Brief Punsly

Position: Research Scientist
Period covered: 10/2016-10/2017

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 2018. The research was directed at finding environmental factors that are related to the switch-on of the general relativistic engine responsible for a few percent of quasars driving 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

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.

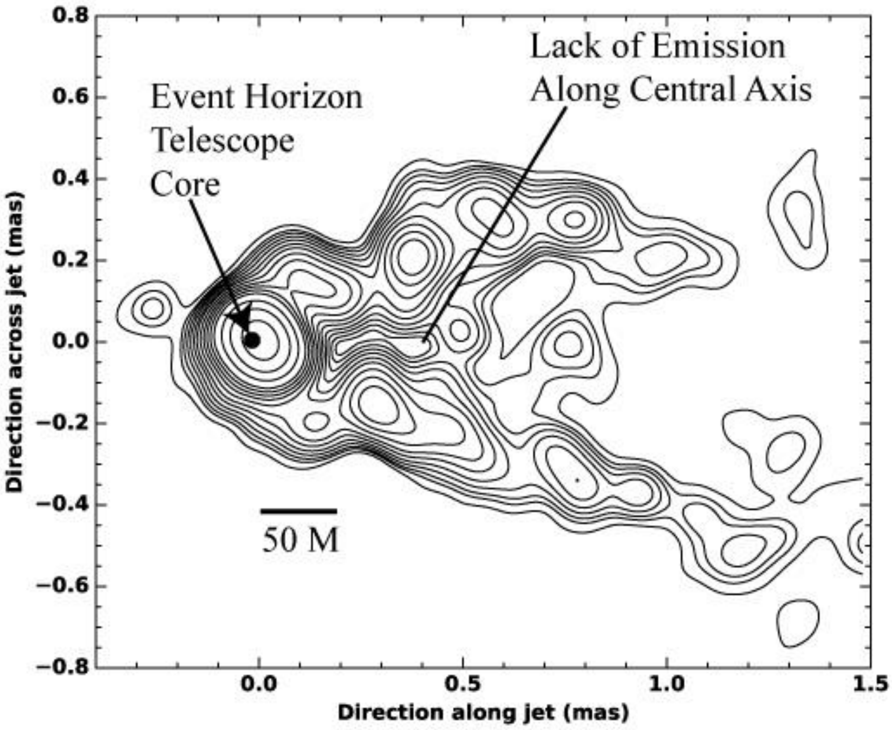

Figure 1. The 3.5 mm, global VLBI, image of Hada et al. (2016) with the EHT detected core at 1.3 mm from Akiyama et al. (2016) and Doeleman et al. (2012) overlaid. Note the extreme absence of emission along the central spine within 50 M of the black hole (the limit of the resolution of the radio image)

There is radio imaging of M87 at 3.5 mm (86 GHz) and detections with the EHT at 1.3 mm (230 GHz). The newest t and most sensitive 86 GHz published image is shown in Figure 1. There is currently no imaging capability at 230 GHz. However, it seems clear from the 86 GHz image in Figure 1 that there is a flux void along the central spine above the event horizon. More specifically, the image reveals a central flux nadir within 50M (where M is the black hole in geometrized units) of the super-massive black hole.

ICRANet adjunct professor, Brian Punsly, has been collaborating with Kazuhiro Hada of Mizusawa VLBI Observatory, National Astronomical Observatory of Japan (the prinicipal investigator on the 86 GHz observation in Figure 1) and Martin Hardacastle of Centre for Astrophysics Research, School of m Physics, Astronomy and Mathematics, University of Hertfordshire in order to study this lack of emission of along the spine. There are two papers. Paper 1 is a collaborative, “A New Solution to the Plasma Starved Event Horizon Magnetosphere: Application to the Forked Jet in M87”. This effort was published in Astronomy and Astrophysics in 2018. It explains the physics that does not allow the event the event horizon magnetosphere to launch a powerful jet in M87, thereby producing the weak flux emission along the spine above the event horizon evident in Figure 1. In summary, for low luminosity AGN, such as M87, it is shown that accreted large scale poloidal magnetic flux is dissipated when it approaches the event horizon and no significant magnetosphere can be obtained.

3. **Revealing the Broad Line Region in 3C 84**

The other prominent jet emanating from a nearby low luminosity AGN source is 3C 84. In the ApJ article "Revealing the Broad Line Region of NGC 1275: The Relationship to Jet Power" written with Paola Marziani (INAF, Osservatorio Astronomico di Padova, Italia), Vardha N. Bennert (Physics Department, California Polytechnic State University, San Luis Obispo), Hiroshi Nagai (National Astronomical Observatory of Japan, Osawa 2-21-1, Mitaka, Tokyo) and Mark Gurwell (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA USA) we finally determine the nature of the accretion source in this famous object.

NGC 1275 is one of the most conspicuous active galactic nuclei (AGN) in the local Universe. The radio jet currently emits a flux density of ~10 Jy at $\approx$1 mm wavelengths, down from the historic high of $\approx$65 Jy in 1980. Yet, the nature of the AGN in NGC 1275 is still controversial. It has been debated whether this is a broad emission line (BEL) Seyfert galaxy, an obscured Seyfert galaxy, a narrow line radio galaxy or a BL-Lac object. We clearly demonstrate a persistent Hβ BEL over the last 35 years with a full width half maximum (FWHM) of 4150 - 6000 km/s. We also find a prominent P*fi* BEL (FWHM$\approx$ 4770 km/s) and a weak CIV BEL (FWHM$\approx$4000 km/s), Hβ/CIV$\sim$ 2. A far UV HST observation during suppressed jet activity reveals a low luminosity continuum. The Hβl BEL luminosity is typical of broad line Seyfert galaxies with similar far UV luminosity. X-ray observations indicate a softer ionizing continuum than expected for a broad line Seyfert galaxy with similar far UV luminosity. This is opposite of the expectation of advection dominated accretion. The AGN continuum appears to be thermal emission from a low luminosity, optically thick, accretion flow with a low Eddington ratio, ~ 0.0001. The soft, weak ionizing continuum is consistent with the relatively weak CIV BEL. Evidence that the BEL luminosity is correlated with the jet mm wave luminosity is presented. Apparently, the accretion rate regulates jet power.

4. **Powerful Gamma Ray Quasars**

In the ApJ article "The Powerful Jet and Gamma-Ray Flare of the Quasar PKS 0438-436" we describe the very powerful gamma ray flare detected by FERMI with Andrea Tramacere (Department of Astronomy, University of Geneva),, Preeti Kharb(National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, Post Bag 3, Ganeshkhind, Pune 411007, India) and Paola Marziani (INAF, Osservatorio Astronomico di Padova, Italia).

PKS 0438-436 at a redshift of z = 2:856 has been previously recognized as possessing perhaps the most luminous known synchrotron jet. Little is known about this source since the maximum elevation above the horizon is low for the Very Large Array (VLA). We present the first VLA radio image that detects the radio lobes. We use both the 151 MHz luminosity, as a surrogate for the isotropic radio lobe luminosity, and the lobe flux density from the radio image to estimate a long term, time averaged, jet power, Q = 1.5 ±0.7 x 10^{47} ergs/s. We analyze two deep optical spectra with strong broad emission lines and estimate the thermal bolometric luminosity of the accretion flow, L_{bol} = = 6.7 ±3.0 x 10^{46} ergs/s. The ratio, Q/L_{bol} =

3.3 ±2.6 is at the limit of this empirical metric of jet dominance seen in radio loud quasars and this is the most luminous accretion flow to have this limiting behavior. Despite being a very luminous blazar, it previously had no γ-ray detections (EGRET, AGILE or FERMI) until December 11 – 13, 2016 (54 hours) when FERMI detected a flare that we analyze here. The isotropic apparent luminosity from 100 MeV - 100 GeV rivals the most luminous detected blazar flares (averaged over 18 hours),~ 5-6 x 10^{49} ergs/s. The γ-ray luminosity varies over time by two orders of magnitude, highlighting the extreme role of Doppler abberation and geometric alignment in producing the inverse Compton emission.

2018 List of Publication

Punsly, B.; Hardcastle, M.; Hada, K. A new solution to the plasma starved event horizon magnetosphere. Application to the forked jet in M87 20118 A & A 614 104

Punsly, Brian; Marziani, Paola; Bennert, Vardha N.; Nagai, Hiroshi; Gurwell, Mark ARevealing the Broad Line Region of NGC 1275: The Relationship to Jet Power 2018 ApJ 869 143

Punsly, Brian; Tramacere, Andrea; Kharb, Preeti; Marziani, Paola, The Powerful Jet and Gamma-Ray Flare of the Quasar PKS 0438–436 ApJ 2018 ApJ 869 174