VERITAS Helps EHT Catch Rare Gamma-Ray Outburst from M87's Powerful Jet

An international team of astronomers, including the VERITAS Collaboration, recorded the first very-high energy flaring episode from supermassive black hole M87 since 2010 during an multi-wavelength observational campaign with EHT.

In April 2019, the Event Horizon Telescope Collaboration (EHT) scientists released the first image of a black hole in the galaxy Messier 87 (M87), and since then have been busy imaging several other black holes. The same EHT Collaboration recently coordinated a second campaign on M87 and detected a spectacular flare from the powerful relativistic jet emanating from the very centre of the same galaxy at multiple wavelengths.

Also known as Virgo A or NGC 4486, M87 is the brightest object in the Virgo cluster of galaxies, the largest gravitationally bound type of structure in the universe. Led by the EHT multi-wavelength working group including scientists and data from the Very Energetic Radiation Imaging Telescope Array System (VERITAS)— which is operated by the Smithsonian Astrophysical Observatory (SAO), a part of the Center for Astrophysics | Harvard & Smithsonian (CfA)— the study presents the data from the second EHT observational campaign conducted in April 2018, involving over 17 ground-based and space-based telescopes.

The authors report the first observation in over a decade of a high-energy gamma-ray flare (detecting photons up to thousands of billions of times the energy of visible light) from the supermassive black hole M87* after obtaining nearly simultaneous spectra of the galaxy with the broadest wavelength coverage ever collected.

"We were lucky to detect a gamma-ray flare from M87 during this Event Horizon Telescope's multi-wavelength campaign. This marks the first gamma-ray flaring event observed in this source in over a decade, allowing us to precisely constrain the size of the region responsible for the observed gamma-ray emission," said **Giacomo Principe**, the paper coordinator, a researcher at the University of Trieste associated with INAF and INFN.Observations—both recent ones with a more sensitive EHT array and those planned for the coming years—will provide invaluable insights and an extraordinary opportunity to study the physics surrounding M87's supermassive black hole. These efforts promise to shed light on the disk-jet connection and uncover the origins and mechanisms behind the gamma-ray photon emission."

The relativistic jet examined by the researchers is surprising in its extent, reaching sizes that exceed the black hole's event horizon by tens of millions of times (seven orders of magnitude) - akin to the difference between the size of a bacterium and the largest known blue whale.

The energetic flare, which lasted approximately three days and suggests an emission region of less than three light-days in size (~170 AU, where 1 Astronomical Unit is the distance from the Sun to Earth), revealed a bright burst of high-energy emission—well above the energies typically detected by radio telescopes from the black hole region.

"The new multi-wavelength data provide a more comprehensive view of the physics behind the accreting black hole M87 and the mechanisms driving high-energy particle acceleration," said **Weidong Jin**, an astronomer at UCLA and a member of the VERITAS collaboration. "This extensive multi-wavelength campaign showcases our ability to collaborate effectively, resulting in an exceptional legacy data set that opens the door for many exciting possibilities and the potential for groundbreaking discoveries."

The second EHT and multi-wavelength campaign in 2018 leveraged more than two dozen high-profile observational facilities, including NASA's Fermi-LAT, HST, NuSTAR, Chandra, and Swift telescopes, together with the world's three largest Imaging Atmospheric Cherenkov Telescope arrays: H.E.S.S., MAGIC and VERITAS. These observatories are sensitive to X-ray photons as well as high-energy very-high-energy (VHE) gamma-rays, respectively. During the campaign, the LAT instrument aboard the Fermi space observatory detected an increase in high-energy gamma-ray flux with energies up to billions of times greater than visible light. Chandra and NuSTAR then collected high-quality data in the X-ray band. The VLBA radio observations show an apparent annual change in the jet's position angle within a few milliarcseconds of arc from the galaxy's core.

"This multi-wavelength campaign has paired the resolution of radio, which pinpoints fine details, with the sensitivity of gamma-ray instruments— and others— that can uncover variability in brightness," said **Amy Furniss**, an astrophysicist at UC Santa Cruz, and the spokesperson for the VERITAS collaboration. "VERITAS was able to identify the flare, and give EHT the information needed to see fine changes in the source, to find the precise place where the particles causing the flare are being accelerated. This could help answer long-standing questions about the origins of very high energy particles that we detect on Earth."

Dr. Wystan Benbow, an astrophysicist at the CfA and VERITAS Director, said, "VERITAS is the world's premier facility for very-high-energy gamma-ray astronomy, and we are excited for this, and future opportunities, to study flares in collaboration with multi-wavelength partners like EHT to unravel some of the most challenging mysteries of our Universe."

Data also show a significant variation in the position angle of the asymmetry of the ring (the so-called 'event horizon' of the black hole) and the jet's position, suggesting a physical relation between these structures on very different scales. The researcher explains: "In the first image obtained during the 2018 observational campaign, it was seen that the emission along the ring was not homogeneous, thus presenting asymmetries (i.e., brighter areas). Subsequent observations conducted in 2018 and related to this paper confirmed the data, highlighting that the asymmetry's position angle had changed."

"How and where particles are accelerated in supermassive black hole jets is a longstanding mystery. For the first time, we can combine direct imaging of the near event horizon regions during gamma-ray flares from particle acceleration events and test theories about the flare origins," says **Sera Markoff**, a professor at the University of Amsterdam and co-author of the study.

This discovery paves the way for stimulating future research and potential breakthroughs in understanding the universe.

The article has been accepted for publication in Astronomy & Astrophysics.

Related journal article: *"Broadband Multi-wavelength Properties of M87 during the 2018 EHT Campaign including a Very High Energy Flaring Episode"*, by The Event Horizon Telescope-Multi-wavelength science working group, The Event Horizon Telescope Collaboration, The Fermi Large Area Telescope Collaboration, H.E.S.S. Collaboration, MAGIC Collaboration, VERITAS Collaboration, and EAVN Collaboration. In: *Astronomy & Astrophysics*.

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