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USNO Astronomers Peer into Hearts of Supermassive Black Holes; Discover New Relationships Between "Quiet" and "Noisy" Black Holes

In a new study published in the January 2021 issue of *The Astrophysical Journal**, astronomers from the U.S. Naval Observatory (USNO), the Space Telescope Science Institute (STScI), George Mason University (GMU), and the Naval Research Laboratory (NRL) report on the first results from the Fundamental Reference AGN Monitoring Experiment (FRAMEx) that suggest that the current model that relates x-ray and radio brightness of supermassive black holes at the center of distant galaxies (called "Active Galactic Nuclei", or AGN) may need to be revised.

Specifically, using the extreme resolving power of the National Science Foundation's (NSF) Very Long Baseline Array (VLBA)—approximately ten times finer than the Hubble Space Telescope—much, or most, of the radio emission for some of these AGN appear to be coming from its interaction with the host galaxy rather than from the AGN itself, as previously believed. "As a result," says paper co-author Dr. Nathan Secrest (USNO), "nearby supermassive black holes act much more like their stellar-mass counterparts than the distant supermassive black holes that shine brightly in the radio."

This work was led by Dr. Travis Fischer, currently at STScI, and formerly the Simon Newcomb postdoctoral research fellow at USNO, working with the USNO team, including Drs. Secrest, Megan Johnson, and Bryan Dorland; current Simon Newcomb Fellow, Dr. Phil Cigan; GMU research associates Dr. Lucas Hunt and graduate student Luis Fernandez; and Dr. Henrique Schmitt of the Naval Research Laboratory (NRL).

FRAMEx is an overarching research collaboration that seeks to better understand the underlying astrophysics of AGN in order to inform the maintenance and continued improvement of the Celestial Reference Frame (CRF), which is a core part of USNO's Department of Defense mission. The CRF is also foundational for both the international astronomical community, the geodesy community, and for aligning the Celestial and Terrestrial reference frames, which enable technologies such as the Global Positioning System (GPS) to function.

For this research, the FRAMEx team observed the 25 nearest AGN simultaneously with the super-resolving power of the VLBA as well as NASA's Neil Gehrels SWIFT X-ray Observatory.

"The VLBA, operated by the National Radio Astronomy Observatory (NRAO)," notes co-author Johnson, "is so powerful in resolving fine details that if the human eye had the same capability, then you could read a newspaper in Chicago while sitting at a café in New York City!"

Since it's quite common for AGN to change their brightness in X-ray and radio wavelengths over short time periods, observing them simultaneously at both of these wavelengths was essential to understanding the astrophysics of the AGN. The VLBA radio observations probed the inner core emission of the AGN, peering down into the hearts of the supermassive black holes, while the X-ray observations measured the rate that matter—mainly hydrogen gas—is falling into the AGN. Together, these two observations paint a coherent picture for the fueling and "feeding" processes of these supermassive black holes.

"What began as a summary of our forthcoming FRAMEx program ended up as an exciting scientific discovery in its own right," observed Fischer. "When our observations didn't produce images for the majority of the sample," he continued, "we knew that there was a possibility for us to produce some compelling science."

The surprise outcome is that the majority of these AGN do not shine as brightly in the radio wavelengths as expected from previous work. In fact, almost 2/3rds of the AGN were not even detected in the radio at the very high spatial resolutions available from VLBA. These findings support the scenario where supermassive black holes have two different modes of feeding: **radio quiet**, in which their radio emission is due to the motions of electrons in a hot X-ray plasma near the black hole, and **radio loud**, in which powerful jets of electrons are launched to great distances.

The U.S. Naval Observatory, GMU, NRL, and STScI are joined in the larger FRAMEx research collaboration by astronomers and astrophysicists at the Paris Observatory, the Jet Propulsion Laboratory, and the Hartebeesthoek Radio Astronomy Observatory. The use of the Very Long Baseline Array described in this paper was provided under the US Naval Observatory's time allocation, which supports USNO's ongoing research into the celestial reference frame and geodesy. USNO's post-doctoral research program through GMU began in 2017; with this program, USNO has had direct access to students, postdocs, research associates, and faculty, who have all contributed to and in some cases, joined the FRAMEx program and the USNO staff.

**Fundamental Reference AGN Monitoring Experiment (FRAMEx). I. Jumping Out of the Plane with the VLBA*
Fischer, T.C., Secrest, N.J., Johnson, M.C., Dorland, B.N., Cigan, P.J., Fernandez, L.C., Hunt, L.R., Koss, M., Schmitt, H.R., & Zacharias, N. 2021, ApJ, 906, 88