Brian Punsly

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 2021. The research was directed at finding environmental factors that are related to the switch-on of the general relativistic engine responsible for the few percent of accreting black holes that drive powerful relativistic jets. This is important since this will relate directly to constraints on the initial state and boundary conditions on numerical models of black hole driven jets.

2. Observing the Time Evolution of the Multicomponent Nucleus of 3C 84

Abstract:

The advent of global millimeter-band very long baseline interferometry (VLBI) in recent years has finally revealed the morphology of the base of the two most prominent nearby, bright, extragalactic radio jets in M87 and 3C 84. The images are quite surprising considering the predictions of jet theory and current numerical modeling. The jet bases are extremely wide compared to expectations, and the nucleus of 3C 84 is very complicated. It appears as a double nucleus in 86 GHz observations with 50 μas resolution and a triple nucleus with 30 μas resolution with space-based VLBI by RadioAstron at 22 GHz. What is even odder is that the double and triple nuclei are arranged along an east–west line that is approximately orthogonal to the north–south large-scale jet on 150 μas−4 mas scales. We explore the emergence of an (east–west) double nucleus in the lower-resolution 43 GHz Very Long Baseline Array (VLBA) imaging from 2018 August to 2020 April. The double nucleus is marginally resolved. We exploit the east–west resolution associated with the longest baselines, ~0.08 mas, to track a predominantly east–west separation speed of ≈0.086 ± 0.008c. We estimate that the observed mildly relativistic speed persists over a de-projected distance of ~1900–9800 times the central, supermassive black hole gravitational radius (~0.3–1.5 ltyr) from the point of origin.

3. **The Bulk Flow Velocity and Acceleration of the Inner Jet in M87**

ABSTRACT:

A high sensitivity, 7 mm Very Long Baseline Array image of M87 is analyzed in order to estimate the jet velocity within 0.65 mas of the point of origin. The image captured a high signal-to-noise, double-ridged, counter-jet extending ∼1 mas from the nucleus. After defining conditions and requirements that justify approximate time averaged bilateral symmetry, a continuous set of Lorentz transformations are found that map the double-ridged counter-jet intensity profile into the double-ridged jet intensity profile. The mapping is realized by a uniformly accelerating flow with intrinsic velocity of ∼0.27c at 0.4 mas (a de-projected distance of 0.38 lt-yr) to 0.38c at 0.65 mas (a de-projected distance of 0.61 lt-yr) from the nucleus. Since the velocity field is derived from the global surface brightness profile and does not depend on the motion of enhanced features, it is most likely a bulk flow velocity as opposed to a pattern velocity. This interpretation is corroborated by the fact that the distribution of the apparent velocities of previously identified individual features (from the literature) within 0.65 mas of the nucleus are consistent with local hydrodynamic shocks being advected with the local bulk flow velocity. The bulk flow velocity of the visible inner jet is a constraint that can potentially break degeneracies between numerical simulations that are designed to replicate both the annulus that was imaged by the Event Horizon Telescope as well as the base of the inner jet.

4. **Did the Event Horizon Telescope Detect the Base of the Sub-milliarcsecond Tubular Jet in M87?**

ABSTRACT:

A high-sensitivity, 7 mm Very Long Baseline Array image of M87 was previously analyzed in order to estimate the bulk flow jet velocity between 0.4 and 0.65 mas from the point of origin using the asymmetry between the well characterized double-ridged counter-jet (unique to this image) and the double-ridged jet. We use this same image to estimate the cross-sectional area of this tubular stream. The velocity, acceleration, cross-sectional area, and flux density along this stream determine a unique, perfect magnetohydrodynamic jet solution that satisfies conservation of energy, angular momentum, and mass (a monotonic conversion of Poynting flux to kinetic energy flux along the jet). The solution is protonic and magnetically dominated. The bilateral jet transports ≈1.2 × 10−4 solar masses per year and≈1.1 × 1042 erg/sec, placing strong constraints on the central engine. A Keplerian disk source that also produces the Event Horizon Telescope (EHT) annulus of emission can supply the energy and mass if the vertical magnetic field at the equator is ∼1–3.5 G (depending on location). A Parker spiral magnetic field, characteristic of a wind or jet, is consistent with the observed EHT polarization pattern. Even though there is no image of the jet connecting with the annulus, it is argued that these circumstances are not coincidental and the polarized portion of the EHT emission is mainly jet emission in the top layers of the disk that is diluted by emission from an underlying turbulent disk. This is a contributing factor to the relatively low polarization levels that were detected.

2021 List of Publication

Punsly, Brian; Nagai, Hiroshi; Savolainen, Tuomas; Orienti, Monica, “Observing the Time Evolution of the Multicomponent Nucleus of 3C 84”, 2021 ApJ 911 19

Punsly, Brian “The Bulk Flow Velocity and Acceleration of the Inner Jet in M87”, 2021 ApJ 918 4

Punsly, Brian and Sina Chen “Did the Event Horizon Telescope Detect the Base of the Sub-milliarcsecond Tubular Jet in M87?”, 2021 ApJ 921L 38