Brian Punsly

Position: Research Scientist
Period covered: 12/2018-12/2019

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 2019. 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. The Origin of the Event Horizon Scale Jet in M87 and EHT

Global millimeter wavelength Very Long Baseline Interferometry (VLBI) is an ambitious program to study the event horizon scale physics of nearby active galactic nuclei (AGN). The shortest wavelength receivers have been designated as the Event Horizon Telescope (EHT). It has been widely advertised that the experiment will reveal how astrophysical black holes can drive powerful jets near the event horizon – possibly proving the Blandford-Znajek mechanism that drives jets from the even horizon itself. There is only one powerful relativistic jet source that can be explored by the EHT with resolution on the order of the event horizon dimension, the jet in the enormous radio galaxy M87. Thus, M87 is the most studied object in radio jet research.

However, I show in a recent ApJ Letter, "Constraints on Black Hole Jet Models Used As Diagnostic Tools of Event Horizon Telescope Observations of M87" (B. Punsly 2019 ApJL 879 11) that the EHT observations do not show a Blandford-Znajek jet based on 60,000 attempts at numerical simulations made by the EHT collaboration. They fail grossly at the most basic level.

Abstract:
Jet models of Event Horizon Telescope (EHT) data should also conform to the observed jet profiles just downstream. This study evaluates conformance of models of black hole jets to images of the innermost jet of M87. This is a basic test that should be passed before using them to perform a physical interpretation of EHT data. Recent 86 GHz Very Long Baseline Interferometry observations of M87 have revealed the morphology and size of the jet near its source (< 65 M, or 0.06 lt-yrs after correcting for line of sight to the jet, where M is the black

hole mass in geometrized units) for the first time. Current transverse resolution indicates that this region is dominated by flux emanating from the edge of the jet. The observed inner jet profiles are compared to all existing published synthetic radio images constructed from \state of the art" 3-D numerical simulations of the black hole accretion system in M87. Despite efforts to produce the characteristic wide, edge dominated jet, these models are too narrow (by a factor of ~ 2) in the region 0.06 - 0.32 lt-yrs from the source, even though the jets (spine and/or sheath) in the image plane might appear conformant farther downstream. Furthermore, the synthetic radio images are not edge dominated 0.06 - 0.32 lt-yrs from the source, but spine dominated. Analyses that implement these models as physical diagnostics of EHT visibility amplitudes are therefore suspect. Thus, these inner jet characteristics are important considerations before applying simulations to the EHT data.

3. **Discrete and Continuous Ejection Models of the Radio Source Associated with GW170817**

From the paper of the same name (B. Punsly 2019 ApJL 871 34)

ABSTRACT:

The gravity wave source, GW170817, and associated gamma ray burst (GRB), GRB 170817A, produced radio emission that was detected in multiple epochs of Very Long Baseline Interferometry (VLBI) and with broadband radio photometry. Three unique pieces of observational evidence were determined: a discrete radio emitting region that moves with an apparent velocity of $\approx 4c$, the discrete region includes all of the radio flux, and there is likely a synchrotron self absorption (SSA) spectral turnover on day ~ 110 and day ~ 160 after ejection.
This unprecedented wealth of data for a GRB provides a unique opportunity to understand the radio emitting plasma that was ejected by the putative merger event. The velocity can constrain the kinematics and the SSA turnover has been used to constrain the size to much smaller than can be done with an unresolved VLBI image, allowing one to estimate the associated plasmoid size directly from the data and improve estimates of the energetics. Models of the radio emission for both a turbulent, protonic, discrete ballistic ejection and a high dissipation region within an otherwise invisible Poynting flux dominated positron-electron jet are considered. On days ~ 110 and ~ 160 post-merger, for the range of models presented, the jet power is 2×10^{39} - 8×10^{40}ergs=s and the ballistic plasmoid kinetic energy is 3×10^{45} -1.5×10^{47}ergs. Even though only valid after day 110, this independent analysis augments traditional GRB light curve studies, providing additional constraints on the merger event.

2019 List of Publication

Punsly, B. Discrete and Continuous Ejection Models of the Radio Source Associated with GW170817 2019 ApJL 871 34

Punsly, B. Constraints on Black Hole Jet Models Used As Diagnostic Tools of Event Horizon Telescope Observations of M87 2019 ApJL 879 11