Brian Punsly

Position: Research Scientist
Period covered: 10/2013-10/2014:

I Scientific Work

Black Holes and Quasars

1. Introduction

This report describes the research performed by Brian Punsly and collaborators in cooperation with ICRANet in 2013-2014. There were three lines of research. The first 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 related directly to constraints on the initial state and boundary conditions on numerical models of black hole driven jets.. The second area of research is based on using the jet in the Galactic black hole, GRS 1915+105, as a test case for black hole driven jets. Thirdly, I also am pursuing the fundamental physics of black hole jet launching.

2. AGN Environments and the Launching of Jets

In 2014, the research was concentrated on the nature of the broad emission line gas in AGN that launch relativistic jets. I am also leading collaborations to perform high frequency (high resolution), time resolved VLBA observations of broad absorption line quasars. Broad absorption line quasars have weak or no central engine for powerful radio jets with the jets rarely strong enough to make it out of the host galaxy. As principal investigator, in collaboration with Paola Marziani and Giovanna Stirpe at Istituto Nazionale di Astrofisica and Shaohua Zhang, we were granted telescope time on the VLT of the European Southern Observatory to study the Hβ line widths of quasars with broad high ionization absorption line flows for the first time. This is a follow-up to previous work with Shaohua Zhang on quasars with low ionization broad absorption lines that indicated narrow Hβ line widths consistent with polar outflows (Punsly and Zhang 2010)..

2a. VLBA Observations of Sub-Parsec Structure in Mrk 231: Interaction between a Relativistic Jet and a BAL Wind

I am leading an effort to study Mrk 231 at the highest resolution. It is the nearest broad absorption line quasar and we have proven that it conforms with the idea of a polar broad absorption line outflow (instead of the popular notion of an equatorial outflow) that was developed in Punsly (1999a,b). This research and proposal is being done in collaboration with Cormac Reynolds (Curtin University of Technology, Department of Imaging and Applied Physics), Christopher P. O'Dea (Department of Physics, Rochester Institute of Technology) and Joan Wrobel (NRAO, Socorro).

2a.1. Large VLBA Proposal Approved

We have been approved annually for the past few years for a very aggressive observation this object.

Abstract

We propose VLBA monitoring at 8.4, 15, 22 and 43 GHz of a high frequency flare in the nearby quasar MRK231. The “target of opportunity" observation (ToO) would be triggered by a flare detected by VLA monitoring at 22 and 43 GHz (see related proposal). The primary goals would be to detect a superluminal motion, estimate the internal energy of the flare from the spectrum and component sizes, and monitor the temporal evolution in order to understand the energy injection mechanism (rise) and the cooling mechanism (decay).

Background

From previous VLBA studies of MRK231 in Reynolds et al (2009) and other RQ (radio quiet) quasar studies, we have seen that RQ AGN can have relativistic outflows with significant kinetic luminosities (but maybe for short periods of time). So this raises the question what is it that makes some sources RQ and others radio loud (RL)? At a redshift of 0.042, MRK231 is one of the nearest radio quiet quasars to earth. The radio core is perhaps the brightest of any radio quiet quasar at high frequency (22 and 43 GHz). The combination of significant 43 GHz flux density and its proximity to earth makes MRK231 the optimal radio quiet quasar for study with VLBA. No other radio quiet quasar central engine can be explored with such high resolution, so it is ideal for studying the high kinetic luminosity relativistic ejecta in radio quiet quasars. 43 GHz VLBA observations can fully resolve nuclear structure to within 3.5×10^{17} cm. We propose to use sensitive high resolution observations to study the temporal evolution of the size and spectrum of a strong flare in MRK231 in order to shed light on why such strong flares cool off and never link to large scale powerful radio lobes.

2b. The Extreme Ultraviolet Deficit and Magnetically Arrested Accretion in Radio Loud Quasars

The nature of the causative agent that makes some quasars radio loud (RLQs) has challenged astrophysicists for more than 50 years. It became clear early on that the optical/ultraviolet (UV) spectra of RLQs and radio quiet quasars (RQs) are very similar. Attempts to look for subtle differences involved statistical studies of optical and UV emission line strengths and widths. These emission regions are far from the central engine, many thousand times larger than the central black hole radius, so it is not clear what they tell us as a second order indicator of conditions in the jet launching region. Are they related to the fueling mechanism for radio loudness, the ionization continuum or jet propagation? Consequently, this research path has provided very little understanding of the jet launching mechanism. Seemingly more relevant to the physics of jet launching, the extreme ultraviolet (EUV) continuum, wavelength less than 1100 Angstroms, is created orders of magnitude closer to the central engine and RLQs display significant EUV continuum deficit relative to RQs. I have explored this in a new ApJ Letter under review.

ABSTRACT:

The Hubble Space Telescope composite quasar spectra presented in Telfer et al. show a dramatic deficit of emission in the extreme ultraviolet (EUV) for the radio loud component of the quasar population (RLQs). The composite quasar continuum emission between 1100 Angstroms and ~ 580 Angstroms, is well represented by the innermost thermal component of an optically thick accretion flow. The deficit between 1100 Angstroms and ~ 580 Angstroms in RLQs has a straightforward interpretation as a missing or a suppressed innermost component of the accretion flow. It is proposed that this can be the result of islands of large scale magnetic flux in RLQs that are located close to the central black hole thereby displacing a significant fraction of the thermal gas (sometimes called magnetically arrested accretion): the gas that is responsible for the EUV emission. These magnetic islands are natural sites for launching relativistic jets. Based on the Telfer et al. data and the numerical simulations of accretion flows in Penna et al., the magnetic islands are concentrated between the event horizon and an outer boundary of < 2.8 M (in geometrized units) for rapidly rotating black holes and < 5.5M for modestly rotating black holes.

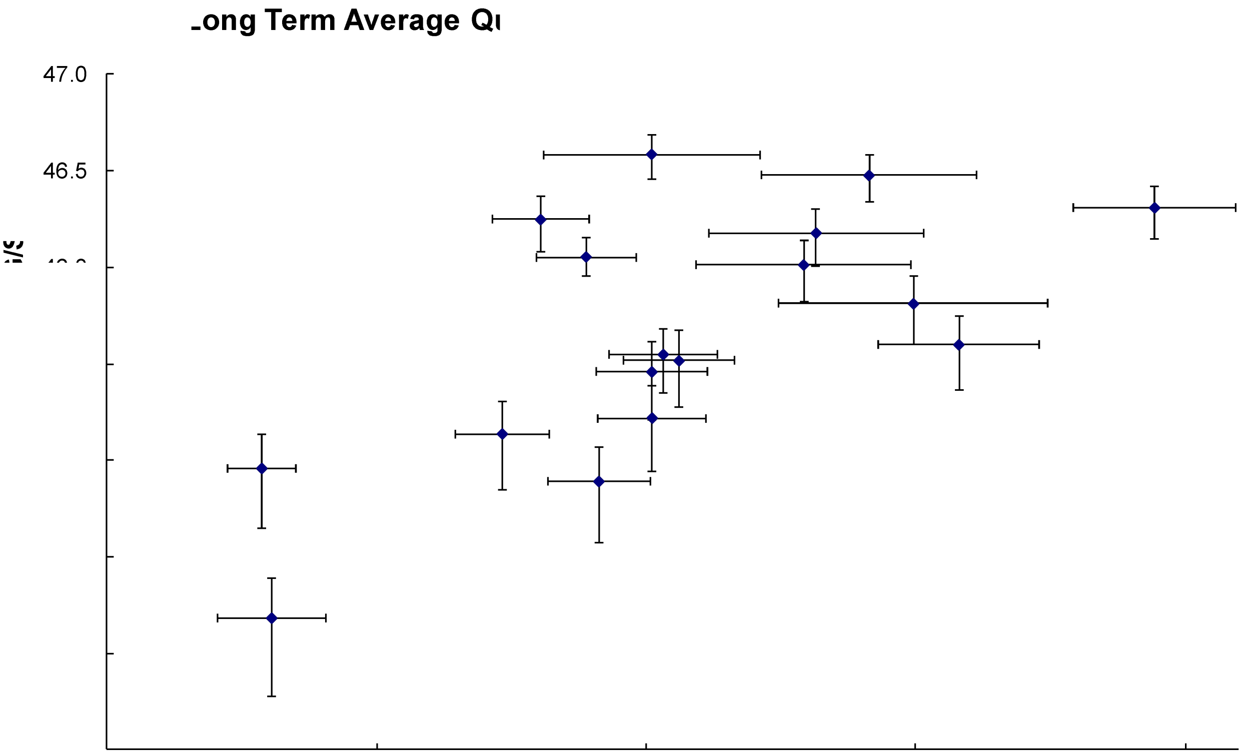

Figure 1. The correlation of the long term time averaged jet power in radio loud quasars with the EUV spectral index. A larger spectral index means a steeper spectrum and a larger EUV deficit relative to radio quiet quasar as a spectral index of about 1.57.

3. GRS 1915+105 as a Laboratory for Studying Black Hole Driven Jets

I am currently embarked on a research program to study the Galactic black hole jet in GRS 1915+105. There is much confusion in this field because it is led by scientist not familiar with the history of astrophysical jets or the theory of black holes. Projects were developed to understand the relationship of the energy output to the state of the accretion flow when the jets are launched. Our effort was published early this year with collaborators Jerome Rodriguez of Laboratoire AIM, CEA/DSM-CNRS-Universit\'{e} Paris Diderot, IRFU SAp, F-91191 Gif-sur-Yvette, France and Sergei Trushkin of Special Astrophysical Observatory RAS, Nizhnij Arkhyz, 369167, Russia.

ABSTRACT from Evidence of Elevated X-Ray Absorption Before and During Major Flare Ejections in GRS 1915+105:

We present time resolved X-ray spectroscopy of the microquasar GRS1915+105 with the MAXI observatory in order to study the accretion state just before and during the ejections associated with its major flares. Radio monitoring with the RATAN-600 radio telescope from 4.8 - 11.2 GHz has revealed two large steep spectrum major flares in the first eight months of 2013. Since, the RATAN receives one measurement per day, we cannot determine the jet forming time without more information. Fortunately, this is possible since a distinct X-ray light curve signature that occurs preceding and during major ejections has been determined in an earlier study. The X-ray luminosity spikes to very high levels in the hours before ejection then becomes variable (with a nearly equal X-ray luminosity when averaged over the duration of the ejection) during a brief 3 to 8 hour ejection process. By comparing this X-ray behavior to MAXI light curves, we can estimate the beginning and end of the ejection episode of the strong 2013 flares to within $\sim$3 hours. Using this estimate in conjunction with time resolved spectroscopy from the data in the MAXI archives allows us to deduce that the X-ray absorbing hydrogen column density increases significantly in the hours preceding the ejections and remains elevated during the ejections responsible for the major flares. This finding is consistent with an out-flowing wind or enhanced accretion at high latitudes.

4. Fundamental Physics of Black Hole Jet Launching.

I have contributed Chapter 6 to the Springer volume in press **The Formation and Disruption of Black Hole Jets**, editors Ioannis Contopoulos and Denise Gabudza. My chapter is entitled "Black Hole Magnetospheres"

ABSTRACT: This chapter compares and contrasts winds and jets driven by the two distinct components of the black magnetosphere: the event horizon magnetosphere (the large scale magnetic field lines that thread the event horizon) and the ergospheric disk magnetosphere associated with poloidal magnetic flux threading plasma near the equatorial plane of the ergosphere. The power of jets from the two components as predicted from single-fluid, perfect MHD numerical simulations are compared. The decomposition of the magnetosphere into these two components depends on the distribution of large scale poloidal magnetic flux in the ergopshere. However, the final distribution of magnetic flux in a black hole magnetosphere depends on physics beyond these simple single-fluid treatments, non-ideal MHD (eg, the dynamics of magnetic field reconnection and radiation effects) and two-fluid effects (eg, ion coupled waves and instabilities in the inner accretion flow). In this chapter, it is emphasized that magnetic field line reconnection is the most important of these physical elements. Unfortunately, in single-fluid perfect MHD simulations, reconnection is a mathematical artifact of numerical diffusion and is not determined by physical processes. Consequently, considerable calculational progress is required before we can reliably assess the role of each of these components of black hole magnetospheres in astrophysical systems.}

2014 List of Publication

Punsly, B. and Rodriguez, J. Trushkin, S. Evidence of Elevated X-Ray Absorption Before and During Major Flare Ejections in GRS 1915+105 2014 ApJ 783 133

Punsly, B. , Black Hole Magnetospheres in **The Formation and Disruption of Black Hole Jets**, eds. Ioannis Contopoulos and Denise Gabudza, Springer in Press