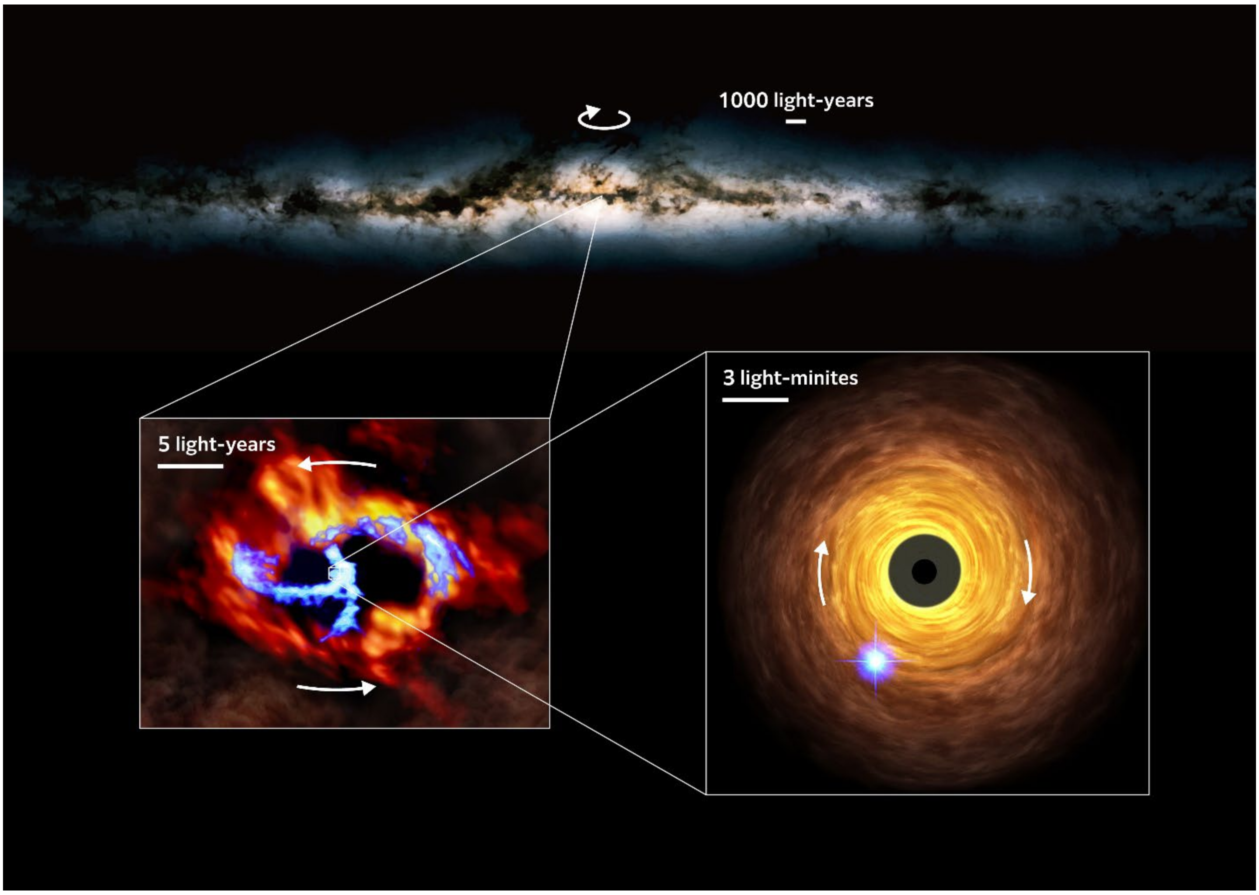

Figure 2. Schematic illustration of a hot spot orbiting the supermassive black hole at the center of the Milky Way.
(Top) Optical view of the Milky Way.
(Bottom left) The molecular gas structure known as the circumnuclear disk (CND) and the ionized gas feature called the mini-spiral in the Galactic Center region.
(Bottom right) The accretion disk surrounding the central supermassive black hole and the orbiting hotspot.
All panels are drawn from the perspective of the Earth, and the arrows indicate the directions of rotation.

4. Future Prospects

This study marks an important step toward linking multi-wavelength variability models of Sgr A*, as well as for refining constraints on its geometric configuration. The precise parameters obtained in this study are anticipated to improve the fidelity of simulations based on general relativistic frameworks. Future work will focus on implementing extended-duration observations with high temporal resolution. Such observations are expected to reveal how gas orbits the black hole while being gradually accreted, and to provide insight into the formation, evolution, and disappearance of short-period variability.

These continued efforts will play a critical role in advancing our understanding of how black holes grow, evolve, and interact with their surrounding environment.

Details of Journal Article

Title: “A Face-on Accretion Disk Geometry Revealed by Millimeter-wave Periodicity in Sgr A*”

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References

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Glossary

*1. Millimeter-waves: Electromagnetic waves with frequencies of approximately 30–300 GHz.

*2. 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.

*3. Relativistic Doppler beaming: An effect in which radiation from a source moving at a velocity close to the speed of light in the direction of the observer appears significantly brighter.

*4. Inclination: The angle between the rotation axis of the accretion disk and the observer’s line of sight.

*5. Quasi-periodic oscillations (QPOs): Periodic variations, commonly detected in X-ray binaries, whose periods gradually change over time.

*Please direct any requests or inquiries to the contacts listed below in advance of any press coverage.

*We have sent this news release to the MEXT Press Club, Science Press Club, and the science departments of other media outlets.

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