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Position: Research Scientist
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I Scientific Work

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Black Holes and Quasars

1. Introduction

This report describes the research performed by Brian Punsly and collaborators in cooperation with ICRANet in 2023. The research was directed at finding observational evidence needed to define the location and kinematics of the jet launching region of M 87.

2. **HST-1 as a Window to the Energetics of the Jet Spine of M87**

Abstract:

A new interpretation of the optical knot in the jet of M\,87, HST-1, is presented. High sensitivity 22 GHz Very Large Array images locate HST-1 to within 6 mas of the jet axis immediately upstream. 1.7 GHz Very Long Baseline Array images of a bright flare in 2005 indicates that the preponderance of emission in the early stages originates in an elongated region that is tilted 12.5° from the jet axis. The superluminal motion, shape, location and the large jet-aligned optical/UV polarization suggest an identification with the putative relativistic spine of the jet. As such, energy flux estimates for HST-1, ~ 870 mas from the nucleus, published in 2006 indicate that the central engine injected $Q_{\rm{spine}}\approx 2.5 \times 10^{41}\rm{ergs/s}$ into the base of the spine ~ 200 years earlier. Furthermore, previous studies reveal a tubular protonic jet on sub-mas scales that envelopes a low luminosity core, presumably the faint spine base. It was estimated that the central engine injected $Q_{\rm{tubular\,jet}}\approx 6.1\times 10^{41}\rm{ergs/s}$ ~ 1.5 years earlier. If one component of the jet is inherently more powerful, a firm constraint on total jet power in the recent past exists. If the emitted jet is inherently dominated by the spine (tubular jet) then the total bilaterally symmetric jet power emitted from the central engine was $<4Q_{\rm{spine}}\approx 1.0 \times 10^{42}\rm{ergs/s}$ ($< 4Q_{\rm{tubular\,jet}}\approx 2.4\times 10^{42}\rm{ergs/s}$) ~ 200 (~ 1.5) years earlier. Assuming a nearly constant central engine injected jet power for ~ 200 years indicates a total jet power of $\lesssim 2\times 10^{42}$ ergs/s in epochs of modern observation or $\lesssim 3.5\%$ jet production efficiency for an accretion rate of 0.001$M_{\odot}$/yr. Seemingly, the focus of Event Horizon Telescope Collaboration numerical models should be biased towards jet powers $\lesssim 2 \times 10^{42}$ ergs/s as opposed to larger estimates from ejections many centuries or millennia earlier.

3. **The cylindrical jet base of M87 within 100$\mu\rm{as}$ of the central engine**

ABSTRACT:

A recent article on high-resolution 86 GHz observations with the Global Millimeter VLBI Array, the phased Atacama Large Millimeter/submillimeter Array, and the Greenland Telescope describes the detection of a limb-brightened cylindrical jet, $25 \mu\rm{as}< z< 100 \mu\rm{as}$, where z is the axial displacement from the supermassive black hole in the sky plane. It was shown to be much wider and much more collimated than 2D simulations of electromagnetic (Blandford-Znajek) jets from the event horizon predicted. This was an unanticipated discovery. The claimed detection of a jet connected to the accretion flow provides a direct observational constraint on the geometry and physics of the jet launching region for the first time in any black hole jetted system. This landmark detection warrants further analysis. This Letter focuses on the most rudimentary properties, the shape and size of the source of the detected jet emission, the determination of which is not trivial due to line-of-sight effects. Simple thick-walled cylindrical shell models for the source were analyzed to constrain the thickness of the jet wall. The analysis indicates a tubular jet source with a radius $R\approx 144 \mu\rm{as}\approx 38M$ and that the tubular jet walls have a width $W \approx 36\mu\rm{as} \approx 9.5 M$, where M is the geometrized mass of the black hole (a volume comparable to that of the interior cavity). The observed cylindrical jet connects continuously to the highly limb-brightened jet (previously described as a thick-walled tubular jet) that extends to $z> 0.65$ mas, and the two are likely in fact the same outflow (i.e., from the same central engine).

2023 List of Publication

Punsly, Brian“HST-1: a Window to the Jet Spine of M\,87”,2023 A&A,677, A180

Punsly, Brian “M87 Jet Within 100$\mu\rm{as}$ of the Central Engine”,2023A&A679, L1