PRESS RELEASE

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Forecasting Jet Ejections from Black Holes Through X-ray Observations

Researchers identify changes in the accretion disk and X-ray variability that precede jet ejection activity by as much as ten days

Black hole jet ejections are powerful outbursts of high-energy photons and particles that provide insights into extreme astrophysical processes. However, predicting when they will occur remains difficult. In a study, researchers from Japan analyzed observations of four black hole binary systems, identifying decreases in the accretion disk's inner radius and changes in emitted X-ray variability as possible predictors for jet ejection. Their findings could help astronomers forecast these phenomena more accurately and coordinate timely observations.

Though best known for pulling matter in, black holes can also launch powerful particle jets that travel through space at almost light speed. These jets emerge from the extreme environment that surrounds black holes, in which gas heats up as it spirals inward in the accretion disk, emitting X-rays in the process. Understanding what triggers black hole jet ejections remains an important unresolved challenge in astrophysics.

Since the discovery of jet ejections over a century ago, astronomers have noticed certain changes in X-ray emission that tend to precede them. Deformations in the emitted X-ray spectrum, as well as decreases in X-ray variability, are thought to signal that the environment around a black hole is primed for a jet ejection. However, these signs have not been reliable enough to predict when a jet will emerge, making it difficult for astronomers to coordinate observations in advance.

To address this challenge, a research team led by Professor Toshihiro Kawaguchi from the Graduate School of Science and Engineering, University of Toyama, Japan, alongside Dr. Kazutaka Yamaoka from the Institute for Space-Earth Environmental Research, Nagoya University, Japan, investigated the changes that preceded jet ejections across several black hole systems. Their paper was published in Volume 1011 of *The Astrophysical Journal* on November 5, 2026.

The present work builds on a 2025 study by the same group that examined XTE J1859+226, an X-ray binary system consisting of a black hole and a companion star. That study suggested that jets launch when the inner edge of the accretion disk, known as the inner radius or $R_{\rm in}$, shrinks quickly toward the closest orbit around a black hole where material can circle safely, called the innermost stable circular orbit (ISCO). To check whether this phenomenon holds more widely, the team analyzed archived X-ray and radio data from three additional systems: XTE J1550-564, GX 339-4, and MAXI J1820+070. They tracked $R_{\rm in}$,

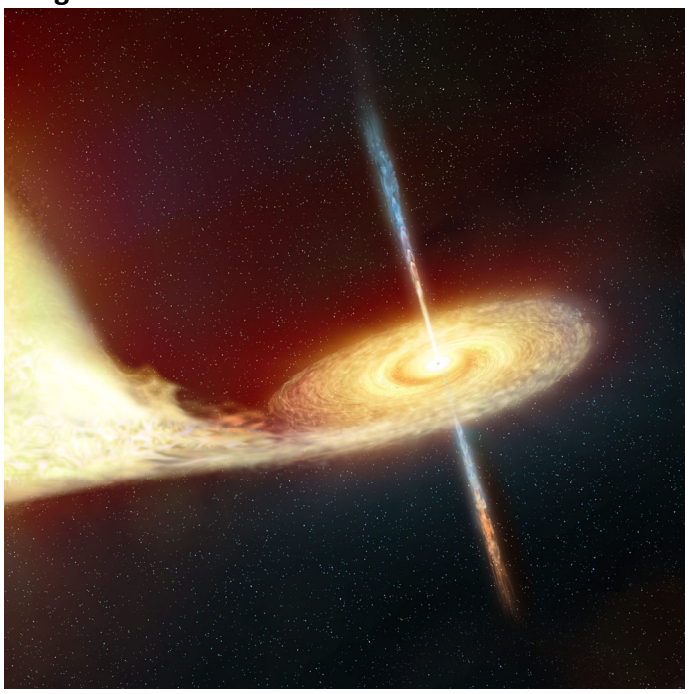
the changes in X-ray variability, and the rate at which gas flows toward the black hole, and then compared these measurements with the timing of radio flares denoting jet ejections.

The results revealed a common pattern across all four systems. Both R_{in} and X-ray variability decreased approximately one to ten days before a jet ejection occurred, but the gas flow rate showed no large jumps. Notably, in two out of the four systems, the jets formed at flow rates below the theoretical threshold at which the outward push of radiation balances gravity, known as the Eddington limit. This makes jet-ejection models that depend on high flow rates unlikely to be correct.

Together, these findings point to the practical value of R_{in}. "*Monitoring of R_{in} seems to be suitable for predicting the timing of jet ejections*," says Prof. Kawaguchi. The researchers propose a forecasting system in which an alert is sent to astronomers when both R_{in} and X-ray variability continue to decrease and R_{in} approaches the ISCO. This would leave astronomers with a window of several hours to several days to decide whether or not to conduct observations, as Prof. Kawaguchi adds: "*The development of a 'jet forecast' would enable us to concentrate observing facilities on the expected timing of jet ejections, thereby accelerating our understanding of jet physics*."

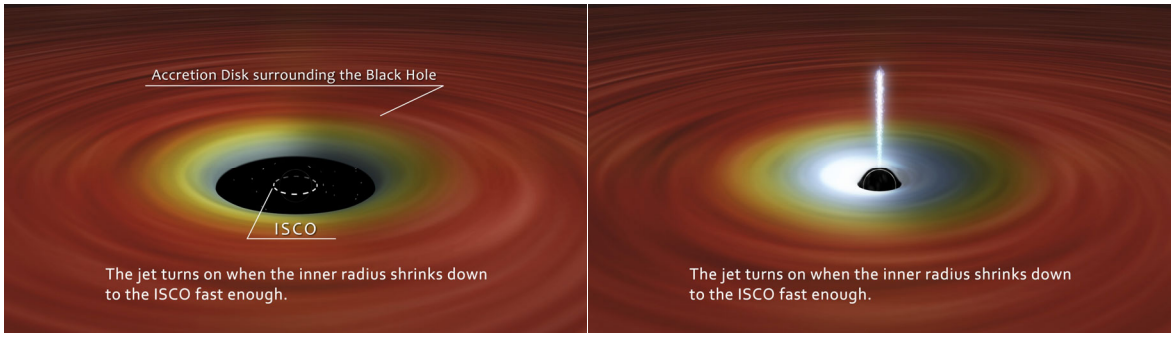
By identifying early warning signals of jet ejections in several black hole binary systems, this study provides a foundation for anticipating these otherwise difficult-to-predict events. More frequent observations will enable astronomers to investigate these physical processes, which power some of the Universe's most energetic phenomena and are ultimately linked to the history of our planet. "*Jet ejections in the Universe produce high-energy photons and particles, such as neutrinos, and such cosmic rays have long influenced the evolution of living creatures on Earth, including human beings*," concludes Prof. Kawaguchi.

Image



Title: Artist's depiction of an X-ray binary system

Caption: These types of black holes, which draw matter from a nearby star into their accretion disk, sometimes eject powerful jets under conditions that are still not fully understood.
Credit: Юрий Д.К. from Wikimedia Commons
Source Link: https://commons.wikimedia.org/wiki/File:Artist%27s_impression_of_a_black_hole_system.jpg
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Title: Artist's depiction of a jet ejection
Caption: The jet from the black hole turns on when the inner radius of the accretion disk shrinks down to the ISCO fast enough.
Credit: Professor Toshihiro Kawaguchi from University of Toyama, Japan and Dr. Kazutaka Yamaoka from Nagoya University, Japan
Source Link: http://www3.u-toyama.ac.jp/kawaguti/researchE.html
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Video

Title: Forecasting black hole jet ejections through X-ray signals
Caption: Changes in the accretion disk's inner radius and X-ray variability could provide early warning signals of black hole jet ejections, potentially allowing astronomers to forecast these powerful events several days in advance.
Credit: Professor Toshihiro Kawaguchi from University of Toyama, Japan and Dr. Kazutaka Yamaoka from Nagoya University, Japan
Source Link: http://www3.u-toyama.ac.jp/kawaguti/researchE.html
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Reference

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About University of Toyama, Japan

University of Toyama is a leading national university located in Toyama Prefecture, Japan, with campuses in Toyama City and Takaoka City. Formed in 2005 through the integration of three former national institutions, the university brings together a broad spectrum of

disciplines across its 9 undergraduate schools, 8 graduate schools, and a range of specialized institutes. With more than 9,000 students, including a growing international cohort, the university is dedicated to high-quality education, cutting-edge research, and meaningful social contribution. Guided by the mission to cultivate individuals with creativity, ethical awareness, and a strong sense of purpose, the University of Toyama fosters learning that integrates the humanities, social sciences, natural sciences, and life sciences. The university emphasizes a global standard of education while remaining deeply engaged with the local community.

Website: https://www.u-toyama.ac.jp/en/

About Professor Toshihiro Kawaguchi from the University of Toyama, Japan

Dr. Toshihiro Kawaguchi obtained his M.S. and Ph.D. degrees in Astronomy from Kyoto University in 1999 and 2002, respectively. He currently serves as a professor in the Laboratory for Cosmic Science Informatics at the Graduate School of Science and Engineering, University of Toyama. His core research focus is astrophysics, specifically active galactic nuclei, supermassive black holes, quasars, and accretion disks. Throughout his career, he has authored over 110 scientific publications in peer-reviewed journals.
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